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“Vue de haut, dans ses rapports avec l’Homme, la Géographie n’est autre chose que l’Histoire dans l’espace, de même que l’Histoire est la Géographie dans le temps.
Ne peut-on dire également que l’Homme est la Nature prenant conscience d’elle-même ?”

“Vista desde arriba, en sus relaciones con el hombre, la geografía no es otra cosa que la historia en el espacio, lo mismo que la historia es la geografía en el tiempo.
¿No podríamos decir igualmente, que el hombre es la naturaleza tomando conciencia de sí misma?”

Elisée Reclus
L'Homme et la Terre, 1905 (Tome 1, p. 5)

“New ideas arise from recombination of the old”

John Holland

CONTENTS

1 INTRODUCTION

An important fraction of major world environmental resources such as fisheries, forests, water and the atmosphere are common pool resources. These resources are facing multiple changes at world and local scales due to diverse causes such as climate change, overharvesting and pollution. These resources support the livelihoods of local communities as well as regional and national economies all over the world. The assumption that underlies most of the research and field interventions in the management of these common pool resources is that all the actors involved share the same basic understanding of the commons problem.

Common pool resources management entails theoretical and empirical problems at different scales. Garret Hardin’s influential article (Hardin, 1968) put on the spot the fundamental problem. When several users of a limited resource that do not hold individual property on the resource units, they could extract as much units as they want to maximize their individual benefits without taking into account other´s benefits, or they can coordinate their actions to produce benefits for all users. The first course of action led to the so-called “tragedy of the commons” which consists in the collapse of the resource. A solution proposed by Hardin was the allocation of individual property rights and external enforcement.

During more than two decades these solutions were followed by national governments and practitioners to solve the management problem. Only after the boom in research on common pool resources in the late 1980s and early 1990s (Baland & Platteau, 2000; Fikret Berkes, 1989; McCay & Acheson, 1990; Ostrom, 1990; Wade, 2007) policy designers started to look at different directions. According to (Agrawal, 2001) it is not possible to argue that research on common resources has produced substantial changes in resources management, but it certainly has influenced the perspectives of policy makers. Since the 1990s the general trends in governmental initiatives towards decentralization and less top down control policies were designed under the commons research influence.

1.1 World's major common pool resources

In this section I give an overview of the state and the academic debate around the most relevant common resources: fisheries, forests and water. I will illustrate how the cognitive dimension has influenced also the scientific discussion at global, local and individual scales.

1.1.1 Fisheries

In 1884 Thomas Huxley stated "*probably all great sea-fisheries are inexhaustible*" (Botsford et al., 1997: 512) at the same time that Ray Lankester expressed his concern about the depletion of spawning stock and the need for targeting another species (L W Botsford et al., 1997). During the 20th century technological and scientific advances produced an immense harvesting capacity of the marine resources, but overexploitation all over the world has been an increasing problem recognized at least during the second half of 20th century (F. Berkes et al., 2006; Jackson et al., 2001; Myers & Worm, 2003). Pauly et al. (1998) stated: if harvesting current trends continue, it would be only jellyfish and plankton to fish. This was said in one of the first papers published that warned about the effects of fisheries in marine ecosystems. Worm et al., (2006) predicted the collapse of world fisheries by 2048. In Latin America ,which "*produces 20% of world marine fish production and employs more than one million people in predominantly artisanal production*", fisheries policies since the mid 70s starting by Chile have oriented the sector towards "*a grand experiment that tests assumptions about common property management and the benefits of free trade in the context of a rapid growth in worldwide demand for fish and sea food*" (Liverman & Vials 2006: 352). Studies about the effects of such policies in Latin America coincide that the success in the short term was accomplished by sacrifying the future sustainability (Liverman & Vials, 2006).

Strong discussions have been carried out between marine ecologists and fisheries scientists about the pessimistic view of the former scholars and the most optimistic of the latter. For example, from the side of fisheries science, Hilborn et al. (2003) assessed the state of the world's fisheries and they concluded that "*The total world catch from marine and freshwater wild stocks has peaked and may be slightly declining*" (Hillborn et al. 2003:359), in contrast with Pauly et al. (1998) and Worm et al. (2006) predictions. And they claim for appropriate institutional incentives for a possible fisheries sustainable future. A synthesis of this discussion, not always friendly, can be found in Stokstad (2009). In

2009 Science published the first joint paper produced by the main research groups in the two mentioned disciplines called "Rebuilding Global Fisheries" (Worm et al., 2009). The importance of this publication is that they revised world fishery databases used by different groups of fisheries scientists and marine ecologists and reinterpreted them. They conclude that in half of the studied ecosystems "*the average exploitation rate has recently declined and is now at or below the rate predicted to achieve maximum sustainable yield for seven systems*" (Worm et al. 2009: 578), but 63% of the studied fish stocks require rebuilding and significant decreases in harvesting rates. The study evaluates the state of fisheries combining stock assesments and ecosystem approaches, therefore the word "system" is used in the ecological comprehensive sense of "ecosystem".

Small scale fisheries

Although the critical situation seems to be general, not all fisheries have suffered the consequences of overexploitation (Acheson, 2004). Among small-scale fisheries, which include artisanal and subsistence systems (Berkes et al., 2001), it is possible to find successful stories of resource maintenance. Though small scale fisheries are not well reported, Worm et al. (2009) estimate that catches were about 21 million tons in 2000 and around 12 million fishers versus 0.5 million of industrial fishermen. The review of management tools for rebuilding stocks in small scale fisheries shows that gear restrictions and closed areas have worked as instruments that have contributed or have been important tools, but the research shows that the most successful tools are community-based management or community co-management, which is classified as essential tool in the studied cases (Worm et al. 2009). These findings could led to misleading interpretations about a one type of management tools for rebuilding stocks as a panacea. Regarding this point Worm et al. (2009) state: "*Finding the best management tools may depend on the local context*" (Worm et al. 2009: 584). Ostrom (2007) discusses the topic in depth in her paper "*A diagnostic approach for going beyond panaceas*". In order to understand the causes of depletion trends, the focus has been placed on stock assessment in the North, with general disciplinary emphasis on biology and economics, and with less intensity in social science (Berkes et al. 2001). It is also relevant to understand which have been the factors that have kept some small fisheries on the safe side, avoiding stock depletion.

1.1.2 Forests

Though world's forest loss rates are highly uncertain and error in measurement have been estimated as +-50% (Achard et al., 2002), United Nations Food and Agriculture Organization estimates that in the tropics forests are disappearing at a rate of 12% per year, and for 2005, 36% of the world's forests were relatively unaffected by human beings (Stokstad, 2008). World's forest decrease is about 7 million hectares per year mainly in the tropics (Sukumar, 2008). But the forest dynamics has had differential regional trends, while the decreasing tendencies have occurred in tropical areas, in North America and Europe forest areas have grown (Agrawal et al., 2008).

The distribution of world forest ownership, according (White & Martin, 2005), shows that 81% of the global forests' property rights are public and 4% of these are managed as common resources by communities and indigenous groups. Eighteen percent of the world forests have private property rights, 7% of these are managed by communities and indigenous groups as common pool resources. There is an important difference between developing and developed countries in the percentage of common pool forests. In developing countries the figure is 22%, while in developed countries is 3%. Knowledge about relations between forest cover and types of ownership is limited (Agrawal et al., 2008; Dietz et al., 2003). In contrast with these authors, (Charnley & Poe, 2007) argue that there is evidence of a more ecologically sustainable forestry, meaning forestry practices that keep ecosystem integrity while continuing to provide ecosystems' goods and services, in communal lands where there are institutional arrangements in which local communities play central roles in developing management rules. Elinor Ostrom's research during the last three decades has offered evidence of successful management of common resources when institutions are crafted by direct users, and these findings include forest cases.

Governance of forests in the world shows three general patterns in the beginning of the 21th century. Decentralization of management mainly for low market value forests which are important for the livelihoods of an important fraction of rural population in developing countries. Entitlements of forest concessions to logging companies in developing countries have positioned as a common practice. And the increasing relevance of certifications oriented towards the marked in developed countries (Agrawal et al. 2008). It is important to explore in which ways such tendencies have been the consequence of the generalized neoliberal policies started about two decades ago. For example, policies in Latin America regarding forest management have been marked by privatization and exports. During the 80s the global attention was put on the deforestation rates reported for Brazil and Costa Rica. Mechanisms such as payments of environmental services have been promoted for forest protection linked to biodiversity conservation and carbon sequestration (Liverman & Vials, 2006). The near future of forest governance will be dominated by management experiments at different scales that will include local communities and civil society, which will curve current privatization trends (Agrawal et al. 2008). In the short term, the private exploitation of forests seems to be part of such management experiments.

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1.1.3 Water

Water availability is a critical issue nowadays for agriculture irrigation, industrial production and domestic use. The last biannual report of *The World's Water* states that world freshwater stock is of 35.000 x 10^3 km^3 which is the 2.53% of total Earth's water (Gleick, 2003a), while the forecasts for water withdrawals and consumptive use for 2010 are 4324 and 2501 km^3 respectively, and world consumptive use of water for irrigation, which is fundamental for food production, is about the 85% of total human consumptive use (Gleick, 2003b). Consumption or water depletion refers to the volume of water that is permanently going out of the usable water system due to pollution, evapotranspiration, and flowing to salty bodies among other.

Projections for world's population by 2050 forecast some 9.2 billion people, consequently the consumption of water for irrigation, domestic, industrial and livestock utilization is projected to increase by 21%, in developing countries the figure is 25%, and for developed countries is expected 11%. Water scarcity will increase, which in turn constrains food production (Rosegrant et al., 2009). Water quality is a public good as well, and its deterioration has negative consequences on human sanitation mainly in developing countries, and also on ecosystems' health. Different strategies have been developed to attract public attention to the problem and change policies and behavior, such as, the concept of v*irtual water*, which is emerging now as a measurement of water needed for the production goods and food that humans consume. For example a cup of tea (250 ml) contains 35 l of virtual water, and a beef steak (200g) contains 3.000 l (Cominelli et al., 2009).

On the side of policies leading water management, the last three decades tendencies have been marked by market solutions. For example, in Latin America privatization tendencies have been controversial, and advocate for a free market governance of the resource. Chile is the classical example of water privatization policies, where the Water Code (1981 in Liverman & Vilas, 2006) encouraged private property rights and favored free markets in water, which led to diverse spatial and social impacts. Examples where increased legal security of private property rights encouraged investment in agricultural water use, especially in areas growing high-value export crops such as fruit. Stronger property rights have also helped to consolidate the autonomy of local canal associations (Liverman & Vilas, 2006) The tendency continued throughout the 80s and 90s mainly with Mexico, Argentina and Bolivia, being this last one of the best cases of the negative effects of water privatization, becoming a world symbol of what can go wrong, and known as the "water war" in Cochabamba (Liverman & Vilas, 2006). Besides that, infrastructure based type of management has been the pattern, with big projects of dams building, rivers diversion and so on, called "hard-path" solutions (Gleick 2003). These types of policies have entailed benefits but also big problems, and eventually have not solved the problem. Currently a call for changing in management styles is being carried out, for a "soft-path" management style, in which, the focus is on social capital and bottom-up approaches (Gleick 2003).

1.2 Problem of research

This dissertation studies the link between CPR management, mental models and institutions as a possible perspective that could provide a basis for the design and assessing of a variety of policy experiments. The fundamental problem I intend to address is the cognitive problem underlying common pool resources dilemmas in social ecological systems (Adams, Brockington, Dyson, & Vira, 2003; Weber, 1995; Weber & Bailly, 1993; Weber & Reveret, 1993).The central point of this dissertation is the need of a perspective of natural resources management that includes human systems relations, human values and cultural conceptions (Rudd, 2004).

The assumption that underlies most of the research and field interventions is that all the actors involved share the same basic understanding of the commons problem. As a consequence the policies externally designed for addressing these problems often have failed. The definition of the problem is fundamental for policy design, but a sound definition is a function of how much effort is put on understanding the different types of knowledge and world visions of actors involved. This knowledge could be broadly understood as constituted by three types: knowledge about the empirical context, knowledge about rules and social norms, and beliefs, myths and ideas (Adams et al. 2003).

Heterogeneity of actor's interests, values and priorities are the superficial expressions of deep structured visions of the world. As Adams et al. (2003: 1916) point "*Failure to recognize the cognitive dimension of conflict results in superficial policy measures that fail to address the deeper underlying (structural) differences between resource users*".

In this dissertation I address the cognitive conflict in commons dilemmas. By investigating three case studies in Colombia: small scale fisheries, water and forestry resources, I intend to link local context, institutional arrangements and mental models in order to explain decision making of resource users. The general research question addresses the relations between mental models of resource users, the institutional landscape and the ecological context they face.

The mainstream perspective has been to see the commons dilemma as a collective action problem focused on costs and benefits of cooperation, rule development, enforcement, sanctioning, monitoring, as well as the main characteristics of resources, infrastructure and communities (Agrawal, 2001; Ostrom, 1998). The problem of commons management, broadly, has been studied mainly from the perspectives of natural resource economics and political science. The focus has been on incentives, rules and cost benefit analysis (Baland and Platteau 1996, Wade 2007, Ostrom 1990, Agrawal 2001). Behavioral economics has been investigating the microeconomics foundations of individual preferences in commons pool resources use, such as trust, reciprocity, risk and inequality attitudes, and time preferences among others (Cardenas, 2001, 2009; Cardenas & Ostrom, 2004; Ostrom et al., 1994). The forms in which users extract, use, organize and distribute the units of the resource, has been called the appropriation problem, which has been studied in deep by Ostrom and colleagues. Weber & Bailly (1993), Weber & Reveret (1993) and (Weber, 1995; Weber & Bailly, 1993; Weber & Reveret, 1993) proposed five types of appropriation of commons resources: forms of use, acces and control, acces rights transferability, distribution and representations.

This dissertation is focused mainly on the domain of the commons' users' representations and their relation with institutional arrangements. According (Weber & Reveret, 1993) the representational dimension is the first level of the resources' appropriation including values, beliefs, clasifiying systems and acceptable behaviors. In the same line Adams et al. (2003), refer to this problem as *the cognitive conflict* in common pool resources management. Assumptions about full understanding of commons dilemmas and evident problems in natural resources management situations have had negative consequences. Adams et al. (2003) illustrate these situations with some examples from Asia and sub-Saharan Africa during 1980s and 1990s in the attempts of governments and donors to solve the fuel wood crisis, and rangeland management in Africa perceived as an overstocking problem. In both sets of cases policies designed and implemented top-down style failed and further evaluation proved that problems were completely different for direct resources users. Failure of policies has been attributed to the strong biased and knowledge assumptions of policy makers. This situation could be seen as an information problem, but the issue is deeper than that. The form in which policy makers understand the situation and structure the problems are heavily influenced by the formal models proposed in the literature such as the ones mentioned above. Therefore, usually the conceptualization of problems of policy makers is different to the direct users' conceptualization, and communication among them about problems usually does not try to explore the essence of the commons situations.

Careful problem definition is critical to craft effective management solutions. Stakeholders frame situations according to many different perspectives often conflicting among them. Differences in problem understanding go beyond interest and material conflicts, I claim, in line with Adams et al. (2003) that such differences have origin at deeper cognitive levels. These authors suggest three dimensions according stakeholders structure their problems: empirical context, knowledge of formal rules, and "*beliefs, myths, and ideas*" (Adams et al. 2003: 1915). The relation between these dimensions, but the myths, is addressed in this dissertation. All these elements are part of cultural constructs, and rules and social norms are one of the multiple expressions of culture in which they are reflected.

The central argument of this dissertation is that common dilemmas situations are strongly influenced by the cognitive conflict. Decision making, policy design, rule crafting, rule compliance, and management styles in common pool resources systems are driven by mental models of stakeholders, and individual and collective mental models usually differ leading to conflict and poor system outcomes. Though mental models have been recognized as an important component of commons dilemmas, (Adams et al., 2003; Moxnes, 1998; Ostrom, 2005, 2009; Sterman, 2008; Sterman, Sweeney, & L, 2007) scholarly literature has addressed partially their role on the common pool resources management, and it needs more formal and in depth research. An important work in this field has been done by the French research team of "Gestion des ressources renouvelables et environement" (Green) at CIRAD[1], which has as one of its two fundamental objectives: "*to consider the plurality of the points of view of the parties involved (experts and non-experts) at different levels of organization*"[2]. Important enough is the fact that context influence mental models and consequently behavior of resource users. Therefore, a comprehensive framework for studying social-ecological systems will be used for guiding and analyzing the research.

1.3 Outline of the dissertation

Having explained above the general nature of the intended research, the structure of the dissertation is as follows:

The state of the art (Chapter 2) is intended to explain the conceptual and analytical framework in which this research is built. A review of the concept of commons dilemmas and conventional versus up to date advances is given. Next section draws on the main aspects of commons management, introducing the concept of socio-ecological systems (SESs). The following section introduces the notion of mental models and offers a review of the origin and definition of the term, a discussion of up to date knowledge on human cognitive and learning processes. Next section discusses the role of mental models in the governance of SESs and the necessity of study in depth this relation. In the next section I give the background of the Institutional Analysis and Development (IAD) and define the main concepts to be used in the research. In the final section of the chapter I explain the general framework for the analysis of governance of SESs based on Ostrom (2007, 2009 and Poteete et al. (2010), in which I frame the concept of mental models and commons management. Next, I establish the theoretical elements I intend to study in the research, which are rules, cooperation, context and mental models and commons management. The chapter finalizes with a conceptual proposal for the study of the relation between mental models and institutional arrangements in SES.

In the Chapter 3 a geographical and historical context is given of each one of the case studies. The aim is to carry out a characterization of each place as a socio-ecological

[1] La recherche agronomique pour le développement (CIRAD). URL: http://www.cirad.fr/

[2] URL: http://www.cirad.fr/ur/green/home_page

system in which social and natural dynamics are coupled. I remark in the conclusion of each case the collective mental model that have been historically built, which has shaped the relation between nature and humans groups, with the direct implications on stiles of use and management through history. This section finalizes with a comparison of the three case studies from the perspective of the SES. The methodological framework to address the questions stated in the previous chapter is presented in chapter 4. First, I provide a brief overview of the different methods implemented and how they are integrated. I consider participative approaches in natural resource management, companion modelling perspective, and experimental economics. Secondly I illustrate in detail the field instruments, methods and the analytical tools used to develop the research. In this last section I discuss the use of institutional analysis and SESs framework and the method to study mental models.

In chapter 5 I use the Institutional Analysis and Development (IAD) (Ostrom 2005) as the orienting framework for the discussion of the commons problem in the three case studies. The last section of the chapter compares the three action arenas and their outcomes. As a consequence of the main findings of the institutional analysis I focus on the cognitive problem of commons dilemmas. Thorough the investigation of individual and collective mental models in the three case studies I give an explanation of the main outcomes of the studied action arenas. Chapter 6 addresses the study of the mental models of direct resource users. In the first part of this chapter, I explain in detail the methodology used to elicit and analyze the mental models in the case studies. For each of the case studies I consider the study of individual models, then the construction and analysis of the collective mental model, and finally I discuss the relation between collective mental models and the SES. In its conclusion I make a comparison and synthesis the most important characteristics of each case study collective mental model. Chapter 7 discusses on the central findings of the research and specifically about the relation between mental models and institutional arrangements in the context of outcomes of the action arena in which common pool resources users are immerse. Finally, the chapter 8 draws the main conclusions of the research.

2 THEORETICAL AND ANALYTICAL APPROACHES

This chapter develops a theoretical, conceptual and analytical state of the art on the fields of science relevant for the developing of the research. Through the discussion of these fields an integrative body of knowledge is structured, which will provide the perspective, used to develop, understand and answer the research questions posed in chapter 1. The discussion will contribute to define the theoretical question that lies at the center of this research.

The underlying idea of the research problem proposed in the introduction is that the common pool resources management entails a commons dilemma, which in turn is strongly influenced by a cognitive conflict. Such cognitive conflict arises as consequence of the diversity of stakeholders' mental models. Failure in management solutions has its roots in the use of general and stylized models instead of study the empirical context, lack of understand the institutional context, and the existence of several beliefs, myths and ideas held by stakeholders and policy makers. The problem involves decision-making and behavior of resource users, policy design, rule crafting and compliance, and management styles. Mental models drive these elements. In order to shed light on the problem I focus on the relation between the mental models and institutional arrangements in common pool resources management.

The conceptual framework developed in this chapter addresses the definition of commons, the different aspects of the dilemma involved, and the notion of socio ecological systems as a conceptual perspective to understand the empirical context of a common pool resource and the management approaches derived from this approach. Mental models notion is also part of the concepts needed in this research, because they constitute one of the most important drivers of human behavior including resource use and rule compliance. The final discussion in this section includes the relation of mental models and socio-ecological systems. The third component of the conceptual framework is a revision of the institutional analysis and development (IAD) approach, which offers key elements to study the commons dilemma. Concepts of rules and the action arena are fundamental for the analysis of actors ‘behavior, rule compliance, rules in use and their relation with mental models. Finally, the conclusions of the chapter propose an analytical framework that integrates the discussed conceptual bodies that will be used in the research to address the problem described in the introduction.

In the first section a definition of the commons dilemma is discussed as well as the main knowledge streams that have developed relevant theories. The section 2.2 explores the issue of common pool resources management and the concept of socio ecological systems as the perspective that orients this dissertation. The section 2.3 develops the concept of mental models that provides a link between the institutions, governance of socio ecological systems and human behavior in decision-making in commons dilemmas. In the section 2.4 I discuss the institutional perspective, which also contributes to build the general perspective of the study. The section 2.5 illustrates a general framework for the analysis of socio-ecological systems that will be utilized in the research. In the conclusion of the chapter I make a synthesis of the general approach, and I illustrate the theoretical knowledge gap intended to address in this study.

2.1 The Commons Dilemma

A social dilemma is a situation in which individual interests, in a human group, are not in line with collective optimal outcomes. The basic two possible types of decisions for an individual immersed in a social dilemma are, on one hand, to maximize his own interest, and, on the other hand, that he or she can cooperate in order to contribute with the group to achieve an optimal collective benefit, loosing part of his personal benefits. In other words, a pro-social behavior implies that individuals care not only about the consequences of their decisions for themselves but for the others, and also they care about the intentions of others. For example reciprocity, inequality aversion, envy and altruism are important types of social preferences (Bowles, 2006). This implies a trade-off between personal and social benefits. This situation constitutes an important aspect of the relation between society and nature. The relation between nature and society has many dimensions. It supports spiritual and material human life, and it is also constructed by the society, but the social structures are strongly influenced by nature as well. If we see the material side, nature provides food, construction materials etc, but also is a sink for pollution generated in human productive activities. In many cases the outcome of this relationship has been the depletion of natural resources in terms of stocks' amount and quality. The fundamental question is why people destroy a key component of their livelihood system: the natural capital. In order to make an attempt to answer this question it is necessary to explore three topics. Do we fully understand the drivers of human behavior? If rules for natural resource management are viewed as the way in which humans relate with ecosystem's goods and services, how is the relation between those rules and the drivers of individual and collective behavior?

When a person faces a dilemma, she has to consider a number of factors before making a decision, either consciously or not. These are: a) Benefit-risk dilemma, which is the tradeoff between the actions that bring individual benefits, but that entail risk as well. This is, to what level of risk is worth it to assume, in reaching certain level of benefits. b) A temporal dilemma, which is the dichotomy between short-term survival and long-term survival. c) A spatial dilemma, which has to do directly with environmental topics. It consists in weighting to what extent an individual should make decisions in order to assure local security, and contribute to conservation of regional and global resources. d) And a social dilemma that is the decision between the assurance of self-survival and collective survival conditions. In sum, a cooperation dilemma in the environmental realm can be seen as a mix of the dilemmas mentioned above (Jager, 2000).

Another aspect of the structure of the dilemma is the perspective that an individual has on it. According to Vlek (1996, in Jager, 2000) a person who faces a social dilemma may not realize the situation he is in. There are four types of unawareness of the dilemma: a) The individual may not perceive that he could generate *negative externalities* to the society in the mid or long term, as a consequence of his short term decision. In other words, the person is not able to perceive the relation between his decisions and the negative collective outcomes. b) The actor may not be aware of the consequences of *accumulation of externalities*. c) The person could think that his behavior generates *small negative collective outcomes* in relation with the benefits. And d) the agent may know the social risk derived from his decisions, but he may think that it is *uncontrollable*, therefore this person can perceive himself being in a no-choice situation (Jager, 2000).

In the above discussion it is possible to see how individual's behavior is the result of the combination of dilemma's characteristics and the way the individual perceives these characteristics and the outcomes of his actions.

A commons dilemma can have two general forms either a *resource dilemma* or a *public good dilemma*. The first, consists in a situation where individual's decision is about take or not, or how much to take from a public resource. The second implies a decision about to contribute or not, or what is the amount of contribution to a public good (Van Langue, 2001).

2.1.1. The "conventional" theory

The conventional theory about commons dilemma (Poteete et al. 2010) has been structured by three paradigmatic works: the tragedy of the commons (Hardin 1968), prisoner's dilemma (Rapoport and Chammah 1965) and the free-riding problem (Olson 1965). The consequence of these three theories was the imposition of rules, by a third party, to govern commons and land privatization in many countries.

In the year 350 BC, Aristotle warned about the commons dilemma: "*…Property that is common to the greatest number of owners receives the least attention; men care most for their private possessions, and for what they own in common less, or only so far as it falls to their own individual share for in addition to the other reasons, they think less of it on the ground that someone else is thinking about it, just as in household service a large number of domestics sometimes give worse attendance than a smaller number.…*" (Aristotle, Written c.a. 350 BC. 1977, Section 1261 b p 77). This dilemma has been used to describe and analyze the tension between individual and collective interests. Machiavelli (1525, in Jager, 2000) wrote about this social dilemma focusing on the political consequences of social inequality. Inspired by Lloyd (1833), Garret Hardin published in 1968 his influential paper "The Tragedy of the Commons", which became the paradigmatic example, explanation and solution of the commons dilemma. He used the example of a common pasture utilized by herders for feeding their cattle that illustrates how the degradation of the commons is the predictable outcome if each herder put more and more animals in order to fulfill his objective of individual benefits. According to Hardin, in absence of external rules and private property rights herders' behavior will deplete the commons resource bringing poverty to the animals' owners. He wrote: "*Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the* *commons. Freedom in a commons brings ruin to all*" (Hardin, 1968, 1244). Hardin put the commons dilemma in the spot for natural resource management, and proposed a particular definition of commons, in terms of property rights, and a solution to the dilemma that has dominated until very recently natural resources and environmental management, influencing economic, sociologic and political sciences fields. The ultimate consequence of this influence is its adoption by public policies. I will explain further how his perspective contributed to structure the conventional theory about the commons dilemma. Next, an explanation of the structure of the commons dilemma is presented.

Hardin's picture of the commons dilemma assumed that common resources were defined by the type of property rights, following the traditional convention, up to date, according what there was three type of goods: communal property, private proverty, and state property. The author claimed that the only way to avoid the destruction of the commons was the imposition, by the state, of external rules and private property rights.

The prisoner's dilemma has been one of the most influential application of noncooperative game theory to the strategic analisis of conflicting interests since the 60s. It formalizes a conflict between private and collective interests, and the effect on outcomes of each agent's decision, of an interdependent structure that characterizes many dichotomic interactions. This structure can explain, not only strategic decisions between two actors, but can be extended to N-person prisoner's dilemmas. The structure of the prisoner's dilemma can be used to explain and analize many situations of interdependence in natural resources's use, and environmental domains. In fact, it can explain in a formal way a commons dilemma. In short, if each agent pursues her own interest, the game's outcome will be inferior to a scenario in which every agent cooperates and the game reaches the social optimum[3].

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[3] The fundamental concept of the game theory is the interpretation of a number of situations as a game. A game is a form of modeling strategic interactions. A strategic interaction is a situation in which the consequences of individuals' decisions and actions depend on others' actions, and that interdependence is recognized by all the individuals involved. A game is composed by identified players, a set of courses of action available for each player, called the strategy set, the payoffs associated with each combination of strategies, the order of play and the information available for each player. Players can be individuals or organizations (firms, public entities, countries, NGOs, etc) in the biological realm may be species, cells or genes (Bowles, 2004). The basic concepts of game theory, bargaining, and other nonmarket social interactions were introduced by John Nash (1950), Neuman and Morgenstern (1944), Shelling (1960) and Luce and Raiffa (1957). The Nash equilibrium has been considered as the solution to the bargaining problem. This concept is central for classical game theory. The idea was proposed by John Nash (1950) based on the assumption that individuals will not agree to modify their strategies in order to reach a collectively efficient outcome. The concept is based on the idea of best response strategy. The notion is that "*there may be one or more outcomes that no individual has any incentive to alter his strategy given the strategies adopted by all the others*" (Bowles, 2004, 33). The Nash equilibrium is a strategy in which all the strategies of all players are best

In his book “The logic of collective action” Mancur Olson (1965) identified three conditions that influence collective action; group size, heterogeneity, and selective incentives. The fundamental problem of collective action situations is that when individuals have to contribute to a collective objective, these contributions are concentrated but the beneficial outcomes are distributed and diffused (Poteete et al. 2010). Olson emphasized the role of incentives and the generation the free riding phenomena, as a pervasive potential behavior of every actor in a collective action situation. Free riders enjoy the benefits of the cooperation effort of other actors in the group. Olson’s logic of collective action predicts that it works only in small groups.

These three theories are self-reinforcing and strongly contributed to a particular perspective of the world, which became the “conventional” theory for the sustainability of natural common pool resources. In sum, this conventional theory predicts that: i) collective action is possible only in small groups, ii) succeful collective actions carried out by groups that have developped their own rules for self-organization are hardly possible (Hardin 1968), and iii) without externally imposed rules, the succesful collective use of natural resources is not possible (Poteete et al. 2010).

The conventional understanding of the dilemma led to several consequences and has fostered plans for land privatization in Africa and other regions (Poteete et al. 2010). Many forests and wildlife zones in India, Thailand and Africa among other regions of the world, were declared as national property, and have expulsed the human population, accepting that this was the only way to protect these areas fron degradation (Arnold and Cmapbell, 1986; Feeny, 1988; Thomson et al., 1992; Sheperd, 1992). Policies of biodiversity nationalization and land and other natural resources privatization neglected local and endogenous forms of natural resources management (Barrows and Roth, 1990; Berry, 1993; Shipton, 1988). In general the consequence has been to think that when people is in a commons dilemma, they are trapped in an evil situation, and that individuals are defenseless without any possibility to overcome the situation by themselves. The policy solutions designed to take out people from the trap have been also of an evil character (Ostrom, 1990). Since the second half of the 1980s empirical evidences started to challenge the conventional theory. An increasing

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responses to the other strategies. This concept permits to predict the result of any game if the players are egoist actors. But in many occasions game theory does not explain how players different types of strategies (Cahuc, 1996).

number of cases of succesful self management of natural resources started to be reported, as well as cases of failure. Some of these empirical cases were documented by Berkes et al. (1989) and Ostrom (1990).

Theoretical expectations about cooperation failed in the domain of experimental economics, the study of property rights engaged in an effort to review and refine the existing concepts about the characterization of different goods, and scholars studying collective action worked on new and more realistic concepts about equilibrium and human behavior (Poteete et al. 2010). The notion of the tragedy of the commons entails a problem in the concept of property rights, an application of the Prisoner's Dilemma that is not appropriate, and a group of assumptions that have been challenged empirically (Ostrom 1990)

In response to the mentioned empirical and theoretical anomalies three reactions have been developed since early 80s. The first is the revision and improvement of the conceptual framework for property rights and types of goods, which will be summarized below. Second, new developments in game theory were carried out in order to improve and make more realistic the analysis of human behavior and collective action. And third, the development of the Institutional Analysis and Development (IAD) framework (Ostrom et al. 1994, Ostrom, 2005 and Poteete et al. 2010), which will be reviewed in a further section of this chapter.

2.1.2. Common Pool Resources (CPR)

One of the dimensions of the relation between human societies and ecosystems has to do with the rules humans design to structure such type of interactions. Ecosystems provide a number of goods and services that provide food, building and genetic materials, and environmental conditions that support human life. Different types of rules structure the relations between societies and such ecosystem's goods and services. A typology of economic goods was developed by Ostrom and Ostrom (1977) based on two attributes: subtractability and exclusion. According to this classification there are four types of goods: private, common, club and public goods. Table 2.1 shows this typology. Common pool resources (CPR) are characterized by the high degree of subtractability of use, for example when one fishermen harvest one kilogram of fish, these fish are no longer available to other users. In terms of exclusion, CPRs are characterized by the high difficulties and costs of excluding users from access to the resource; this characteristic is a consequence of its biological and ecological nature (Ostrom et al. 1994). Its important to clarify the difference between a property rights regime and the type of goods. A CPR can be managed by any type of property rights regime: government, private, common ownership, or now defined oenrship. The type of good is defined by the exclusion and the subtractability. A common confusion is that public goods are understood as common goods. Public goods should not be equalized to common goods, a “common property” has collective rights to exclude others, while in an “open acces” or public good is very difficult to exclude users. The recognition of the difference between resource’s characteristics and the ones who hold the property rights allows the existence of collective property rights (Poteete et al. 2010).

		Difficulty of exclusion	
		Low	High
Subtractability	High	Private goods	Common-pool resources
	Low	Club goods	Public goods

Figure 2.1. Typology of goods. Source: Poteete et al. (2010, 70).

The distinction between a renewable resource stock and the resource flow is fundamental when it comes to considerations about norms, fairness, efficiency, equity and ethics became central issues when excluding beneficiaries of a CPR.

> The “*stock makes available a flow of resource units over time that are appropriable and substractable in use… It is the resource units from a CPR that are subtractable. The fish being harvest are a flow, appropriated from a stock of fish.*” (Ostrom et al. 1994, pp. 8)

The flow of resource’s units are the regeneration rate, and if the number of units harvested from the resource do not excceds this regeneration rate, the stock will not be depleted. Ostrom et al. (1994) typifies the problems faced by commons’ users, by grouping them in two categories; appropriation and provision problems.

Appropriation problems are related with the flow of the resource, and entail the question about how to regulate access to attractive common resources. When this problem is not solved, attempts to maximize individual utility will lead to overexploitation and possibly depletion. *Appropriation externalities* are the first type of problems which are generated when a resource user increases the extraction, the benefits for other users diminishes. *Assignment problems* have to do with the heterogeneity character of the resource. The effect is that the potential yield is not the same for all the space that occupies a resource regarding a community of users, for example, in fisheries, usually there are the fishery spots and zones with very low productivity, or in an irrigation canal, users upstream obtain more water than those located downstream with the same effort. If this problem is not solved the use of the commons is inefficient and may generate conflicts in the user's community. *Technological externalities* are produced when heterogeneity is present in the technology that individuals use, and the utilization of a specific technology increases the costs for the users of others technologies.

The provision problem is related with the resource's stock, and has to do with efforts to provide a healthy resource to be shared by the appropriators. The term is most appropriate for the case when human effort is needed to make the resource available (e.g. building dams and channels for irrigation). The challenge in this case and also with resources that do not need human provision effort, is to understand complex bioeconomic systems characterized by dynamics, nonlinearities and stochasticity. When this problem is not solved, overexploitation and depletion is again a likely consequence. The provision problem can be complicated to manage, especially when the resource is characterized by long-lasting stocks, i.e. different from a river that flows by at a constant rate. Then the management problem can be characterized as *"a dynamic, nonlinear optimization problem under uncertainty and ambiguity"* (Moxnes, 1998b). Given this complexity it should come as no surprise that renewable resources are at times severely mismanaged. However, due to the dominance of the commons theory, and the apparent conflicts between resource users when resources are depleted, it is not easy to observe the effect of misperception of feedback from the resources. The author focuses on this notion of misperception of feedback meaning the difficulties for resource users to read the signals coming from the resources and involve this information in their use decisions. Moxnes claims that in order to observe this effect more clearly, it is necessary to consider management situations where the commons problem is not present. Following Ostrom et al. (1994), the provision problem has two dimensions; the demand and the supply sides. The demand side provision problem captures the impacts that users do on the resource, and the supply demand side "*lies in the individual incentives to free ride on the provision activities of others*" (Ostrom et al. 1994, pp. 14), it focuses on the efforts for providing and maintaining the resource.

2.2. Common pool resources management

In this section I will present the theoretical bases to be used in this research for the approach to the fundamental problems of environmental and natural resources management: i) the control of accessing the resources, and ii) the design and enforcement of rules among users in order to solve the problems inherent to the dilemma between individual and collective rationality (Berkes & Folke, 1998). According these authors there is a vast evidence of poor ecosystem management practices during most of the 20th century. Scholars have cited several causes; some have talked about human "*shortsightedness and greed*", others mention the *laissez-faire* ideology of classical economics (Daly and Cobb, 1994). Others have blamed the underlying perspective according that humans dominate nature, vision that have led to an utilitarian and exploitative worldview (Gadgil and Berkes, 1991, and McNeely, 1993). When it comes to ecosystems and natural resources viewed as common pool resources explanations for the so called poor ecosystem management practices have been strongly influenced by Hardin's tragedy of the commons and theories of collective action (Olson, 1965). Management has focused on static concepts about maximum sustainable yield (MSY) and carrying capacity, which are to be optimized. Berkes & Folke (1998) distinguish between two thought currents in natural resource management that differs to the classical utilitarian approach. The first is the system approach and adaptative management, and the second focuses on institutions and property rights. Nonetheless, both approaches conceive the social and nature systems as a "*black box*" respectively. The Social Ecological Systems (SES) approach attempts to fill this gap, trough out the integration of several fields. These efforts have led to new conceptions of environmental and natural resources management as well as new sustainability definitions. In the next section I give a definition of social-ecological systems as well as a brief discussion of the main characteristics of social and ecological system. Finally, I take up again the commons dilemma and discuss the lessons from SESs approach for commons management.

2.2.1. Social Ecological Systems (SES)

It is important to discuss the characteristics of social systems end ecosystems in order to support the reasons for the methodological choices of this investigation. Westley et al. (2002) offer a discussion on the differences and characteristics of the two kinds of systems, which helps to the conceptual and methodological approach of this study. The question addressed by these authors is if the two systems, people and nature, are equal, or is it one of them subordinated to the other? The first part of the question can be answered by discussing the characteristics of each system.

An ecosystem is composed by biotic and physical entities located in a specific space. Their interactions produce self-organization processes at different spatial and temporal scales (Levin 2000). Space and time are the fundamental dimensions of ecosistemic structure. Ecosystems exist in a wide spectrum of spatial scales, from centimeters to thousands of kilometers. An important characteristic of ecosystems is the pattern of discontinuity across spatial scales, which "*is attributed to self-organizing processes operating at distinctly different scale ranges*" (Holling 1992 in Westley et al. 2002, pp. 106). The temporal dimension of ecosystems produces dominant cycles that can be observed in time series of key variables. Homeostatic mechanisms working thanks to balancing feedback processes are responsible for self-organization in ecosystems (Levin 2000).

A definition of social system is given in (Westley et al. 2002, pp.107):

> "*A social system is defined as any group of people who interact long enough to create a shared set of understandings, norms, or routines to integrate action, and established patterns of dominance and resource allocation. Like any system it is dynamic, meaning that is is difficult to change any one part of it without considerable effects on other parts. Depending on how boundaries are drawn, social systems canm be as small like a family or as large as a nation. Like natural systems, social systemsmust fulfill key functions. They must be oriented toward certain goals or objectives, they must create mechanisms for integration and adaptation, and they must create mechanisms for self-reproduction (Parsons 1951*)"

Social systems have temporal and spatial dimensions as well as the ecosystems, but are also structured by a symbolic dimension. According to Giddens (1987), this symbolic dimension is composed by “structures of signification”, “structures of domination”, and “structures of legitimacy”. These three types of structures are the building blocks of society. The contents of these categories are of paramount pertinence for the analytical framework of this research. The structures of domination account for the power relations and structures of authority. The structures of legitimacy are defined by the norms, rules, routines and processes working in a given social system. The elements in the structures of signification clearly differentiate social systems from ecosystems. These elements are the capacity of abstraction, reflexivity, forward looking, and of externalization of societies’ logic in technology (Westley et al. 2002).

Societies are able to invent and reinvent meaningful orders and behave accordingly to this invented world. The process of sense-making is fundamental for the construction of a solid place to live in. Sense-making generates signification of the environment, and in turn, it becomes a shaping force for the environment as well as a third dimension of the same category of time and space, in order to structure social system dynamics (Westley et al. 2002). In words of the same authors (p. 108), social systems create “*structures of signification that provide a ‘virtual reality’* ”. The abstraction ability is possible thanks to communication, language, and symbols, which allow a high level of self-organization than ecosystem organization. This characteristic gives to social systems the ability to change from one kind of organization to other faster than ecosystems. These structures of signification produce an ability on social systems to detach, to some point, from space and time. According to the same authors, these characteristics are fundamental to understand resilience in social systems. From this perspective management is central because it becomes a matter of deciding which kind of system is desirable and how to manage towards a specific equilibrium:

> “…*as long as the structures of signification stay in place, the whole system will not transform radically, but rather will return to a previous equilibrium. The opposite is also true, as studies of communities in crisis indicate: If meaning is lost, human systems seem unable to recover*” (Westley et al. 2002 p. 108)

The capacity of reflexivity of social systems at individual and collective levels allows the system “*to consciously maintain the notion of integrity and identity while becoming disorganized al lower levels (…) reflexivity means that processes at lower scales have the potential to disturb processes and structures at higher scales*” (Westley et al.

2002, 110). In contrast, ecosystems have the ability of remembrance but in a non-conscious manner.

The capacity of social systems of *forward looking* is another element of the structures of signification that differentiates them from ecosystems. Human behavior is driven, in a high percentage, by the expectations on future results of the present actions. One of the fundamental aims of this research is to contribute to the understanding of the cultural filters and institutional frameworks that inhibit the capacity of social systems to foresight the consequences of its current strategies. This idea is taken from Redman (1999 in Westley et al. 2002), whose concern is based on his studies societies that failed in the prevision of their course of action's consequences, and continued with auto destructive strategies until their definitive collapse.

The externalization of symbolic constructions in technology is another capability of social systems. The power of the structures of signification is the ability of translating the *virtual realities* into external technical system (Westley et al. 2002). The relation of this capability with environmental and natural resource management is straight forward, in the sense, that technical solutions and approaches have been pervasive in command and control management styles. Technological solutions have produced positive and negative impacts on society and ecosystems. These solutions, most of the time, have targeted one or few variables in terms of optimization, without taking into account their effects on other parts of the system.

The symbolic dimension of social systems, in addition to confer the major difference with ecosystems, is responsible for the lack of adaptability and responsiveness to environmental information, what Moxnes (2004) calls misperception of feedback. The methodological framework designed for this research takes advantages of these components of the structures of signification.

The term social-ecological system implies the notion of dependence and relations between society and nature. This concept has not been evident for occidental science during the last two centuries. However, since the ancient Greece, philosophers recognized this integration. Economists like Malthus acknowledged the environmental constraints of human population growth. Geographers and anthropologists interpreted culture, space and territory as a social construct shaped by the environmental conditions. Ecologists from Odum's school, and conservationists (Leopold 1949) focused on the impacts of society on ecosystems.

Berkes and Folke (1998) coined the term "social-ecological system" to explain their perspective about the interactions between nature and humans, they expressed the concept as follows:

> "*We hold the view that social and ecological systems are in fact linked, and that the delineation between social and natural systems is artificial and arbitrary. Such views, however, are not yet accepted in conventional ecology and social science. When we wish to emphasize the integrated concept of humans in nature, we use the terms social - ecological system and social – ecological linkages.*" (Berkes & Folke, 1998, p. 4.)

Research organizations such as the Stokholm Resilience Center includes in its web site the following definition of SES:

> *"Social-ecological systems are linked systems of people and nature. The term emphasizes that humans must be seen as a part of, not apart from, nature — that the delineation between social and ecological systems is artificial and arbitrary. Scholars have also used concepts like 'coupled human-environment systems´, 'ecosocial systems´ and 'socioecological systems´ to illustrate the interplay between social and ecological systems. The term social-ecological system was coined by Fikret Berkes and Carl Folke in 1998 because they did not want to treat the social or ecological dimension as a prefix, but rather give the two same weight during their analysis."* (Stockholm Resilience Center)

The Resilience Alliance is an international organization of scholars and practitioners whose objective is to contribute to study the dynamics of social-ecological systems. They define the term social ecological system as "*an integrated system in which the dynamics of the social and ecosystem domains are strongly linked and of equal weight. Evidence suggests that social-ecological systems act as strongly coupled, complex and evolving integrated systems*. (Resilience Alliance)

Davidson and Berkes (2003) made an overview of the intellectual fields that have attempted to understand the relation between nature and society during the 70s and80s. As the authors call them, they are "*integrative areas*" used specifically for the purposes of resilience thinking framework structuration. In order to illustrate the intellectual provenance of the questions guiding this study, I will mention these "*integrative areas*".

Environmental ethics' scholars identified the need of a philosophical inquiry and development of the understanding of the relations between people and their environment, since traditional ethics cares about the relations among people. Davidson and Berkes (2003) mention the ecosophy (Naess 1989 in Davidson and Berkes 2003), the diversity of spiritual and ethical traditions (Callicott 1994 in Davidson and Berkes) and the variety of cultural attitudes towards the natural world (Berkes 2001).

Political ecology field includes the cultural and political dimensions in the analysis of ecosystems. Power relations and inequalities are addressed by practitioners. The political ecology vision claims that it is necessary to consider the existence of different actors with heterogeneous ideas about knowledge, ecological relations and different resource management styles, and at different scales. Environmental history has risen on the great quantity of material that documents the relations between societies and environment (Worster 1998 in Davidson and Berkes 2003). Through the research of the root causes of environmental problems, the field has documented and discussed "*how ecological relations became more destructive as they became more distant, especially after the great transformation following the Industrial Revolution*" (Worster 1998 in Davidson and Berkes 2003).

Ecological economics' field attempt has been in the direction of the integration of ecology and economics, conceptualizing the economy as a system included the ecosystem. One of the important contributions of ecological economics to a more integrative vision of the relation between society and nature is the use of a conceptual basis that rests in the general systems theory, neoclassical economics, adaptive environmental management among other fields of knowledge (Costanza et al. 1997). Though ecological economics use some of the approaches and methodological tools of environmental economics, they are taken as one information sources among others, and their results are interpreted in a more integrated form with ecological and social contexts. The field has shifted the focus from isolated parts of the system towards relations, structures and processes. But one of the main fundamental paradigmatic shifts has to do with the notion of growth. While conventional economics understand the economy as a continuous growth function, ecological economics visualizes a steady-state economy (Daly & Farley, 2010).

The approach of common property field to the study of environmental management and social systems has been through the analysis of institutions and the commons dilemma (see previous section about commons dilemma and the further section on institutional approach). The field of study of local, indigenous or traditional knowledge of ecosystems where human groups live in, has a close relationship with common property studies, in the sense, that endogenous rules are crafted according local understanding and belief systems regarding ecological and social dynamics. In this research I take the concept developed by Berkes (1999, 8) about traditional ecological knowledge (TEK): "*a cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment*". By "traditional", this approach "*means an historical and cultural continuity, but at the same time we recognize that societies are in a dynamic process of change, constantly redefining what is considered what is 'traditional'* " (Davidson and Berkes 2003, 12).

The fields mentioned above contribute to the epistemological approach adopted in this research in the task of addressing the relation between human groups and the rest of the natural world, and give solid bases for the conceptualization of social-ecological systems.

2.3 Mental Models

Gaining insight into those aspects of human cognition that underpin preferences, action, and behavior is of great value to the field of natural resource management (NRM). Environmental problems are largely driven by human decisions and actions, as are the strategies designed to address such problems. In the past, NRM researchers have attempted to understand behavior by focusing on stakeholders' attitudes, preferences, and values. These social science constructs, while providing important insights, fail to account for the human capacity to predict outcomes or analyze cause-effect relationships and hence frame their selection of responses.

One of the central issues in natural resource management and evolution of institutions from the perspective of complex adaptive systems are the assumptions of natural and social systems functioning that people hold. What Holling et al. (2002) call the worldviews or myths about nature that people hold, which have implications on policies, institutions and decisions. These perceptions lead "*...to different assumptions about stability, different* *perceptions of the processes that affect that stability, different perceptions of the processes that affect that stability, and different policies that are deemed appropriate*." (Holling et al. 2002). Walker et al (2006) among a set of 14 propositions for understanding change in social-ecological systems, as well as a number of research questions that serve as orienting ideas for a research agenda about change and governance of SESs. Their proposition number 9 is a call for mental models studies because they "*provide the framework for perceiving and judging the direction and desirability of system change*" (8), they states that "*mental models drive change in social-ecological systems, and adaptability is enhanced through partially overlapping mental models of system structure and function.*" (8). They pose two questions; the first inquiries about the forms in which mental models change over time and its influence in the evolution of formal models, governance arrangements, institutions and policies. The second is a question about the importance of knowing the circumstances of strong changes, and its relation with the phases of the adaptive cycle (Holling and Gunderson 2002) at different scales in the panarchy.

2.3.1. Definitions of mental models

The concepts "schemas" and "mental models" have been used to deal with cognitively accessible representations of past experience saved as chains of neuronal circuits. Schemas have been defined as "*subjective theories derived from one's experiences about how the world operates.*" (Markus and Zajonc 1985 in Harris 1994, 310). Harris (1994) complements the definition: "*Schemas serve as mental maps which enable individuals to traverse and orient themselves within their experiential terrain and guide interpretations of the past and present expectations for the future*." (310). In this research I use the concept of mental models due to its operative implications and its use in natural resources and environmental topics by several authors (Moxnes 1998, 2004; Abel et al. 1998, Becu 2006, Walker et al. 2006, Sterman & Booth Sweeney 2007, Biggs et al. 2008), the suggested necessity of understanding the link between mental models and institutions (Denzau & North, 1994, North 2007, and Ostrom 2005), and the role of mental models in SESs gobernance (Walker et al. 2006, and Ostrom 2007, 2009).

Definition of mental models from cognitive science

From the perspective of cognitive sciences I use the concepts developed by authors such as Craik (1943), Johnson-Laird (1983), Gentner & Stevens (1983) and Norman (1983). The doctrine of functionalism has been central in the development of cognitive science. The first author that built a conceptual framework from this perspective was Kennet Craik in his book "The Nature of Explanation" (1943). The research about understanding of human thinking processes was central for this author. Since my interest in this review is the development of the concept of mental models, I take Craik's ideas that conduct to a further conceptualization of mental models in cognitive science. An idea that I see as precursor of the essence of a mental model is: "*Thinking is the manipulation of internal representations of the world*" (Craik, 1943). This statement contains the two essential characteristics of mental model concept, representations and internal manipulation of them. The manipulation of internal representations could include its simulation, as further developments postulate. Craik's concept of model sheds light on the functionalism approach of cognitive science:

> "*By a model we thus mean any physical or chemical system which has a similar relation-structure to that the processes it imitates. By "relation-structure" I do not mean some obscure non-physical entity which attends the model, but the fact that it is a physical working model which works in the same way as the processes it parallels*" (Craik, 1943).

In this way, the author characterized mental processes as concrete procedures that could be mimicked by a computer program. The emphasis in the "function" of the structure and relations of internal models parallelling external models has dominated cognitive sciences at least until late 80s. As Johnson-Laird (1983) wrote "*The computer is the last metaphor; it need never be supplanted*". According Johnson-Laird (1983) people build working models in order to understand the world, but, these models are incomplete and simpler that the external reality they intend to represent. From his perspective the way the mind work is "*intrinsically computational*", therefore, the construction and communication of mental models contents is a computational process. This vision synthetizes the functionalist doctrine position.

Norman (1983) remarks that "*In interacting with the environment, with others, and with the artifacts of technology, people form internal, mental models of themselves and of the things they were interacting with. These models provide predictive and explanatory power for understanding the interaction*." (Norman, 1983, pp 7). In the study of mental models, Norman urges to consider three aspects: the target system, the conceptual model of the target system, the user's mental model of the target system, and the scientist's conceptualization of that mental model.

In words of the author, the conceptual model "*is invented to provide an appropriate representation of the target system*" (Norman, 1983, pp 7). Additionally he remarks that "*mental models are naturally evolving models"* (Norman, 1983, pp 7), by means of interactions with the target system. These models need to be functional, but mental models' construction is constrained by experience, "*and the structure of the human information processing system*" (Norman, 1983, pp 8). The author gives six general observations about mental models; five of them are relevant for this research analysis:

> *(1)Mental models are incomplete. (2)People's abilities to "run" their models are severely limited. (3) Mental models are unstable: People forget the details of the system. (4) Mental models do not have firm boundaries. (5) Mental models are "unscientific"*. (Norman, 1983, pp 8)

The modeling of a mental model can be expressed by distinguishing the target system (t), a conceptual model of the system, $C(t)$, and the user's mental model of the target system, $M(t)$. It is fundamental to differentiate the researcher's conceptualization of a mental model $C(M(t))$, and the real mental model that the researcher thinks a given person has $M(t)$ (Norman 1983). It is necessary to take into account three properties of $M(t)$ and $C(M(t))$: Belief systems, which consists on the beliefs about a given system acquired by observation, instruction, or inference. Observability, that implies that *should be a correspondence between parameters and observable states of C(M(t)) and the observable states of t*. (12). And predictive power, which is rooted in the idea that the objective of any mental model is to permit understanding and anticipation of the behavior of a given system; "*in other words, it should be possible for people to "run" their models mentally* (12). Norman gives a methodological important advice for investigating and modeling mental models: getting much more reliable information depends on the form researcher elicits information. Generally, when people are asked directly for explanations about actions, decisions and behavior, they give answers according to their mental models about researcher's expectations, therefore is much more reliable to ask persons to describe activities rather than explanations.

A formal definition of mental models was carried out by (Holland et al. 1986), which is illustrated in this section. The definition is based on the mathematical structures called morphisms. The authors recognize the main characteristics of mental models mentioned by several authors:

> "*A useful general definition of mental models must capture several features inherent in our informal definitions. First, a model must make it possible for the system to generate predictions even though knowledge of the environment is incomplete. Second, it must be easy to refine the model as additional information is acquired without losing useful information already incorporated. Finally, the model must not make requirements on the cognitive system's processing capabilities that are infeasible computationally*." (Holland et al. 1986, 30).

These authors claim that a mental model is a "*representation of some portion of the environment*" (Holland et al. 1986, 30), in consequence, they argue that it is fundamental to understand the relation between the mental model and the environment. The environment can be represented by a group of states and a transition function, which allows to reach a next state to the system, this is, the transition function tell us how the system's state changes over time. A fundamental task in a construction of a mental model is a representation of such transition function. Homomorphism is the mathematical structure used to conceptualize the mental model definition. Quasi-morphism (q-morphism) is the structure that mental models construct. The mental model is composed by complex multilayered q-morphisms. "*The construction of a q-morphism involves generalization as well as specialization*" (Holland et al., 1986, 36). Figure 2.2 illustrates Hollands' formalization of mental models in which S stands for be the set of states of the environment, S(t) the state of the environment at time t. *O* represents the set of outputs of the cognitive system that act on the environment. The state of the environment at time t+1, S(t+1), is given by T [S(t), *O*(t)]. The next state S(t+1) can be the same regardless of *O*(t). Transition function T, which includes mechanisms and laws that drive the change of the state of the system. P represents a categorization function that translates the detected properties and maps sets of world states into smaller number of model states, and T' is the model transition function that tries to mimic the transition function T of the world.

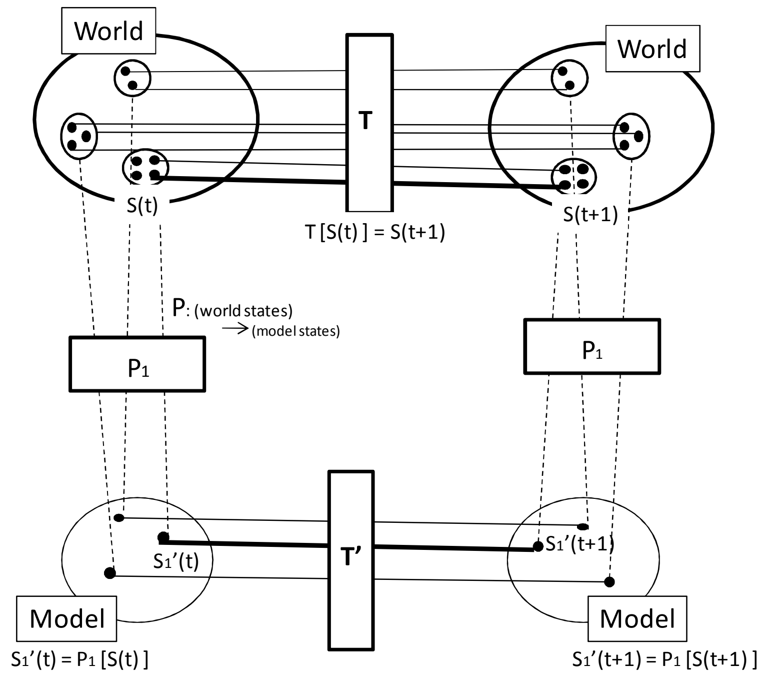

Figure 2.2. Holland's formalization of mental models (Source: Holland et al. 1986)

Gentner and Stevens (1983) contributes to the mental model's definition adding two characteristics. First, the support for mental models is qualitative rather quantitative relations. Second, when persons become familiar with a system, they do not make full mental simulations, but they access to the stored knowledge of the result. The third characteristic is that a person is able to construct and use several mental models for the same system, and they are not necessarily consistent.

Mental models in system dynamics

From the very beginning, during the sixties, when founded by Jay Forrester, based on systems thinking principles, system dynamics domain has used the notion of mental models as one of its fundamental concepts in order to understand human decision making. The field, emerged from the industrial engineering, has had a strong influence in business management, public policy and environmental management. Mental models concept from the perspective of system dynamics has been used in management science (Senge 1990, Sterman 2000), public policy (Vennix 1996), organizational theory (Senge 1990, Morecroft and Sterman 2000) and environmental and natural resources management (Moxnes 2004, Castillo and Saysel 2005). In words of Forrester mental models are pervasive in human activities:

"Each of us uses models constantly. Every person in private life and in business instinctively uses models for decision making. The mental images in one's head about one's surroundings are models. One's head does not contain real families, businesses, cities, governments, or countries. One uses selected concepts and relationships to represent real systems. A mental image is a model. All decisions are taken on the basis of models. All laws are passed on the basis of models. All executive actions are taken on the basis of models. The question is not to use or ignore models. The question is only a choice among alternative models." (Forrester 1971. 4)

According Forrester:

"Mental models are fuzzy, incomplete, and imprecisely stated. Furthermore, within a single individual, mental models change with time, even during the flow of a single conversation. The human mind assembles a few relationships to fit the context of a discussion. As debate shifts, so do the mental models. Even when only a single topic is being discussed, each participant in a conversation employs a different mental model to interpret the subject. Fundamental assumptions differ but are never brought into the open." (Forrester 1971. 4)

Peter Senge developed the mental models concept in his book "The fifth Discipline" (1990) in the domain of organizational development and business management. He defines a mental model as the image that people carry in their head about how the world works, which could be simple generalizations or complex theories, and that the most important propriety is that they determines people's behavior. The issue about mental models is not that they are right or wrong, the relevant question is that they are tacit and belongs to the domain of unconscious mind. Emphasis is done in the fact that mental models can impede or boost learning, as well as their key role in communication.

Doyle and Ford (1999) urges for a standardization of the concept for system dynamics practice "*A mental model of a dynamic system is a relatively enduring and accessible, but limited, internal conceptual representation of an external system (historical, existing or projected) whose structure is analogous to the perceived structure of that system*." (414). But an operational definition is given by the same authors "*A mental model is a conceptual representation of a social problem that can be externalized in the form of a causal loop diagram.*" (414). In a study about public mental models about global warming and green house effect Sterman and Sweeney (2007) give a definition that synthesizes cognitive sciences and system dynamics approaches:

> "*Definitions of the term 'mental model' are many and varied, including domain knowledge, typologies for categorizing experience, and heuristics for judgment and decision making, among others (see, e.g., Axelrod 1976; Gentner, and Stevens 1983; Johnson-Laird 1983; Morgan et al. 2002). As used here, the term 'mental model' includes a person's (often implicit) beliefs about the networks of causes and effects that describe how a system operates, along with the boundary of the model (which factors are considered endogenous, exogenous, or immaterial) and the time horizon considered relevant.*" (Sterman and Sweeney 2007, 215).

The most common representation of mental models in system dynamics has been the causal loop diagrams, which are based in the cognitive maps method developed by Axelrod (1976). Other methods include hexagons (Hogdson 1994), flow diagrams and stock and flow diagrams. The next section offers an overview of the role of mental models on the learning process, conceived as the basic process for decision-making.

Collective mental models

Coping with complex systems such as SESs implies the use of mental models, but also it is needed a way to capture information. Beratan (2007) identifies two processes that use groups of people and individuals: filter and specialization. It is necessary to filter strategically the huge quantity of information that comes from the environment, and to integrated it into a predictive model. Mental models work as filter in this process. The second ability is the specialization, which consists in

> "*the division of cognitive labor among a group of people" and it "serves as a collective strategy for increasing the usefulness of the implicit and explicit predictive models that form the cognitive basis for action…each individual's sub model*

> *contributes to a greater or lesser degree to a collective system model, expressed in part as cultural norms and collective expectations. How well the sub-models are integrated and coordinated is a significant factor determining the effectiveness of collective decisions and actions. Integration and coordination occur primarily by means of interpersonal interactions, and thus governance systems that provide abundant opportunities for face-to-face interactions among both those making and affected by decisions should be more effective over the long run, particularly in times marked by change*." (Beratan 2007, 5)

According to North (2007), common institutional and educational structures create beliefs and shared perceptions. Therefore, a common cultural patrimony entails a mean to reduce divergent mental models among the members of a society, and it is the instrument for the intergenerational transference of integrative perceptions. In fact authors such as Louis and Sutton (1991 in Harris 1994) have defined cultures as "shared schemas".

Risk, uncertainty and perception

It is important to define risk, uncertainty, and perception because they are fundamental concepts to understand the relation between mental models, institutions and management of socio-ecological systems. Human societies face permanent change in their environment and inside themselves. This condition implies important levels of risk in individual and collective decisions and a necessity to deal with uncertainty. In order to structure the environment and have the possibility to preview possible outcomes of their actions, humans build institutions, understood as the set of norms and rules that structure social interactions. According to North (2007), human beings attempt to use their perceptions of the world to structure their environment in order to reduce the uncertainty that embodies their interactions. The institutions restrict and provide prescriptions to human interactions and "*the culture of a society is the cumulative structure of rules and norms (and beliefs) inherited from the past which shape our present and influence our future*" (North 2007). Douglas North offers a clear conceptualization of these terms and their relations.

North (2007) complements the definitions of Frank Knight (1921) of risk and uncertainty. The first, according to Knight, is a condition in which it is possible to infer a probabilistic distribution of outcomes, with the aim to secure against it. Uncertainty is a condition in which there is not probabilistic distribution of outcomes at all. Though this definition of risk is a reduction to a probabilistic problem, it provides a solid base to the problem. A more integral view states that humans have a pulse to make more predictable their environment. Heiner (1983, in North 2007) specifies that there is a gap between the agent’s competency and the difficulty of the decision problem, and humans, facing this gap, will build rules to constrain the universe of options in such uncertainty situations. Beliefs systems and institutions only make understood as a response to diverse levels of uncertainty that humans face. Though the deep origin of institutions has been the human effort to structure the environment in order to make it more predictable, this effort contributes in many cases, to increase the uncertainty. The creation and adjusting of institutions that caused the reduction in the physical environment generated a highly complex social environment with a new set of uncertainties (North 2007).

A more comprehensive vision of uncertainty is given by North (2007,) by establishing five degrees or types of uncertainty:

1. *"Uncertainty that can be reduced by means of an information increase, given the existent flow of knowledge.*
2. *Uncertainty that can be reduced by means of an increase in the flow of knowledge in the existent institutional framework.*
3. *Uncertainty that only can be reduced by means of the modification of the institutional framework.*
4. *Uncertainty in novel situations that entails a restructuration of beliefs.*
5. *Residual uncertainty that supplies the foundations of the "no rational" beliefs."*

As mentioned above, humans use mental models to reason and make predictions about the environment; this is a way to deal with and reduce with uncertainty. One of the sources of information for mental models is what individuals perceive from their environment. Perception is vital to understand how humans acquire information about the environment, but human perception is not perfect. If individuals were capable of perfect perception, perhaps there would not be institutions needed, even facing uncertainty because uncertainty is a function of knowledge (North 2007). The imperfect perception of an individual is defined as an erroneous probabilistic distribution about risk states or the attribution of probabilities to uncertainty states (North 2007). "*In a word of imperfect perception, uncertainty is a function of knowledge and institutions*" (North 2007, my translation). Individual and collective decisions are made in order to affect the environment and solve problems, in turn; decisions are fed by mental models. Since human environment is dynamic and characterized by uncertainty, as it has mentioned above, the resulting effects of such decisions tend to be counterintuitive due to delays in the feedback from the environment and its dynamics. This condition leads to inquiry about the construction of mental models and how they are used to cope with such dynamic and uncertain environment. Denzau and North (1994) point out that:

> *" in order to understand decision making under such conditions of uncertainty we must understand the relationship between the mental models that individuals construct to make sense out of the world around them, the ideologies that evolve from such constructions, and the institutions that develop in a society to order interpersonal relationships*." (Denzau & North 1994)

2.3.2 The general structure of human learning process

The notion of mental models is central to decision making processes. These processes have been linked to learning proceses, therefore mental models are central in learning. It is necessary to comprehend the human learning process to have a conceptual framework for understand how individuals face uncertainty. This necessity is identified by North (2007, my translation): "*It is essential to know how learning is produced in the mind in order to understand how human beings manage uncertainty*". I cite the approaches of John Dewey (in Sterman 2000), Kolb (1984 in Barnaud 2008), Argyris and Schön (1995), Sterman (2000), Holland et al. (1986) and Hayek (1952) because they offer insights regarding mental models formation, decision making and institutions crafting.

John Dewey, philosopher, psychologist and educator born in 1859, could be positioned as a pioneer in the recognition of the feedback character of the learning process at the early beginning of 20th century. He described learning as an iterative process through the cycle of invention, observation, reflection, and action. Since his contribution the interpretation of behavior and learning in the context of feedback processes has been permeated most of the social and management sciences (Sterman 2000). Kolb (1984 in Barnaud 2008) developed a learning theory based in the experience, known as experiential learning. According to this approach, experience is the most powerful individual learning mechanism. He proposed the Kolb's learning loop, which relate action – experiential observation – reflection – cognitive change in a feedback process, showed in figure 2.3.

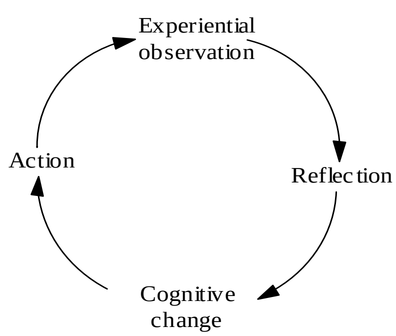

Figure 2.3. Kolb's learning loop. Source: Barnaud (2008)

Argyris and Schön (1995) developed a highly influencing theory that shed light on individual and organizational learning, which take into account feedback processes like Kolb's theory. For the authors, learning includes detection and correction of errors product of individual decisions and unintended consequences for the individual and others. They proposed a first loop of learning, which includes actions, consequences and the feedback as input for the next action. This loop does not imply a change in values, goals or plans. In other words it does not imply a cognitive change, and this is the so called single-loop learning. When the feedback from consequences not only affects the actions and strategies but, what the authors call the *governing variables*, there is a cognitive change more in depth learning occurs, and then the double-loop learning comes out (Figure 2.4.). The authors include three groups of key variables:

> *"<u>Governing variables</u>: those dimensions that people are trying to keep within acceptable limits. Any action is likely to impact upon a number of such variables – thus any situation can trigger a trade-off among governing variables. <u>Action strategies:</u> the moves and plans used by people to keep their governing values within the acceptable range. <u>Consequences:</u> What happens as a result of an action? These can be both intended - those actor believe will result - and unintended. In addition those consequences can be for the self, and/or for others"* (Argyris & Schön 1974).

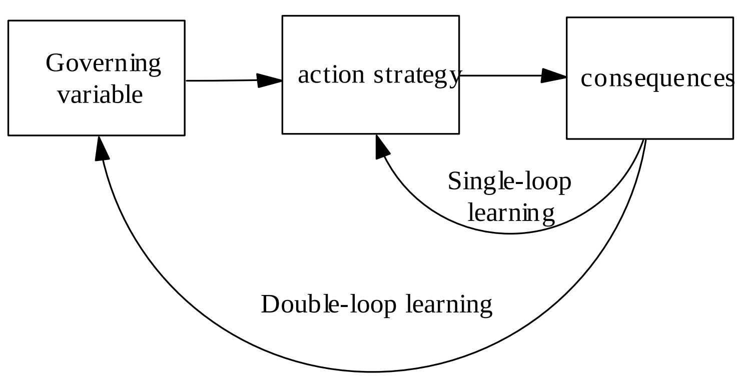

Figure 2.4 Single and double loop learning proposed by Argyris and Schön (1995).

This approach was the base for the model proposed by Sterman (2000) which include explicitly the concept of mental models. Learning and mental models have been central topics in System Dynamics field. Figure 2.5 portraits the simplest learning feedback loop , which is *"a classical negative feedback whereby decision makers compare information about the state of the real world to various goals, perceive discrepancies between desired and actual states, and take decisions that (they believe) will cause the real world to move towards the desired state."* (Sterman 2000).

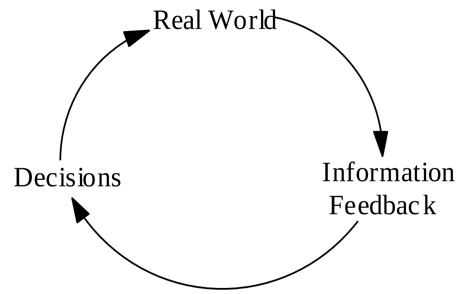

Figure 2.5. Learning as a feedback process. (Sterman 2000)

Feedback information from the environment is not the only input for decisions, policies and decision rules are the other source of information for decisions, in turn, these policies and decisions rules are built according mental models of the real world. While mental models remain unchanged, the figure 2.6A, represents what Argyris and Schön (1996) call the single-loop learning, and are equivalent to the *governing variables* of figure 2.6. As Sterman points out "*single-loop learning does not alter our worldview*". When information from the environment not only is an input for decisions but, for mental models construction the double-loop learning, proposed by Argyris and Schön (1996), is working (figure 2.6B). In words of Sterman (2000):

" information feedback about the real world not only alters our decisions within the context of existing frames and decision rules but also feeds back to alter our mental models. As our mental models change we change the structure of our system, creating different decision rules and new strategies. The same information, processed and interpreted by a different decision rule, now yields a different decision. Altering the structure of our systems then alters their patterns of behavior… and then redesign our policies and institutions accordingly." (Sterman 2000).

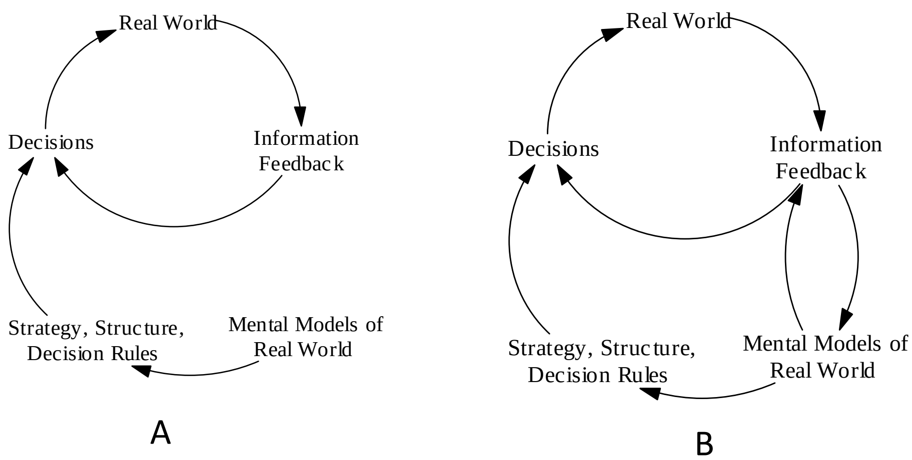

Figure 2.6. A. Single loop-learning. B. Double-loop learning (Sterman 2000).

This approach implies that mental models are characterized, among others, by a high degree of inertia, and that our mental structure is not trained to update information feedback from the environment, at least in a fluent and fast way. The theory gives a high degree of inertia and resistance to change of mental models. In fact, one of the fundamental goals of System Dynamics is to activate the links between information feedback with mental models which would allow designing policies, strategies and decision rules in tune with the dynamics of the surrounding environment. Other authors conceive mental models as continually updated structures. Rules are the building blocks of mental models (Holland et al. 1986).

> *"Learning entails developing a structure by which to interpret the varied signals received by the senses. The initial architecture of the structure is genetic, but the subsequent scaffolding is a result of the experiences of the individual. The experiences can be classified into two kinds-those from the physical environment and those from the socio-cultural linguistic environment. The structures consist of categories-classifications that gradually evolve from earliest childhood to organize our perceptions and keep track of our memory of analytic results and experiences. Building on these classifications, we form mental models to explain and interpret the environment-typically in ways relevant to some goal. Both the categories and the mental models will evolve, reflecting the feedback derived from new experiences: feedback that sometimes strengthens our initial categories and models or may lead-to modifications-in short, learning. Thus the mental models may be continually redefined with new experiences, including contact with others' ideas."* (North 1994, 362 -363)

The previous paragraphs have given an overview of decision making as a learning process in which mental models are central. The next section explains the more relevant aspects of cognitive processes for understanding the role of mental models in human cognition.

2.3.3 Cognitive processes

Theories about brain functioning are relevant for the understanding of mental models formation. Neuroscience researchers have reach a consensus about a connectionist model of brain functioning. In this model, neuronal networks gain experience through the modification of its connection patterns after repeated expositions to the environment. In essence, such networks, form impressions in the same way that an astronomic photography with a long exposition time when it collect passively data trough time. Several expositions to a situation or an object allow neuronal networks to extract regularities from the environment, and these regularities are stored in stable connection patterns (Donald 2001, in North 2007). According this model it is possible to say that the brain works according a reasoning based on patterns, which are essential to explain decisions in an uncertainty world. According to North (2007), this way of brain functioning has several consequences for human cognitive processing. Firstly, humans are efficient in understanding if the situation is highly similar to other past events occurred in our experience. Secondly, it is difficult to include into one's culture strange mindsets, not grounded in the norms developed in one's own culture. Thirdly, people perceive, remember and understand through pattern comparison. This is the key of our ability to generalize and to use analogies. Such capability allows people, not only to model the world, but also to build theories in order to face uncertainty. And fourthly, the discovering of patterns where they do not exist is coherent with the pervasive human effort for make theories or dogma to explain the world even when there are no scientific explanations. Therefore mental models are built, based on patterns and regularities in order to explain and predict.

The study of human cognitive processes, that is, the way in which "*the human brain absorbs information, recognizes and frames problematic situations, and causes appropriate responses*" (Beratan 2007, 2), has still a significant gap between the knowledge about the biology of the brain and the outcomes or products of brain activity, such as memory and decision making. In spite of such gap, the current knowledge offers enough elements for interpreting and explaining individual and collective behavior. There is consensus about the biological fundaments of thinking and memory, which are neuronal circuits arranged in neuronal patterns of connections. Experience entails the activation of neuronal networks, and thinking processes consist of dynamic of pattern connections of neurons (Beratan 2007).

Neuroscience researchers have identified two mechanisms of memory, which help to link mental models building and behavior of persons. These are implicit and explicit memory. The first implies forms of memory marked by emotions, behavior, perceptions and body or somatosensorial aspects (Siegel 2001). The second, explicit memory is activated by slow learning of regularities from repeated experiences (Smith & DeCoster, 2000). "*Both type of memories are stored as patterns of neural connections; whenever one part of the pattern is activated (by sensory input, for instance) activation spreads through the whole interconnected set of neurons. These connections are strengthened with use.*" (Beratan 2007. p. 3). The link between mind and memory, and individual decision making have been represented by a "dual process model" (Chaiken & Trope 1999) of cognition. This model involves two parallel process of reasoning: nonconscious and conscious processing forms. Nonconscious mode utilizes implicit memory, and is automatic, "*and thus contextualizes the current situation in light of background beliefs and knowledge that reflect the learning history of the individual*" (Evans et al. 2003). Decisions made in this mode are based on the assumption that the outcomes of a given decision are going to be similar to the ones in similar situations in the past. The processes that belong to the consciousness domain are actions of which the individual is aware, and they are effort demanding and susceptible of control. This processing allows persons to cope with novelty and figure out new strategies for dealing with problems in the long run. (Beratan 2007).

A common description of a decision making process is when individual engages in a deliberation process among several possibilities. If the situation is like past ones, the nonconscious mind tests the situation against saved past ones, and chooses an option that has worked in the past. But if there are no coincidences with saved patterns, the mind starts to test hypothesis for different options. Then, the outcome of the process is saved as experiential knowledge for future use by the nonconscious mind (Beratan 2007).

Current neuroscience research has found that this is not the functioning of the cognitive basis of behavior; instead there are non-linear processes of emergence (Beratan 2007). The mechanisms can be described as follows: First of all, a pattern of neurons representing the desired outcome is activated. Second, this pattern interacts with other patterns that represent perceptions of current conditions triggering "*a cascade of neural activity, shaped by connections formed through past experience*" (Beratan 2007 p. 4). Third, a new pattern emerges that guides the actions. This process emerges from non conscious cognitive processing. And, very important is the fact that the conscious processing comes up when the individual is asked to explain decisions or actions. In this point a logical rationale for the decision made is constructed (Beratan 2007).

But the brain keeps a high number of "*potentially relevant stored patterns formed as a result of past experience*" (Beratan 2007, 4). The way persons react to specific situations depends on which neural pattern is activated. Neuronal pattern activation belongs to the domain of non conscious process. Patterns are activated by any sensory input, "*contingency has a strong impact on the emergent pattern*" (Beratan 2007. p. 4). If this explanation of behavior generation is plausible, then "*It is likely that many "heuristics", rather than being logical decision rules (even "boundedly rationale" ones), are actually patterns of neural connections that retain a record of general regularities encountered through experience*" (Beratan 2007, 4).

The following section reviews the importance and use of the mental model notion in governance of SESs.

2.3.4 Mental models and governance of SESs

The concept of mental models have been studied in natural resource management by Moxnes (1998, 1998b, 2004) in the study of reindeer and fisheries decision making and management in Norway, Sterman (2002, 2007) in the study of public understanding of global warming process, Becu (2006) in a research about the local management of watersheds in the north of Thailand, Abel et al. (1998) studying the role of mental models in communication among researchers, extension officers and pastoralists about resources management and ecosystem's functioning in Australian rangelands. Denzau and North (1994) also stresses the importance of communication in order to build collective shared mental models. Bigss et al. (2008) reports the results of the study carried out as a consequence of the discussion in the Resilience Alliance meeting of 2006 about the effect of different stakeholders' mental models have, on natural resource use and management, and on resilience of social-ecological systems. The project was conducted in South Africa, aiming to illustrate a practical example the importance and relevant methods for understanding mental models. Mathevet et al. (2011) stressed the importance of mental models in water management in Camarge biosphere reserve in the south of France. Stone-Stone-Jovicich et al. (2011) applies consensus analysis, an anthropological method to asses mental models of stakeholders about water management in a watershed in the South Africa. Etienne et al. (2011) presented the ARDI method, developed in collaboration with Green researchers of CIRAD in France, to construct representations of stakeholders' mental models of SESs. Du Toit et al. (2011) used mental models for negotiation processes in water management in South Africa. And, Jones et al. (2011) carried out a complete review of the concept in relation to natural resources management.

Denzau and North (1994) and North (2007) have stressed the link between mental models and cognitive processes and institutions. Individuals design rules as a way to structure the surrounding environment; in turn the cognitive systems of individuals create mental models, which are representations of the external environment with the objective to interpret it. The human environment is a construct of rules, norms, conventions and forms of doing things that define the human interaction framework (North 2007). Therefore, the way in which individuals and human groups interact with ecosystems necessarily have to do with rules and mental models. In this sense Ostrom (2005) extends this relation to common pool resources, she uses an adapted version of the framework proposed by Denzau and North (2000), to explain the relationships between information, decisions and mental models, for explaining the central aspects of institutional analysis regarding individual and collective information processing in institutional dynamics. The multitier framework, developed by Ostrom (2007, 2009), aiming to link the local context and institutional and policy design in SESs, includes mental models as one of the key variables to be understood for sound governing of SESs.   This proposal is called the sustainability framework, which will be presented in the section 2.5 of this chapter. In the next section I present a revision of the concepts of institution and the analytical framework for its analysis in the context of SESs

2.4. Institutional Analysis and Development (IAD) framework

The approach adopted for this research is the one developed in the New Institutional Economics, which origins are usually attributed to Coase (1937). It is from 70s that the field started to call the general attention, and from 1991, when Coase won the Nobel Prize, followed by Becker (1992) and North (1993), the field reached its maturity. The approach was positioned as the studies of a group of economists and science policy scholars concerned about the relation between institutions and individual behaviour, as well as the form in which such institutions shape productive and exchange activities (Hauditier 2007). But it is until 2009, that the attention is given on the development of the neo institutional approach in the field of natural resource management and concretely in common pool resources governance, with the awarding of the Nobel Prize to Elinor Ostrom.

In brief, according Acheson (2006) the neoclassical economics conceives individuals as rational agents that perceive perfectly the environment. It is assumed that knowledge of goods is enough to make decisions in the competitive markets exchange. Institutions are not considered to have an important influence in markets and decisions, or they constitute obstacles and constraints to the invisible hand of the economy. In turn; scholars belonging to the new institutional economics stream assume that individuals have bounded rationality and that information acquisition has high costs. Assumptions include also that individuals exhibit opportunistic behaviour, and different moral systems. It is assumed that institutions are the result of political processes, and that they affect the behaviour of individuals, and that they have an important influence on markets efficiency and wealth generation. In line with these contributions, Acheson (2006) defines a research program of five main topics for the new institutional economics: 1) Institutions, property rights and their effects on economic performance, 2) the conditions for collective action, 3) the relation between rules and real interactions among actors, 4) the development of different types of firms and markets in capitalists societies, and 5) explanation of institutional development through time.

The Institutional Analysis and Development (IAD) (Ostrom et al. 1994, Ostrom 2005) is one of the academic developments inside the New Institutional Economics that has been used to study the problem of CPR management. In this section I, first, give the definition of institutions according the mentioned school, and then develop the aspects of the IAD framework that will be used and discussed in this study.

2.4.1 Definition of institutions

In line with authors such as North (1990), Ostrom (2005) and Janssen (2002) humans design rules in order to relate with the environment and these institutions are designed according perspectives of the world. North defines institutions in this way:

> "*The institutions are the rules of the game in a society or, more formally, they are the constraints created by people that shape human interaction. Therefore, they structure incentives in human exchange, political, social or economic. Institutional change is the way in which societies evolve through time; hence it is the key for understanding the historical change*." (North 1990, 13, my translation)

Institutions define and constrain individuals' decision making, and have an important characteristic which is that the enforcement, monitoring and sanctions are costly not only in monetary terms, but in social terms. To know human organizations means to analyse governance structures, institutions, capabilities and learning, which will determine the success of the organization. The principal function of institutions is to reduce uncertainty creating a more stable structure, which does not mean an unchanged structure, in fact they are in permanent change (North 1990).

For Ostrom the set of rules and norms that people use to relate themselves with the ecosystems constitute the institutions which are defined as *"the prescriptions that humans use to organize all repetitive and structured interactions ... at all scales. Individuals interacting within rule-structured situations face choices regarding the actions and strategies they take, leading to consequences for themselves and for others."* (Ostrom 2005, 3). Janssen (2002) points out that

> "*Institutions are made up of formal and informal constraints. Formal constraints are rules, laws, and constitutions. Informal constraints are norms of behavior. Institutions often react to surprises by adding additional rules to repair external effects. New rules can be added in a relatively brief time, but changing or removing rules is usually a slow process.*"

Davidson-Hunt and Berkes (2003) remark that the set of rules, which form an institution is a fundamental link between social and ecological systems. Institutions are a construct that evolves along with social collectives and, in the case of the relation with ecosystems, they may or may not evolve with them. Rules and norms are part of the strategies that society develops for adapting to change. As Ostrom (2005) states "*Rules can be thought of as the set of instructions for creating an action situation in a particular environment [...]Rules combine to build the structure of an action situation*".

It is important to establish the differences between rules, norms and strategies. Ostrom (2006, 2) defines the terms in this manner: rules are "*shared prescriptions (must, must not, or may) that are mutually understood and predictably enforced in particular situations by agents responsible for monitoring conduct and imposing sanctions*". Norms are "*shared prescriptions that tend to be enforced by the participants themselves through internally and externally imposed costs and inducements.*" And strategies are "*regularized plans that individuals make within the structure of incentives produced by rules, norms and expectations of the likely behavior of others*"

Rules in use are the things that people do and the ones that don't, which are learnt in everyday life, and that may be contradictory with rules written in formal documents (Ostrom 2006). The rules in use could include rules, as defined above, and norms.

2.4.2. The Institutional Analysis and Development Framework (IAD)

The IAD framework is aiming to guide the analysis. It helps to identify variables and relationships needed to carry out the study and evaluation of institutional arrangements. The framework constitutes a meta theoretical language for comparing theories. In this way the framework contribute to pose relevant questions according to each case (Ostrom 2006). The usefulness of a guiding framework is that different theories can be used depending on the type of problem and specific context. At broader scale it is possible to start the description of the framework by a central element, which will be discussed in detail below; the *action arena.* Figure 2.7 illustrates the general framework. The action arena depends on a group of exogenous variables composed by three sets of variables: biophysical, community and rules. These three groups determine the action arena, which produces interactions that in turn generate outcomes. The framework jointly with theories used could make predictions of outcomes. The outcomes, in turn feeds back the exogenous variables and the action arena structure. Outcomes could be evaluated by several criteria depending of the interest of the study; such as: economic efficiency; equity; adaptability, resilience, and robustness; accountability, and conformance to general morality (Ostrom 2005).

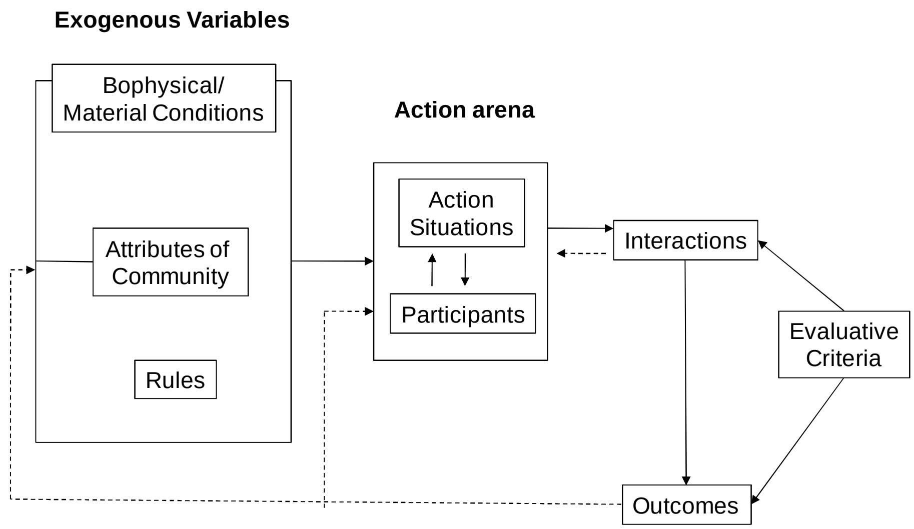

Figure 2.7 Framework for institutional analysis (IAD). Source: Ostrom (2005).

The action situation

A central concept is the *action situation*, which is the Focal Unit of Analysis of the Institutional Analysis and Development (IAD) framework (Ostrom et al. 1994, Ostrom 2005) that will be utilized as part of the analytical framework of this research. An action situation is then defined according Ostrom (2005, 32) in this way;

> *"Whenever two or more individuals are faced with a set of potential actions that jointly produce outcomes, these individuals can be said to be "in" an action situation. Typical actions situations include: [...] users of a common-pool resource withdrawing resource units (such as fish, water, or timber)".*

In turn, an action situation is structured by a set of variables which are:

"(1) the set of participants, (2) the positions to be filled by participants, (3) the potential outcomes, (4) the set of allowable actions and the function that maps actions into realized outcomes, (5) the control that an individual has in regard to this function, (6) the information available to participants about actions and outcomes and their linkages, and (7) the costs and benefits-which serve as incentives and deterrents-assigned to actions and outcomes." (Ostrom 2005, 32).

The action situation in which a human group that highly depends on a common-pool resource is immersed has the natural ecosystem, not only as necessary action scenario, but as set of subsystems that necessary influence at different levels the variables mentioned above. Figure 2.8 portraits the variables and relationships among them that structure an action situation. The variables induce a number of questions that should be answered in order to start the analysis:

"-The set of participants: Who and how many individuals withdraw resource units (e.g., fish, water, fodder) from this resource system?

-The positions: What positions exist (e.g., members of an irrigation association, water distributors-guards, and a chair)?

-The set of allowable actions: Which types of harvesting technologies are used? (e.g., are chain saws used to harvest timber? Are there open and closed seasons? Do fishers return fish smaller than some limit to the water?)

-The potential outcomes: What geographic region and what events in that region are affected by participants in these positions? What chain of events links actions to outcomes?

-The level of control over choice: Do appropriators take the above actions on their own initiative, or do they confer with others? (e.g., before entering the forest to cut fodder, does an appropriator obtain a permit?)

-The information available: How much information do appropriators have about the condition of the resource itself, about other appropriators' cost and benefit functions, and how their actions cumulate into joint outcomes?

-The costs and benefits of actions and outcomes: How costly are various actions to each type of appropriator, and what kinds of benefits can be achieved as a result of various group outcomes?" (Ostrom 2006, 7)

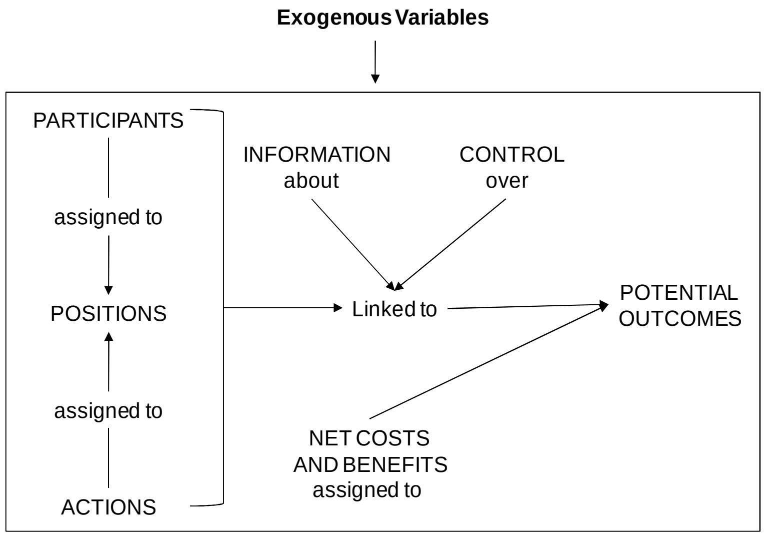

Figure 2.8 Internal structure of the action situation (Ostrom 2005, 33)

The action arena is then, a dependent variable of the state of the system, the characteristics of the community and the system of rules, which in turn, produces certain outcomes depending on the values and configuration of these variables in a given circumstance. A group of people are immersed in different action situations in their daily life, for example a fishery community face a unique action situation when they are fishing in the sea, but it could change when they are in a meeting of the local fishermen association, as well as in their individual household context.

The outcomes of the action situation are strongly influenced by norms and rules. Norms and rules, as already mentioned, structure interactions in an action situation and allow making predictions on the outcomes. Norms are viewed by several scholars as the internal valuation that actors give to actions and outcomes, and they include in formal theoretical models of payoff functions explicit parameters to represent intrinsic values or other regarding preferences different to external values. The level of impact of a norm on behavior depends on the force of the norm and the context of the action situation (Ostrom 2005). The same author define norms as

> "*prescriptions held by an individual at an action or outcome in a situation must, must not, or may be permitted. Norms can be represented in formal analyses as a delta parameter that represents the intrinsic benefits or costs obeying a normative prescription in a particular situation.*"(121)

In this way, one can consider formalization of the payoff function for the traditional *Homo economicus* as being the internal and external values of actions and actions equal, therefore it would not have a parameter representing a social norm of reciprocity for example (Ostrom 2005). But in real action situations generated in commons local dilemmas it is needed to recognize the heterogeneity of actors. Not only that some actors are representative of the *Homo economicus* and others are strong reciprocators and other types behavior, but that a individual can be a mix of several types of behavior in different action situations. Of course the consequences for institutional analysis are important, as (Camerer 2003) explains it "*Institutional arrangements can be understood as responding to a world in which there are some sociopaths and some saints, but mostly regular folks who are capable of both kinds of behavior*" .

Crawford and Ostrom (1995) developed what was called a grammar of institutions, which has been presented as integral part of the IAD in Ostrom (2005) and included as one of the elements to build a complexity theory for sustainability by Norberg et al. (2008). This approach contributes to clearly define norms, rules and strategies through an institutional grammar (AD*I*CO). A set of general actions to classifiy the actions is defined:

> *"A-Attributes of the person(s) involved,*
>
> *D-wether a Deontic operator-a must, must not, or may-is involved,*
>
> *I-the aIm of an action,*
>
> *C-the Conditions involved, and*
>
> *O-wether or not there is an Or else-a punishment."*
>
> (Norberg et al. 2008, 59)

Therefore, a *strategy* is of the type A*I*C, and describes what actors try to achieve (aim or purpose). A *norm* includes *ADI*C, and it is formed by adding a deontic principle and a condition, and a *rule* is formed by AD*I*CO, what means that the rule includes a consequence for not following the rule. If the description of strategies, norms and rules are written consistently in this way it is easier to compare institutions in diverse settings, providing a useful tool for analyze institutional evolution (Ostrom 2005).

For understanding the role of rules in the outcomes of the action arena I use the ADICO grammar of rules (Ostrom 2005). Analyzing rules by looking at their building blocks helps to characterize the institutional statements and define what role they are playing in the action arena as rules, norms or shared strategies. This analysis is done "to discover the linguistic statements that form the institutional basis for shared expectations and potentially for the observed regularity in behavior. Essentially, this entails discovering which of the components exist in these statements and the contents of those components" (Ostrom 2005: 171). The components that form the ADICO are: Attributes, Deontic, Aim, Conditions and Or else. According to the content of an institutional statement a rule has the five (ADICO) components, a norm has four (ADIC) and a shared strategy has three (AIC). For example, a prescription for extracting timber from a forest could be:

In order to guarantee the replacement rate of the forest, users from a given community cannot harvest trees with trunks of a diameter less that 20 cm, if a logger is caught cutting trees of minor diameter, she must pay a fine.

The Attribute component of the prescription is all the individuals of the community that use the forest. The Deontic component is that users *cannot harvest trees with trunks of a diameter less that 20 cm*. The Aim component would be: *In order to guarantee the replacement rate of the forest.* The Conditions in this statement are not explicit but, indirectly they are present; the statement applies for the forest used by this community, meaning the area where the statement applies. The Conditions also include the time in which the prescription applies, in this example, since it is not explicit; the temporal default condition is all the time. The Or else condition in the example is: *if a logger is caught cutting trees of minor diameter, she must pay a fine*.

This system can be use also to do a classification of rules, which is fundamental to understand the way in which institutional arrangements affect an action situation. In order to understand the rules in use I use the AIM rules classification approach, which consists in the classification according the AIM of the rules. The AIM element of a rule is the "specific description of a working part in an action situation to which an institutional statement refers" (Ostrom 2005: 148). Classifying rules through this sorting mechanism allows studying generative and regulatory rules, and also is useful for the three levels of the IAD framework (Ostrom 2005). Seeing rules through the AIM element it is possible to classify them in seven types according to their influence on the action situation. These categories are: position, boundary, choice, aggregation, information, payoff and scope rules. They are explained below.

Position rules affect the number of participants in a position. This includes the lower and upper limits or the absence of limits.

Boundary rules prescribe who are the participants and how to enter and exit the action situation. These types of rules specify: who is eligible to enter a position, the process that determines which eligible participants may enter (or must enter) positions and how an individual may leave (or must leave) a position.

Choice rules regulate the actions that each participant can carry out according to a given position. They specify the required, allowed and forbidden actions, "by widening or narrowing the range of actions assigned to participants, choice rules affect the basic rights, duties, liberties, and exposures of members and the relative distribution of these to all." (Ostrom 2005: 201). In synthesis, these types of rules distribute the power among participants in a given action situation.

Aggregation rules aim to solve the problem of how to decide what participant in which position has to act.

Information rules intend to regulate the information available to participants in the action arena; they define channels of information and the possibilities of communication among participants. These rules are relevant to inform about past actions of participants. Information rules can define the channels of information flow, the frequency and accuracy of communication, the subjects of communication and the official language.

Payoff rules assign rewards or sanctions to given actions by paying or receiving something of value. Therefore these types of rules affect the costs and benefits of the action situation. Scope rules define the number of the state variables affected; they influence the outcomes of an action situation. In fact the objective (AIM) of these rules describes an outcome rather than an action.

A general classification includes Position, Boundary, Choice, Aggregation, Information, Payoff, and Scope rules. Figure 2.10 illustrates which variables affect each type of rule.

In the context of SESs institutional arrangements pose a big challenge in terms of SES's governance. Since ecosystems are not stable Holling and Gunderson (2002) and environmental change needs to be faced, institutional arrangements are to be designed accordingly. Diversity and complexity in ecosystems and the society is pervasive, consequently institutions must function in the same language. The above approach offers a framework that contribute to understand and give policy reccomendations for achieve sound SESs gobernability.

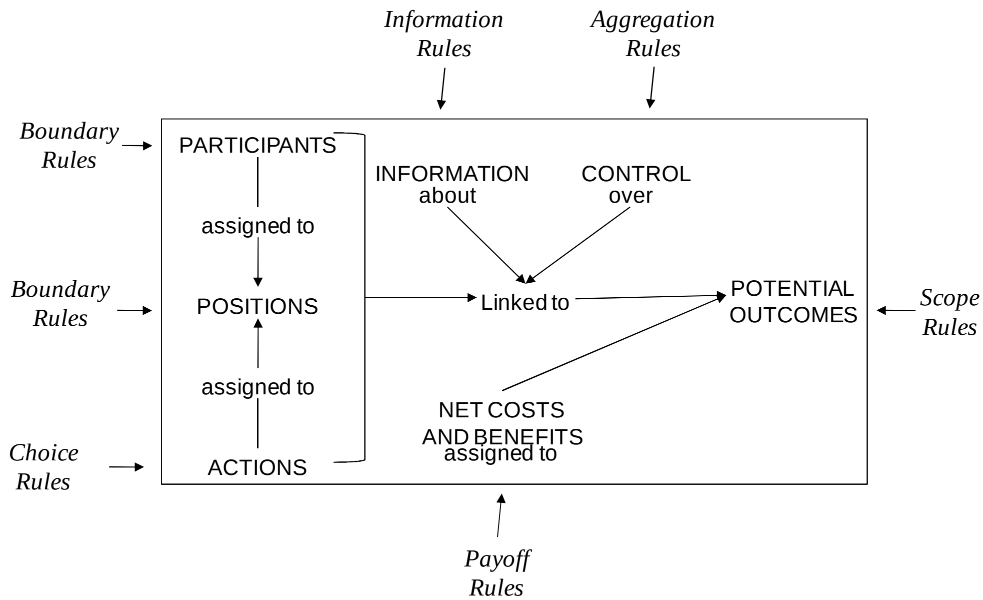

Figure 2.10 Different types of rules affecting the elements of an action situation (Ostrom 2005, 189).

I analyze the institutions using two approaches: (1) the AD*I*CO building blocks, which gives information about rules, norms and shared strategies being used in the action arena, and (2) the A*I*M component of the institutional statement for giving information about what components of the action situation are being affected by which rules.

The action situation and space

Action situations happen in geographical spaces and institutions, social, cultural, economic and ecological dimensions structure them. In turn, the outcomes of action situations usually affect variables in the geographical space, this is, they affect and transform in different forms the ecosystems and in a more general perspective the geographical space. In this dissertation the concept of action situation will be used as one of the main units of analysis of interactions of actors in each case study.

Social and natural dynamics, spatial laws and history produce the geographic space. While landscape is produced by natural dynamics and the territory is generated by the history. Landscape and territory are mental constructions and individual social representations (Brunet, 1990). The space generates the territory, which is the result of an action carried out by an actor who exerts power in order to own a space, this is; the actor territorializes the space (Raffestin, 1980). The territory is the place including actors and their attributes (Laurin et al. 2001). The territory is defined by Debarbieux (1995) as the product of the agency of material and symbolic resources that structure the practical conditions of individual and collective existence. This agency process feeds back this social group and the individuals about their identities. Therefore, the territory has a double dimension: material and ideal. As a consequence the territory is a form of appropriation of the space. The territory is also spatial configuration, which entails the definition of a bounded unique entity where different actors exert the power. This spatial configuration is the place where the interaction among different scales converges. Is in this sense that the territory becomes a spatial form of the society (Retaillé, 1997). Hence, the territory stays open, and adapts to every spatial combination that emerges from human interactions, in terrestrial surface and individual experience (Di Meo, 2001). Territory becomes then a concept completely plastic open to contemporaries mutations. The territory is a social construct that mediates social relations, and its existence is possible thanks to a tacit or explicit agreement, imposed or consented, among the members of a community. In addition to that, the territory carries the values of the social group that lives in, and allows the development of an individual and collective identity (Velasco-Graciet, 2006).

The action situation and mental models

Actors immersed in an action situation make decisions according to the internal variables of the action situation itself, the external set of variables, and the previous outcomes. Therefore, in order to understand and have predictive elements for different types of outcomes it is necessary to have assumptions about components of human behavior. A useful starting theory is constituted by the assumptions of rational choice theory that establishes three elements. The first, is about information utilization, and includes its acquisition, processing, representation and storing. The second element is the question of the valuation that actors in an action situation give to the action and outcomes. And third, the ways in which actors have to choose strategies having into account the resources available (Ostrom 2005). Many assumptions could be made for each of these elements, as well as numerous theories give different assumptions about each one. Ostrom (2005) recommends focusing in one of the elements at a time regarding the assumptions to adopt.

Ostrom (2005) locates mental models under the first component of choice theory the use of information in terms of obtaining, processing, representation, storing and utilization.

Frohlich and Oppenheimer (2002 in Ostrom 2005) argue that a situation has two relevant aspects; salience and vividness. Salience is “*the degree to which an element is linked to possible changes in the welfare of the decision maker*” (107). And vividness is the “*amount of quality of the sensory details of the objects encountered*” (107). These are the fundamental characteristics of the information to which actors are exposed in an action situation. The information is perceived by the person and it is filtered by the mental model, which process and represents such perceptions in order to choose possible actions to carry out. Figure 2.9 portraits the role of mental models in the action situation. Mental models are fed by a minimum of two sources of information; feedback from the external environment and shared culture or the belief system in which an individual is immersed (Ostrom (2005). Once chosen actions are carried out, they lead to actual outcomes, and then information from the external environment is perceived and if expected outcomes are different from actual ones, then the mental model is revised.

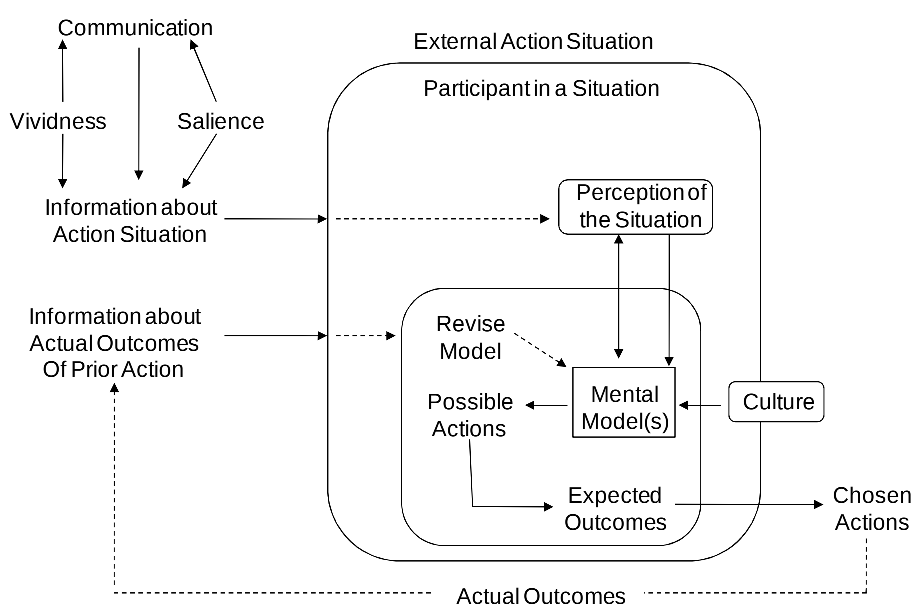

Figure 2.9 The role of mental models in an action situation (Ostrom 2005, 108)

If mental models belong to the first component of rational choice mentioned above; use of information, strictly, behavior is in the third element; the strategies that lead to concrete actions. Multiple theories of human decision making exists being the most popular and common used the neoclassical *Homo economicus*, whose main characteristics are: self-interest, outcome oriented, he always maximizes his own wealth, has discount rate that privileges the short term, and full capacity of information processing (Gintis 2000). These characteristics do not pose any problems in environments as competitive perfect markets with complete information, but out of this world it seems not to resemble the way most of persons behave. People in strategic situations are cooperative and pro social, they behave more as *Homo reciprocans* being strong reciprocators. They cooperate when others cooperate, but people punish others if they defect even if the punishment is costly (Gintis 2000, Gintis et al. 2003).

General moral conformance as evaluative criteria of the action situation's outcomes

Though necessary, mental models are not enough to know the reasoning behind people's decisions. Mental models are strongly influenced by cultural and moral systems; therefore it is necessary to revise the notions of morality. Evaluative criteria are essential in the analysis of the outcomes generated by the action arena. These criteria are defined by the objective of each study; in this case the investigation has been oriented to explore levels of trust, cooperation and rule compliance. These variables are a function of the general morality conformance constructed through time in a community and the different action arenas in which common pool resources users are embedded could constantly reinforce that. A given set of institutional arrangements could promote a moral system in a particular action arena (Ostrom, 2005). Therefore a conceptual body is needed to interpret these outcomes. In this section I revised the conceptual state of the art in morality studies and discuss a conceptual framework useful to interpret the action arena's outcomes.

From the economics perspective, traditionally the outcomes of actor's decisions have been studied with the utility concept, which put all the importance in the results and its net benefits for the actor. Frey et al. (2004) contested this concept arguing that people is not guided only by the outcomes utility but also by the *procedural utility*, meaning that "*people not only value actual outcomes, i.e., the* what, *but also the conditions and processes that lead to these outcomes, i.e., the* how." (377). The authors emphasize that procedural utility is an essential factor for human well-being. Questions about the fairness of the processes to reach an outcome, and the easiness of rule breakers to reach high payoffs among others, are central to evaluate the results of action arenas. This vision brings the issue of the morality in the processes to reach outcomes.

Morality is fundamentally a personal decision, which corresponds with the notion that each individual has about her life, and the public and private issues. However, this does not mean that moral principles are absolutely relative and depend on each individual, on the contrary there are some minimum principles that each human being has genetically programed as part of her evolutionary inheritance. Scholars from the moral psychology field claim that humans have developed a “moral instinct” independently of gender, education, culture and religion (Hauser, 2007).

The morality issue is at the center of cooperation mechanisms, which in turn is fundamental in the management of CPR. One of the mechanisms that produce important levels of cooperation is reciprocity understood as the behavior in that a person cooperates if the other person cooperates. This mechanism contributes to individual reputation building and requires of two conditions: availability of good information about the others’ actions (Nowak & Sigmund, K, 1998), and capacity to punish people with bad reputation, even scarifying individual benefits, what is called “altruist punishment” (Nowak, 2006). According Nowak (2006) there are five mechanisms that have contributed to the evolution of cooperation: Familiar selection, direct reciprocity, indirect reciprocity, network reciprocity, and group selection. The basis of these mechanisms can be explained with the notion of the evolution of the “moral instinct”, and that the evolutionary selection has occurred not only at individual level but also at group level (Haidt & Kesebir, 2010). The need of eliminating the individual selfishness in groups contributed to morality development during last 10.000 years. But this morality not only has to do with the principles of harm, rights and justice that protect the individuality; it is a broader morality that has to do with collective interests, and reinforces the idea about moral values strengthening human groups. Scholars have proposed five hypothetical basis for morality: 1) Harm and care, 2) Justice, fairness and reciprocity, 3) In-group loyalty, that has to do with the membership duties, self sacrifice and monitoring of possible defection, 4) Authority and respect, related with the social order and the obligations of hierarchical relations such as obedience, respect and the compliance of duties according to a role in the group, and 5) purity and sanctity, concerned with physical and spiritual values such as chastity, integrity, and desired control (Haidt, 2007; Haidt & Kesebir, 2010).

The field of moral economy explores the quiet resistance of peasant societies facing the structural mechanisms of domination. Authors such as Thompson (1971) and Scott (1977, 1987, 1992) have studied the characteristics of the resistance in the popular discourse. Scott's work has focused in the Asian Southeast but has had an important influence in the Third World countries. The approach integrates the historical analysis, the perception that communities have about themselves, and remarks the politic and cultural characteristics that link the economic structure and collective action in rural and pre capital societies. With these elements moral economy studies the way these societies face the subsistence challenge and express economic criteria through moral normative content (Floréz 1991). Moral economy studies the patterns of the shared norms expressed in rights and duties of dominant and subordinate human groups, and how these systems built the foundations for a rebellion collective action without coordination in most of the cases. Therefore, this dynamics originates a shared moral universe, meaning a common notion of fairness. In this type of analysis there are two important principles: 1) Reciprocity norms, which is the basis for the interpersonal behavior, and 2) Subsistence rights, that define the minimum needs to satisfy by the community members in the context of reciprocity (Floréz 1991). This form of distinction between legitimate and illegitimate practices emerges from a consensus about an ideal past that has the power of inspire collective action in the present (Arnold 2001). From this perspective legitimacy is embedded in the notions of "shared moral universe" (Scott, 1977) or "shared way of life" (Ramsay 1996). Arnold (2001) proposes a redefinition of the field. One of his points is that the ideas of universals and shared systems do not allow observing the different sources of common legitimacy in a given moment, hiding the reasons of communities for choosing different groups of legitimizing rules.

The author proposes a moral economic political analysis based on social goods such as water or in general common resources that communities are highly dependent on. Arnold (2001) argues three reasons: 1) the notion of social goods is not limited to time and culture, these goods and their moral economies are present in pre-modern and modern societies. The issue of resistance is only one dimension of moral economies. 2) Social goods and moral economies are not only the general moral economy, there are several systems functioning at the same time. In words of Arnold, they are plural not singular. And 3) moral economy is at the core of specific and dynamic social relations, not in static, generalized and mechanistic moralities, or romanticized pasts. This conception of moral economy contributes to evaluate the outcomes of the action arena in terms of the general morality conformance, specially the notion of moral systems based on social goods that can be classified as common pool resources.

Individual and collective moralities are fundamental for reaching or not high levels of cooperation and trust, regarding common resources management. Moral systems are linked to culture; therefore it is necessary to relate culture with natural resource management. Pahl-Wostl et al. (2008) proposes a useful framework to explore the role of culture and morality in natural resource management. Morality offers value judgments about what is morally acceptable or not about specific situations (Pahl-Wostl et al. 2008). A cultural framework includes "*ideas, and ideals (values, attitudes, beliefs, norms) and traditions and institutionalized social practices (e.g. behavioral rituals, language, rules, legal practices)* (Pahl-Wostl et al. 2008: 488). In terms of outcomes two levels of morality conformance are identified: (1) normative and generalized beliefs that describe the particular judgment of a given action in the case of the first, and the connection between an action and an effect but without a value judgment. (2) I call second level of general morality conformance with three sources of behavior regulation; moral, cultural and legal. The criteria for classifying types of behavior into moral, cultural and legal groups arises from the detailed field observations carried out in each of the three case studies of this investigation. The examination of these three sources contributes to understand the "gap between law, morality and culture" (Mockus 2002) for explaining the relation between behavior and rules.

General morality conformity could be understood as the ultimate consequence of the levels of cooperation and trust present in the system, or a condition for outcomes. This is one of the issues I will explore in this research. Morality is understood as the value judgments about what actions are right or wrong in this particular action situation. The concepts of normative and generalized beliefs help to interpret the answers to the questions posed by Ostrom (2005: 67), when discussing general morality outcomes:

> "*Are those who are able to cheat and go undetected able to obtain very high payoffs? Are those who keep promises more likely to be rewarded and advanced in their careers? How do those who repeatedly interact within a set of institutional arrangements learn to relate to one another over the long term? Are the procedures fair?*"

A fundamental condition for rule compliance is their legitimacy among the members that cover the Attribute characteristic. But the legitimacy is a function of the perception by individuals of the rule’s fairness. The AD*I*CO model provides a basis for the study of fairness perception of rules. Sources of legitimacy or lack of it could be found in one or several components of the rule. The effects of rules on the different components of the action arena, through the examination of the A*I*M of rules is also relevant to understand rule legitimacy and complements the insights from the AD*I*CO approach. These two perspectives contribute to understand how the rules shape the outcomes of action situations. The legitimacy of rules finally determines the outcomes of action situations and produces a shared moral system when the institutional arrangements have been working for a period of time. This perspective suggests a relationship between formal law and moral. In the path from formal rules to operational rules, in addition to a moral system, the culture is the other critical characteristic of a social system that determines the level of rule compliance. The social norms that emerge from a cultural system generally are closer to rules in use, than to the formal prescriptions from the law. The cultural system is related with the law and with the moral systems. The distance among these three components is of vital importance for the levels of rule compliance, but also and more relevant, for morality system interpreted as one of the outcomes of the action arena.

The following concepts proposed by Mockus (1994, 2002) contribute to evaluations of this particular outcome of the action situation. Following Carillo’s concepts, in an idealized democratic society the regulation of human behavior is achieved by three types of systems: cultural, moral and legal. Morally valid behavior, according to the moral judgment of the individual is usually accepted by culture, but the contrary is not necessarily true: some culturally accepted behaviors are not followed by certain individuals, due to moral considerations. In turn, culturally allowed behavior coincides with what the formal law permits, but the opposite is not necessary valid: some formally allowed behaviors are rejected culturally. In brief, in such societies, culture demands more than formal law and morality more than culture (Mockus 2002). The idea of a separation among formal law, morality and culture as an explanation of many social problems is expressed as follows:

> "*By the "gap between law, morality and culture" I mean the lack of consistency between cultural regulation of behavior and its moral and legal regulation, a lack of consistency that is expressed as violence, delinquency, corruption, illegitimacy of*

institutions, weakening of the power of many cultural traditions and a crisis or weakness of individual morality." (Mockus 2002: 23)

According to these relationships, Mockus identifies Colombia as a society that exhibits a wide gap between law, morality and culture. From this perspective there are three types of formal lawbreakers. The rule breaker by conviction breaks the rules because he has a number of ideals and interpretations about reality that push/motivate him, and his behavior is regulated by moral considerations. The rule breaker by necessity or convenience breaks the rule because he has particular utility motivations. And the *cheating* player, who regulates his behavior by shared cultural codes, and has some respect for the game he is in. The last two types of players can find moral justifications for their behavior but they are aware that others could have better moral arguments (Mockus 1994). The concepts discussed in this section will be fundamental for the study of action arena's outcomes in this research.

In this section I have discussed the role of institutions in SESs` governance and the proposed framework of the Institutional Analysis and Development (IAD) to for the analysis. The IAD offers a framework in which the action arena is the unit of analysis where actors act constrained by institutional arrangements, and guided by their mental models to choose what actions are the bests for their interests. The evaluative criteria for the outcomes of the action arena though could be very diverse; I focused in the general morality conformance as one of the main products of the action arena dynamics, and as the driver of levels of trust and cooperation in a SES. In the next section I present the general framework for the analysis of SESs proposed by Ostrom (2007, 2009) as a diagnostic and multitier system to describe and analyze a SES. This framework allows to see the system from a general perspective, but also permits to explore in detail certain subsystems and variables. The section ends with a revision of the model of collective action (Ostrom 1998) interpreted as the core variables in a cooperation dilemma and its importance for the governance of a SES. This revision attempts to connect this model with the contextual variables of the general framework for the analysis of SES.

2.5. A framework for the analysis of governance of Social-Ecological Systems (SESs)

The integral understanding of ecosystems in which action situations occur is of paramount importance. In recent publications (Ostrom 2007, Ostrom 2009, Poteete et al. 2010) special attention has been paid to the construction of a unifiying language and a framework for describing and analyse complex SESs. The multilevel framework is aimed to understand complex SESs and the relationships among the different levels at different spatial and temporal scales. For that purpose, it is necessary to know specific variables and their relationships (Ostrom 2009), therefore "*we must learn how to dissect and harness complexity, rather than eliminate it from such systems*" (420). The framework elaborates on IAD and the framework by Anderies et al. (2004) discussed above in the resilience section (Ostrom 2007). The framework aims to help researchers to develop answers to the following questions when studying SESs:

1) *"What patterns of interactions and outcomes … are likely to result from using a particular set of rules for the governance, ownership, and use of a resource system and specific resource units in a specific technological, socioeconomic, and political environment?*
2) *What is the likely endogenous development of different governance arrangemengts, use patterns and outcomes with or without external financial inducemenmts or imposed rules?*
3) *How robust and sustainable is a particular configuration of users, resource system, resource units, and governance system to external and internal disturbances?"* (Ostrom 2007, 15182).

The author remarks the importance of developing governance arrangements that match with specific problems of SESs by urging "*policy makers adopt a learning process rather than imposing final solutions*" (Ostrom 2007, 15181). Author's call is for not developing policy panaceas, or single sector policies that could have negative effects on other subsystems, and hence on the outcomes of a SES. Governance of complex SESs could not be achieved by simple and inflexible solutions, it needs policy design and tools able to cope with diversity and complexity of problems taking into account contexts at different scales.

The multilevel nested framework for analysing outcomes in SESs is proposed by mentioned authors is explaining next. The first-level core is composed by resource system (RS), governance system (GS), resource units (GS) and users (U). These first-level systems are linked with social, economic, political settimgs (S), and with related ecosystems (ECO). The interactions (I) among the first- level subsystems of a SES produce different outcomes (O). Figure 2.11 portraits an overview of the framework.

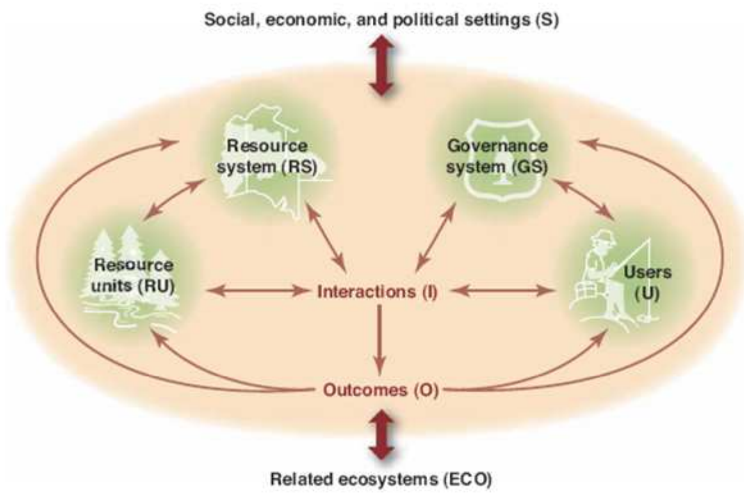

Figure 2.11 First level subsystems, interactions (I), outcomes (O) and linked social, economic, and political settings (S), and related ecosystems (ECO). (Ostrom 2009, 420)

Each first-level system is composed by several second-level variables that are listed in Table 2.1 These second – level variables, in turn, are composed in deeper-level variables. For example in the study of mental models (U7), a second-level variable belonging to the first-level variable Users (U), must be included variables such as time horizon (U7*T*), number of causal relationships (U7*R*), model relevant variables (U7*V*), boundaries of the model (U7*B*) and processes (U7*P*). For example if the purpose of the analysis is to evaluate self-organization in a SES, Ostrom (2009) recommends to have measures of the ten variables indicated with an asterisk in Table 2.1.

Table 2.1 Broader settings, first-level, and second-level variables of the multi dimensional SES's framework.

Social, economic, and political settings (S)	
S1 Economic development. S2 Demographic trends. S3 Political stability.	
S4 Government resource policies. S5 Market incentives. S6 Media organization.	
Resource systems (RS)	*Governance systems (GS)*
RS1 Sector (e.g., water, forests, pasture, fish)	GS1 Government organizations
RS2 Clarity of system boundaries	GS2 Nongovernment organizations
RS3 Size of resource system*	GS3 Network structure
RS4 Human-constructed facilities	GS4 Property-rights systems
RS5 Productivity of system*	GS5 Operational rules
RS6 Equilibrium properties	GS6 Collective-choice rules*
RS7 Predictability of system dynamics*	GS7 Constitutional rules
RS8 Storage characteristics	GS8 Monitoring and sanctioning processes
RS9 Location	
Resource units (RU)	*Users (U)*
RU1 Resource unit mobility*	U1 Number of users*
RU2 Growth or replacement rate	U2 Socioeconomic attributes of users
RU3 Interaction among resource units	U3 History of use
RU4 Economic value	U4 Location
RU5 Number of units	U5 Leadership/entrepreneurship*
RU6 Distinctive markings	U6 Norms/social capital*
RU7 Spatial and temporal distribution	U7 Knowledge of SES/mental models*
	U8 Importance of resource*
	U9 Technology used
Interactions (I) → outcomes (O)	
I1 Harvesting levels of diverse users	O1 Social performance measures (e.g., efficiency, equity, accountability, sustainability)
I2 Information sharing among users	
I3 Deliberation processes	
I4 Conflicts among users	O2 Ecological performance measures (e.g., overharvested, resilience, bio-diversity, sustainability)
I5 Investment activities	
I6 Lobbying activities	
I7 Self-organizing activities	O3 Externalities to other SESs
I8 Networking activities	
Related ecosystems (ECO)	
ECO1 Climate patterns. ECO2 Pollution patterns. ECO3 Flows into and out of focal SES.	

*Subset of variables found to be associated with self-organization.

2.5.1 From Core Relationships in Commons Dilemmas to the Broader Context of a SES

As discussed above, models of human behavior need to be taking into account carefully when one is analyzing commons dilemmas, and constantly inquiring if the neoclassical egoist actor is a plausible model to formulate prescriptions of behavior, or if there are different possibilities. Ostrom (1998) developed an alternative model of rationality in commons dilemmas, which establishes the importance of variables such as reciprocity, reputation and trust for cooperation. These variables form a feedback structure that could improve or erode cooperation and net benefits depending on certain values for structural variables; such as size of group, equality in interests and resources, time horizon, and costs of production function. Castillo and Saysel (2005) developed a dynamic model to test the dynamic consistency of this behavioral model, by adding structures that allow to include freeriding behavior, egoist actor and learning capabilities through time.

Poteete et al. (2010) elaborate on Ostrom (1998) model and call the structure formed by trust, reciprocity and cooperation, and learning, the Core Relationships in Commons Dilemma, called in this study simply core variables. Structural variables proposed by Ostrom (1998) are revised and renamed as Micro-situational variables, which constitutes a micro-situational context. The fundamental issue that has to be tackled in this type of dilemmas is to improve cooperation by building trust among resource users in order to generate reciprocity and to minimize the possibilities of free riding (Poteete et al. 2010). Common pool resources users are immersed in arrangements of different nested interrelated contexts at different scales, therefore core variables are affected by micro-situational variables, and these both levels are influenced by the Broader Context (Poteete et al. 2010). Broader Context variables belong to the multi-level framework for the analisis of SESs illustrated above. Micro-Situational variables (MSV) revised and defined by Poteete et al. are the following: S1: Marginal per capita return, S2: Security, S3: Reputation, S4: Time horizon, S5: Enter/Exit Capacity, S6: Communication, S7: Size of group, S8: Availability of information about average contributions, S9: Sanctioning capabilities, and S10: Hetereogeneity in benefits and costs. The first six micro-situational variables have been proved empirically to improve trust and positive outcomes. Variables S7 to S9 have produced a variety of outcomes in commons dilemmas. Variable S10 is usually associated with low levels of cooperation (Poteete et al. 2010). Figure 2.12 illustrates the mentioned nested contextual levels. An action situation is the concrete expression of the interaction of all the contextual levels, which outcomes may feed back in different forms upper scale contexts.

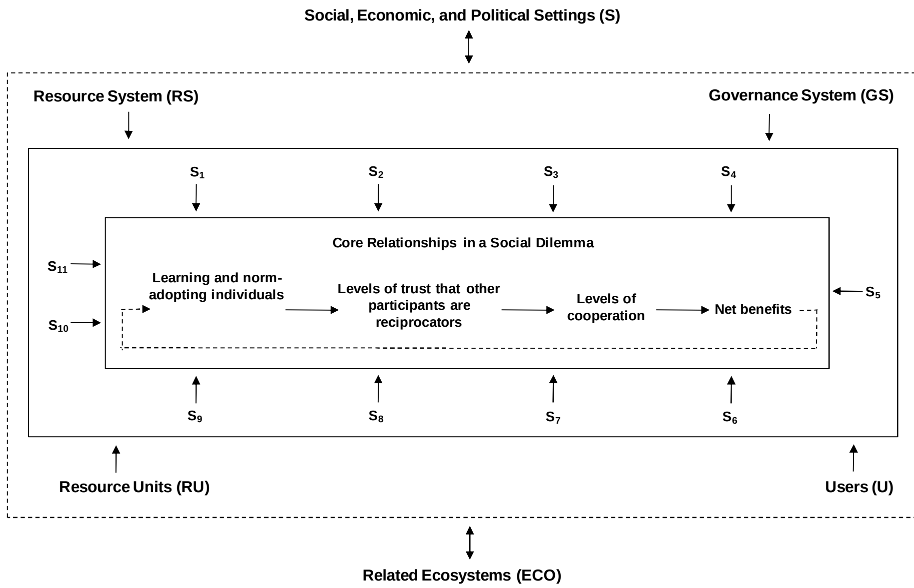

Figure 2.12 Core Relationships in Commons Dilemmas, Micro-Situational context and subsystems of the broader context (Poteete et al. 2010).

2.6 Conclusion

The central topic addressed in the conceptual discussion is common pool resources (CPR) governance, and I have explained how a broader perspective, such as the socio-ecological systems (SES), is appropriated as analytical approach, therefore the general problem becomes a problem of SESs governance. A CPR can be viewed as a SES because it entails a human group that is dependent on a resource or a set of them, an ecosystem that provides one or several resources and a system of cultural constructs that allows humans interact with the ecosystem. The theoretical advantage of conceptualizing the system as a SES is that we are, explicitly, accepting the complexity of a multidimensional problem at spatial and temporal scales, and including the different contextual scales.

I have discussed a concrete perspective of dynamics and management of SESs; resilience thinking, which constitutes the theoretical guide of the research. A conceptual and analytical framework has been addressed which will constitute the ground for the study of institutional arrangements in SESs, which is the Institutional Analysis and Development (IAD) approach as well as the conceptual approach to institutions from new institutional economics stream.

Figure 2.13 shows schematically the general conceptual approach used in this chapter. The central topic is framed in the context of CPRs, which constitutes a class of social dilemma. This dilemma has been conceptualized and tried to solve through out the “conventional theory” built upon Hardin (1968)’ tragedy of the commons, the use of the prisoners dilemma methafore through game theory, and the theory of collective action proposed by Olson (1965). This approach assumes the rational actor as the standard model for human behaviour, which basically sees people as selfish that are driven only by the maximization of their own benefits. As a consequence coordination and cooperation among individuals is difficult to achieve, therefore it needs private property rights, and external and imposed rules to avoid the so-called “tragedy”. This situation has been formalized with the Prisoners Dilemma model that permits predictions of outcomes based on the previous assumptions. The natural resource management has been deeply influenced by this approach during the second half of the twentieth century, focusing on command and control policies. On the other hand, the alternative to this theory starts to emerge with the seminal work of Ostrom (1990) with the study of many cases of successful cases of CPR management carried out without external imposition of rules giving evidences of self-governance capabilities of local communities. This program of research produced the so-called the alternative model of collective action (Ostrom 1998) that includes variables such as trust, reciprocity and reputation in a behavioural model of decision-making in CPR contexts. Also the model remarks the important role of the context in CPR decision-making. Experimental economics also contributed to the volume of evidences that have undermined the *Homo economicus* model as the generalized model of human decision-making.

In the figure 2.13 the “CPR Alternative model of collective action” is linked to socio-ecological systems (SES) box due to its usefulness and pertinence regarding the theoretical basis and perspective of SES management. Among these common points are concepts such as self-organization, diversity, learning, adaptation and complexity. The grey box in figure 2.13 represents the main subsystems of a SES, and illustrates how the unit of analysis proposed by the Institutional Analysis (IAD), the Action Arena, is where the interactions (I) among actors and the different subsystems occur. These interactions generates outcomes (O) that feedback the SES’ subsystems. The SES box includes the concept of resilience management because this is a notion that includes the dynamic perspective to the SESs analysis, and moves the natural resource paradigm from command

and control towards a management of change. The so-called resilience thinking needs approaches that include adaptive capacity, self-organization, social learning and in general complexity concepts to deal with uncertainty and change. Under this conceptual umbrella the emphasis was made is in the governance (GS) and users systems (U) in the light of the action arena. The conceptual tools used, and represented schematically in figure 2.13 contribute to understand the functioning of the CPR conceptualized as a SES.

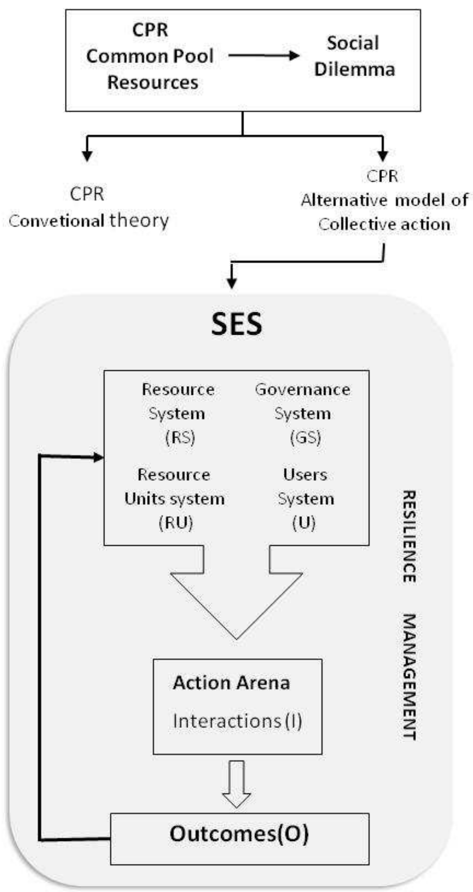

Figure 2.13. General conceptual diagram that guides the conceptual state of the art

Figure 2.14 shows the variables in which the conceptual revision has been focused. Four variables from the users and governance systems are relevant for the study: social norms (U6) and mental models (U7) from the users system, and operational rules (GS5), monitoring and sanctioning processes (GS8) from the governance system. These variables synthetize the institutional arrangements and the mental models of CPR users. In order to understand the relation between these two variables a theoretical revision has been made to define them. Therefore an analytical framework for the study of rules and norms was used: Institutional Analysis and Development (IAD). The action arena was used, as unit of analysis of the interactions and the evaluative criteria for outcomes is the conformance to general morality, which underlies the levels of trust and cooperation of the group of users of a CPR. The theoretical revision (figure 2.14) helps to shed light on the issue of the CPR management regarding the relation among users' mental models, rules and social norms. In order to study the outcomes of the action arena it is necessary to establish the evaluative criteria that will guide the analysis. These criteria are conformance to general morality and cooperation and trust levels. Therefore, it is necessary to take into account concepts related to moral economy and behavioral sciences. In the figure 2.15 the relations among these concepts are illustrated.

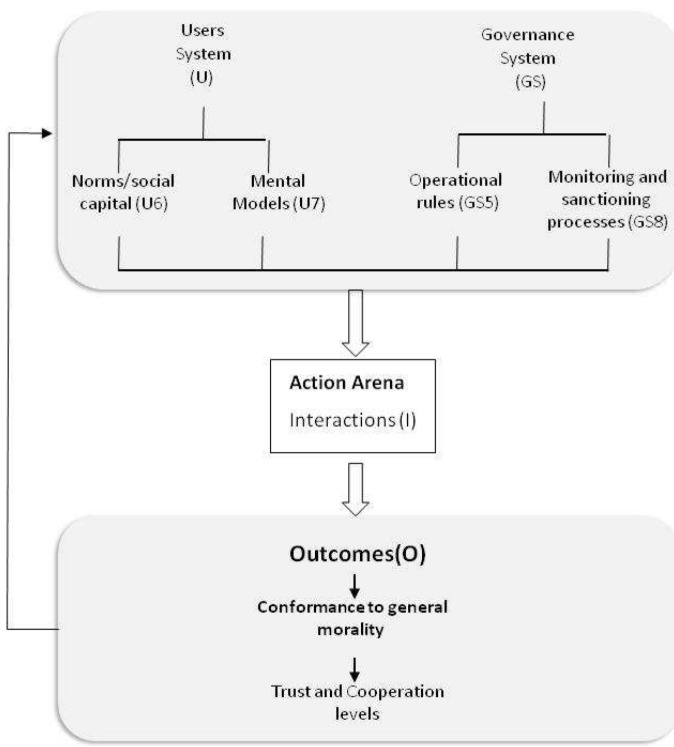

Figure 2.14. Specific variables studied in the conceptual state of the art.

Figure 2.14 portraits a general scheme conceptual scheme in which the action arena is at the core of the system as the unit of analysis, which produces a set of outcomes that are evaluated by specific evaluative criteria. In order to illustrate the use of these criteria a zoom in the action arena's outcomes (O) is necessary to study the relation among institutional arrangements, mental models and moral systems. Figure 2.15 portraits a general diagram that explains the concepts discussed in the chapter. The moral instinct that humans have developed by evolution (Haidt, 2007; Haidt & Kesebir, 2010; Hauser, 2007) is a first input for the moral systems. According to Arnold (2001) these moral systems are attached to social goods (CPR). This relation is used to build a particular moral economy. Moral instincts and moral economies contribute to shape the first level of morality conformance. This level is composed by generalized and normative beliefs (Pahl-Wostl et al. 2008). This level generates a second level of morality conformance. This second level assumes that there are three sources of regulation in human behavior. These three sources are moral, culture and formal prescriptions (legal). The examination of these three sources contributes to understand the "*gap between law, morality and culture*" (Mockus 2002) for explaining the relation between behavior and rules. The result of these three fields is one of the generators of trust and cooperation levels, and the behavioral spectrum showed in the central box of the figure. The other inputs for behavior are the mental models that are composed by variables, and cause-effect relations between them. The behavioral spectrum feeds back the moral economy, and becomes in a reinforcing driver of the moral system. On the other hand, three aspects feed the mental models: cultural elements, generalized beliefs and the feedback from the general outcomes themselves. Finally, the institutional arrangements are influenced by mental models, and they affect the moral economic system, which in turn feeds back key aspects of these institutional arrangements such as rule compliance, norms, endogenous rules and agreements.

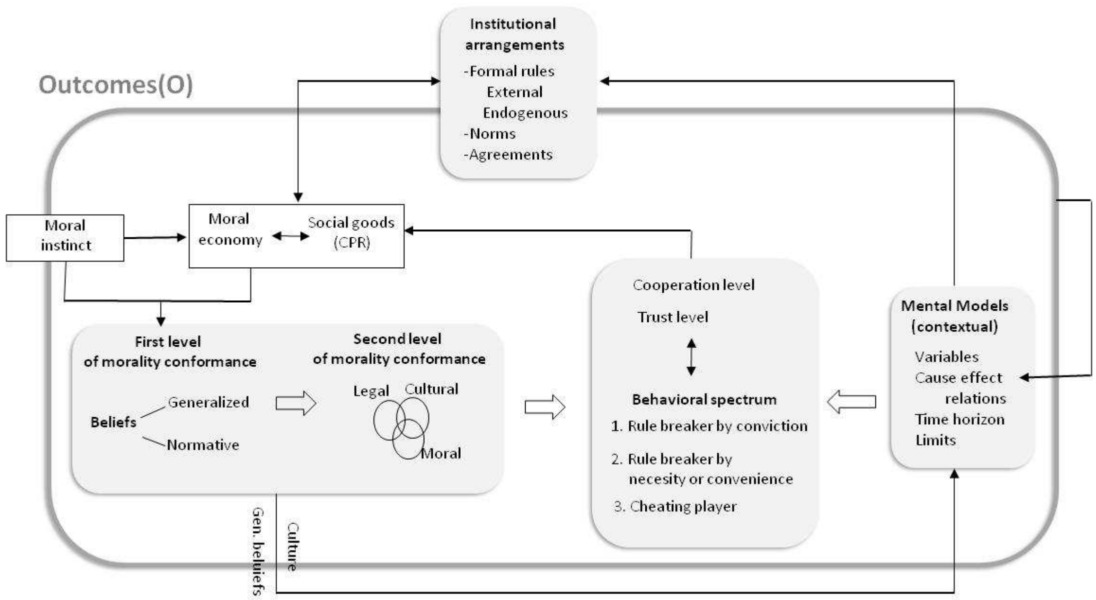

Figure 2.15 Conceptual functioning of outcomes

Throughout this chapter a gap have been evidenced: the relation between mental models and the creation of rules. This need of knowledge has been mentioned by Denzau and North (1994), North (2007) and Ostrom (2005), and it is expressed in a general form by Denzau and North (1994) "*We need to develop a framework that will enable us to understand and model the shared mental models that guide choices and shape the evolution of political economic systems and societies*". The necessity of understand the first gap mentioned above has been expressed in the field of experimental economics and behavioral economics. In a recent paper Vernon Smith (2008) remarks the fact that experimentalists interpret decisions of subjects, in experiments, as if they think with the same logic of game theory, in brief that "*the subjects reason like economists*." He urges to study mental models and explanations of experimental economics data assuming that people do not think, represent and process information as economists think. Camerer (2003) calls for new directions in the research on decision making: "*Theorists analyze games in the form of matrices or trees but players presumably construct internal representations that might barely resemble matrices or trees*" (Camererer 2003, 229), and he poses questions for future research "*What do mental representations of games look like?*" (230).

Cognitive processes that human mind carries out, as they are understood so far, offer concrete elements for the understanding of mental models and the ways in which they could be measured. A central insight is that they are formed by the unconscious mind and that logical rational to explain them comes after actions have been carried out, elaborated by the conscious mind. This fact has methodological implications. Elicitation of mental models implies the use of not direct questioning tools to natural resources users, it needs tools that allow to connect actions, users nonconscious constructs, and contextual environments. The detailed discussion about the methodological approach is developed in chapter 3.

An analytical umbrella that has been described towards the end of the chapter is the general framework for analyzing sustainability of SESs (Ostrom, 2007 and 2009). This framework elaborates on IAD, Anderies et al. (2004) framework for robustness of SES, as well as on the call for the inclusion of a number of critical aspects in the analysis of SES made by Walker et al. (2006).

3 METHODOLOGICAL FRAMEWORK

In the introduction I have identified a research problem throughout a revision of the situation of the major world common pool resources, which focuses in the link between CPR management, mental models and institutions as a possible perspective that could provide a basis for the design and assessing of a variety of policy experiments in common pool resources governance. The topic that will be addressed in this study is the cognitive problem underlying common pool resources dilemmas in socio-ecological systems (SES). Therefore the research question that I intend to answer is: What is the relation between mental models of common pool resources' users and the institutional arrangements to manage the common resources? In the theoretical state of the art developed in chapter 2 I have provided a conceptual framework to address the research problem identified in the introduction. This conceptual approach provides the basis for the formulation of three specific objectives to address the question stated above, and the methodological framework as well. From this conceptual exposition it is clear that common pool resources (CPR) need to be studied in the context of the social-ecological system (SES) that they are embedded in. Therefore, the first specific objective of this research is to define the socio ecological system of each case study. From this SES scale I focus on the institutional arrangements as a relevant sub-system (of the SES) that structures, not only the relation between societies and ecosystems from an aggregated perspective, but also at individual level. Consequently, the second specific objective of this study is to carry out an institutional analysis (IAD) to understand the action arenas in which CPR users are immersed and its outcomes as well. But according to the conceptual discussion (chapter 2), on one hand, there is an agreement among neo-institutional and sustainability scholars in that the institutional arrangements are strongly influence by collective and individual mental models. On the other hand, in order to understand the decisions of CPR users in action arenas, which in turn are embedded in an institutional matrix, is necessary to investigate the mental models. Therefore, the third specific objective of this study is to study the mental models of the CPR users in each of the case studies. The aim of this chapter is to construct a methodological framework to address each of these three objectives, and contribute to understand the relation between mental models and institutional arrangements.

The chapter is organized in three sections; research posture, the methodological process and the tools utilized, and a brief conclusion. In the research posture section, I first discuss the companion modeling (ComMod) perspective and its implications for common pool resources (CPR) management; next I present a brief overview of participation in natural resource management and modeling tools, and finally, I explain the relation between the ComMod perspective and experimental economics. The following section presents the methodological framework and explains each one of the tools used in the research, and a brief conclusion finalizes the chapter.

3.1 Research posture

The nature of the topics addressed by the research question requires the combination of several methodological approaches and tools. This need comes from the fact that any methodology has limitations and that there are trade-offs when a researcher privileges one method over others. In order to solve this problem it is necessary to utilize multiple methods, which are complementary. There are some conditions for adopt a multi method approach: scarce data, difficulties in data collection, and not easily comparable. The study of informal institutions and non-elite populations are among topics that have the characteristics mentioned. The research on collective action for the management of natural resources, which is the general theme of this dissertation, has all the mentioned conditions (Poteete et al., 2010). In addition to that, it is important to remark that the methodological choice in this study represents values, beliefs and practical considerations of the researcher and his position regarding science and the people object of the study.

The methodological position from which this research has been developed relies on specific premises which are in line with, Bousquet & Barreteau (1999), Bousquet et al.(2003), Barreteau & and others, (2003), and Ferber (1999) . The general perspective can be expressed with the following ideas. The SES are complex objects in which the decision making process could not seek system prediction. Instead, it seeks to understand organizational aspects, to incentive system interactions that drive change, to monitor these changes, to provide ideas for adaptation and learning. Every actor and stakeholder has an experience that contributes to the development of his own perspective of the SES. These are social constructs that have been built according to actors' specific culture and values. In consequence, decision-making and natural resources management processes rely on dialogue processes among different actors, with the consequence that the decisions are jointly constructed (Bousquet et al., 2011) .

The approach of the companion modeling (ComMod) developed by a group of CIRAD researchers offers postures and premises that have adopted in this study. ComMod is, first of all, a posture with ethical consideration about participatory modeling (Barreteau & and others, 2003) . Secondly it proposes a methodology (Bousquet & Barreteau, 1999) that comprehends a set of innovative, flexible and dynamic tools to foster diverse forms of collaborative management which include strategies to monitor change in SESs. The approach assumes that mental models of all the actors involved in SESs, including, researchers and regulation agencies are relevant, and the knowledge produced by each stakeholder has to be included in the solutions to governance puzzles in SESs. It provides the space for different stakeholders to express their points of view, and it acknowledges the fact that actors do not have the same weight; they are embedded in power relationships. In this line, the conceptual and methodological proposal has a clear posture, in the sense that the different perspectives of the problems have to be integrated in the solutions. Possible management arrangements in a given context have to be crafted according to the particular characteristics and needs of the SESs instead of implement a blueprint solution as a panacea (Berkes, 2007; Ostrom, 2007). At the core of this posture is the "*discussion of pluralistic approaches, such as the distribution of authority across multiple institutions*" (Berkes, 2007) and the understanding of social organizations and their relation with natural resources management policies, in order to collaborate to find ways to reach local scale sustainability that has into account regional and national institutional arrangements.

3.1.1 Companion modeling and co-management of common pool resources

The ComMod approach has been developed to support collective management of ecosystems, and particularly it has been inspired by adaptive management, co-management approaches and patrimonial mediation (Bousquet & Trebuil, 2005). The approach was proposed in 1999 "*for better understanding and modeling of the decision-making process and for better management of natural renewable resources*". (Bousquet et al., 2003).

Ollagon (1991 in Bousquet and Trebuil (2005) defines patrimonial as "*all the material and non material elements that work together to maintain and develop the identity and autonomy of their holder in time and space through adaptation in a changing environment*." Bousquet and Trebuil (2005) define a patrimonial representation of a territory as "*an area, or a set of resources links, past, present, and future generations of managers, focuses on the owner's obligation more than on the owner's right, and promotes a common vision of sustainability that reconciles the needs and opinions of various actors*".

In a collaborative management process where multiple and different interests and perspectives play, negotiation methods and skills are fundamental in order to reach management agreements. Concertation is the negotiation tool that companion modeling approach utilizes as a way to facilitate reaching agreements, and it consists of a third party that facilitates, transfer knowledge and proposals among stakeholders.

Governance of local common pool resources is especially complex because of their characteristics in terms of exclusion and subtractability due to property rights regime, in addition to resource dynamics when we refer to natural renewable resources. In such context stakeholders' mental models and interests' differences in reaching consensus about resource dynamics, rule preferences and rule crafting are especially critical. In order to face this type of puzzle; sharing and representation of actors' perceptions, tools to construct and simulate different management scenarios contribute to negotiate collective strategies to reach sustainable institutional agreements. Companion modeling offers an adaptive methodological framework for research and problem solving in resources management, that enables collective modeling of perceptions, discussion and negotiation, and also contributes to the understanding and practice of co-management.

3.1.2 Management, participation and modeling tools

Several approaches have been developed to support problem solving in environmental management using participative modeling and simulation. System dynamics field has provided a framework developed in business administration arena focused on decision-making processes and organizational learning known as Group Model Building (Vennix, 1996) using stock and flow and causal diagramming representation. Platforms such as Stella, Vensim and Powersim software have been the most used in the field. Pioneering works in applying this approach to environmental management are (Costanza & Ruth, 1998) and (Van den Belt, 2004). System dynamics modeling approach allows to representing and simulating non-linear complex systems and feedback-controlled structures from an aggregated perspective. A review of participatory modeling to support problem solving in environmental management has been carried out by Bousquet et al. (2003), in which they remark the work of several authors who illustrate different approaches to participatory management and assessment process, some of them including geographic information systems (GIS) tools. A common characteristic of the literature mentioned above is that models have been developed by researchers in order to offer a platform for consensus building, negotiation, strategic planning or assessment, and the models has been constructed in order to represent the ecosystem or resource at stake.

Multi Agent System (MAS) is a term applied to a system comprising an environment, a group of objects, an assembly of agents representing the active entities of the system, an assembly of relations, a group of operations which make possible for agents to perceive, produce, consume, transform and manipulate objects, and a set of operators (Ferber, 1999). MASs allows representing and simulating communication and interactions among agents, individual decision rules, and can include mechanisms to self-transformation of the system. It is possible to observe and study emergent behavior patterns at global scale arisen from micro scale interactions among agents. MAS modeling have been used to represent perceptions of agents regarding natural resources and observe the consequences of decision based on such mental models on the whole system (Janssen, 2003).

Companion modelling framework includes MASs linked to role games assuming that they "*share a common representation of complexity and can thus enrich each other*" (Bousquet et al., 2003). The MAS concept is fundamental in the ComMod approach. It is used at conceptual and analytical level, but also it is used to represent and implement concrete artifacts such as computer simulations and role-playing games or a combination of both. In a companion modeling process there are three objectives for which models are used: To make heterogeneous perspectives visible and open to debate, to discuss the consistency of different viewpoints and the possible scenarios product of their simulation in relation with the real world, and to generate a space for exploring scenarios collectively using simulations in virtual worlds (Le Page et al., 2011) . In this approach a constructivist position is adopted in the sense that the reality is constructed by each actor and at the same time is the result of the interactions of such constructions. Therefore, each vision of the world can be represented and constructed trough the modeling process, which is an "*explicit writing process in which knowledge and heterogonous hypotheses are distributed* *in the same artefact*" (p. 70. (Le Page et al., 2011). In this view, representing the "real world" means representing hypotheses about it that can interact among them. This representation of actor's perspectives of the problem being studied is usually carried out through MAS models.

Different from other modeling approaches the MAS approach entails the description of a world where there are active entities (agents) that play roles aiming to manage the system. From this perspective MASs are taken as metaphors of reality and strictly speaking the concept does not make any reference to computer science (Le Page et al., 2011). This precision is important because the MAS concept can be used to represent and interpret natural resources management problems without implementing simulation models, for example role playing games (RPG).

3.1.3 Companion modeling and experimental economics

Companion modeling approach aims to "*facilitate dialogue, shared learning, and collective decision making through interdisciplinary and "implicated" research to strengthen the adaptive management capacity of local communities*" (Gurung et al., 2006). In order to achieve such objectives modeling is at the core of the approach to understand and integrate actors mental models. Models include any kind of problem or system representation in which a level of abstraction is used. Such models can be geographic representations, multi-agent systems, stock and flow diagrams, causal diagrams and role-playing games among others. Comodians, term coined by (Barreteau et al., 2011) to refer to researchers familiar with the ComMod approach and following the approach ethical principles, have focused in multi-agent systems and role games (Barnaud, 2008). In this research we have utilized economic experiments as a complement to role-playing games, and the ComMod posture, as a modeling device and second phase in order to answer specific research questions in a controlled setting that could be reproduced.

It is important to clarify that experimental economics is a modeling exercise of the researchers and it intends to produce information about decisions and rationalities of actors. It is important to clarify that game theory and experimental economics are not considered a participative approach, but it constitutes a useful modeling perspective that open the door to a ComMod process. Experiments are not considered as integral part of the companion modeling approach. The hypotheses of a game theory model is implicit in the economic experiment and is not transparent to the participants. Its usefulness rests on the possibility to present the researcher's model of the problem to the actors starting a discussion towards the collective construction of a role playing game. Experimental economics is a methodological approach based on game theory. Its objective is to test economic theories through the modeling having specific hypothesis with the aid of game theory.

Game theory approach allows to model situations of interdependence among actors where all the possible choices are known, and the strategies of agents are used to study different rationalities. This is accomplished by carrying out experiments with human subjects in a highly controlled environment. Traditionally, experiments have been done with students in universities, but (Cardenas & Ostrom, 2004) and others have done experiments with real users of natural resources in rural environments. Hypothesis about how variables such as information, cooperation, reciprocity, risk aversion, effect of institutions and communication, among others affect decision making in the use of natural resources have been tested with rural common pool resources users by several authors. Economic experiments coupled with simulation modeling (MASs and System Dynamics) have been used to understand, test dynamic consistency of theoretical behavioral models and generate new hypothesis to test (Castillo & Saysel, 2005; Deadman P, 1999) proposing a double loop of decision making inquiry using both tools in a continuous feedback research system (D. Castillo & Saysel, 2005). In sum, the researcher's model (experiment) serves as basis for a more complex model (role-playing game) in which mental models of several actors are represented.

Role Playing Games have been used numerous times in the field of fisheries management since the developing of the emblematic Fish Banks Ltd. (Meadows et al.1989), to help students and stakeholders to understand problems and the tragic consequences of overfishing. The approach followed in this research uses RPG to understand rule-crafting dynamics and adopts the principles of Companion Modelling (Barreteau et al. 2003). A complete review of RPGs and modeling in natural resource management is done by Bousquet et al. (2002). The co-construction of a RPG refers to a group of participants that in the experiments, along with researchers, design and test a game with the objective, set collectively, to discuss and negotiate rules of use regarding the common resource. The process allowed for observation of how the participants bring the most relevant elements into the new game from their micro-situational and broader context variables; as well as their attitudes towards rules and the collective rule crafting process .

RPGs and modeling constitute the core of the Companion Modeling (ComMod) approach (Barreteau et al. 2003). According to Bousquet and Trebuil (2005), the methodology is epistemologically based on the idea that people build their own realities through the process of social learning. Barreteau et al. (2003) states that the results that the methodology could yield can be classified in three types: 1) change of stakeholders' perceptions, 2) modeling, the transformation of existent knowledge in a formal tool to be used as a simulator, and 3) concrete actions. This approach can be used in two different contexts, the first has to do with knowledge production about complex systems, to be used here, and the second is oriented towards the companion of the decision making processes (Barreteau et al. 2003).

Role playing games and modeling either multi-agent based modeling or system dynamics tools are part of the ComMod (Barreteau et al. 2003) methodological framework. According to Bousquet and Trebuil (2005), the methodology is epistemologically based in the idea that persons build their own realities through the learning in social processes. The so-called hard sciences that emphasize objectivity can demonstrate the biophysical conditions and problems in an ecosystem, "*but sustainable land use is defined as the outcome of human interaction and agreement, learning, conflict resolution, and collective action*" (Bousquet and Trebuil 2005).

Companion modeling implies an iterative permanent procedure between theory and field context, therefore the method is based in a loop between models and field. Barreteau et al. (2003) state that the results the methodology could yield can be classified in three types: 1) knowledge production about complex systems, 2) modeling, the transformation of existent knowledge in a formal tool to be used as a simulator, and 3) concrete actions. The approach can be used in two different contexts, the first has to do with knowledge production about complex systems, and the second is oriented towards the companion of decision making processes (Barreteau et al. 2003). In this research, the method is oriented towards the first purpose, knowledge production about complex systems. Although it is necessary to verify by monitoring of communities, we claim that there is an effect of awareness and learning that could strength the local adaptive management. This objective does not make part of this research.

The general structure of the process is cyclic, and comprehends three states that could be repeated as many times as needed: 1) Field research and secondary sources collection in order to generate explicit hypotheses for the modeling process, 2) transformation of knowledge in a formal in a formal tool to be used as a simulator, and 3) simulations carried out according an experimental protocol in a computer and in a role game, with purpose of compare the initial knowledge about the system and to identify new key questions and returning to the field (Gurung et al., 2006). Figure 3.1 shows the cycle. Inside this cycle there are some general phases. 1) building of a base line that allows to have a problem definition and its context, 2) sensibilization, 3) model conceptualization, 4) role game implementation and associated model, 5) test and validation of role game and model, 6) scenario simulation and assessment, 7) actors feedback and 8) monitoring and assessment (Gurung et al., 2006). Immerse in this methodological approach are the historic information collection and analysis from primary and secondary sources. Semi- structured interviews and economic experiments in order to have experimental information about individual decisions and rule preferences also are part of the process. In the next section the methodological framework is presented based on the previous research postures.

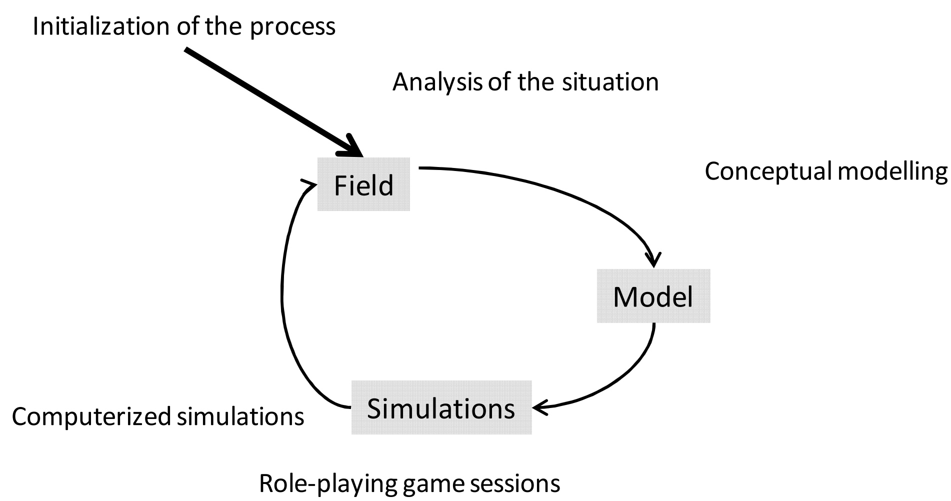

Figure 3.1 Companion modeling cycle. (Gurung et al. 2006)

3.2 Methodological process and tools

In this section I will describe the process and the specific methodological instruments applied in each of the case studies. The general objective of the research is to understand the relation between mental models of common pool resources' users and the institutional arrangements to manage the resources. To reach this general purpose, first is necessary to define each SES of each case study. The second objective is to study the action arena, its context and outcomes for each case study. The third objective aims to study the mental models of common pool resource users regarding institutional arrangements for CPR management. The methodological framework is constituted by four main phases: 1) construction of an historical and geographical context of each SES, 2) economic experiments, 3) collective building and testing of a role playing game, and 4) implementation of the role game with relevant stakeholders. The phases 2 and 3 include surveys, semi structured interviews, and direct observation. One characteristic of the methodological framework is that each instrument do not attempt to match with each specific objective, instead, the process attempts to develop the specific objectives in an integral form. This is, each methodological tool contributes to several objectives through the process.

The methodological framework proposed in this research combines two approaches: experimental economics and companion modelling. One notion behind both methods is the modeling of relevant problems, in this case, CPR problems and SES definition and representation. The second idea is the use of intermediate and polysemic objects "*speak in different voices for different audiences*" (Suchman et al., 2002, 174), which are the experiments and RPG that become "talking tools" that address participants and researchers by talking in their names (Vieira & Castillo, 2010). This is, when participants face an experiment or a RPG, they are using an object to express their rationality and mental models. In the same way, when researchers design an experiment or a RPG they express a particular understanding of a problem. These devices provide an important level of anonymity to express themselves in contrast with tools such as surveys and interviews that imply a direct relation with the researcher.

In this line, the economic experiments open the door to a ComMod process by providing and sharing with local CPR users a particular vision of the problem, and serve as starting point for the collective modeling exercise at the same time that provide information about participants' decisions. In sum, experimental economics offers a solid departure point in a process that starts in a conceptual construction of the local problem from the side of researchers that allows moving from a highly controlled environment to a more contextual an free tool, the RPG. Local users of resources participate in a gradual process of appropriation of tools at the same time that they exchange points of view. The more they participate and appropriate of the tools, the more they commit and generate ideas for possible solutions. Starting with experiments also offers a body of quantitative information that could be used to compare and to complement the qualitative information of the RPG.

Table 3.1 synthetizes the methodological framework illustrating how the specific objectives are addressed by the phases of the process. The table also shows the correspondences among the chronological order of the process (Phases), the tools used in each one, the activity and who participated in the design of the tool (What and Who), the variables or aspects to observe with each of the tools, and the expected results. They are all explained in the following chapters of this document.

Table 3.1 Synthesis of the methodological framework.

<table>
<tr><th>Specific Objectives</th><th>Phases</th><th>Tools</th><th>What and Who</th><th>Aspects to observe</th><th colspan="2">Expected results</th></tr>
<tr><td>To define the SES of each case study</td><td>1</td><td>Analysis of secondary information for each case</td><td>Content analysis: researcher</td><td>-Broader contextual variables</td><td colspan="2">-Geographical context
-Historical context
-Definition of SES (Chapter 4)</td></tr>
<tr><td rowspan="5">To study of the outcomes of the action arena

To study the mental models of CPR’ users</td><td rowspan="2">2</td><td>Economic experiments</td><td>Modeling: researchers</td><td>-Decisions
-Outcomes
-Rule decisions</td><td rowspan="2">-Institutional analysis
-Action arena’s outcomes (Chapter 5)</td><td rowspan="5">-Institutional analysis
-Action arena’s outcomes (Chapter 5)</td></tr>
<tr><td>Individual surveys</td><td>Designed by researchers</td><td>-Identity layer
-Contextual group layer
-Micro-situational variables</td></tr>
<tr><td>2 and 3</td><td>Interviews</td><td>Designed by researchers</td><td>-Mental models variables and relations</td><td>-Individual mental models (Chapter 6)</td></tr>
<tr><td>3</td><td>Collective construction of RPG</td><td>Modeling: CPR users
Facilitation: researcher</td><td>-Interactions
-Rule crafting
-Definition of SES according CPR users
-Definition of action arena according CPR users</td><td rowspan="2">-Collective mental models (Chapter 6)</td></tr>
<tr><td>4</td><td>Implementation of RPG</td><td>Playing: SES’ actors
Facilitation: researcher</td><td>-Negotiation
-Consensus
-Scenario and management design</td></tr>
</table>

3.2.1 Phase 1: Definition of the SES

Phase 1 was carried out using secondary information about each one of the case studies. On one hand, information about the biophysical characteristics such as geology, physical geography, and natural ecosystems was collected and analyzed to understand the natural context. On the other hand, information about the social system was analyzed with emphasis in the relations of local population with the natural system. According the conceptual framework of chapter 2 the time is a fundamental variable for the social ecological systems, therefore, this information analysis is done in a historical perspective. The result is a SES' characterization that allows a concrete definition using (Ostrom, 2009) 's framework for the analysis of sustainability of SESs. Consequently, for each case study, the conclusion synthetizes the context in terms of possible shocks, and a concrete definition of the SES using the multitier framework proposed by Ostrom.

3.2.2 Phase 2: Field Experiments

The approach used in this research includes economic experiments as integral part of the modeling and learning process. Through experimental economics it is possible to explore the motivations and behavior of individual decision-making and, to analyze how institutions and rules of the game influence the individual rationality when facing a dilemma of cooperation between common pool resources users. The experiments used in this project has been designed to tackle the role of ecosystem dynamics complexity on individual decision making in common pool resources dilemmas as well as rule preferences and its effects in their management. The experiments used in this research have been designed in the framework of the project "Dynamic of Rules in Commons Dilemmas" presented in the introduction of the dissertation. Cardenas et al. (in press) describe the experiments and preliminary findings. The authors propose a new generation of experiments that include the dynamics of the resources in the study of social dilemmas and natural resources problems. The experiments designed in the context of the project introduce in the experimental design several elements: a) the resource dynamics over time, b) decisions that comprehends not only effort allocation but spatial, and c) provision and appropriation problems (Ostrom, 1990). Expected outcomes of the experiments were information about individual actions, earnings, rule preferences, rule compliance, resource remaining and cooperation levels that could yield insights about the dilemma between individual and collective interests.

In each of the case studies 60 people participated in the experiments, 20 in the fishery experiment, 20 in the water management experiment and 20 in the forestry experiment. In each session 5 persons participated for a total of 12 sessions by case study. For the analysis in this dissertation I used only the 4 sessions, for each case study, that were run with the experiment corresponding to the resource of the village. For example in Baru (fishery case study), 20 persons participated in the fishery experiment. The data were used for the analysis in this document. Table 3.2 shows the experimental design and the sample used in this research. The analysis of the whole sample is in (Cardenas et al., in press; Castillo et al., 2011; Janssen et al. 2012; Janssen, et al., submitted; Janssen et al. 2011),. The participants in the experiments were recruited by word of mouth; participants had to be 18 years or older to participate. The participants were accepted if they were adults from households in which the resource use was a significant source of income, and only one member of a family was allowed during the ach game session (Juan Camilo Cardenas et al., in press). For the three experiments, participants know each other, but they can’t know the decisions of the other individuals during the 20 rounds that the experiment lasted. For each group only the aggregate outcomes of the decisions were presented to the group. They are not allowed to communicate with other players. For those players who had difficulty with reading and/or arithmetic the facilitator gave assistance.

Table 3.2 Experimental design and sample.

	Fishery case (Baru) Dates of field work 1: February 12 to 18, 2007	**Water management case (Lenguazaque)** Dates of field work 1: April 9 to 13, 2007	**Forestry case (Salahonda)** Dates of field work 1: June 8 to 11, 2007	**TOTAL**
Fishery experiment	20 people 4 sessions	20 people 4 sessions	20 people 4 sessions	60 people 12 sessions
Water management experiment	20 people 4 sessions	20 people 4 sessions	20 people 4 sessions	60 people 12 sessions
Forestry experiment	20 people 4 sessions	20 people 4 sessions	20 people 4 sessions	60 people 12 sessions
TOTAL	60 people 12 sessions	60 people 12 sessions	60 people 12 sessions	120 people 36 sessions

The grey boxes indicate the data used in this dissertation.

Fishery experiment

The experiment is designed for five participants that are not allowed to communicate between themselves. Public information consists in the aggregated outcome of each round of the experiment. It consists of two stages of 10 rounds each one; the first stage has no management rules and participants must decide to go to fish to a fishery spot, A or B, and what level of effort to allocate of three possibilities: 0, 1 or 2. Fishery places, A and B, could be in a high or a low level condition. If a participant goes to a fishery place in a good condition, her payoff could be of 0, 7 or 8 points depending on the level of effort allocated. If the player goes to a fishery place in low condition she would obtain earnings of 0, 2 or 3 points depending on the level of effort allocated. Fishery spots can change from a high condition to a low condition depending on the pressure exerted on them. In the same way a fishery place can pass from a low condition to a high condition depending on the number of rounds that players diminish the effort (Table 3.3).

Table 3.3

Returns (tokens) from effort and fish availability in one location

Payoff table			
Fish available in location	Fishing effort		
	0	1	2
High	0	7	8
Low	0	2	3

The payoff table (Table 3.3) is the same for both locations, and the initial state of the resource is of high fish availability. However, when the total effort in a location is five or more units in a round, the state of the fish stock will move to the low availability for the next round. This situation can only be reversed when in two consecutive rounds not more than one unit of effort is invested in that location by those who had decided to fish there. When participants behave opportunistically they move to the low state of both resources in two rounds, and get stuck in that situation for the remainder of the rounds since there is no individual incentive to refrain from fishing due to the opportunity cost of fish not caught. For a sequence of 10 rounds, this opportunistic behavior will result in 200 tokens extracted by the group. However, if they were to coordinate their efforts, the cooperative solution leads to 382 tokens by spreading the effort equally and alternating over the two fishing sites so that at least two people do not exert the maximum effort. Experimental literature in the study of CPR has demonstrated that communication between individuals lead to a higher probability to solve the commons dilemma without third party intervention or externally imposed rules (Ostrom et al. 1994). In contrast, there is no clear understanding how experience with resource management would affect those choices of rules and its effect on cooperation in a common dilemma; therefore we decided to include this type of treatment instead of communication in line with objectives regarding the research. In small scale fisheries social dynamics can lead to conflicts among fishers breaking communication and affecting organizational capacity, consequently generating suboptimal outcomes. The main reason for banning communication in the experiment had to do with the focus of the project, and given the experimental results reported in the literature mentioned above, we wanted to isolate preferences and behavior regarding rules. Communication between participants with the rest of the villagers was not tracked once they had left the room. Monetary incentives and conversion of tokens into money were calculated in such a way that each participant could earn, in average, the equivalent to one labor day - 8 USD.

The second stage of the experiment starts with a presentation of three management rules that they can vote in order to play another 10 rounds with the elected rule. The three rules are designed to solve the commons dilemma and they simulate a property rule, a lottery rule and a rotation rule. The three rules are designed to solve the commons dilemma and they simulate: 1) random access, 2) rotation and 3) quota rule. If two rules were tied, an additional round of votes between those two candidates was used to solve the tie. The first round after the election had the same starting situation as round 1 of the experiment. As we mentioned before, after ten rounds the participants could vote for one of the following three rules:

- *Rule 1 (Random access):* In each round the location where each of the participants is allowed to fish is randomly determined by rolling a dice. If a participant harvested in a location not permitted, a roll of a six of the dice led to paying back the harvested points.
- *Rule 2 (Rotation of Access):* In each round one of the locations is banned from fishing. A in rounds 1 and 2 and B in rounds 3 and 4, etc. If a participant is caught

fishing illegally, also with a one-sixth (1/6) probability of inspection, the harvested amount had to be returned.

- *Rule 3 (Quota of effort):* Each participant can exert an effort of 0 or 1 per round regardless of the site they have chosen. In the case of a participant putting in two units of effort, again with a probability of one-sixth (1/6) of being inspected, the participant had to return back the harvested amount.

Details about experimental design and results are reported in (Cardenas et al., in press). The protocol and forms of the experiment can be found in the Appendix I. The costs of breaking the rules were calculated according to the most common penalty for small-scale fisheries, which is the confiscation of the yield. If four of the players exert an effort of 1, in fishery spots in high condition, and one of them breaks, for example the quota rule, choosing an effort of 2, the group earns 36 tokens; and if the offender is inspected a fine is applied and the collective losses in one round represent 22.3% of the total payoffs of the group. In general, the fines range regarding collective losses and are between 20 and 27.3%. Besides, the monitoring probability of one-sixth is much higher than the actual possibilities of environmental authority, at least in the case studies. Therefore, the cost of breaking any of the rules is a strong incentive to cooperate (Castillo et al., 2011).

The participants were recruited via word of mouth and flyers hung throughout the village inviting participants of 18 years and older to participate. Special effort was made to recruit adults from households engaged in the resource extraction of that village. Only one member of a family was allowed during the same session. At the end of the series of experiments a handful of people were identified for in depth interviews. Those individuals were selected among the participants to be a representative sample of the community. At the end of the week, a session was organized to discuss the experiments.

Forestry experiment

This experiment is designed for five players that harvest a forest with a maximum carrying capacity of 100 units. The resource is explicitly represented in a magnetic white board. Each tree is a token with a green tree drawing. The initial amount of the resource has maximum amount of 100 trees. In each round the participants can take a maximum of 5 trees from the resource (Table 3.2). The stock will regenerate each round. For every 10 trees remaining in the resource, one tree is added as regrowth, with a maximum of 100 trees. When the stock is below 25 trees, the maximum number of trees each individual is allowed to extract is given by table 3.4. The players see when the facilitator extracts the harvested units and make the calculations for regeneration each round.

Table 3.4. Maximum harvest table

Current Resource Level	Individual Maximum harvest level
25-100	5
20-24	4
15-19	3
10-14	2
5-9	1
0-4	0

When participants collect as much as possible as fast as possible, the stock will be depleted in 5 rounds, and the trees collected by the group are 115. When they cooperate and maximize the group earning the group total can increase to 165 (figure 3.3), for a sequence of 10 rounds.

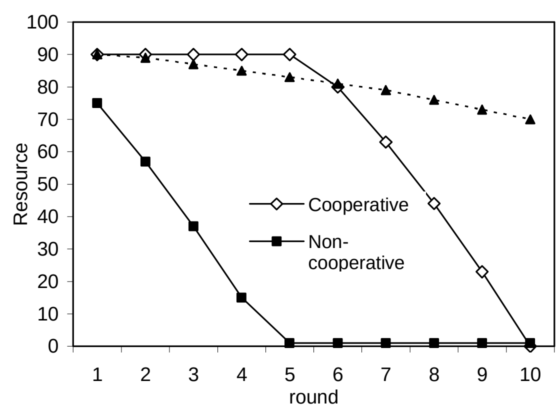

Figure 3.3: Resource size patterns for non-cooperative and cooperative equilibrium as well as when the rules are implemented and followed in rounds 11-20.

After ten rounds the participants can vote for one of the three following rules:

- *Rule 1 (Lottery):* Each round two participants are drawn for who can harvest. If somebody harvest when (s)he is not allowed to do so, a penalty may be received. In each round a dice is thrown, and when a six is through, an inspector comes and rule breakers get a penalty. The penalty consists of paying back the harvested amount plus extra 3 tokens.

- *Rule 2 (Rotation)*: A fixed schedule is defined which two participants are allowed to harvest each round are able to harvest. In round 1 A and B can harvest, then C and D, then E and A, etc. The same mechanism of monitoring and sanctioning is used as rule 1.
- *Rule 3 (Property):* Everybody has the right to harvest 0, 1 or 2 units per round. If a higher amount is harvested, a dice determines whether the participant is caught, pays back the harvest plus 3 tokens.

Participants can vote for their preferred rules, which will be implemented in a subsequent series of rounds if three or more players vote for it. If two rules get two votes, an additional round of votes between those two candidates is used to determine the final chosen rule. All rules are aimed at solving the resource dilemma by regulating the over extraction of the resource in the appropriation stage, and thus achieving the goal that the resource lasts all ten rounds and each of the five players have an equal share of the resource over the duration of the game.

Ten rounds are played with the new rule implemented. The first round after the election has the same starting situation as round 1 of the experiment. If participants would be selfish and rational the non-cooperative equilibrium would be the same. The reason for this is that breaking a rule would result in a lower expected penalty than can be derived from breaking the rule. For rules 1 and 2 the expected penalty for breaking a rule is 8/6 while gaining 5 tokens if one is not allowed to harvest. For rule 3 the expected penalty is again 8/6 but this time the gain is 3 tokens. Due to receiving penalties, the expected group earnings in the non-cooperative equilibrium is reduced to 95 for rules 1 and 2, and 81 2/3 for rule 3. The expected level of penalties for rules 1 and 2 is equal to 3 players each round have a 1/6 probability being caught and pay 8 (5+3) tokens for the first four rounds and 6 (3+3) for the last round before the resource is depleted. This leads to an expected penalty of 20 tokens. For rule 3 5 players have each round the risk of being caught. This leads to an expected penalty of 33 1/3 tokens.

If the rules are followed the resource size declines slowly. Since the resource is not fully depleted when the experiments end the total earnings are 100 trees for all three rules. This is higher than the Nash equilibrium. If a group was able to coordinate to increase it's earning a profitable strategy would be to follow the rules for 6 rounds, and then harvest the maximal level for four rounds. This would lead to expected earnings of 144 for rules 1 and 2 and 123 1/3 for rule 3 (Cardenas et al., in press; Janssen et al., in preparation).

Water management experiment

The water experiment is designed also for five players hat have positions A, B, C, D or E. A has the first choice to extract water from the common resource. Then B has the next turn to extract water from whatever amount was left by A, and so on. The location of the five players is randomly determined before the first round and remains fixed over the first set of ten rounds of the game. Participants receive an endowment ω of 10 tokens in each round. First each participant makes a decision x_i on how much to invest in a public fund that generates the infrastructure and therefore determines the amount of water available for the whole group to share. In Table 3.5, the water provision generated is defined as a function of the total investments of the five participants.

Second, each player, in sequential turns from upstream to downstream players decides how much to extract from the available water to her, that is, the water produced minus the water extracted by those before in the sequence. Each token kept (not invested) in the first stage has a monetary value for the player that is equal to the value of each unit of water extracted in the second stage.

Table 3.5. Water production as a function of units invested in the public infrastructure

Total units invested by all 5 players	Water available
0-10	0
11-15	5
16-20	20
21-25	40
26-30	60
31-35	75
36-40	85
41-45	95
46-50	100

This experiment includes a first dilemma of upstream participants who need the contribution of downstream participants to maintain the structure of their common resource, which is crucial for the production of water in the game. However, the downstream participants can only obtain benefits from the resource if upstream participants avoid the temptation to deplete the common resource and leave little water for downstream players.

Under this asymmetric game, participants first experience a provision dilemma in the contributions stage, and then face a resource appropriation dilemma when they extract from the generated resource. The earnings of the participants are the result of contribution and extraction decisions, and the resulting payoff for each player from adding the extracted tokens plus the tokens they keep from the initial endowment in each round.

Due to the shape of the production function, no analytical formulation can be derived. However, we can calculate the Nash equilibrium and the cooperative equilibrium numerically. If participants were rational self-interested individuals nobody would invest in providing the infrastructure in the first round. Since the upstream participant is expected to collect the whole resource, downstream participants will not invest. For participant A there is no benefit to invest when others don't. If this is the reasoning of the participants in the last round of experiment we find via backward induction that the same happens for all earlier rounds. Thus, the Nash equilibrium for this game is that no one invests and all receive 10 tokens for group earnings of 50 tokens.

To define the cooperative solution we calculate the maximum amount of the infrastructure plus tokens not invested. There are multiple social optimum outcomes. For a 41 tokens investment, a resource of 95 tokens is generated, and for a 46 tokens investment a resource of 100 tokens is generated in each round. The total earnings of the group in the cooperative solution amounts to 104 tokens, doubling the social earnings of the Nash equilibrium. After instructions and practice rounds, the participants play for 10 rounds under a baseline treatment. After the 10^{th} round, three different rules are presented for choice by the participants:

> *Rule 1:* Each round, after participants have contributed to the maintenance of the irrigation system, and the size of the water available is announced, the order in which one can take water for irrigation will be assigned randomly to participants.
>
> *Rule 2*: There will be a fixed rotation in which one can collect water. This order is a 5 round rotation system: ABCDE, BCDEA, CDEAB, etc.
>
> *Rule 3*: Each of the participants has a right of 20% of the water of the irrigation system. This amount is calculated after the available water is announced. The order to extract water remains the same for all the rounds: ABCDE. A dice is

thrown in each round. When 6 is thrown, an inspector arrives and will check the water extraction. The participant pays back the extra amount taken, and an extra amount of 6 units if more than 20% is taken.

Each participant can vote for their preferred rules, which will be implemented in a subsequent series of rounds if three or more players vote for it. If two rules get two votes, an additional round of votes between those two candidates is used to determine the final chosen rule. The three rules are effectively a lottery in access to water, a rotation in access to water or a maximum legal water quota. All rules are aimed at solving the resource dilemma by regulating the over extraction of the resource in the appropriation stage, and thus achieving the goal that each of the five players has an equal share of the resource over the duration of the game.

Ten rounds are played with the new rule implemented. The first round after the election has the same starting situation as round 1 of the experiment. Before the participants receive their payments, they fill out a general survey on their demographics and resource use within the village. The duration of an experimental session was about 3 hours and the typical earnings of the participants was worth between one and two days of labor (Cardenas et al., in press; Janssen et al., in press)

Individual surveys and Semi-structured interviews

Interviews and individual surveys were designed to apply after the experimental sessions to each player. The survey details are in the Appendix 2. The variables that we wanted to inform with surveys are guided by the micro situational variables proposed by Poteete et al. (2010) and discussed in chapter 2, and by the identity and group context layers of information that Cárdenas and Ostrom (2004) identified as brought by people to CPR experiments in the field. The Identity layer of information includes: wealth, occupation and experience; other regarding preferences; values about external vs. self-governance; gender, age, education and skills; and, membership to civic organizations. On the other hand, the group context layer information contains: shared norms, heterogeneity and inequality; group identity and cooperative or competitive setting. In addition to that, after the experiments participants are asked to answer a brief survey bout their opinions of the three rules. Furthermore, during the experimental fieldwork five people were selected among participants in the experiments to carry out semi-structured interviews about CPR management and institutional topics. During the second field phase a second group of participants in the role playing construction and experiments were interviewed (10 per case study) with the aim of understanding mental models of resource users. These interviews were designed according the insights from the conceptual state of the art of chapter 2. The work of (Abel et al., 1998) provided important practical recommendations for the elaboration of the questions.

3.2.3 Phase 3: Collective construction of a role-palying game (RPG)

The third phase was the co-construction of a role play game having as a departure point the economic experiments designed by the researchers (Cardenas et al., in press). The co-construction of a role game refers to the fact that a group of participants in the experiments along with researchers design and test a game with the objective, set collectively, of discuss and negotiate rules of use of the common resource. A next step is to implement the role game with relevant stakeholders and with the designers as observers along with researchers. The role game allowed observing mental models, interactions, conceptualization of the SES from the perspective of resource users, to understand what are the key variables of the problems are for participants and observe collective processes of rule crafting.

The objective of the RPG was set with people according to their needs in terms of their problematic regarding resource management. A second objective was to understand mental models of participants regarding the experimental context and possible relations with the real system. Our hypothesis was that people were going to modify three groups of possible variables in the RPG that in experiments were simplistic: 1) resource settings, 2) individual decisions, and 3) collective decisions like rule negotiation, sanctions or inclusion of new roles. One of the aims of this process was to allow, “collective learning” about resource management. Collective learning means to say the least, a point of view exchange; it can also become concrete decision-making. The field phase of the third part of the search was carried out in Barú island (fishery case) from April 24 to 28, 2008 with 18 persons, in Salahonda (forestry case) from June 16 to 20, 2008 with 19 persons and Lenguazaque (water management case) from May 23 to 30, 2009 with 20 participants. The co-construction of the role game was carried out through the following steps:

Step 1: Feedback and discussion of experimental results

The purpose of this first step was to carry out a discussion about experimental results with participants, and to make a linkage with RPG construction. Another objective of this phase was to understand: what kinds of variables were relevant for participants in the experiments; what were the most relevant relations between variables; and discuss their rule preferences and reasons for that. Therefore, a workshop was organized. We reminded the mechanisms of experiments and presented the results of the analysis of experimental data to participants. The facilitator made a synthesis of the experiments. Next, a presentation of the results was done in an interactive format. The idea was that people helped to understand their reasons for their decisions and the links participants do with their real production system. At the end, the idea of co-construction was announced in order to represent more concrete and realistic the CPR problematic in each case study. By the end of the workshop a group of about 10 people, who represented about half of the attendants to the feedback workshop, were invited to work in the design of the new game (RPG). The agenda for this step is shown in the table 3.6.

Table 3.6 Agenda for the workshop on a discussion of experimental results

1	Presentation and objective	
2	Introduction of the participants	
3	Fishery/Forestry/Irrigation game	
	3.1	How does the game work?
	3.2	How did people play?
	3.3	What if everybody were selfish?
	3.4	What is the game solution?
	3.5	Lessons from the game
4	Can we improve the game?	

The purpose of this first step (items 1 through 4 in Table 3.6) was to carry out a discussion about experimental results with participants, and to link them with the RPG construction. Another objective of this phase was to identify the variables relevant for participants in the experiments, the most relevant relations among variables, and discuss their rule preferences and reasons for them. The facilitator reviewed the experiments, followed by a presentation of the results in an interactive format. This allowed understanding their decision-making reasoning and the links participants perceived with their real production systems. At the end, the proposal for co-construction was announced inviting about 10 people to build a representation of a more concrete and realistic CPR situation. The criterion for inviting these people was their interest in the activity, their representativeness regarding leadership and age.

Step 2: Co-construction of the RPG

The collective construction of the RPG started with a participative setting of the objective of the game and the construction of the RPG building agenda (Table 3.7). The role of facilitators was not to guide participants in the activity, but to observe their discussions and what they wanted to change regarding the experiments towards a RPG. We already had an initial model, namely the experiment; therefore, if they do not make changes, we kept it as it was in the experiment and concluded that they endorsed it, asking each time if there was consensus about keeping such variables as they were in the experiment. We provided all the necessary material to craft any kind of board, tokens or formats they could design. This step could last one or two days of collective work. The main purpose was to observe what kinds of modifications players were going to perform on the experiment. Finally, a test of the RPG was performed with the same designers.

Table 3.7

Protocol for the co-construction of the RPG

1	Setting the objective of the RPG	
2	Board game / Spatial setting:	
3	Actors	
4	Representation of the activity:	
	4.1	Effort
	4.2	Condition of the resource
5	Organization of the round	
6	Meaning of 1 round	

3.2.4 Phase 4: Implementation of the Role-Playing Game (RPG)

The last activity was to carry out the RPG with people invited by the designers including resource users and other actors defined the previous days such as environmental authorities or resource users from other communities. At the end of the RPG, a debriefing was done with a summary of principal insights and agreements emerged form the activity.

3.3 Conclusion

In this chapter I have presented and discussed the methodological approach to address the main research question of this study namely: “What is the relation between mental models of common pool resources’ users and the institutional arrangements to manage the common resources?” In chapter 2 I built a conceptual approach that provided the three specific objectives needed to answer the research question: to define the SES of each case study, To study of the institutional arrangements and the outcomes of the action arena in each case study, and investigate the mental models of CPR’ users. In short, the methodological proposal combines experimental economics and ComMod approaches. To develop these questions a set of three case studies have been selected, each one represents an important CPR situation: fisheries, water and forestry. The following chapter develops the first specific objective by providing a geographical and historical context that allows to define the SES of each case study.

4 GEOGRAPHICAL AND HISTORICAL CONTEXTS

Formal and informal institutions that human groups develop in order to relate with natural resources, and in a more broad perspective with ecosystems they live in, are no static prescriptions. Institutions are a construct that evolves along with social collectives and, in the case of the relation with ecosystems; they may or may not evolve with them. Rules and norms are part of the strategies that society develops for adapting to change. As Ostrom (2005) states "*Rules can be thought of as the set of instructions for creating an action situation in a particular environment […]Rules combine to build the structure of an action situation*". Human groups face action situations and produce outcomes constantly, this dynamics produce, on one hand, a given territorial construction, and, on the other, a history of Socio Ecological Systems (SES). In the three case studies of this research, there are particular territorial constructions that have evolved through time as part of the history of each of the SES studied.

The previous statement is based on a conception of the territory in line with cultural geography, in which, "*The territory is not only a material form of spatial organization, it is also what each individual does … The territory is the spatial expression of a person or a group's membership to a terrestrial portion"* (Deneux, 2006: 170 - my translation). According Deneux, the geographers that differentiate space from territory (Brunet, Le Berre and others), define territory as one of the faces of the geographic space, the one that has the historical marks of the development (*mises en valeur*), and the one that expresses the social appropriation of the space; "*In a space, nature "would produce" the landscapes, while societies "would produce" the territories*." (Deneux, 2006: 170 – my ranslation). This conception is in tune with the geography concerned on behavior that express belonging forms, development and space exploitation (Deneux, 2006). The Dictionaire Critique of geograqphy (Brunet et al.,1993), express appropiately the essence of this conception of territory: "*The territory is to the space, what the class consiouseness is to the class … The notion of territory is therefore, at the same time, juridical, social and cultural,* *and affective. The territory implies always the space appropriation: it is different to the space* ".

The Socio Ecological System (SES) notion has the same relevance in this study. These systems are composed by social and ecological coupled systems that are adaptive complex systems. Social systems include governance issues such as property rights and access to natural resources, knowledge systems regarding ecosystems, resource use, ethic visions about the relation between society and nature, culture and economic dimensions. And the ecological system refers to self regulated organisms interacting with their environment (Berkes et al., 2003.). I enpasize the coupled aspect of the SESs in terms of a strong and direct human dependence on the CPR, fisheries, forest and water for each one of the case studies. I quoute the ecosystem's concept according the Assessment Millenium Ecosystem Assessment Synthesis Report (2005), which is relevant for this research:

> "*An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment, interacting as a functional unit. Humans are an integral part of ecosystems. A well-defined ecosystem has strong interactions among its components and weak interactions across its boundaries. A useful ecosystem boundary is the place where a number of discontinuities coincide, for instance in the distribution of organisms, soil types, drainage basins, or depth in a water body.*"

In order to complement the definition in terms of processes Levin (1999) in Westley et al. (2002) states that the ecosystem components *"interact in such a way that a dynamic set of processes produces a complex and diverse set of structures. The interaction is described as self-organizing- that is, structure and processes mutually reinforce each other*". The ecosystem exists in a space and constructs a territory. The spatial dimension, localization and form of the space where the different systems exist is important, as well as its physical limits.

The geographical dimension is then fundamental to understand the action situation. If the aim is to understand institutional arrangements, and mental models regarding them, then it is essential to go to the history of SESs. This geographical and historical context is an attempt to place a picture of the SESs, as we observe it today in a more complex collage. A geographic and temporal collage that could explain the *why* of actors, positions, agreements, behaviors, and beliefs that have given shape to the rules that this particular human group has for its relation with the nature, in this case a common-pool resource. This kind of context gives sense to the, perhaps, static picture we see today, otherwise such picture appears as an historical and spatial accident, and it does not exist.

In this chapter I provide a geographical and historical context for the SES in which each case study is immersed. The map of figure 3.1 shows the geographical location of the three case studies studied in this dissertation.

Figure 3.1. Location of case studies in Colombia's territory. The boxes in the figure indicate the figures in the chapter. Figure 3.2: Fishery community case study (Barú). Figures 3.3 and 3.4: Forestry case study (Salahonda). Figures 3.5 and 3.6: Water case study (Lenguazaque).

4.1 Fishermen community of Isla Barú

Fishermen community is a social group that has lived in a particular geographical zone for decades. The spatial and biophysical characteristics of this environment have shaped this human group but also they have influenced the natural environment. The culture that has developed in this area has produced a dynamics in institutional arrangements that have determined the way this society interacts with the ecosystem.

In the next paragraphs I provide a regional geographical context as a way to facilitate the understanding of the problem addressed by this study. Figure 1 shows the geographic location of Isla Barú and Islas del Rosario Archipelago.

4.1.1 The Coastal Colombian Caribbean region

The fishermen community chosen as case study lives in the village of Barú located in the island of Barú in the C{Citation}olombian Caribbean coast. The region, far from being a homogeneous territory comprehends a number of different geological settings, ecosystems and socio-cultural human groups and histories. The area has the highest coastal mountain (5.775 meter above sea level), Sierra Nevada de Santa Marta, a vegetation that ranges from tropical sub desert zones to humid tropical forests. This territory comprehends also 320.000 hectares of wetlands flooded permanently and 900.000 hectares flooded during six months each year. The Colombian Caribbean is localized in the northern area of South America, in the equatorial strip, where there are climatologically different conditions due to the ocean that surrounds the region as well as the trade winds from northeast. The landscape is characterized by a number of small scale hill ranges, from the minor foothills of the western Colombian mountain range, to the north east part of La Guajira peninsula. What is considered the Colombian Caribbean is composed by sea, coast, continental land, insular areas and it is a gathering space of flora, fauna and people coming from the north, the isthmus and from the south. It is a region of compulsory transit towards the Caribbean or towards the Andes (Zambrano 2000), in the words of the same author, the Colombian Caribbean region is a space of cultural, social and biological gathering. The territory is shared by several indigenous groups and, according Abella (2001), there are at least eight types of cultural areas in the region. *Costeños* (people who lives in the coast border), *sabaneros* (people from the savannas), *montañeros* (people from the hills), people from the river, *cachacos* (Andean people), *guajiros* (people from the Guajira peninsula), indigenous people and islanders. They are Caribbean people not due to their cultural affinities but because of their capacity of assimilation of new cultures which is the Caribbean principal cultural characteristic (Abella 2001). Fishermen from Barú, most of them descendents of African slaves, belong to the group *costeños* mentioned by Abella.

4.1.2 The biophysical environment

The Colombian Caribbean region has 132.244 km^2 of terrestrial territory, 44 km^2 of insular lands and 536.574 km^2 of marine area, for a total of 668.862 $km^{2.}$ The coast has about 1560 km from Cabo Tiburon (8º 40’ N, 77º 20 W) in the border with Panama to the mouth of Sillamana River (11º 50’ N, 71º 25’ W), border with Venezuela. The region comprehends, in addition to its coastal lands a wide area of marine areas with several islands, keys and fishing-grounds located between Central America coast and the Antillas Menores separated by a deep basin called the Colombia Basin. The Economic Exclusive Zone area[4] is about 288.000 $km^{2.}$ (PNNC 2006).

Geomorphologic and Geological setting

The coastal region could be described by a number of physiographic units, from east to west, The Guajira Peninsula, Northern foothills of the Sierra Nevada de Santa Marta, Magdalena River Deltaic Complex, The Central Caribbean Coast and the Uraba Gulf (Zambrano 2000)

Isla Baru belongs to the Central Caribbean Coast, as described by Zambrano (2000), in physiographic terms; this zone is marginal as well as convergent due to its closeness and parallelism to the boundaries of the tectonic plates that surround it. It includes the hill

[4] “*The concept of the exclusive economic zone is one of the most important pillars of the 1982 Convention on the Law of the Sea. … It consists of: a twelve-nautical-mile territorial sea; an exclusive economic zone of up to 200 nautical miles in which coastal states have preeminent economic rights and which obviates the need for a territorial sea of 200 nautical miles claimed by some states; extension of the continental shelf regime to the margin, with revenue-sharing obligations beyond the exclusive economic zone; a regime for transit passage through straits used for international navigation and for archipelagic sea-lanes passage; guaranteed access to and from the sea for land-locked states; a regime for the administration and development of the common heritage resources of the international sea-bed area; protection and preservation of the marine environment; and adequate mechanisms for settlement of disputes concerning the interpretation and application of the provisions of the Convention.*” (FAO, 1987)

Ranges of San Jacinto, San Jeronimo and Luruaco. In this zone, the Sinu River has its mouth, and the Canal del Dique also pours its waters into the sea. These characteristics of micro mountain ranges and hydrological regimes generate a high variety of complex ecosystems which allow differential management regimens. The island of Barú is located to the southwest of Cartagena city. In the southwest tip of the island we found the village of Barú, essentially a fishermen settlement. Isla Barú is considered part of the archipelago of Islas del Rosario and Barú. This group of islands and coral reefs is considered as the richest and most important coral reef formation of the Colombian continental Caribbean region (Prahl and Erhardt 1985).

The surface of the Caribbean coast can be described geomorphologically by four types of landscapes: 1) the cliffs 2) inherited marine and riverine terraces 3) deltas and 4) mosaic of landform of Caribbean coast (IDEAM 1996). One of the landscape units of this mosaic is the *landscape of small hills*, which is constituted by a series of elongated separated by a hydrographic network moderately dense. Its morphogenetic environment is depositional, but currently is erosional. Isla Barú is located in this landscape of small hills. Formally, the cartographic unit is called Unit of Barú and Tierra Bomba Hills (Cbt), which hills have no more than 50 MSL (meters above sea level), they have short slopes, convex of low inclination; an intermittent and incipient drainage network of subdendritic pattern, and wide bottom valleys. The erosive characteristics are associated to the scarce vegetation due to de hydrologic deficit of the area (IDEAM 1996).

The Islas del Rosario archipelago and Isla Barú are located southwest of Cartagena with a total area of 1573 km2, 22.5% of emerged lands and 75.1% of coral reefs of recent formation with, less than 10.000 years (IGAC 2002). The archipelago is composed by a set of islands, keys and coral barriers spread with an east-west direction around the two major islands, Isla Grande and Isla Rosario. These islands are marine terraces of +3 m. bordering with reef lagoons of depths until -25 m. (IDEAM 1996). Isla Barú is a Miocene formation of eroded clay and limestone and filled by Pliocene and Pleistocene material modeled afterwards by the marine transgressions of recent Quaternary. The islands are constituted by a series of small hills of maximum height of 50 MSL in Barú (IDEAM 1996).

Isla Barú and the village of Barú are in the border of the National Natural Park Corales del Rosario y San Bernardo. The northwest border of the Park is 45 km southwest from Cartagena de Indias. The Park is, in essence, a marine protected area of about 1200 km^2, with coral reefs as one of the most important ecosystems, several islands, coastal lagoons, mangrove forests, tropical dry forest, rocky and sandy coasts and phanerogamous prairies. This is the territory where fishermen of Barú develop the artisanal fisheries activities, therefore it is important to give a brief description of the marine geomorphology which determines the spatial places where the marine fauna allows to establish the fishery spots or *"bajos"* as they are known locally.

Cendales et al. (2002) carried out a geomorphological and ecological study of Islas del Rosario and Isla Barú which is taken as basis for this description. The zone is a reef complex of islands and coralline banks. These banks are the fishery spots and they are located inside the Natural Park. The coralline formations are over abrasion limestone terraces that surround the islands. There are also, isolated from the islands, coral banks. The study defined 5 geomorphologic units: 1) emerged zones, 2) terraces, 3) fringing reefs, 4) banks and 5) soft bottom

The marine area of the Colombian Caribbean region is in the Caribbean tectonic Plate, and the terrestrial portion is in the South American Plate. The region is composed by rock formations ranging from the Proterozoic (1300 Million years), in the mountain massif of the Sierra Nevada de Santa Marta, to recent times, arranged in complex superimposed geologic structures due to successive tectonic, sedimentary and volcanic events. The Colombian marine platform is composed by islands and archipelagos of coralline origin with low relief. The coast lines are formed by mangrove forests associated to estuarine environments, coastal lagoons and sandy and muddy beaches.

Locally, the area is located in the so called Sinu Belt composed by sedimentary rocks interpreted as deposits from marine and coastal environments. The ages of these sedimentary formations, presents in Isla Barú, are from the Paleocene epoch (50 million years in average) to Recent. Today, the island is formed by beds of Miocene-Pliocene (from 20 to 2 million years old) beds of mudstone, quartz sandstone from Pleistocene (2 million years), reef limestone with abundant fossil contents of corals and mollusks from Pleistocene and beach deposits from Holocene (Present) (Reyes et al. 2001). This configuration is the result of Miocene eroded formations of mudstone and limestone filled by Pliocene and Pleistocene material modeled by marine transgressions during the Holocene. The resulted landscape is a series of small hills with maximum heights of 50 meters above sea level. The area is affected by current marine streams and sediments from Magdalena River and the so called Canal del Dique (IDEAM 1996).

Climate

The Colombian Caribbean region is under the influence of the North-South displacement of the Intertropical Convergence Zone (ITCZ). The ITCZ is a low pressure belt located between the subtropical regions of the North and south hemispheres. Its main effect on the zone is the existence of two main seasons: dry and humid, and strongly influenced by the Trade Winds. In areas where the ITCZ' zone of low pressures is displaced in the equatorial line about 10 º N, such as the Caribbean, the Trade Winds that cross the Equator from the Southern hemisphere modify their direction towards the West. The Earth rotation movement diverts the Trade Winds towards the West; therefore, the ITCZ generates strong and uniform Trade Winds from the Northeast over the entire Caribbean basin.

Colombian Caribbean zone is influenced by the trade winds which blow from Northeast to Southwest with higher intensity from December to April generating a summer period or a non-rainy period due to their dryness. During the Northern hemisphere summer season the anticyclone that produces the Trade Winds moves towards the north and they stop, allowing the normal atmosphere stratification in the Caribbean. This situation produces the characteristic Caribbean rainy season with small rain peaks during May and June and its higher intensity in October and November. In spite of this general condition the Colombian zone has a high variety of precipitation regimes in the zone from an average of 250 mm in the Guajira Peninsula to the North, 500 mm in the central portion to 2000 mm in the Urabá zone towards the southwest.

The particular climate in the area of Isla Barú is a Tropical Semiarid type with two well defined year periods: humid rainy season and dry or windy season. The main characteristic is a water deficit period during the first 3 or 4 months of the year and the most important dry period towards middle of the year. Its annual average temperature is 24^0C (PNNC 2006).

The temperature in Isla Barú oscillates between 31.5^0C and 24.2^0C, the annual termic amplitude is less than 5^0C according to the meteorological station of Cartagena (IDEAM). The higher temperature values of 33^0C are registered during the month of May and the lowest during the months of December and April. Because of the cloudiness the air temperature tends to decrease towards an average monthly of 27.9^0C and 28.6^0C (CIOH 1993). The relation between the precipitation and the temperature produces a dry season during February and March and a higher precipitation during the period August-November with a maximum in the month of October.

The direct localization in the sea of Isla Barú generates a high humidity regime almost constant oscillating between 78 and 86%. The minimum values occur during the dry season and maximum values for the rainy season from April to November with a short interruption during the months of June and July (PNNC 2006). The humid seasons are intense with frequent precipitations which absolute values generally are over 100 mm and the dry season is characterized by the absence of precipitation due to the increase of condensation of water steam as an effect of the heating of humid soils and covered by vegetation. The precipitations are variable in quantity and distribution, with an average annual precipitation about 993 mm from which the 93% falls during the period from April to November.

The yearly average of precipitation is 993 mm. There are three characteristic precipitation periods during the year. A dry period from December to April with average values of 12.10 mm/month. An intermediate period from May to August with an average of 99.5 mm/month. And a rainy season from September to November with an average of 154 mm/month. These averages are based in a database from 1970 to 2001 made by Martinez from the Central de Pronósticos Meteomarinos del CIOH.

Ecosystems

The region of Islas del Rosario and Isla Barú area is composed by a set of terrestrial and marine ecosystems, in this section a description of both will be provided. The intention is not to give a detailed and exhaustive explanation of their components and processes, instead of this, I intend to give a general description of the ecosystemic structure of the area that is taken from the natural park management plan 2005-2009 (PNNC 2006).

- Coastal and Terrestrial Ecosystems

In this section are included the terrestrial vegetal formations as well as estuarine areas, deltas and coastal lagoons. The ecosystems described are 1) Tropical dry forest 2) Mangroves and 3) Coastal lagoons.

1) *Tropical Dry Forest*. The vegetal covertures in these islands are limited by the high superficiality of soils, high erodability and high carbonate concentration. The forests in islands are classified as Tropical Dry Forest and Mangroves. In the ecosystem of Tropical

Dry Forest there are three types of vegetation: xeromorphic structure[5] (*Xerophytia*), mangroves (*Halohelophytia*) and beach formations (*Psammophytia*). The fauna associated to this ecosystem is mainly of reptile species, from aquatic to terrestrial species, such as turtles, the *Boa constrictor*, *crocodilian* reptiles (*Caimán crocodrilus*), lizards such as iguanas (*Iguana iguana*) and other minor species. Turtle species are of special interest because its environment comprehends open sea, coral reef shallow lagoons and beaches where they deposit the eggs. According Becerra et al (1998) in PNNC (2006) inhabitants of the islands reports that turtles were abundant in the past but today they are very scarce. The main species is the hawksbill turtle (*Eretmochelys imbricada*) which is classified as critically endangered according the World Coservation Union (IUCN). People use to hunt them and sell their meat and eggs in Cartagena in spite of the illegality of this practice. Bird species are of paramount importance for conservation in the islands because they are places for nesting of several species. Islanders say also that bird population was much more abundant and diverse in the past. The decrease of vegetal covertures due to human deforestation has occasioned this loss of biodiversity.

2) *Mangroves*. In Islas del Rosario the mangroves are located in the south part (leeward) frequently associated with coastal lagoons. Isla Barú has a mangrove belt in the coastal area and subxerophytic vegetation inland. Towards the inland the island presents subxerophytic vegetation. Mangrove ecosystem is home of terrestrial and aquatic organisms from marine as well as fresh water dominium. Gastropods, bivalves, oysters, crustaceans, bryozoans, tunicate and sponges species live in the roots system of the mangroves. This vegetal formation offers a number of ecosystem goods and services. These formations have been affected by anthropic exploitation in order to build infrastructure and also the necessity to clear zones in order to offer lands to buyers from outside the islands. Until recent years still people practiced intensive logging for fuel or coal elaboration, but

[5] A xerophyte or xerophytic organism (*xero* meaning dry, *phyte* meaning plant) is a plant which is able to survive in an ecosystem with little available water or moisture, usually in environments where potential evapotranspiration exceeds precipitation for all or part of the growing season. The typical morphological consequences of these adaptations are collectively called xeromorphisms. *D. J. Taylor, N. P. O. Green, G. W. Stout (2001). Biological Science 1 & 2, third edition. Cambridge University Press.*

this activity has diminished due to the propane gas availability. In the mangrove zones, people use to collect oysters but its cutting generated an increasing scarcity of the mollusks.

3) *Coastal lagoons*. Coastal lagoons are important ecosystems that offer important environmental services such as buffer for perturbations, nutrients recycling, refuge habitats of several organisms. These ecosystems have communication with the sea permanently or during certain seasons, they serve as communication, for several species, between the sea and mangrove ecosystem. In addition, these lagoons, due to its landscape beauty are used as recreation places during tourism activities.

- Marine Ecosystems

The marine ecosystems of the islands are 1) Sedimentary bottoms 2) Rocky coast 3) Beaches 4) Sea grass and 5) Coral reefs.

1) *Sedimentary bottoms*. They are located five meters below surface level, in the infra-littoral zone until the break point of the continental platform. They present grain textures such as sandy, clay and silt which are the home place for several biological organisms (benthonic communities). Several authors (Vega-Vélez 1980, and Levinton 1995 in Steer Ruiz *et al.* 1997) have found low primary productivity of these benthonic communities and it depends of the organic matter present in the water column transported from another ecosystems. This ecosystem has an important role in the recycling process of nutrients, biological control and food production. Several organisms of commercial importance for the artisanal fishery such as mollusks, fish species and crustaceans like shrimps are part of this ecosystem.

2) *Rocky coast*. This ecosystem is composed by biologic communities living on rocky substrates in the tidal zone. These platforms usually form rocky cliffs and they have developed from hard calcareous platforms, from ancient coralline formations, emerged due to earth crust movements. These types of ecosystems occur in zones of high energy due to waves and intense sea currents which determine the type of organisms. These organisms are principally algae communities and invertebrates, mollusks and crustaceans of commercial importance.

3) *Beaches*. In general the islands present coralline sandy white beaches. In some sectors they are accompanied by mangrove patches. Crustaceans, mollusks, birds and reptiles are part of these ecosystems. Particularly the hawksbill turtle (*Eretmochelys imbricada*) and some bird species use some of them as nesting places. This ecosystem is of particular economic importance due to its principal attractiveness for tourism.

4) *Sea grass*. This ecosystem is composed mainly by vascular plants that carry out their life cycle under salted water or a mix between fresh and sea water, also named marine phanerogams (mainly *Thalassia testudinum*). Important areas of macro-algae (*Halimeda incrassata*, *Penicillus* spp and *Rhipocephalus* spp) are part of the ecosystem. The maximum depth in the zone is of 30m at which it is possible to find them, they reach their maximum development at less than 10 meters depth and over sandy substrates in highly illuminated and calm waters. They carry out a number of important ecological functions such as, food production, high productivity, offering of substrate for epiphytes fixation, recycling of nutrients and sediments stabilization. In the Caribbean, they are one of the most important ecosystems of coastal and marine zones, and for this reason they are considered as one of the five strategic ecosystems for the country, as well as coral reefs, mangroves, rocky littoral and sedimentary bottoms (PNNC 2006). The marine phanerogams are dominant components of the submarine landscape in some areas, and they serve as refuge for a considerable number of fish in larval and juvenile states. The major extensions of this ecosystem are found towards the south of the islands. These prairies surround completely some of the islands and occupy a big percentage of the coral banks. They occupy an area of 835 hectares. In Isla Barú they are present along 13 km of its northern coast.

5) Coral reefs. These ecosystems are the submarine landscapes that have been modeled and dominated by the geomorphological and ecological processes of coralline formations. They are the ecosystem more diverse, biologically more complex and productive of the planet, and perhaps one of the more fragile. The current coral formations have established about 5000 years ago over tertiary reef platforms. A set of ideal climatic and marine conditions are present in the area for the development and permanency of this ecosystem: warm temperatures between 20 and 29^0C, clear water, low depth (less than 50 m), high salinity (33 to 36 ppm), a protected geographic position and influenced by the Trade Winds, and short and low energy waves. These conditions have allowed the formation of the most important coralline ecosystem of the coastal Colombian Caribbean. These organisms are characterized by a very high productivity; therefore they are not located in zones of high discharges of sediments. Their 3D structure provides a complex structure of micro environments with different types of luminosity, currents, nutrients and oxygen concentration. As a consequence they serve as habitats for a high number of species as well as a refuge place for fish from open oceans from depredators and as a resting place.

In the area there are 16 ecological units of coral reefs that could be mapped. They are different among themselves due to substrate nature, biotic components and characteristic elements of fauna and flora. The coralline ecosystems occupy an approximate area of 145 km^2, and are located in the Northeast of Isla Barú, around Islas del Rosario and forming several banks in the continental platform close to the coast. Cendales et al. (2002) established seven ecologic units for coralline area, each one characterized by the predominance of a coral gender[6]. The coral reef ecosystem is of paramount commercial importance in the area because is in the coral banks where are localized the most important fishery spots where fishermen from Barú develop their main economic activity.

4.1.3. Barú: The social system

The geographic character of Islas del Rosario and Isla Barú has been modeled not only by climatic and biophysical aspects; population processes, cultural inheritance, economic activities and institutional dynamics have played a fundamental role in the configuration and dynamics of the current Islas del Rosario and Isla Barú social-ecological system.

Population

In order to understand the present situation of the fishermen community of Barú Island it is relevant to know the origin of such human group and its relation with the ecosystem they live in. The way they understand and relates with the fishery resource is necessary the result of a history that starts with pre Hispanic mixed with European and African practices. In this section, a brief overview of this history is presented.

Pre Hispanic population

The reconstruction of the history of human settlement in the Caribbean region faces a number of problems, according to Zambrano (2000): a) the human groups that lived in the region before the arrival of the Spaniards had no writing. Therefore, it is impossible to compare the observations of the chronicles of Europeans whose descriptions where more an

[6] These units are: 1) *Millepora-Palythoa* 2) *Acropora palmate* remains 3) *Montastrea spp*. With remains of *Acropora cervicornis* 4) *Porites porites* 5) *Agaricia tenuifolia* 6) *Montastrea spp*. 7) *Agaricia spp*. with *Montastrea franksi*. 8) Mixed unit and 9) Soft bottom with vegetation (*Thalasia* prairies) and minimum presence of coral.

attempt to justified the conquest and the dominium strategies used with the American natives. b) Another source of information is the record of the population census made by the Spaniards. But they were made late, and were made in populations already modified by the Spaniards; their way of life was modified as a function of Spaniards needs, they relocated the native settlements, the tribes were merged and the land use patterns were modified, among others. c) Regarding the material vestiges left by native Caribbean human groups, the archaeological research still does not offer a clear view; furthermore the archaeological research in Colombia has given more importance to archaeology of sites than a contextual archaeology (Zambrano 2000).

There is very few information specifically about the region of Barú. The presence of human population in the Colombian Caribbean archipelagos, close to the coast dates back to times before Columbus. In the Spaniards conqueror's chronicles the aboriginal settlers they found in these lands where from the Mocanas culture that belonged to the Karib family, whose livelihoods where derived from mollusks collection and fishing (PNNC 2006). According to CINEP (1998) "*The mocaná of Karib language, who crossed the sea in big canoes, where magnificent sailors, they had an abundant population…they mainly cultivated. Their principal food was the corn*". According Zambrano (2000) in the Caribbean Colombian Coast, by the discovery time, the groups were Calamares o Turbacos from the Karib family.

Dolmatoff (1989) (in Zambrano 2000) gives a more complex description of the pre Hispanic inhabitants. This author, based on archaeological evidence, states that, through thousands of years several cultures consolidated themselves by taking advantage of the high coastal ecological potential. They were cultures that developed a way of life supported in the dependence of the sea fauna as source of proteins, and the cropping of roots, mainly yucca, the use of palm trees, hunting of small preys and the collection of mollusks. The corn agriculture was not practiced in South America until the first millennium B.C., coming from Mesoamerica (Zambrano 2000). According Zambrano (2000) there is a consensus about a correlation between the introduction of corn and a change in the social organization towards a more complex type of society. Before corn introduction the type of societies were organized as tribes, more or less egalitarian where hierarchical relations were temporal and not associated to lineage, and the work division were associated to a primary sexual differentiation. While the population increased, the cropping of corn solved the food necessities and changed the technologies and labor division promoting the chiefdoms[7] which implied a hierarchical society with different classes of people. At the arrival of Spaniards most of the indigenous groups in the Colombian Caribbean coast had evolved to the chieftainship social organization. In 1492, the Karib family was one of the exceptions to this pattern in terms of corn dependency. Instead, it was characterized by the dependency of the yucca crop, with corn as a more marginal product and a lineal geographic distribution along the sea coasts and rivers.

The Conquest in Barú

Since the discovery of America, the Caribbean and particularly Cartagena region was the entrance of Europeans and Africans to the current Colombian territory, which triggered the human crossbreeding and ecosystem transformation that has given shape to the current territorial and ecosystem configuration.

In 1501 Rodrigo de Bastidas arrived to Cartagena harbor, Islas de San Bernardo archipelago, Islas del Rosario archipelago and Isla Baru (Siegert 2006). He meets inhabitants from Isla Barú and left records about his encounters with them, from which we know that the human groups settled in the zone were Bahaire-Baru, Coco-Polonia and Baricuica- Baricuica, usually they carried the group name taken from their chief (PNNC 2006). In 1533 the Spaniard commandant Pedro de Heredia founded Cartagena in Calamarí Island where there already was an indigenous settlement (CINEP 1998) from the Karib group. Isla Baru was considered part of the rural area of Cartagena that became the center of military expeditions during Spanish conquest. In 1538 the Spanish king gave his authorization for the distribution of indigenous among the neighbors, meaning, Spaniards already settled in the rural regions. In this form, Cartagena and its rural surroundings became a colonial society of "encomenderos"[8] . The harbor became more important due to its protected characteristics and its closeness with Panamá.

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[7] *Cacicazgo* or *caciquismo* in Spanish

[8] "*In colonial Spanish America, the granting of Indian people as slaves to individual conquistadors (settlers) by the Spanish crown. The system was based on the assignment of Moorish villages to members of the military orders in medieval Castile, but was revived in the colonies from 1503, with the idea that native labour was exchanged for protection. Abuses led reformers such as Bartolomé de las Casas (1474–1566) to call for its abolition. It declined slowly after 1550, being replaced by repartimiento, another system of forced labour*." The Free Dictionary. By Farlex. Web site: http://encyclopedia.farlex.com/Ecomienda

African population

Between 1576 and 1592 Spaniards discovered the first gold mines in the Nueva Granada. Spain was facing a difficult situation in Nueva Granada, the socio-political and territorial structures of indigenous population were fragmented and there were an indigenous demographic crisis due to war, epidemics and forced labor. The slavery became the solution for the replacement of indigenous labor force.

Cartagena de Indias became the main slavery port of Spanish America until 1640. According to Del Castillo-Mathieu (in Maya 2004), most of Africans brought to America and particularly to Cartagena came from the Bantús or Angolas ethnic groups between 1580-1640, between 33 to 50% of slaves were from this origin. According Del Castillo-Mathieu cited in Maya (2004) the calculated number of slaves entered through Cartagena de Indias was of 169.371 in the period from 1580 to 1640.

During the first half of 17th century the predominant cultural African groups present in Cartagena were the Bantús which had their origins in valley of the Congo River, an environment of equatorial forest where they developed a style of life based on cereal agriculture and the intensive utilization of iron (Maya 2004).

From 1640 to 1703 Spain lost the control of slaves' trade due to the war with Portugal and the general decadence of the Spanish Kingdom, this activity was carried out illegally by Dutch merchants. During this period the Cartagena slave provision was from Curazao Island where the Dutch traders brought the slaves from center West Africa. As a consequence there were a dominium of slaves from the Benin Gulf of Ewé-fon culture, particularly a group called Ararás. During this period it has been calculated that Cartagena should have received a similar number of slaves than Lima, 20.000 and the entire Peru, 30.000 persons, without counting the illegal traffic from Dutch traders (Maya 2004).

Between 1703 and 1740 the slave commerce was dominated by France and England. Until 1713 "The French Company of Guinea" basically bought the slaves to Dutch merchants in Curazao. From 1714 to 1740 the English Company "South Sea Company" introduced 30.000 slaves in Cartagena. In these years the presence of Ewé-fon culture began to decline and it was replaced by people coming from the Biafra Gulf. According to Del Castillo in Maya (2004) the first half of 18th the black people from

Guinea rivers have disappeared in Cartagena while Carabalíes from the Biafra Gulf began to arrive massively. The decline and final of slavery commerce took place from 1740 to 1810 (Maya 2004).

The models of society, culture, economies and the way in which African groups brought to America from 16th to 18th centuries definitively marked the construction of territory and the relation with ecosystems of Afro Colombians communities until 21th century.

Cartagena became one of the main ports of the New World and Spanish farms with their slave population were established in Isla Baru. Slaves who managed to escape from Spaniards gathered in small villages called "*palenques*" where today, there are the villages of Santa Ana, Baru and Ararca. Coconut economy was of main importance in Isla Barú from late 19th to early 20th century. This product was sold in Cartagena. Towards 1949 the coconut crops suffered from the "porroca", a worm who attacks the crops, marking the end of this agricultural success (Siegert 2006). Regarding specifically the settlement in Isla Barú, the first known record dates back from 1777 consisted in a letter from people settled in the north part, to the Spaniards authorities in Cartagena asking for permission to move to the south. In 1839 Barú village appears as a parish church with 673 inhabitants and a reference of their activities such as fishing, agriculture and sailing. In 1889 Isla Barú is formally recognized as an administrative territory (*corregmiento*) and in 1919 their legal spatial limits are set (PNNC 2006). There are no evidences of permanent settlements in Islas del Rosario before XX century, only since 1950 some fishermen from Isla Barú settled in the islands and carried out activities of coconut agriculture in addition to artisanal fisheries. During the 70s arrived accommodated families from Cartagena and the interior of the country and built holiday houses and the islands began to be known as an important touristic place (PNNC 2006).

Duran (2007) characterizes the history of Barú village and Rosario Islands during 20th century with three periods: 1) the insertion in Cartagena's market, and in the Caribbean illegal trade, 2) the drug smuggling, and 3) the tourism. The author calls these periods, the "Prosperity epochs" which have marked the history during the 20th century. The first period was based in the agriculture of coconut palm and other products, and the trade of other type of products, mainly electrical domestic appliances. Thanks to these economic activities, mainly the agriculture, several families developed and increased their wealth. But this epoch finished towards the middle of the century due to a coconut palm plague, as mentioned above. According Duran (2007) this period marked the entering into modernity of this society. The local economy passed from self consuming and barter patterns to an intensive production model, mainly coconut. At the same time Barú was linked to the Caribbean commercial circuits and the illegal traffic of products such as electric appliances was an important activity.

An important consequence of the declining of coconut agriculture was the establishment of the first foreigners, from Cartagena elite, mainly to the islands. Local people abandoned their plantations and sold their lands, and native people began to work as domestic employees and guards of these new owners receiving very low wages. Toward the late 70s Cartagena started a process of popularization of the tourism, and the flow of people from the interior of the country increased. The islands became the place for Colombian high elite holidays, including the presidential family. This status triggered the arrival to the islands of drug smuggling capitals during late 80s and 90s. Local people benefited economically of this situation due to the labor market distortion that these capitals produced; it was much more money for the same kind of jobs they were use to, in the same type of servant work. According interviews to local people, in Duran (2007), natives affirm that that was the best epoch because the population really beneficiated economically from the "narcos". As I mentioned the touristic business in the zone has been almost the most important economic activity since the late 70s.

According Duran (2007), "Prosperity epochs"or economic peaks are seen, by local people, as external phenomena that generates social changes and economic benefits, but right after the good period arrives the crisis. The "good times" leave their long term consequences, now the cost of life is higher, as the elder natives say "*there is more money but less food*" (Duran, 2007:16 – my translation).

4.1.4 Barú today

Barú became an island in the 16th century when Cartagena was interested in finding a fluvial communication with the Magdalena River, which was the only connection with the Andes and the rest of the new territories. The aim was to take advantages of a zone with a set of riverine wetlands. The first evidences of fluvial-terrestrial traffic date back from 1571 between Cartagena and Magdalena River.

There are two perceptions about the territory of Barú, on one hand, the local inhabitants' territorial model, and on the other hand, the administrative and tourists operators' model. According to the first, the territory has an urban center, which is Barú village, and the rest, including the islands is the rural agricultural periphery. In fact Barú inhabitants consider the islands as an integral part of their territory, and locally they call them as "Islas de Barú" (Barú Islands) (Durán, 2007). For the second territorial perception, Barú island's urban settlements; Ararca, Santa Ana and Barú are the places where the natives live, and the rural zones where the touristic installations are established, and the where the wealthy people from Cartagena and the interior of the country have their luxury houses. The Rosario Islands are a separate entity in which the National Park rules, tourist operators work and also foreign people has properties. The state, at the same time, considers most of the rural zone as "empty reserved national lands"[9], fact that has been source of conflict with other actors, this will be explained below.

According PNNC (2006), today there is no reliable information about the population of Baru Island and it is possible to find different figures from different sources. Cardique (2001) reports a change in Isla Barú population from 5.000 to 6.000 inhabitants in the period 1981-1996. The study from CIOH-Cardique (1998) gives a figure of 9.734 inhabitants distributed in this way; Barú village 6.240, Santa Ana: 2.731 and Ararca: 763 inhabitants (PNNC 2004). The Land Use Plan document of Cartagena (2001) (in PNNC 2004) establishes as a main population growth driver the vegetative growth and gives especial emphasis to the emigration of young people towards Cartagena in search of better labor conditions. Fishermen population is about 100 inhabitants of Afro Colombian origin with low incomes and high poverty indexes. They allocate their workforce, mainly, to artisanal fishing. In the village, 33% of inhabitants do not allocate their time to any economic activity though they are capable of that. The unemployment levels generate social problems and a high pressure on natural resources (PNNC 2004).

Barú village community is a relatively homogeneous population in terms of socio economical aspects; most of the population derives its income from fisheries and tourism sector. Islas del Rosario population is about 600 persons (Durán, 2007) and they belong to the same families that people from Barú village. During the first half of the 20th century there was a peak of agricultural trade with Cartagena and Panama represented mainly by the coconut monoculture. Several families which descendants are present today in Barú village and the islands, beneficiated from these activities and they became the most

[9] "baldíos reservados de la nación"

prestigious such as the Gómez, De la Rosa, Morales, Molina, Vargas, Geles and Medrano (Durán, 2007). As an important fact, in order to understand social organizations in the zone, is that the community of the islands, whose main settlement is called Orika, is now organized as a Communitarian Council in order to claim territorial rights, according the Law 70[10]. People from Barú are in the process of becoming a different Communitarian Council. This fact is relevant because one of the important problems in Barú, is the land property conflict between the state, external owners and native population.

Since the late 19th century natives have used the lands for agriculture, but at the same time the state has considered the rural territory as "empty reserved national lands"[11]. These are the same lands that, since the fifties, have been occupied by wealthy people from Cartagena and touristic operators. One of the consequences was that many people have been hired for low wages in hotels and private houses during years. Since 1984, all these lands are in a legal dispute, because they have been claimed by the state. In 2006, the first land expropriations were carried out by the state, and the lands were given to the natives of the islands, at the same time that the conformation of the Islands Communitarian Council was in the conformation process. However, still the Colombian government does not recognize the ancestral presence of Afro - Colombians in the zone. The allocation of the expropriated lands was done because of the legal written evidence of property rights from the first half of twentieth century (Durán, 2007). As a consequence, people from Barú village started an organizational process in 2007 in order to organize the Comunitarian Council of Barú.

Economic activities

Artisanal fishery and tourism are the main economic activities in the islands which depend completely from the ecosystems of the area. According the Natural Park management document (PNNC 2006) these activities contribute to the constant pressure on the hydro-biological resources of the zone, and it qualifies them as overexploitation of the resources. Ecosystems such as coral reefs, sea grass prairies and mangroves offer food and protection to fish larvae, crustaceans and mollusks of high commercial interest, and the same

[10] The Law 70 is explained in detail in the forestry case study section.

[11] "baldíos reservados de la nación"

ecosystems are the habitat of many of these species in their adult stage (INVEMAR et al. 2003 in PNNC 2006).

Fisheries

Islas del Rosario and Isla Baru fishing areas are located in the South west of Cartagena bay, in central zone of the Caribbean Colombian continental coast in the surroundings of Isla Grande (10º 11' N y 75º 48' W), to the East Periquito island, to the North Isla del Tesoro, to the West Isla del Rosario and to the South Isla Arena. The coralline formations are located in the North East border of Isla Barú, surrounding Islas del Rosario and forming several banks over the high relief of the continental platform. The coralline area is about 145 km^2. The emerged areas, Islas del Rosario, are 51,8 km^2 and marine areas occupy 67,7 km^2. According (PNNC 2006) the main fishery spot is an area close to Isla Arena, one of the Islas del Rosario archipelago islands, but usually fishermen move among spots looking for better caught. The fishery is mainly developed in the banks, which have been named by local fishermen according to geographical places or dominant species[12]. The most important fishery spots are *La Botella*, *Bajo Largo, Punta Del Medio, Las Palmas* y *Tortugas* (see Figure 8)

In Islas del Rosario the purpose of the fisheries activity is self consumption, commerce and sportive fishing. The 81% of the families are dedicated to the fisheries as a first income activity followed by tourism activities. The fishing gear utilized consists in nylon cord, harpoon, different types of local fishing nets, hooks for lobster capture, diving and nasa (CIOH-Cardique 1998 in PNNC 2006).

The main species caught in the zone are, yellow mackerel (*Caranx chrysos*) red snapper (*Lutjanus spp*), barracuda (*Sphyraena spp*.), and grouper (large genera: *Epinephelus* and *Mycteroperca).* The most abundant species during the whole year are the barracuda and yellow mackerel. In the last years touristic and fishing activities have increased due to the lost of local people lands as a production factor. But the tourism dedication is temporal and the main activity is the fisheries (PNNC 2006).

[12] The names of the fishery spots according PNNC (2006) are: *Pelota del Papá José, Mina Alta, Las Pelotas, Tortuga, Las Picuas, Maravilla, Palmito, Bajo Patancoro, Zona de Pargo, Tío Sorda, Lapa de la Tortuga, Lapa de la Cojinúa, Risco de Nando, Coco afuera, Las Nubes, Bajo El Medio, Bajo Fríjol, Bajo Bunne, Bajo Rabio Ahorcado, Bajo Chara, Bajo Las Piedras.*

In Baru village exists a fishermen organization called Pesbaru founded in 2002 with 24 fishermen as members (PNNC 2006), the main fishing gear utilized by people in this organization are the nylon cord and harpoon. In average the organization buys to its members 50 Kg of fish weekly and approximately 50% is sold in Cartagena. There are other buyers who go directly to Barú (PNNC 2006). Fishermen have seen the decreasing in the caught and an increase in the effort they have to do. According PNNC (2006) there are two principal problems that affect fishermen from the islands: 1) the difficulties in obtaining bait (*carnada*) due to the lack of appropriate equipment and 2) the industrial fishery which is accused of been responsible for the collapse of a number of species due to their highly harmful fishing techniques (trawl fishery in Spanish: *pesca de arrastre*) over reproduction areas.

According INVEMAR (in PNNC 2006) the maximum extraction pressure has been exerted on adult individuals of main species during reproductive season, which could affect the recruitment (Hernández et al. 1997 in PNNC 2006). The same source reports a lack of control in captures as well as absence of adults individuals according local population. Hernandez et al. (1993 in PNNC 2006) shows an overexploitation of the resource, by that time, which indicates that natural regeneration rate was low. Reported causes of this situation are, according (PNNC 2006), the utilization of inappropriate fishing methods and intensive exploitation due to the increase in fish demand during last 30 years. According Becerra et al. (1998 in PNNC 2006) one of the more harmful fishery methods is the dynamite, which utilization is not mentioned by fishermen, the authors affirm that it is the most used in the natural park. One of the consequences of dynamite utilization is the destruction of important coralline areas. Other highly damaging fishery gear is the trammel net (*trasmallo*) also widely used. The general trend of the economic activity has been a decrease in catch and a decrease in the stock of commercial species.

The Natural Park was created in 1997, and it has increased its area from 17.800 Ha in 1977 to 19.506 Ha in 1988, and in 1996 to 120.00 Ha. Park's headquarters are located in Cartagena, but it has two other offices, one in Isla Grande and other in Isla Tesoro, these are part of the Islas del Rosario. In Isla Tesoro there is the holidays' house of the Colombian President (Durán, 2007). The Park has around 20 functionaries, which include professionals (biologists, social workers) and other type of workers whose task consist of Park's territory surveillance among other technical duties. Between 2000 and 2004 the Park's administration was carried out working closely to the local communities. Many of the rules were agreed with local fishermen and, in general terms Park authorities had a good relation with them (Fisherman interview, 10/07/2008). Even the internal rules of the local fishermen association were designed according the Park's proposals and the Ministry of Environment Law (Fisherman interview, 4/07/08). In 2004 the central National Parks' headquarters changed its policy and the director of the park was replaced by a military one. This new administration changed its policies in terms of rule implementation towards favoring the external imposition of the rules, and their strict application. As a consequence, the relation with the community deteriorated and the previous administration's work on rule agreements and awareness has been lost. Currently, the general attitude of local inhabitants towards the Park authorities is characterized by hostility, and prevention with any Park's proposal, situation that has led to conflicts, with fishermen in general, and specially with the organization Pesbarú.

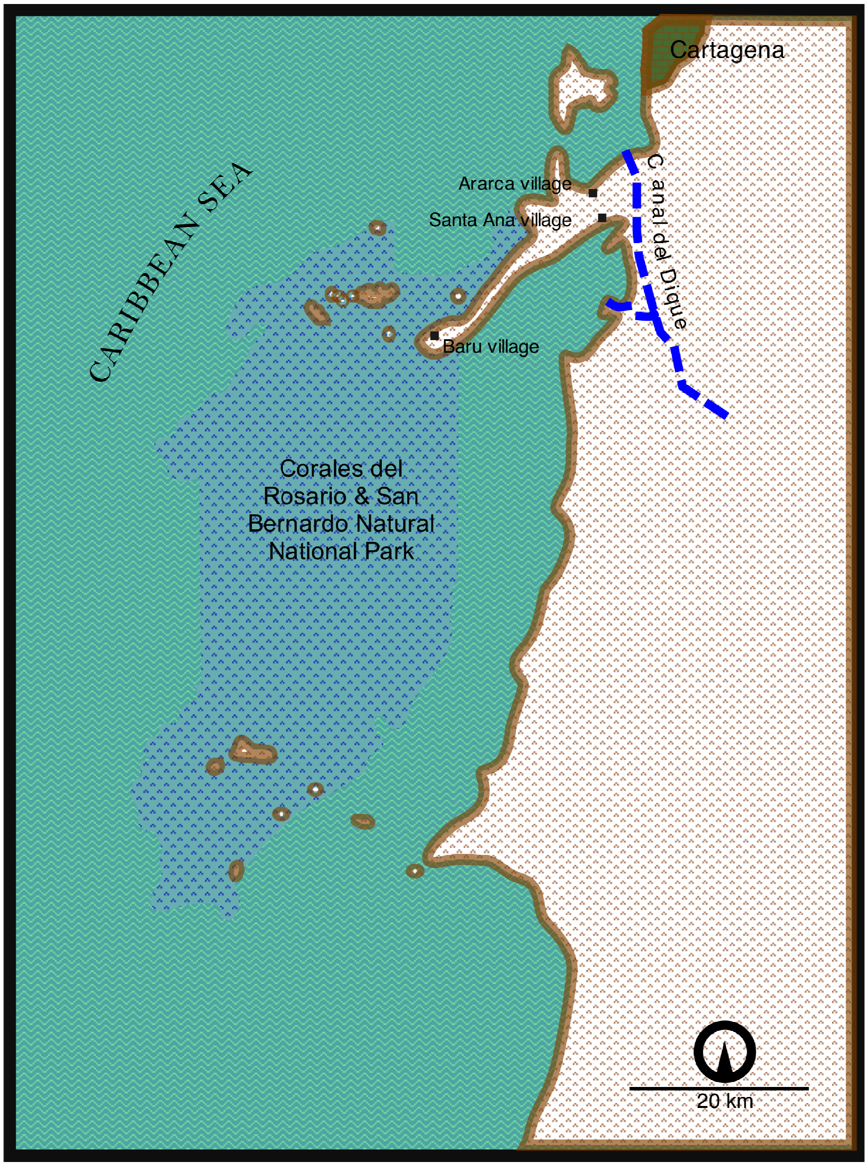

Figure 3.2. Map of the National Natural Park Corales del Rosario y San Bernardo. The purple line represents the park border.

Tourism

Touristic activities are other important economic activity for people from the zone. Due to its natural characteristics the zone has been a touristic place for people who visit Cartagena. In Isla Baru are localized several luxury hotels, restaurants and aquatic sportive facilities. According to the developing plan of Cartagena district, Isla Baru, has been classified as a touristic development zone (Decree 14 of 1993), status that has triggered a number of problems due to the lack of basic public services and land property conflicts.

Touristic activities are important for inhabitants of Islas del Rosario and Isla Barú mainly during holidays seasons, December, January, Easter week and June and July, they carry out diverse activities such as guidance, selling of food and handicrafts and sea transport services. Particularly in Isla Baru a communitarian initiative of eco-hostelling has been developing during last years, the activity is managed by women. Besides the scarcity of public services in the area, the lack of training in hostelling and restaurant services is an obstacle to develop the activity.

According to Duran (2007), the touristic development of the islands and Barú has been a process of exclusion and displacement of native inhabitants, instead of prosperity creation for all the community. The touristic industry generates indirect employment, local people is employed in construction, infrastructure maintaining, and in some cases for cooking. The author states that the native inhabitants have had a permanent difficulty to adapt to this market. The explanation seems to be in the differences between the cultural and economic models of tourist entrepreneurs and natives.

Agriculture

Few people carry out agricultural and cattle rising activities in Isla Barú. Traditionally the zone produced corn, yucca, rice, banana, coconut, prunes, melon, mango, and nispero, and their harvest used to fulfill local necessities and also generated and income surplus by their commercialization in Cartagena markets. Currently the harvest is only for self consuming (PNNC 2006).

4.1.6. Barú: Problems and Potential Shocks

The SES of Barú is about to face several possible economic and social strong perturbations: 1) the strong and imposed environmental institutions, from Park authorities, could cause the deterioration of local livelihoods, 2) the governmental and private capitals interest in the touristic development of the region.

Geographic location of Barú, it is in the south tip of Barú Island, which is the closest point to the Rosario Islands, makes this village a strategic point for future touristic industry. Importantly enough is to mention that currently there is not a proper terrestrial communication with Cartagena, the regional metropolis, but one of the first steps for this touristic development is the construction of the road. This topic has been an issue among local population during the last few years.

The most important source of food and income for the local population is the fisheries, that necessary has to be practiced inside the Natural Park. The general perception among local fishermen and Park authorities is that the fisheries resource has been depleted and that today is in a critical situation. This resource is of fundamental importance for both, the touristic industry and the local population.

There are five elements that influence environmental institutional dynamics:

1) The priority of formal institutions is the conservation of marine resources without taking into account the local population and its ecological knowledge as part of the system.
2) As it has been traditional in Colombian environmental policies, the mental model that persists about the nature is what Holling et al. (2002) calls the "Anarchic Nature", which is dominated by positive feedback mechanisms that could easily trigger changes in equilibrium, and the environmental policies clearly have been characterized by the precautionary principle.
3) The local cultural and economic model does not favors the accumulation of capital, instead, it is a rationality of daily recollection of the proteins for the household, or the economic means for obtain the food. This has been documented by Duran (2007) in his anthropological study of this community. This cultural behavior has determined the exclusion of natives, in their own territory, by entrepreneurs, that do not hire locals because due to their perception about natives as lazy people.
4) Park authorities see natives as intruders, denying systematically their population history. And, locals in turn, do not perceive the Park as a natural authority.
5) Local population has been historically immerse in situations where the rule is the illegality, and have beneficiated from this state of affairs. In addition the perception of the Colombian government is strongly linked with corruption.

4.2 Forestry community of Salahonda

The forestry case study of this research offers an interesting contrast with the other two sites (Barú and Lenguazaque) regarding the political meaning of the relation between society and ecosystems. The community of Salahonda has, not only a strong economic dependence on forestry resources, but cultural and political dependency with the tropical forest, biodiversity and the territory. Next, I tell a history of a region in which the relation between humans and ecosystems has been lived, perceived and conceptualized by the community and the state, integrally without the classical separation. The SES approach has been naturally used, in institutional crafting by the state and the communities, but with different purposes, and at the service of different political discourses and objectives. In this case, is almost impossible not to understand the historical and geographical context without revising the political ecology field. Concepts such as territory, space, social movements and governance are central to understand cultural identity, forest management and ecosystem governance.

Salahonda village is located in the south of the Pacific Coast lowlands of Colombia in the Patia River delta 30 km from the city of Tumaco. His Afrocolombian population has adapted to the environment since they were brought as slaves in the 16th century, through the development of daily spatial configurations conforming what Oslender (1999) has called an "aquatic space" that has influenced social structure and social movements in the region.

4.2.1. The Pacific lowlands

The Colombian Pacific region has one of the highest values of biodiversity in the world. It comprehends an area of ten million of hectares, 62% of Colombian territory (Oslander 1999). From a regional perspective we can quote the classic geographical work of Robert West about the region:

> "*Seen from the air the canopy formed by the giant trees resembles a sea of green, overlapping umbrellas, broken only by streams and occasional clearings. Hundreds of rivers, often in flood, run through the forest from hill and mountain slope to sea. They are the pathways for human travel and their banks are the main sites of human habitation*" (West, 1957).

Fifty years later, and in spite of the high deforestation rates of 53.000 hectares/year (DNP 1998) one has a similar perception of the region as Oslender states about West description:

> "*this is still the impression that a bird's eye view gives of the Pacific Lowlands, a region considered to contain one of the highest levels of biodiversity in the world, although only an estimated 50 percent of its plant species are known and identified to date. It covers an area of around ten million hectares, some 6.2 percent of Colombia's total land surface, and extends from the Western Andean slopes and the border with Ecuador in the south to the Darien gap on the Panamanian border in the north" (*Oslender 2002).

The region is located within the Intertropical Convergence Zone, a low pressure belt with converging humid air masses which creates such special conditions to be consider as one of the highest precipitation levels of the world with annual averages of 10.000 mm in some areas. A dense network of rivers that usually flood, which go from east to west, from the westerly Andean Range to the Pacific Ocean, is the main hydrographical characteristic of the region. The south part of its 1.300 km of coastline is composed of mangrove areas which are an important source of ecosystem services and goods. The tidal range in the Pacific Coast goes up to 4 meters and enters upstream around 20 km (Oslender 2002), this characteristic determines the way humans groups live in the region in many ways.

At regional scale, it is possible to refer to the Pacific area of interest as West (1957) did it, "the cultural area of Pacific lowlands". Physically, according West (1957), the region comprehends the Colombian western part, the north part of Esmeraldas province in Ecuador and most of the Darien province in the south east of Panama. This is a belt of almost 1000 km length and a wide between 80 and 160 km. This area is located between the Pacific Ocean and the west slope of the Andean western mountain range. In Colombia this territory is part of the administrative departments of Choco, northwestern limit of Antioquia and the west of Valle, Cauca and Nariño.

According West, the physical unity of the region is its climate, humid and warm and the tropical forest which covers most of the space. These characteristics go beyond the Colombian territory and even, towards the north, it includes the coast of Costa Rica and Nicaragua, and towards the south it reaches Guayaquil. Therefore, the limits of the cultural area of Pacific lowlands are determined "*by the predominance of black population, by a common way of life based in subsistence agriculture, artisanal fisheries and primitive* *mining, and by its common historical development, which differs from the adjacent areas*" (West 1957). Entering the 21 century, these characteristics remain in addition to the logging activity developed during the second part of 20th century, activity that has contributed to enrich the identity of the cultural area, and to reinforce the strong territorial dimension of the cultural identity of its inhabitants. An important number of scholars (Restrepo, Oslander, Escobar, Friedeman, Almario, among others) have studied social processes of afro Colombian groups in this region from anthropological perspective, and one of the important insights is that all identity formation processes are strongly linked to territory and the geographic and ecosistemic conditions. Almario (2001) concludes that, the ethnic battles during the 90s, of Afro-Colombians from the Pacific region, have had as a guiding thread the defense of the territory. Evidence of this fact, Almario continues, has been the social movements against a number of economic and political events and situations regarding natural resources and territorial dimensions. The most important have been the social mobilization against the digging machines for modern mining in the middle and upper part of the rivers, denounces against the intensive natural resources extraction practices by big and external enterprises, the awareness of the serious consequences of the construction of the so called Canal Naranjo[13] , social mobilizations against oil spills in their coasts, the exigencies to include in their ethnic territories the mangrove areas, the resistance to coca crops fumigation, the battle in order to reach the common property titles of their territories and the big social organization of the communitarian councils to control and manage the territory (Almario 2001).

4.2.2. The biophysical environment

Figure 3 portraits the Pacific Colombian region which eastern border is the western Andean mountain range and the Pacific Ocean to the west. At regional scale I will focus on

[13]In 1973, the timber entrepreneur Enrique Naranjo built a small channel (1.5 meters wide, 2 meters depth, and 1.8 km long) between the Patía and Sanquianga Rivers in their upper part of the basins. These rivers are the most important of the region. His purpose was to transport timber from the Patia to the Sanquianga river, where he had a sawmill. As a consequence, the Patia River started to pour its waters into the Sanquianga, hydrologic dynamics was altered for both rivers. Floods and lose of productive lands along all the Sanquianga river banks in the entire region started to occur, while in the Patia river basin and delta the effect was of big droughts and decreasing of river levels. The environmental, social and economic impacts included erosion, water dams, destruction of crops and houses, people displacement, modification of navigation ways among others (Leal & Restrepo, 2003; Corte Constitucional de Colombia, 1995). This, initially, small infrastructure intervention generated a big proportion impact, without antecendents in the entire SES of the region.

the Pacific lowlands, term coined by Robert C. West in the most important geographical work of the area at regional scale so far; "The pacific Lowlands of Colombia, A Negroid Area of the American Tropics". Though it was written in 1957, his clear and rigorous description of the region is still a compulsory geographical reference for the region. The next description of climate, geomorphology and landscapes are based mainly on this work, except for the geological setting which knowledge has been increased considerably since the 70s.

West classifies the entire Pacific region in three macro landscape types: 1) recent alluvial plains, 2) hills of dissected Tertiary sediments, and 3) Mesozoic complex mountain areas. The lowlands are constituted by the two first landscapes, which altitudes are less than 600 meters above sea level.

The northwestern region of South America is formed, geologically, by a long structural depression called Bolivar geo syncline. During the Eocene and Pliocene, this structure connected periodically Pacific with Atlantic oceans. A series of basins with east-west axes, perpendicular to the main geo syncline axe, shape the geo syncline. These basins have each one its own fluvial system, and are separated by small anticline structures. The axe of the geo syncline Bolivar corresponds to the current coastal line of the lowlands; the western flank has been eroded and covered by the sea. These structures are located in the wastern flank of the Western Mountain Range of Colombian Andes which is formed by volcanic rocks from Upper Cretaceous (Ingeominas 1997 in Toro-Ramírez 2005) and Tertiary sedimentary rocks, as well as volcanic and plutonic rocks from Mesozoic and Tertiary age (Case et al.1971 in Toro-Ramírez 2005). These geological formations are deformed due to the tectonic dynamics of the region, producing important fault zones.

Perhaps the most important tectonic characteristic of the Colombian Pacific Border is its location in the border between Nazca and South American tectonic plates. Geologically, this border constitutes a subduction zone, where the oceanic lithosphere (Nazca plate) slides underneath the continental crust (South American plate). According Toro-Ramírez (2005) the speed of is 17 mm/year (towards the east) and it is being accumulated in tectonic deformation. The consequence of this geological dynamics is the earthquake generation when deformation forces are liberated. The entire Colombian Pacific coast is classified as high seismicity risk. This dynamics is associated to the main earthquakes in the zone recorder during the 20th century, 1906, 1942, 1958 and 1979 (Toro-Ramírez 2005). The earthquake of 1979 that affected mostly the southern region of

Colombian Pacific coast (December 12^{th}, 7.9 in Richter scale) generating a posterior tsunami is an example of the effects of the zone geological setting.

Particularly, in the south Pacific coast, Salahonda area is located in the tectonic basin of the low Patía River. The landforms are formed by Quaternary sediments delimited by low hills from Tertiary (Parra and Jaramillo 2006). In the low hills there are intercalations of claystones, mudstones and sandstones from Tertiary. Locally, these sedimentary rocks are covered by Plio-Pleistocene sedimentary bodies formed by volcanic clastic rocks and tuffs which form soft landscapes. The area is located in the delta of Salahonda that is part of the Patia River mouth (Parra and Jaramillo 2006).

The recent alluvial plains have a wide between 8 and 5 km in the whole Pacific lowland region except in the study zone, on the north of the city of Tumaco, where it has a 55 km wide in the Patia River delta. An important characteristic is the dominance of mangrove forest on the sea margins, with fresh water wetlands on their back area. Most part of the Pacific lowlands is formed by hills of Tertiary sediments, where there are terraces that are inhabited mainly on the rivers' banks. These terraces are dissected by fresh water streams that end usually in the river and form small waterfalls (West 1957). "*Far from the main rivers, prevails a labyrinth of slopes covered by tropical rainforest*" (West 1957).

Climate in the South Pacific Lowlands

The climatic distinctive characters of Pacific lowlands are its high humidity and precipitation levels. The whole region is probably the rainiest area of the entire American continent, with a yearly precipitation between 5.000 and 10.000 mm (West 1957). According West, high precipitation levels of the area seem to be related with the Equatorial Convergence Zone, which is located across the Pacific at the latitude of 5^{o} north, where the humid and unstable air masses rise over the warm Equatorial cross-current producing abundant oceanic precipitations. Colombian Pacific lowlands are located in the east corner of this zone. In the region of Tumaco the less rainy season corresponds to September, October and November months, and the other period of minimum precipitations is from February to March. In average, the rainy days are 232 in the region of Tumaco. If one observes the precipitation regime in the Equatorial climate, the characteristic is more the variety than the monotony that usually people associate with the Tropic.

Temperature is the typical of the most of the humid tropical areas, with monthly averages with a very low seasonal variation, less than $1^{o}C$ which rarely area higher than

28^{o}C. Maximum average temperature is not higher than 31.5^{o}C and minimum is not less than 22 ^{o}C (West 1957). The author remarks that these figures are averages and they do not show "*the real extremes which are the ones that determine plant growth and people well being*" (my translation). A record for Tumaco, the closest meteorological station to the study zone, between 1934 and 1947 gives an absolute maximum of 32^{o}C and an absolute minimum of 19.6^{o}C (Anuario Metereológico, 1934-1947 (Bogotá) cited in West 1957). Clouds prevent the temperature excess and the sky usually is completely covered towards 3 or 4 pm except February and March, the dryer months of the year (West 1957). The relative humidity daily average for 7 a.m, 12 m. and 4 p.m are 94.2, 79.5 and 82% respectively (West 1957). These values make the humidity, maybe the most remarkable climatic characteristic for the person who visits the zone. Humidity is high even in the sunny days. The values are higher in the morning due to the low relative temperature.

Ecosystems of the South Pacific Lowlands

Forestry formations in the Colombian Pacific region is briefly summarized from Leal and Restrepo (2003) description. The forest has been classified in homogeneous and heterogeneous forest. The first group is characterized by few species and its name comes from the dominant one, such as catival, manglar (mangrove) and naidizal. The heterogeneous forest is characterized by several species and it is not possible to name them with one type of tree. For the logging industry each type of forest has its own usefulness; the homogeneous forest allows efficiently extracting big quantities of ordinary wood for one single purpose. Heterogeneous forests are characterized by a composition of many species in low densities, generally in low hill landscapes between the rivers. In these types of forests, the effort is oriented towards the extraction of fine and highly valuable wood. This variation of forest types is central in order to understand the different forms of timber extraction in the region.

According Ospina (2008), the Patía River delta is composed of the following ecosystems, from the tidal plains to the flooding plains.

Mangroves. Located in the interface sea – river characterized by brackish water. The main species are: *Rhizophora* spp., *Conocarpus erectus, Laguncularia racemosa, Avicennia* spp., *Pelliceria rhizophorae*.

Natales. This is a narrow zone located behind the mangroves in which the Nato (*Mora megistosperma*) is predominant. This zone works as a transition towards the

Guandales zone. The Nato is a big tree that needs less salty water, and it is mixed with the Naidi palm (*Euterpe oleracea*), the Sapotolongo (*Pachira aquatica*) and the Garza (*Tabebuia rosea*).

Guandales. Far from the brackish waters, this ecosystem is located in the flooding zones. They are classified by UICN as fresh water forestry wetlands in peat marshes. There are several associations in these forests, which have been the main source of the timber that have been harvested from the Pacific region. There are four main associations. 1) Sajales: these are forests where the dominant species is the Sajo (*Campnosperma panamensis*). 2) Cuangariales: the predominant species is the Cuángare (*Otoba gracilipes*). 3) Naidizales: it is a forest dominated by the Naidi palm (*Euterpe oleracea*). And, 4) Mixed Guandal: dominated by a species of oak tree (*Terminalia amazonia*), Ceibo (*Ceiba pentandra*), Jigua (*Aniba puchuryminor*), and Cuángare among others (Ospina, 2008). Heterogeneous forests located in the Tertiary hills near to Salahonda are characterized by a high number of species but in low densities (Leal & Restrepo, 2003).

4.2.3. Salahonda: The social system

Spaniards never colonized the area due to the access difficulties which still exist; currently there are just three main roads that communicate the zone by land with the Andean central region of the country. According DANE (1993) there are 1.3 million inhabitants in the Pacific region of Colombia, 90% are Afro-Colombian, 5% indigenous of several ethnic groups and around 5% of *mestizos*. Afro-Colombian people are the descendants of African slaves brought to the region to work in the gold mines since the 16th century or to work in the agriculture and domestic service (Colmenares 1976; del Castillo 1982; Maya 2004). The groups of slaves that resisted and escape were called "*cimarrones*"; they settled in the river banks and formed free villages. Currently, the settlement pattern in the Pacific Coast is composed by villages along the riverbanks, coastal small villages located in the beaches, mangrove areas and close to river deltas, and several urban centers from north to south Quibdo, Buenaventura and Tumaco.

Salahonda village is the urban center of the forestry case study, which is located 50 Km North from Tumaco. The forest used by its inhabitants is part of the ACAPA's territory. The textual meaning of ACAPA is the *Gran consejo Comunitario de comunidades negras del Río Patía Grande sus Brazos y la Ensenada* (Great Communitarian Council of the Black Communities of the Patía River its Branches and the

Bay – my translation). The Law 70 (1993) gives to the Afro-Colombian people the right to self govern their territories, and the responsibility of its environmental conservation. In order to put in practice self governance processes, the Law creates the figure of the Communitarian Councils. The rights to the territory are given, by the Law, not individually but collectively. The Communitarian Council[14] is the legislative form that allows the collective land entitling to the Afro – Colombians, and it is expressed as community government (Rivas, 2001). In the Colombian Pacific region there are 87 communitarian councils with 3'939.454 ha (IGAC 2002) of land under common property titles; this figure represents the 3.5 % of Colombian territory. The land title of ACAPA has 103.607 hectares (ACAPA 2005) of collective property.

ACAPA's territory is composed by 32 *veredas*, located in three municipalities of the Department of Nariño: Tumaco, Salahonda and Mosquera, and in its territory live 8.106 persons. The main influence area of the Council is the territory of Salahonda. Rural inhabitants of the Salahonda municipality belong to ACAPA. The total population of Salahonda is 7.075 (DANE 1993 in Rivas, 2001), and 3344 live in the rural zone, this means that the 50% of Salahonda municipality are ACAPA members. In contrast with Tumaco and Mosquera municipalities, only 5 % and 0.5%, respectively, of the population belong to the Council. This fact gives an important strength to Salahonda members (Rivas, 2001).

[14] The Comunitarian Council is formed by the Assembly, which is the higher government instance. This Assembly is conformed by representatives of each *vereda*, a directive committee, and the Comunitarian Council Committee, formed by people elected by the Assembly (Rivas, 2001). .

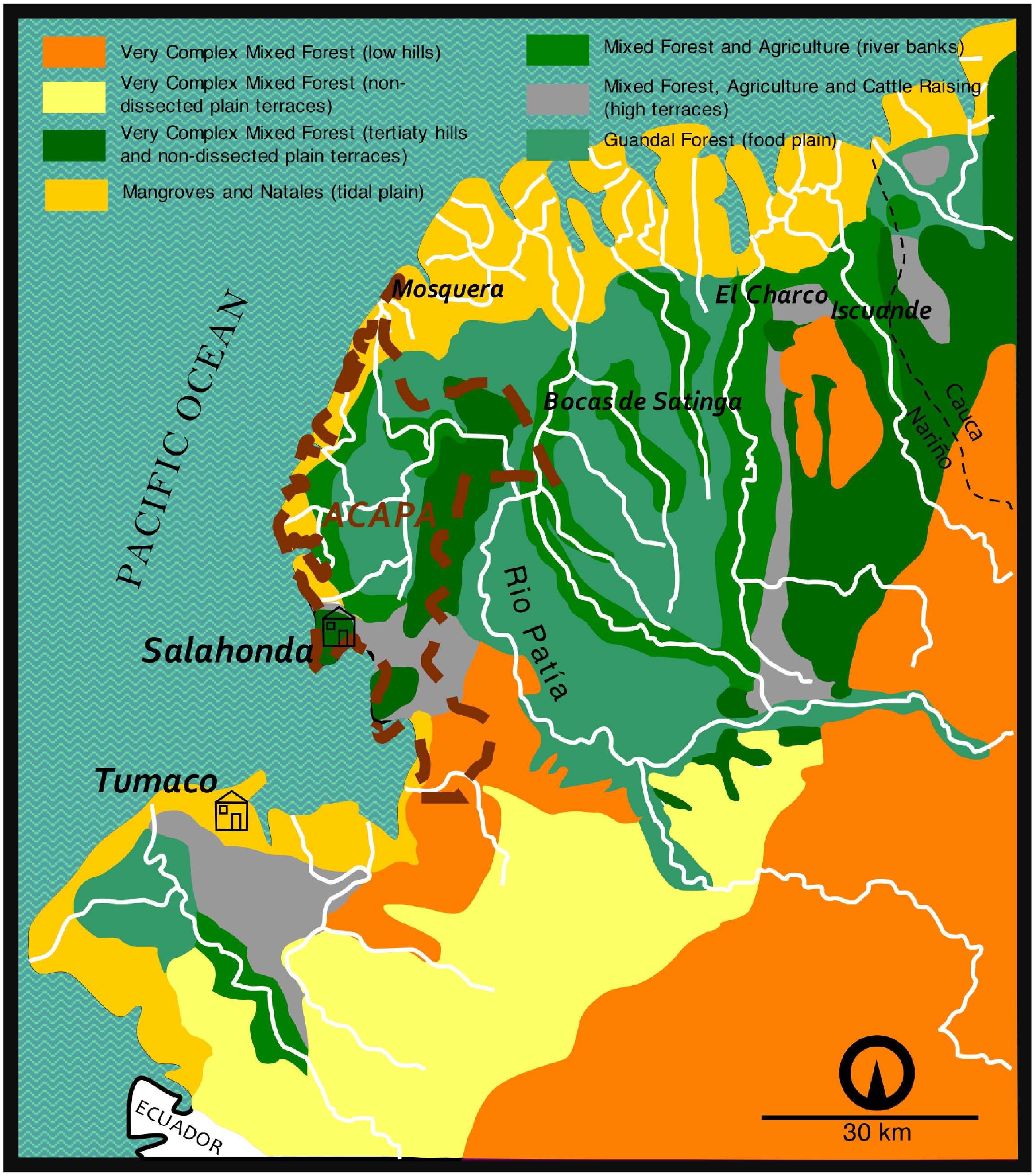

Figure 3.3 Location of the Forestry community. Salahonda village and vegetal cover map. Modified from Del Valle, 1996.

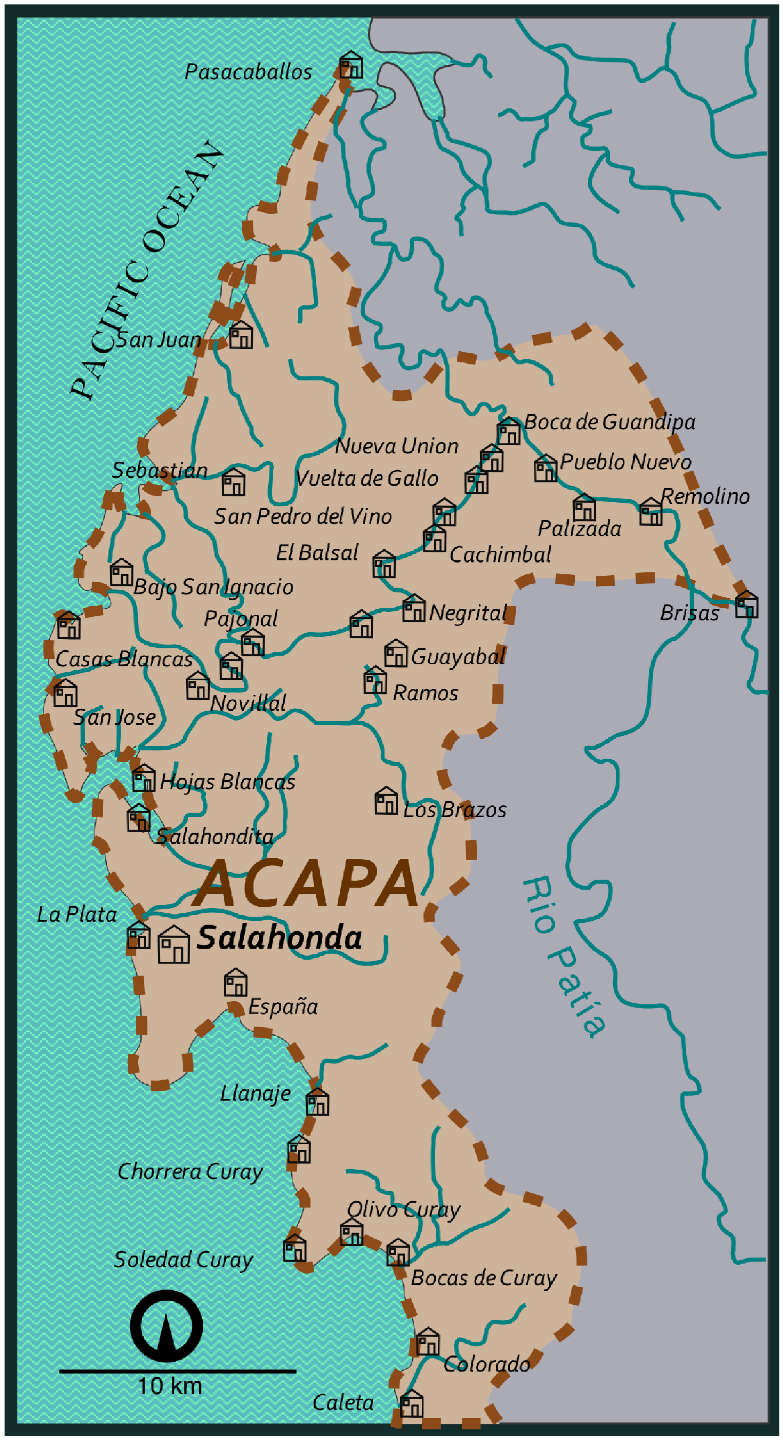

Figure 3.4. ACAPA's territory in the context of the Colombian Pacific Region. Territory map modified from ACAPA (2005).

Brief historical overview of population processes

Next I will give a brief overview on the population history of the region. I used information produced by ACAPA (2005) and other authors that have investigated the Coquest and Colonial periods.

First vestiges of human population in the South Pacific Lowlands date back from 7.000 B.C. Mangroves has been considered as an strategic ecosystem for pre- Hispanic settlers. During IV and II centuries BC archeologists have recognized a cultural complex called Tumaco – La Tolita present in the North Pacific Coast of Ecuador and the South Colombian Pacific Coast. One of the characteristics of pre-Hispanic cultures in the region was the intensive utilization of Mangrove and marine ecosystem resources, especially mollusks. During Tumaco - La Tolita period, according archaeological studies (ACAPA, 2005), population density was high and it was necesary the knowledge, adaptation and utilization of the different ecosystems.

Spaniards found, in XVI century, a several indigenous groups who made a strong opposition to the Europeans. The main groups were Tumas, Iscuandés, Nulpes, Guapis, Sindaguas and Barbacoas, their resistance was based on the sprawl settlement pattern, a low social stratification (ACAPA, 2005), and the hard environmenmtal conditions to which the invaders were not used. Finally, according Oviedo (1996), in 1536 the main indigenous chiefs were assasinated and the Spaniards can rule the territory without major resistance.

According ACAPA (2005), between 1600 and 1650 Spaniards started their occupation, exploitation and spatial distribution proceses in the region. The fundamental economic activity was the gold mining, and the rest of produvctive activities developed around it. From mining enclaves Europeans explored the upper and middle parts of the rivers. Towards the middle of XVII century, indigenous labor force induced to the Spaniards to the introduction of African population, as slaves, for mining activities. As a consequence African people started to be numerically higher than the other groups, while the remaining indigenous groups were displaced to the higher parts of the Colombian Western Cordillera, towards the East.

The arrival of African slaves started the second aluvial gold mining exploitation in the late 17^{th} century (Maya, 2004). Africans arrived from Cartagena that was the legal slave trade port and from Panama, the illegal ones. The origins of African population was Sudan, which people came from the Kingdoms of Ghana, Fanti and Ashanti. People from the rivers of Guinea, Sierra Leona, Arará, Mina, Carabalí, Congo and Angola, but the majority of Africans that came to the Colombian Pacific coast were from Guinea coast and Congo (Flórez & Millán, 2007). Most of the slaves, in 1759, were from the Ashanti Confederation (28,7%), from Ewe-Fon of Dahomey and Youruba of Benin (19%), from Bantu kingdoms form Congo and Angola (16,3%), and from Mali kingdoms the 4,1% (Sánchez et al. 1993, in (Flórez & Millán, 2007). According Flórez and Millan (2007), the prefered groups for the mining work were from Congo and Carabali tribes because of their physical strenght.

The settlement pattern of Afro-Colombian population is explained by (Oslender, 2002). There were two forms, for slaves, for becoming free people in the Colombian Pacific. They could escape, becoming *cimarrones*, or they could buy their freedom with gold. The first, settled in the farthest parts of the rivers, and the latest, used to follow the Spaniards gold mining troops in their movemenmts along the rivers and slowly they abandoned the activity, settled down in the banks of the rivers and slowly changed their productive activities to agriculture and river fisheries. Through this process, "*the slavery was entered in another phase…of black free territoriality construction*" (Romero, 1993 cited in Oslender, 2002), which led to a particular space structuration, which Oslender calls "the logic of the river". However it was only since 1851, with the slavery abolition, that the sprawl population process along the rivers was consolidated generating the "*lineal village in line on the river bank*" (Aprile, 1993 cited in Oslender 2002). In addition to the advantages regarding productive soils for agriculture and a risch fishery offer, the the rivers became the roads of the Pacific (Oslender, 2002). This form of structuring the space persists today and determines people daily life, social relations, society nature relations, and forest use.

In the next section I will go through the history of the natural resources extractive cycles and a small description of economic activities, focusing on the forest utilization.

4.2.4. Salahonda: Economic activities

Agriculture in the ACAPA's territory is constituted by associated crops except for the rice and occasionally plantain. In the farms there are several products such as cacao, sugar cane, yucca, corn among other tropical crops. Artisanal fisheries are important in the territory, the activity is practiced in the Patia River, small lakes and the sea, and a high variety of fishery gear is used. People from ACAPA's territory practice hunting taking advantage of the tropical humid forests of the region. Main species captured are rabbits, fox, armadillos, Tiger Cat or Tigrillo (*Leopardus tigrinus pardinoides*), some monkeys species and several birds of the Cracidae family, among others. They use, as hunting gear, rifle and traps (Ospina, 2008). The author remarks the fact that this activity has been decreasing due to cultural and ecosystem changes. People use to collect diverse forest products for household consumption, medicines, construction materials and tools manufacture. Mangrove ecosystem is an important source of clams, which are collected mainly by women and children, and represent an important economic activity for household consumption and local trade. The mollusk species they collect is the *Anadara tuberculosa*, which is harvested in the whole south Pacific coast, including Ecuador north coast. Livestock, as pigs and poultry, is maintained in households for self consumption. In some areas people have cleared the forest in order to maintain cattle of small scale (Ospina, 2008).

During the late 90s coca illegal use crops have started to occupied important areas of the territory (Ospina, 2008). According the Colombian National Police information service in the municipality of Salahonda there were 1.350 Ha of coca crops in the year 2002 (Martínez, 2006).

Forest exploitation is the most important economic activity of the region. The Pacific has been international and national exporter of timber during some periods of the 20th century. Next I synthesize this history for the region of Tumaco with emphasis on ACAPA's territory, based on the research of Leal and Restrepo (2003) and Ospina (2008).

Natural resource extractive cycles

The economic model that has dominated the Colombian Pacific Region during more than three centuries is an extractive economic model (Leal and Restrepo 2003). According the authors, an extractive economy implies that the resources are mainly created by nature instead by the human work. The term economy implies also that the extractive processes must be the axis of the region's economy, such processes are the set of activities which generate accumulation, and it means that subsistence extraction is out of the concept of extractive economy. The region has served as a big pantry since Spanish conquest times in a number of cycles that began with the gold extraction from 16th century to the end of 19th. The next cycle consisted in the collection of Tagua (*Phytelephas macrocarpa*) seeds and latex from rubber trees for commercialization in the United States and European markets, this phase lasted until the middle of 20th century. The second half of 20th century has been characterized by a wood extraction cycle (Leal and Restrepo 2003). As the same authors state several wood extraction decades have modeled the physical and social landscape of the region, and in order to understand the Colombian Pacific region it is necessary to take into account the history of logging activity (Leal and Restrepo 2003).

The logging in the Colombian Pacific has three main extraction areas, from south to north, the first is located in the influence area of Tumaco city, second, Buenaventura city and the coast, and the third in the Atrato River basin (Leal and Restrepo 2003). The case study (Salahonda village) is located in the Tumaco influence area which has had three historical phases, according Leal and Restrepo (2003), which will be summarized next.

- *First phase: Late XIX century – 1950.*

The mechanized forest exploitation started towards the end of the 19th century, until the peak of timber exportations in the middle of 20th century. This phase was characterized by the existence of few sawmills in Tumaco and Salahona. The incipient industry satisfied mainly local markets, and the wood was extracted from forests near to the villages. Specialization of loggers was minimum, sawmills bought the wood to people who cut timber as one activity more among several others for household subsistence. Between 1940 and 1943 the timber experts increased towards the United States in order to satisfy the demand for the war airplanes in the Second World War. By this time there were two sawmills installed in Salahonda (Leal & Restrepo, 2003).

- *Second phase: 1950 – 1975*.

Middle of 20th century marks the timber extraction peak in the region characterized by "*alien capital intervention, technologic innovation in sawmills, extraction boundary advance, the growing importance of the sector for the zone, and the consolidation of a group of loggers and wage earners dependent of the industry*" (Leal & Restrepo, 2003: 49

– my translation). This peak period in timber extraction industry has its causes in the 30s and 40s decades. The development of synthetic substitutes for the Tagua (*Phytelephas macrocarpa*) and the natural rubber production in the Asian South East, in these two decades, led to the collapse of both extractive activities (Leal & Restrepo, 2003; West, 1957). During this period Salahonda was an important place for the collection of the timber from the whole Patia River. In 1957 there were around 14 sawmills in the Pacific Zone of the Nariño department, by 1965 there were 39, in 1969, the figure reached 55 sawmills. Tumaco and Salahonda concentrated most of the sawmills of the department.

The history of the most important forestry company that operated in the zone gives an idea of what happened in the zone during this period. The company started its work in 1954 with a mix of Colombian and foreingn capitals, and controlled all the exports to USA and Canada. In 1963 was sold to a USA corporation, but in 1967 went banckrupt and passed to another USA corporation control, and in 1969 it had a consesion of 72 thousand HA in the banks of the Patia River. From 1971 to 1973 it was composed again for mixed capital, Colombian and USA, and it export tens of thousands tons of timber. Finally in 1976, the company stopped to pay wages generating an important laboral and social conflict (Leal & Restrepo, 2003). According these authors the causes of the final failure, not only of this company, but of the peak extraction cycle finish, were three: a) the depletion of wood stocks in the Patía River, and b) the building of Naranjo Channel, which change the timber exploitation towards the north, the zone of the Sanquianga River. Until the middle of 70s Tumaco and Salahonda region produced the 65% of the timber in the Nariño Pacific Coast (Leal & Restrepo, 2003).

- *Third phase: 1975 – present time.*

The third phase of timber extraction industry is characterized by the existence of few sawmills, which sell their products to companies in the interior of the country, and a small percentage of the production satisfies the local demand. In contrast with previous phases, in this period, there are *corteros* (chain-saw men) that go directly to the forest and sell timber to the sawmills, and the main tree species exploited is the Sajo (*Campnosperma panamensis*) (Leal & Restrepo, 2003).

The early 90s mark a milestone in the institutional framework for the relation between the society and ecosystems in the whole Colombian Pacific Region inhabited by Afro – Colombian population. According the 1991 new Colombian constitution, the country is a multi cultural and pluri ethnic state. The constitution also sets a framework for a National Environmental System tightly related with social dimensions. One of the consequences is the Law 70 of 1993, or the black community's law, that fundamentally gives autonomy to Afro-Colombian population on the governance of their territories. In this scenario, ACAPA has the responsibility and the right to decide how to negotiate and to plan the forest management of its territory. However, the governance of the Council is constrained by the different armed groups that enter into the territory defending the coca crops (Ospina, 2008), and sometimes the interests of national and international capitals interested in the timber and the new African palm plantations projects. In this way, the first formal local ethnic governance system with possibilities to design institutions for the forest management is limited by armed actors interested in the territory (Ospina, 2008).

4.2.5. Salahonda: Territory, space conceptions, and social organization

Black social movements in Colombia, before the Constitution of 1991, were focus on social inclusion and anti discrimination vindications influenced by USA black movements for social rights of the 60, 70 and 80s (Rivas, 2001). After 1991 "*Colombian black community is defined by its cultural singularity, as a result, on one side, of a common origin and ancestral roots in the African continent, and on the other side, by shared traditional practices, configured in the historic experience of an isolation and territorial construction strategy*" (Restrepo, 1997: 300 in Rivas, 2001). This new dynamic, in the Colombian Pacific region is fed by the Law 70 for black communities, the collective land entitlement, cultural traditions, and the biodiversity and sustainable development discourse (Escobar, 1997). This new period leads to a particular definition and inclusion of the notion of territory in institutional crafting and natural resources management strongly linked to cultural characteristics.

Before to discuss the notion of territory in the region, it is convenient to, briefly, explain the type of space upon which the territory has been built. As I mentioned above, the river has been the axis of the life in the Pacific, and it has been the main communication way, therefore it has consolidated as the most important social space, around which all economic, cultural and social interactions have been structured (Oslender,2002). Oslender has coined the term "aquatic space" regarding to how the "*specific ways in which "aquatic" elements, such as the high levels of rain, tide impacts, the labyrinthine networks of mangroves and rivers, and the frequent floods, among others, have influenced the daily* *life forms*". Of course the logging is not an exception to this fact, the high changes in water level due to the tides, not only in the marine coast line, but through the whole extension of the rivers, determines the timing and the form of take out from the forest and transport the timber. Hoffman (2002) calls the "fluvial bank dispositive" to the specificity of the region that was taken into account by the mentioned Law 70, which recognizes singular agrarian and ethnic conditions that have produced a very particular socio-espatial configuration. According Oslender (2002), "*In the local geographic imaginary, different parts of a river are mutually interconnected, and they have to be considered as integral parts of the same socio-cultural and economic system*". The conexion in any particular basin is given, not only by the fluvial trade flow, but, by the land distribution (Oslender, 2002).

Scholars, and particularly anthropologists refer to the Colombian Pacific region as a "*different world, with a very particular cognitive and structural model, and a univers of different meanings*" (Escobar, 2000: 151- my translation). This vision has to do with the political discurse that has been built, by local social organizations, since the 90s, around the concept of territory, biodiversity and culture. According the anthropoligist of the development, Arturo Escobar, social movements in the Pacífico have introduced several important conceptual innovations. The first is the definition of biodiversity which is equal to *territory plus culture,* in the second place it is the *territory-region of ethnic groups,* which represents an ecologic and cultural unit produced trhough the community daily practices. "*The territory-region is a management category that points out the construction of of alternative life and society models … it is an attempt to explain the biological diversity from the ecocultural logic of the Pacific. The territory is the space used to satisfy community needs…The territory represents the community life project*." (Escobar, 2000: 137- my translation).

This notion of territory is an attempt to remark the relation between space, culture and nature, where the territory is a conceptual unit and a political project. The concept has one of their more relevant axes around the relation between land collective entitlement and settlement patterns (Escobar, 2000).

4.2.6. Salahonda: Problems and Potential Shocks

Since early 90s formal institutions, at national level, have produced important changes at regional and local scale in the Pacific Coast. The political discourse developed of Afro-Colombian activists has focused on the relation between society and nature, and specially the notion of territory has served to vindicate their autonomy in natural resource management.

Environmental policy focus has changed from a traditionl conservationist perspective to an integral vision of ecosystems and society. Several authors have affirmed that the Law 70 have been possible thanks to two kind of situations: internal logics of the country such as violence regional issues, and international pressure such as Human Rights violations, ethnic minorities abandon, and environmental defense (Agudelo, 1999; Hoffmann, 1998, in Rivas, 2001). But according to Rivas (2001) the fundamental interest of Colombian government is the biodiversity protection, and the law is not really an institutional framework for Afro Colombians, but for the country insertion in the international arena of biodiversity conservation[15]. The way black communities of the Pacific are integrated to environmental conservation process, consists in the compulsory character of conserving the environment that comes with the collective land titles (Rivas, 2001).

ACAPA was created in 1992 as a traditional peasant organization and it was transformed in a Comunitarian Council in 1997, when it applied to the colective territory entitlement. This fact has deep implications in the real relation between people and natural resources, and particularly in forest management, because people traditionally managed their lands with private property rights, and under the individual production unit peasant logic (Rivas, 2001). The Law 70 is based on the idea that local communities traditionally have carried out their productive practices in tune with biodiversity conservation. According Rivas (2001), the productive history of the Pacific have been characterized by two contradictory production forms: the intensive extraction of natural resources by corporations of national and international capitals, the timber extraction from forest by

[15] The "Biogeographic Choco" ("Chocó Biogeográfico"), which includes the entire Colombian Pacific Coast, has been recognized as the region with the highest biodiversity per unit of the world. This is, 400 vegetal species and 800 invertebrates species, which is higher than the Amazonian figures (Rivas, 2001).

locals as a unique livelihood, and the permanence of "sustainable" practices based on the combination of several crops in their individual parcels.

In this scenario, there are four points that constitute the main problems and perturbations that is facing the community of Salahonda that influence institutional arrangements:

1) Illegal crops (coca) advancement, lead by paramilitars and the subsequent conflict, and control of the territory. It implies a modification of the formal and informal institutionality that could affect the forest management and ACAPA's gobernance of the territory.
2) Incentivated by the national guvernment, the implementation of agroindustries and monoculture (African Palm plantation projects) by national and international capitals.
3) The territorial-ethnic-environmental discurse of local activists does not reflect the daily life practices of the population, in terms of the pretended ancestral communitary use of the land. This fact leads to conflicts among leaders of ACAPA difficulting an effective process of institutional arrangements crafting.
4) Until the late 20th century the mental model about nature that drove official environmental policy and the society's perception towards the region was of a "Balanced Nature", dominated by negative feedback processes (Holling et al., 2002).

4.3 Aqueduct community of Lenguazaque village

4.3.1. The Central Colombian Andean Region

Colombian territory has been divided in five Natural Regions according altitude, geology, and soils. The Natural Andean Region includes the Western, Central and Eastern Cordilleras and the intra Andean valleys of the Rivers Cauca and Magdalena. Climate and vegetation are highly variable and the height is the characteristic that determines the bioclimatic zones, which include 20 sub-regions (IGAC 2002). One of these sub-regions is located in the central area of the Western Cordillera which is called the Cundiboyacense high plain.

The dominant character of the region are the mountains with steep slopes which surround the extense plains. Altitudes are from 2.000 to 3.500 masl, which give the possibility of a high variety of climatic zones. This fact allowed pre hispanic inhabitants of the zone, the Muisca ethnic group, to develop a wide range of agriculture activities and favouring high population densities. Though water is essential for Andean population processes, it plays a secondary role compared to mountains, in the organization of dayly life and economic activities. In the pre Hispanic society settlements stablishment searched convenient location regarding water bodies, but they were abundant during the year, instead, the variation of slopes were the main driver for land use allocation decisions (Herrera 2002). Another consequence of this physiographical configuration is the devlopment of micro climatic conditions, which give a high variability conditions on daily basis. It means that, in periods of global dry conditions, locally, could be rainy and sunny days in the course of one week for example, and vice versa with high precipitation global periods.

The most recent official Atlas of Colombia (IGAC, 2002) classifies the population according cultural criteria. About Andean population in general it states that it is the wider and complex culture of the country's center, and it is classified as a "*cultural region of Hispanic origin*". Its main origin is *castellano*[16] because the Spaniards settlers in the region

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[16] In English, *Castilian,* refers not only to a specific language (Spanish), declared in the Spanish constitution as the official language, but to the central Spanish region, origin of the modern country, and the main provenance of the Spanish conquerors.

were, mainly, from this Iberic province. The racial mixing with the aboriginal Muiscas was intense, compared with afro descendents' influence. Andean region has been the most densely populated by pre and post Hispanic periods (IGAC, 2002). One of the cultural types, in this region, is the so call Cundiboyacense, the one that irrigation case study of this research belongs to. The Atlas characterizes this cultural type as "*of high racially mixed type between Spaniards and aboriginal, respectively from Andalusia and Chibcha indigenous family. A natural from this region is traditionalist, proud, hard worker, individualist and reserved. … Religiosity is deeply rooted among its population, and supports the social structure*" (IGAC, 2002: –my translation).

The irrigation case study is a SES located in the Northest part of the Cundiboyacense high plain, in the upper part of the so called Fuquene or the Ubate – Chiquinquira Basin. Although I have organized the text with these titles, dynamics of the different dimensions, geology, landscape, ecology, socio-cultural and economics, are understood as interdependent. The relation of people with the ecosystem and its goods and services in part is product of a partiular culture and economic rationality. In this region, water management is maybe the dimension that best reflects these particular rationality, having into account that, as it will be discussed below, water, was until the beginning of 20th century, an abundant CPR withouth the problems that we find today in the zone. Cooperation dilemmas, social norms functioning, collective action problems, and institutional dynamics are specially challenging in a watershed context plenty of externalities at different scales with severe individual, collective and ecosystemic consequences. We will see how the combination of a specific cultural setting, social control, and institutional dynamics produces poor conditions for CPR gobernance.

4.3.2. Lenguazaque: The biophysical environment

The irrigation case study is located in the Eastern Cordillera of Colombia, which includes several inter-Andean basins. In its central part the diameter of the Cordillera increases and includes the high flatlands of the intra-Andean high plains. From south to north there are the Basin of Bogotá and the Basin of Ubaté-Chichinquirá. Lenguazaque village, were the irrigation community belongs, is located in the northern basin, which is still covered by an important body of water called Lake Fúquene. The modern geomorphology of the central area of the Eastern Cordillera is characterized by the presence of intra-montane valleys surrounded by folded Cretaceous and Paleogene rocks. These valleys collected lacustrine sediments during the Pleistocene (Sarmiento et al. 2008). Lake Fuquene is one of these remanents of big Pleistocenic lakes and it is the center of Fuquene Basin or Ubaté-Chichinquirá Basin.

The irrigation case study site is localized 100 km north from Bogotá. The area is part of the Fuquene Basin, which has an area of 1.752 km^2. Human population of the watershed is 229.000 (DANE, 1993). The zone is the second largest highland plateau after the Sabana de Bogota in the Eastern highlands, ranging from 2.500 to 3.300 masl. The region is about two hours' drive by car from Bogotá. The village of the case study, Lenguazaque, is located in the eastern border of this watershed.

Lenguazaque's historical, geographical, environmental, economic and socio cultural context cannot be separated from the Fuquene watershed region. Problems facing by the irrigation community studied in this research are representative from the region. In terms of ecosystem importance, the wetland system of the Cundinamarca and Boyaca high plateau, to which Fuquene watershed belongs and it is one of the most relevant, is the Andean center of biological diversity and endemism of fresh water biota more important of the North of South America. The system belongs to the biodiversity *hotspot* of the tropical Andes defined by Conservation International (CI) as world conservation priority area (Humedales).

The problems of the region related with ecosystem services and function, land use conflicts, socio-cultural and economic practices affect and are affected by one key resource: water. Fuquene Lake has been, since pre Hispanic until current times, a central geographical accident of religious, socio-cultural and economic importance for the different population groups that have occupied the region. According ethno historical and geological sources, the area of the lake in pre Hispanic times was about 1.000 km^2 (Maya et al. 2004). Between 1940 and 1955 the desiccation rate was of 17,65 Ha/year, and between 1993 and 1999 was of 39,93 Ha/year, according these data, in 2034 the lake will disappear completely (JICA, 2000). 1.204 Ha out of the 3.000 Ha of current lake area are invaded by massive bodies of aquatic plants (*Elodea Canadensis, Limnobium laevigatum* and *Scirpus californicus*) due to intense eutrophication processes generated by nitrogen and phosphorous from productive activities and non treated sewage from human settlements (Fundación Humedales).

The landscape structure of the region that one observes today, which height varies from 2.400 to 3.750 masl, is formed by sedimentary rocks from Cretaceous, Tertiary and Cenozoic geological periods. The geology of the area has been studied by Hubach (1953), Etayo (1968), McLaughlin & Arce (1975), Ulloa and Rodriguez (1991) and Sarmiento et al. (2008). Part of the stratified rocks that forms the relief of the zone were deposited in shallow sea bottoms and marine coasts during the Cretaceous period. Another important rock bodies were deposited in wide estuarine and swampy environments during Tertiary period, these formations contain the coal deposits that are very important for the present economic activities towards the East of the zone. Cenozoic deposits from fresh water lakes post Andean raising are filling the plain intermountain valleys. All these deposits, which at the end of the Mesozoic (65MA b.p.), were at the sea level, began to rise during the Paleocene, when the uplift of the Andes began in the Paleocene (65 – 55 MA b.p.) as a consequence of tectonic plates crash between Pacific and South American plates. The Andean uplift finished in the Plio-Pleistocene (5 -4 MA b.p.) reaching nowadays altitudes. The region was finally shaped by a sequence of several glacial and interglacial periods during the last part of the Quaternary period (44.000 – 21.000 b.p.). Since the Plio-Pleistocene a series of global and local climatic changes drove the dynamics of the present main ecosystems of the region: lakes, high Andean forests and paramo[17].

Hydrography and the sub-dendritic drainage system (CAR 2006) of the basin has been mainly controlled by "*the characteristics of the bedrock units and tectonics; erosion by ice masses formed glacial cirques, hanging valleys, and deep U-shaped and V-shaped valleys. Lake Fúquene is fed by the Ubaté River which has a natural drainage in northern*

[17]The paramo is an Andean ecosystem which starts at 3200 to 3300 masl covered by tropical alpine grasslands. The paramo is found between 3200 and 4500 masl. The importance of this ecosystem is in its water producing, regulating and stocking function. It is characterized by extreme environmental conditions, low atmospheric pressure, low air density, low mean temperatures, high air and soil temperature with direct solar radiation and low temperatures when there is no sun radiation. The vegetation is of low height exposed to strong winds. Annual mean temperatures varies from 15 ºC to -5 °C. The main vegetal species is the "frailejon" (*Espeletia spp.)*, and extended grasslands with wetlands occurrence (Guhl, 1982). Soils are highly productive and suitable for potato agriculture and cattle rising, uses given by peasants today. The ecosystem has a high degree of endemism of vegetal and animal species, which makes the paramos a strategic ecosystem regarding evolution and conservation. The paramo has been considered as a sacred place by local indigenous communities.

direction" (Sarmiento et al. 2008). Lake Fúquene is drained by the Suarez River towards the north. The southernmost part of Fuquene valley is connected to many narrow and steep valleys coming from the highest locations of the drainage basin. In one of these side highest parts of the basin, towards the East is located the territory of Lenguazaque municipality, which is formed by Cretaceous and Tertiary sedimentary rocks. Towards the higher zones (East) where the irrigation community is located the geologic setting is dominated by the Guaduas Formation (Tertiary) in which lower strata are the coal beds relevant for modern mining activities. The municipality is part of the Lenguazaque River sub-basin, with an area of 28.862 Ha (CAR 2006), which is a tributary river of the Ubate river, which is the main input of the Lake Fuquene.

Climatic conditions have minimal variations in Fuquene Basin. Precipitation has a bimodal behavior with maximum values in the months of April and October, and minimum values in January, February and August. Between December and Mars the mean values for the rain are the 19% of the annual average, and rainy months are the 15% and 16% of the total annual value. The driest months are January and February, with a participation of 2,3% and 3,6% of the total annual values. In October there are precipitations with values around 100 mm in the upper part of the basin, and 160 mm in the lowest zone. Minimum values are close to 30 mm. Annual precipitation varies between 800 and 2400mm (CAR 2006). These values are taken from the climatologic stations closer to the case study, which are located in the Languazaque river sub-basin.

Temperature values are almost constant during the year. Monthly mean values range between 12 and 13°C. Extreme temperatures, minimun and maximun values, registered in the period 1995-2005 are – 5°C and 30°C. Registered daily variation is between 23°C at noon, and –4°C early morning. Variation in extreme temperatures are higher during the dry period at the begining of the year, which produces values of 0°C early morning generating frosts. Humidity in the region has very little variation during the year, monthly mean values are 70,2 – 76,4 % (Novilleros station) and 73,6 – 79,1% (Tólon gates station). Monthly mean relative humidity varies between 67% in July and 74% in October (CAR 2006). Prefered months for the starting of cropping of semestral cultives are April and May and October and November. The menhtioned frosts are a conditionant factor in croping scheduling (CAR 2006)

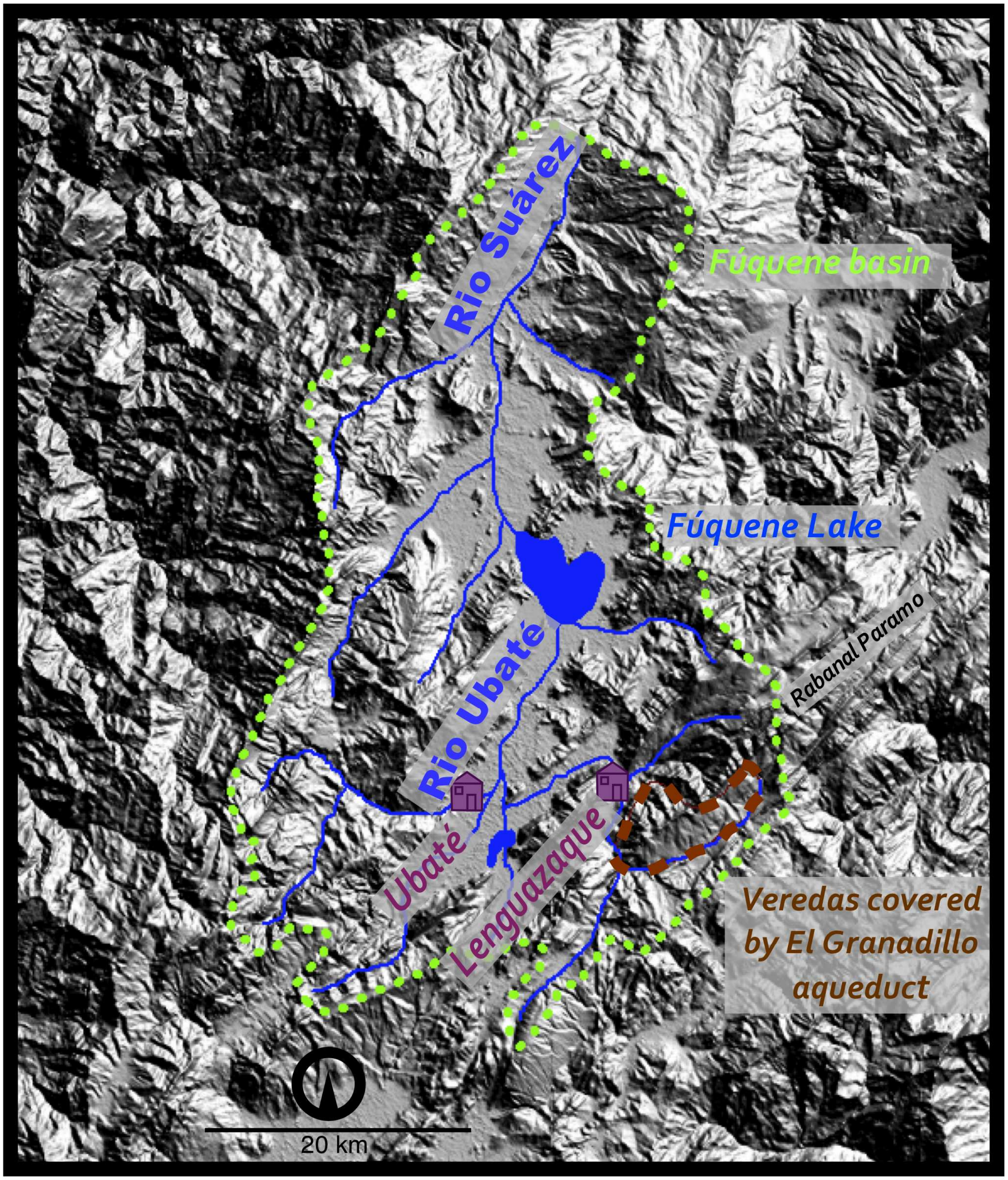

Figure 3.5. Location of the irrigation site, indicated by the polygon labeled "Veredas covered by El Granadillo aqueduct". The map shows the relief and the area of the Fuquene basin and the main water bodies; in the center the Fuquene Lake.

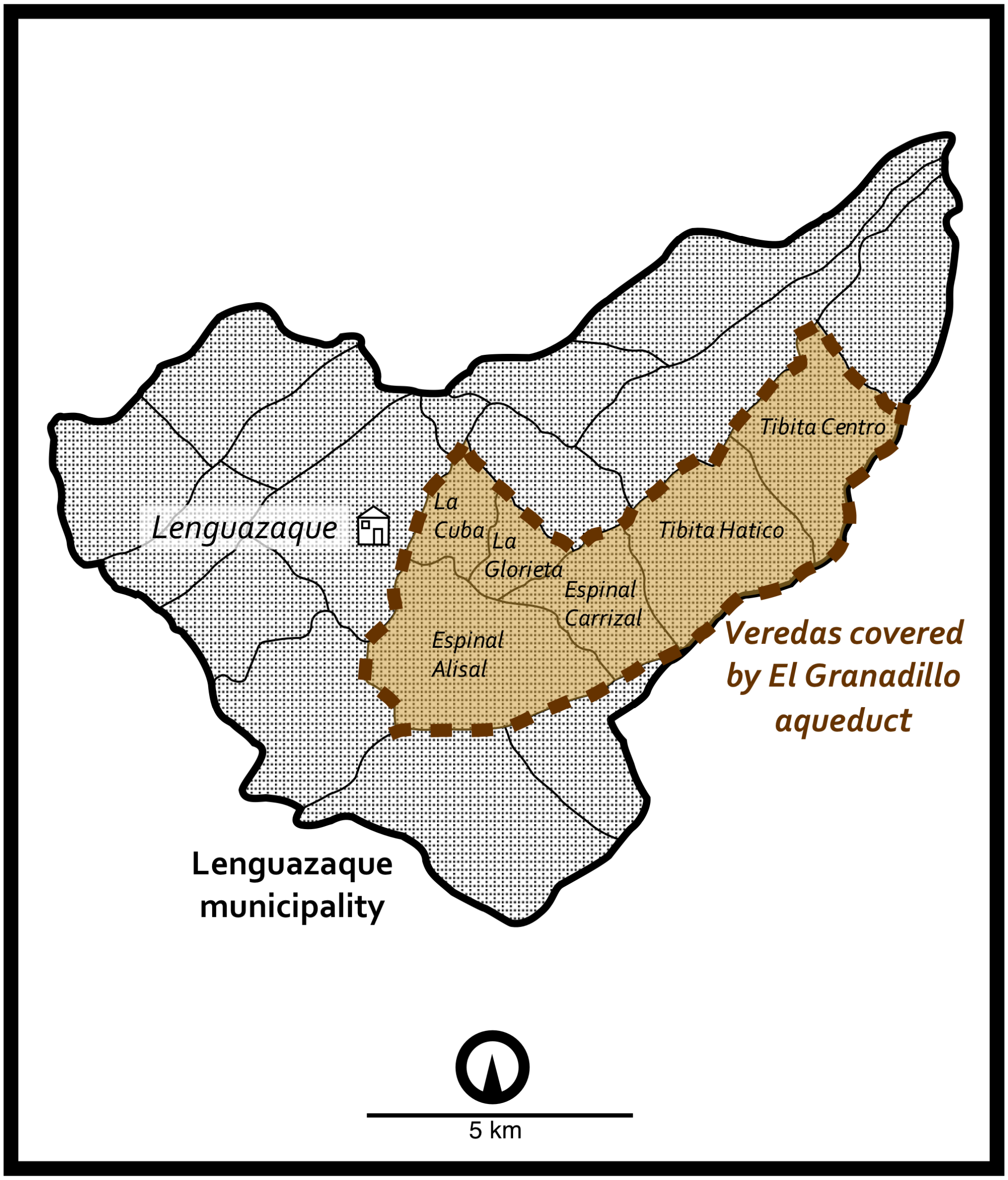

Figure 3.5. Location of the area covered by the Granadillo aqueduct in the Lenguazaque Municipality.

4.3.2. Lenguazaque: The Social System

The currently population of the Fuquene region is the product of a racial mix between the ancient ethnic indigenous group, the Muiscas, whose language belonged to the Chibcha linguistic family, and Spaniards ethno-linguistic group, mainly belonging to Castilian subgroup. This mixed produced the cultural type called Cundiboyacense, whose individuals are adapted physiologically, and in terms of their relation with the ecosystems, to the Andean environmental conditions.

The vereda Tibita Centro belongs to the municipality of Lenguazaque where Gonzalo Jimenez de Quesada, Spanish conqueror of the Central Colombian Andeans, arrived in 1539 and annexed the region to the invaded territories with the name of Sevilla. In 1780 it was categorized as Municipality and was given its modern name, Lenguazaque, which was the original Muisca name that means "*the end of the Zaque's dominion*"[18] (Dirección Departamental de Estadística., 1954). Lenguazaque has a total area of 17.327 ha, with 32 ha of urban area and 15.635ha of rural area, which is divided in 21 veredas (Rubio, 2001). Inhabitants of the municipality belong to the cultural group called *campesino*[19] *cundiboyacence.* Lenguazaque has a total population of 9.769 distributed in 2.094 in the urban area and 7.675 for the rural zone (DANE 2005). The community where the case study was carried out is located in the vereda[20] Tibita Centro which population is 249 (DANE 2005).

In the next section I give a short journey of the history of the Fuquene region, in terms of human population, relation with the environment, settlement patterns, social change and political organization. Given the overwhelming historic literature focused on the Colonial and subsequent periods for the region, and the relatively scarce studies on pre Hispanic history I tried to balance the information in order to offer the most relevant elements for the purpose of this research. Sources of information available for the history of Central Andean regions range, from archaeological findings, ethno historical sources like

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[18] At Spaniards arrival, the Muisca Confederation was divided between two Kings: The Zipa and the Zaque. The Zipa controlled the southern part, towards Bogotá, his name was Tisquesusa, and the Zaque that controlled the Northern region, whose name was Nemequene, and the center of his dominion was Tunja.

[19]The closest translation in English for "campesino" is "peasant".

[20] The "vereda" is a rural territorial division of administrative character of Colombian municipalities. "Veredas" include human settlements that can be sprawl or concentrated in some areas.

chronicles in the first centuries of Spanish invasion, descriptions of the XIX century European naturalists and travelers and modern historiography and geographic studies.

History of population processes in the zone

The first evidences of human population in the zone dates back from the year 800 BC (Langebaek, 1995), but the emergence of the Muisca society occurs around year 1000 AD encompassed of climatic changes that caused the decreasing of the Cundiboyacense high plain's big water surfaces, allowing territorial expansion (Rubio, 2001). In Langebaek's study "Regional Archaeology in the Muisca Territory", carried out specifically for the Fuquene Basin region, he proposes four periods to understand the evolution of population settlement in the zone. Preceramic and Herrera Periods (800 BC. to 800 AD.), Early Muisca (AD 800 – to 1200), Late Muisca (AD 1200 to 1600), and the Colonial Period (AD 1600 to 1950).

Preceramic and Herrera Periods

Langebaek reports only one archaeological place with possible evidences of preceramic settlements, with abundant pressence of lithic material. The author concludes that, if the site was inhabited in a previous time of the ceramic introduction, this occupation was higly limited. The first evidences of ceramic introduction with liable radiocarbon dating have been allocated to the period called The Herrera Period[21]. In this period population was small and it was far from the environmental carrying capacity. There is a poor correlation between fertile land and Herrera settlements. Regarding social organization, there are no important evidences for political centralization. There is no doubt that the demographic density is low in this period with a range that could variate from 3 to 10.8 persons per km^2. Interestingly enough, according Langebaek, is that these figures are inferior to a density of 64 persons per km^2 ., which is considered as the minimun for many societies to practice intensive agriculture (Netting, 1990 cited in Langebaek, 1995). The author concludes that Herrera population was small, and also a society with egalitarian

[21] Broadbent (1970 cited in Langebaek, 1995) carried out the first archaeological research, not systematic, in the Lake Herrera in the South of Bogotá, where he reported ceramic material different to the classical Muisca type. Cardale (1974, 1981 cited in Langebaek, 1995) established formally the Herrera period, geographically and temporally. Spatially, sites with these characteristics have been found in several locations in all the Cundiboyacense high plains (Langebaek, 1995).

levels of socio-politic integration. Herrera settlers probably were in the capacity to self sustain with corn produced in their settlements' surrounding lands. Finnaly, regarding social interaction with another societies, there is absence of evidences of practices of product exchange for this zone (Langebaek, 1995).

The Early Muisca Period

Langebaeck observes dramatic changes between the Herrera Period and the next Early Muisca Period (AD 800 – to 1200) in terms of pottery, settlement patterns and mortuory practices. Some authors associate these differences with invations from other regions. The continuity of Herrera settlements may suggest some kind of ethnic continuity. The demographic density in this period was in a range from 6 to 21.8 inhabitants per km^2. In contrast with Herrera settlemnts, which are located without any defensive logic, Early Muisca sites show a location not always closer to the more suitable agricultural places, but in former islands with abrubt elevations from the shore. In this period there is no evidence of interregional trade. There are radiocarbon dates that suggest that mummification and goldsmithing were introduced in this epoch. The Early Muisca, in syntheis is characterizd by an increase in social complexity and population, warfare was an important factor in orther to decide settlements location, and still it is evident a settlements' descentralization. Archaeological evidence, suggests that the Caciques[22] took social distance from the common population forming a political elite. Warfare, trade, and feasts, were important elements for the social control (Langebaek, 1995).

The Late Muisca Period

The Late Muisca Period (AD 1200 to 1600) is characterized by several factors: a population increase of great proportions, strong evidences of interregional trade, the fact that fertile land acces was an important factor for settlement establisment, and political centralization. Estimated figures for population density in this period range from 19 to 81 persons per km^2. According Langebaeck, in this period there are evidences that favors the hypothesis that demographic density levels were over the carrying capacity of the ecosystems. Population

[22] Political chiefs of the chiefdoms.

increase could have been between 176 and 318%, and most of the population may have been localized in the plain lands on the valley of the Lake Fuquene. Politically, the Muiscas were organized in chiefdoms that controlled a number of small villages in the region. During the XVI century those chiefdoms were territorial units, which domains usually coincided with the modern municipalities (Broadbent, 1964 cited in Langebaek, 1995). Capitanías were territorial and kinship entities that correspond to the current veredas. From etno historic sources it is known that the main settlement of the chiefdom of Nemoga was located in a mountainous zone near to Lenguazaque River. In the XVI century indigenous population produced abundant agricultural land products and practiced intensive agriculture. Spaniard's crhonicles suggest that the Muiscas were in constant internal and external warfare. All Late Muisca Period's settlemts were below 2.900 m. (Langebaek, 1995). The same author calculated for this area a carrying capacity between 2.220 and 2.535 persons.

Palinological record shows that human ocupation of paramos started around 1200 AD (van der Hammen, 1968). The Muiscas combined different survival strategies such as agriculture, hunting, fishery and collection of wild products. Their productive activities were based on the microvertical exploitation, depending on the climate, of agricultural products like corn, potato, , sweet potato, and other Andean tubers[23] (Van der Hammen, 1992). With the Sapaniard's invasion, intensive creals crops were introduced and the agriculture frontier advanced due to food demand of the increasing population. The hillsides started to be cultivated, and Andean forests began to be cut, ascending in altitude approaching to paramo zones. Deforestation processes initiated due to the massive utilization of timber by the Spaniards (Hofstede, 2002). Soil degradation processes in the Cundiboyacense high plains was already happening before Spaniards' arrival, according to Langebaek study, mentioned above, there are evideneces, at least for the Fuquene region, that carrying capacity was overshooted at the beginning of the Late Muisca period. In the XVI, Spaniards introduced exotic fauna absolutly new for the Andes, such as cows, sheeps, goats, pigs, chikens, donkeys among others. In terms of vegetation, they introduced species

[23] Ibias (*Oxalis tuberosa*), Chuguas (Ullucus tuberosus) and Arracacha (*Arracacia xanthorriza)*

to be cultiivated in the high Andean mountains, specially wheat, and barley, carrots, lentils, onion and garlic among others (Luteyn & Buck, 1999).

The Colonial Period

Settlement patterns were one of the first aspects of change in two forms. The first was the dsiplacement of Muisca populations from their original settlemnts to new villages with the squared structure according the Spanish way. And the second was the Spanish invasion of productive lands and displcements of indigenous towards the worst lands, meaning the hiilsides of the basin. The first type of organization was done by the creation of two types of settlements: "*pueblos de mison*" and "*pueblos de indios*"[24]. The the first type was a temporal religious kind of village, "*which was considered as a transitional phase of adecuation to the colonial order"* (Herrera, 2002:53 - my translation). The *"pueblos de indios"* were the final place where Spaniards located native populations, which "*spatial ordering … played a fundamental role in the process by means of which the population interiorized the hierarquical order of the colonial society*" (Herrera, 2002:161 - my translation).

This period was marked by an important decreasing in Muisca's population. This decreasing was fundamentaly driven by the illness brought by Spaniards. By the end of XVII Fuquene region had almost exhausted the native population (Moreno y Escandón, 1985, cited in Langebaek, 1995). Total human population increases considerably due, first to the growing of Spanish and mestizo[25] population, and second, although the decay of native population was dramatic during the first centuries of the invasion, lately total population, including indigenous, increased considerably. Langebaeck estimates the native population size for the beginning of this period in a range between 2.340 and 7.334 for the region. In spite of the population growth during this period, the author shows how the environmental degradation that started before the Colonial period, but with Spaniars invasion was incremented, is the result of land distribution patterns rather than a big population.

[24] The literal translation is Mision village and Indigenous village.

[25] Mestizo refers to the mixing between Europeans and indigenous people.

Regarding social complexity, the study concludes that only since the early Muisca period it is possible to talk about tendencies towards social complexity. The Late Muisca Period portraits important evidences of social change and the end of egalitarian societies, which is consolidated during the Colonial Period.

The last 500 years are fundamental to understand the modern state of the socio ecological system in the Fuquene region, and of course the current relation between people and ecosystems, and problems that face the community of Lenguazaque highest zones including our case study in the vereda Tibita Centro and its irrigation system. In the next paragraphs I will synthetize the most relevant aspects of since the Colonial period to modern times.

The history of the region in the first half of the XX century *"is the continuity of a long term adaptation proccesses of its Amerindians inhabitants facing the presence of Sapanish colonizers, and later, as a mestizo campesino community*[26] *facing the milk productive "haciendas" controlled mainly by European descendents and some mestizos economically succesful"*. (Flórez, 2005: 59 – my translation). The most important institution used as a strategy to control the indigenous population and exploit the natural resources during the Colonia was the *encomienda*[27]. This institution evolved, after Independence in 1810, towards the *hacienda*[28]. During the Colonial period, the *encomenderos*, in spite of the prohibition by the Spanish Crown of entitling the *encomienda* lands to the Sapaniard in charge, they managed to create property titles and leave these lands to their descendants. In the Fuquene region the *hacienda* structure was established in the plain zones, as I already mentioned, the Spaniards dispalced indigenous to the sidehills and upper parts of the watershed. This displaced population adapted to this dry environment, and became a *campesino* society of *mestizo* and indigenous origin, that was subordinated to the owners of the *haciendas* in the fisrts half of XX century trough political and specifically electoral means (Flórez, 2005).

Maybe the most important ecological change produced by the introduction of exotic fauna, in the 16th century by the Spaniards, was the cattle. By the 19th century, the ecology

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[26] mestizo peasant community
[27] Encomienda definition in page 24.
[28] Hacienda is the Spanish word for a big ranch where one or several productive activities were carried out, from plantations, extensive cattle rising, mining or even factories.

of the plain zones of the basin were grass lands for milk cattle raisnig purposes. Hence, the milk production cattle raising vocation of the economic activities in the valley were consolidated in this century. By this time, while the *hacendados*[29] made strong efforts to control the waters of lakes and rivers due to the frequent floodings that harmed the grass lands and cattle, *campesinos* from the hillsides and mountains struggled for survival due to the intense dry seasons and erosions processes. Since the beginning of 20th century, native vegetation were already scarce on the hillsides. Guvernemental efforts were oriented to the dissecation of the Fuquene Lake until the first half of the 20th century, in order to aquire new productive lands. The small *campesino* units of hillsides were characterized by agriculture production and sheep rising, wich gave place to the wool handicraft production that, currently, is one of the attrractivenes of the region, besides milk products. Since the beginning of the 20th century the growing and permanent food demand from Bogotá boosted the agricultural production, and allowed the consolidatrion of a regular market of agricultural products, especially potato from the higher zones of the mountains. About the 5% of the potato cultivated area could be irrigated, the rest was, and still today is, strongly dependent on the rain. Potato agriculture contributed to the serious erosion processes and later to the water pollution of creeks and rivers trough the agroquemichal inputs. By the 50s of the XX century coal miners arrived to the zone in a wave of poor and landless migrants mainly from Northest Andean zones, which were isolated from the *campesino* world of the region, and seen as "foreigners" (Flórez, 2005).

The result of the socio economic processes during the las 500 years is the folloging configuration of the zone: On one hand, a population of *campesino mestizo* of indigineous orgin without an ethnic community character, in the higher parts of the basin, and on the other hand a large state property on the plain lands of the valley. This history produced a *campesino* with an individualistic rationality with small properties and productive units[30], and an indigenous past of communitarian character regarding land property and production (Flórez, 2005). Population increase in these parts of the basin has produced the fragmentation of properties in order to distribute land among descendants. This process is still working in the study zone.

[29] Hacendado is the Spanish word for the owners of the *haciendas*.
[30] The appropriated word in Spanish is *minifundio*.

From 1948 to 1963 Colombian history was characterized by a period called "The Violence" because of the conflict between political parties. The Violence affected specialy the rural world, but the zone of Fuquene Basin was atipically almost untouched by the conflict at least in terms of armed actions. Flórez (2005) documents this period in his book "Una isla en un mar de sangre"[31] where he explains the causes of this situation as a consequence of the relation of the Muiscas with Spaniards, and later, the owners of *haciendas* and small *campesinos*, based on strong links with the ecosystem dynamics and political culture. An important element to take into account is that the Muiscas were allies of the Spaniards in their wars against neighbohouring indigenous groups, and that the European invaders did not faced violent resistance in this region. The last part of the 20th century has been characterized in this region by a relative calm in terms of conflic, with some periods of guerrilla presence in the Eastern higher parts of the basin, concretelly in the territories of the case study.

Economic activities

The economic activities of the Fuquene Basin are cattle rising, agriculture, coal minning and handicrafts. Regionally, the most important productive activity is the cattle rising, with a high technique level, for milk production and milk products. In the plain zones of the basin carrying capacity is about 4,5 animals/ha with an average production of 15 Lt/cow/day. The dominant breed is the Holstein in the plain zones, while in the hillsides is the Norman breed and carrying capacity and average production in these areas are respectively: 1,5 animals/ha and 3Lt/cow/day (CIP).

Agriculture is the second activity in the basin. There are 16.933 Ha of potato crops, 1.860 Ha of peas, 1.440 ha of corn, and 880 Ha of wheat. Of these plantations, the corn is the only that counts with irrigation systems in the Northern municipalities of the region, in the lowest zone of the basin. Coal mining is the third economic activity; there are 280 formal mines that extract 763.712 Tons per year. These mines pour residual water into the creeks and river of the region without any treatment. Handicrafts are the fourth economic

[31] "An Island in a blood sea" my translation.

activity of the region, and it is oriented towards two products: wool products and objects made of a vegetal fiber that grows in the Lake Fuquene (CIP).

Productive systems of Lenguazaque are constituted by coal mining, potato agriculture. Most part of agricultural areas are allocated to potato crops which cover an important proportion of local and regional markets. The area allocated to potato crops in the municipality is 3.000 Ha, with a production of 120.000 Tons/year (Proyecto Páramo Andino, 2008). There are also small areas with peas, corn and bean crops principally for self consumption. Coal mining is the principal livelihood source for many rural households especially in four “veredas” of Lenguazaque which geological structure is formed by Tertiary coal sediments. Our case study is one of this “veredas”. Coal mining, agriculture and in minor proportion, cattle rising, are traditional economic activities (Proyecto Páramo Andino, 2008).

4.3.3 The aqueduct

The irrigation system takes water from the uppermost part of the watershed, where there are natural springs in the paramo[32] ecosystem. This ecosystem occurs above 3.000 meters above sea level and it is of strategic importance for water production. The community of the “vereda” Tibita Centro organized themselves 15 years ago to build an aqueduct and bring the water to the households of the veredas in the highlands of the municipality. Currently the aqueduct “El Granadillo” has 600 users and it covers six veredas. The maximum capacity of the aqueduct is 1500 users. There is an Aqueduct Council which includes one representative of each vereda. The council meetings take place each six months. Each household has to pay a maintenance fee each two months o $ 4.500 Colombian pesos (USD 1.8).

[32] The multiannual mean temperatures are inferior to 8 degrees C, above 3.300 meters temperatures are less than 6 °C, in the highest zones temperatures are below 3 °C.

4.3.4. Lenguazaque: Problems and Potential Shocks

The resource affected and affecting almost all the problems in the relation between society and ecosystems in the Fuquene Basin, is the water. Land use, and water pollution are the main components of the regional problems. Land use conflicts, mainly in the higher parts of the basin, among potato agriculture, coal mining, cattle raising, and conservation uses have their origin in alteration of water production zones. Deforestation in this ecosystem is carried out in order to increase the areas for potato agriculture and, in less proportion, cattle raising. Mining activities residual water disposal is done into the creeks and rivers without any treatment, contributing to water pollution. Intensive potato agriculture is done using large amounts of agrochemical products, mainly for pest control. These substances go in to water bodies and contribute to water pollution. Strong erosion processes due to agricultural use in steep hillsides generate a high sediment load that finally goes in to the Fuquene Lake producing its filling and depth decreasing. Additionally, sewage from urban centers is not treated, producing high inputs of organic matter into the Lake, leading to dramatic processes of eutrophhication. One of the impacts of these dynamics is the decreasing of the Lake's area as well as important biodiversity losses.

The hypothesis of this research is that the relation between society and ecosystems is mediated by the norms and rules, which are crafted according human's understanding about the ecosystem and society's functioning itself. Institutions are the framework in which the ecosystem goods and services management, in this case the CPR type, is done. If norms and rules express the relation between nature and society historically built, we can infer, from the history of the Fuquene Basin SES, an institutional arrangement evolution built upon the following elements:

1) A relation of adaptation, from indigenous and later the peasant *mestizo*, to the dominant power. This adaptive process implied strategies of daily resistance processes in which norms, rules and agreements are accepted in the discourse, but not in the practice. Several authors have documented this behavior in religious and social arenas, where traditional practices are hidden in the externally imposed behavior (Herrera, 2005).

2) Institutions designed to support an extractive economy model, from Colonial to the first half of 20th century, such as the *encomienda.*

3) Natural resource management based on the idea of the possibility of control of the nature by humans.

4) A mental model of ecosystems characterized by the idea about nature as a "Nature Balanced", globally stable and dominated by negative feedback processes (Holling et al, 2002). If this mental model have led institutional arrangements and decision making, the consequences have been dominated by surprises such as floodings, extremely dry seasons and strong eutropization processes in Fuquene Lake.

These elements are reflected in ecosystem management strategies like hydrologic cycles modification and controlling efforts. The ecosystems have produced environmental goods and services that have supported a constant growing human population and intense economic activities during hundreds of years. The hypothesis, I propose, for the region is that, globally, there are variables that have already passed critical thresholds, and that the SES is close to a stability dominiun change. The study of a local SES, such as the irrigation case study in Lenguazaque, gives insights about how the regional and national scales have affected individual and collective behavior, and rule compliance have affected the management of a CPR like water.

4.4 Synthesis of the case studies contexts

In this section I compare the three case studies using the framework for socio ecological systems (SES) analysis proposed by Ostrom (2009) and explained in the chapter 2 (Conceptual state of the art). I use the diagnostic variables of this framework to make a synthesis and a comparison of the three SESs. The subsections correspond to the different subsystems of the SSEs. Each subsystem is briefly compared and synthetized in a table. Finally two tables with the main outcomes and the main potential external shocks to each SES are included. The potential shocks are no part of the original framework proposed by Ostrom (2009).

4.4.1 Resource System (RS)

The three case studies focus on small-scale peasant economic activities relating with 3 different natural common pool resources: fisheries, forest and water. The cases are located in three different regions, two coastal zones but with different socio-cultural constructs as well as different biophysical characteristics. These two coastal zones contrasts with a Andean region where the water case is located. The 3 cases are limited with different logic: collectively built according culture and territorial constructs in the fishery case, formal community organizational processes in the forestry case, and the activity of a communitarian service (aqueduct), in the water case. These logic implies different relationships with the resources, while being CPR, the have specific characteristics. The CPR boundaries are defined by the use and not by the formal and legal territorial planning. In the fishery case (Baru) the resource system is marine, in contrast with Lenguazaque (water) and Salahonda (forestry) are terrestrial resources. The forestry system is much bigger; it covers several municipalities, than fisheries and water systems.

The communitarian infrastructure is an expression of the type of agreements that have been built to manage the CPR. The system which limits are defined by a formal collective agreement (forestry, Salahonda) seems to have a poor infrastructure development managed by the middlemen. In the fisheries case the infrastructure is a product of the organization, which is highly exclusive and it is in the borders of the law. The water case has the more developed infrastructure totally dependent on the users decisions. Regarding the storage characteristics of the resource, in the fisheries case, the temporal limits are important, that is why the fundamental infrastructure is the freezing facility. But even if this facility were functional, the temporal limit still is important, which implies short-term relations with the market, and in consequence a short term income. The timber, in the forestry case, does not have time storage problems, but it has space and transformation limitations that can not be assumed by the loggers. There is no time pressure, but the middleman is essential, and the earning has not the short-term character of the fisheries. In the water case, there are no time restrictions for storage it is possible to accumulate. The water in this case is not a resource for accumulate and sell but for stock and use. These resource storage characteristics produce different use logics.

Table 10. Resource system variables for the three SESs.

RESOURCE SYSTEM (RS)			
	FISHERY	**FORESTRY**	**WATER**
Sector (RS1)	Artisanal fisheries	Peasant forestry	Communitarian aqueduct
Clarity of system boundaries (RS2)	Traditional collective fishing grounds (Aprox. 200 years ago)	Formally collectively defined (20 years ago)	Collectively defined according to the physical limits of the watershed (15 years ago)
Size of the resource system (RS3)	40.000 marine hectares	103.607 hectares of collective property	600 users (households). The aqueduct covers six “veredas”
Human constructed facilities (RS4)	Fish aggregation devices (Payaos) (Local organization) Fishing boats and gear (individual fishermen)	Sawmills (Middlemen)	Water inlet, tanks, protection fences, distribution networks (tubes), control keys (Local organization)
Productivity of system (RS5)	High productivity in the coral reefs	High productivity charactyeristic of tropical rainforests	Low during summer (December, January and February) High: the rest of the year.
Equilibrium properties (RS6)	Fish species regrowth rates. Relatively homogeneous trhough the year.	Forest species regrowht rates. Several years cycles (7-20 years)	Precipitation has a bimodal behavior in the year
Predictability of system dynamics (RS7)	Low predictability due to mobility and impossiblity to explicitly see the resource	High predictability	High predictability. Dependent on the climate dynamics. Seasonal
Storage characteristivs (RS8)	Freezing cilities (scarce)	Sawmill facilities (middlemen)	There are no storage structures except the tank next to the water inlet in the upper part of the creek
Location (RS9)	Caribbean coast, included in a marine protected area	Pacific coast low lands	Andean mountains

4.4.2 Resource Units (RU)

The mobility of the resource units in the three case studies implies different forms of perception, appropriation, and management. In the fisheries case, the resource units are highly dynamic and fishermen cannot see them directly. The forestry case is different. The resource units are static and appropriators can see them. But the size of the resource system can generate a perception of infinity, which, in turn could determine the resource management. In the water case, the resource is a flow resource, where appropriators can see it and easily make judgments about scarcity and abundance, which in turn determines specific management practices. The regrowth rates of resource units are different in the three cases as well. In the fisheries it's possible to say that the regeneration rates are faster in relation with the forest. But with the water case the renewal of the water sources depends on several factors such as climate and maintaining the ecological conditions of the sources surroundings.

The value of resource units in the fisheries and forestry cases is associated with economic benefits. In the fishery case the resource units are used to generate economic income and also for household consumption, which is fundamental for the families source of proteins and survival even if the fish is not sold. The resource units in the forestry case are use to generate economic income, but it is not possible to use them for daily household self-consumption, the loggers have to sell the product always. In the water case, the resource does not generate economic income, but wellbeing by increasing the quality of life. Instead of producing economic benefits, users have to pay periodical fees in order to receive the resource. These differences change the relation with the resource.

In the fishery case the resource units are concentrated in specific spots that coincide with the coral reef patches. The general spatial pattern is a discontinuous configuration of the marine zone where the resource units are concentrated. Regarding temporal distribution, there are not specific patterns, at least recognized by fishermen. The temporal restriction for extracting units of the resource has to do with weather conditions that affect navigability. In the forestry case resource units are more homogeneously distributed. However, there are spatial patterns of some species in the forest that have to do with the biological associations and physical characteristics of the terrain (flood zones and hills). In the water case there is a seasonal pattern of water availability consisted in scarcity during two months a year and the rest of the year the supply is normal. The source of water for the aqueduct is located in the upper part of the creek where the inlet is installed, which in turn is feed by the water accumulation in the higher "paramo" ecosystem.

Table 11. Resource units variables for the three SESs.

RESOURCE UNITS (RU)			
	FISHERY	**FORESTRY**	**WATER**
Resource unit mobility (RU1)	High mobility	Sedentary	Flow resource
Growth or replacement rate (RU2)	Fast. Fish species regrowth rates.	Slow. Forest species regrowht rates. Several years cycles (7-20 years)	Seasonal, depending on the climate
Economic value (RU4)	Prices vary according each species, being the highest lobster and shrimp species. 1,5 EUR / kg scaled fish	Depends on the species	Users do not sell water units. The benefit is household well-being.
Spatial and temporal distribution (RU7)	Discontinuous spatial distribution	Discontinuous spatial distribution depending on the physical characteristics of the terrain	Heterogeneous spatial distribution depending on the watershed location. Season dependent temporal distribution

4.4.3 Governance system (RU)

The forestry and water case have in common that the main governmental formal rules for the management of the resources are designed and enforced by the regional governmental agencies in each area (Autonomous Regional Environmental Agencies). In the water case the Municipality has a relevant role in the facilitation and support for rural aqueducts. In the forestry case the municipality does not have competency in rural zones. In contrast, in the fisheries case, the environmental authority is the Natural Park, and also the governmental agency for the fisheries regulation, which has no presence in the zone. In practice the Natural Park interacts with fishermen. In the three cases there are community organizations that influence directly the use and management of the resource: the fishermen association, which is the weakest, in the forestry case there is the Comunitarian Council (ACAPA), the most comprehensive in terms of governance because they are in charge of territorial governance, and the Aqueduct Council in the water case, which is the oldest and the most effective in resource management terms. The presence of NGOs in the three cases is different. In the water case predominates the local community organization. In the fishery case there are several NGOs focused in environmental, cultural issues and local development. In the forestry case there is a high number of humanitarian NGOs and weak presence of environmental organizations.

In the three cases the networks are based in familiar relations and the main nodes belong to the oldest families. However, in each case the flows and links have different meanings. In the forestry case the cultural inheritance that flows through the network is the basis for the Communitarian Council' legitimacy. In the fisheries case the cultural aspect is not as important, instead, the flows of the network conveys other type of information more practical and linked mainly to economic aspects. In the water case, the interaction among families is weak due to cultural and geographical aspects, and the network mobilizes information strictly necessary for collective problems solving.

In the three cases the resources are commons. But the territoriality that each group of users has developed is different. Lenguazaque (water) has a traditional private land property regime, that exists at the same time that the common property character of water. In contrast, Salahonda (forest) has a tradition of private owned parcels with great areas of land managed as commons where the forest is located. This regime of property rights has changed, in the last 20 years towards a collective property scheme, which is formalized with Communitarian Councils. In Barú (fishery) the marine resources have a property regime that is linked to a specific territoriality traditionally constructed by the locals.

Regarding the rules used to use and manage the resource, in the forestry and water cases, they have been developed by the community, which is represented by the Communitarian Council and the Aqueduct Council in the water case. These institutions are fully recognized by the government. In Baru (fishery) the predominant rules are the ones proposed by the environmental agency (National Park). The fulfillment of rules, by the users, in the three cases depends upon different aspects. In the fisheries case, it depends on the relationships with the National Park officers. In the forestry case the rule compliance is a function of the Communitarian Council' legitimacy. In the water case it depends on the correct functioning of the Aqueduct Council. These are factors that, in the three cases, have direct relation with the legitimacy of rules. These factors are essential when users think it is rational following the rules. In the three cases most of the rules are promoted by the governmental environmental agencies. The monitoring of rule compliance and sanctions are a function of the rule design. In the fishery case the formal monitoring and sanctioning is carried out by the agency that designs the rules: the national Park. In the forestry case the Communitarian Council makes the monitoring and sanctioning, but illegal armed groups present in the region limit this task. In the communitarian aqueduct (water case) is the community organization (Aqueduct Council) that carries out the monitoring and sanctioning.

Table 12. Governance system variables for the three SESs.

GOVERNANCE SYSTEM (GS)			
	FISHERY	**FORESTRY**	**WATER**
Government organizations (GS1)	National Natural Park	Regional Environmental agency	Regional Environmental agency Municipality
Non-gov. Organizations (GS2)	National environmental Local development Community fishermen association	Community council Humanitarian International environmental	Community association (aqueduct)
Network structure (GS3)	Familiar Oldest families are the main nodes Fishermen association gathered around two leaders	Familiar Political	Familiar Low betweenness Low centrality
Property rights system (GS4)	Common property Informal Culturally built since aprox. 200 years ago	Common property Formally established 20 years ago	Common property Formal (national law)
Operational rules (GS5)	Developed by the fishermen organization in line with marine protected zone	Collectively developed	Collectively developed
Monitoring and sanctioning processes (GS8)	Low monitoring capacity Park authorities are in charge of monitoring	Low monitoring capacity Regional environmental agency is in charge of monitoring and sanctioning	High monitoring capacity Carried out by paid members of the community

4.4.4 Users (U)

The number of users in the three cases studies ranges from 200 fishermen, approximately 1400 loggers[33] and 600 households in the water case. ACAPA's territory has a population of approximately 8000 people that derive their livelihoods from forest logging. The UBN[34] is useful to compare the three case studies in terms of the socioeconomic characteristics of users. The index integrates housing conditions, water and sewerage coverage, education access and income related indicators. The forest users have a UBN[35] indicator of 68%, which means that a high portion of the of the region's population does not access their basic livelihoods needs. In contrast, the fishery and water cases have similar UBN percentages (35,5% and 36,4%) showing that approximately one third of the population in the respective regions does not have access to basic livelihood needs. These figures can be compared with the national UBN for Colombia: 53,3%. In the forestry and water case studies is particularly important the property rights regime. In the forestry case, the land is collectively owned and consequently the forest. In the water case the land is private and the properties range between 0,5 and 5 Ha. In the fishery and forestry cases the economic dependence on the resource is high. In the water case the situation is different because they do not depend on the aqueduct for their production; the aqueduct generates well being for the users.

Regarding the history of use, fishery and forestry cases have between 200 and 150 years of traditional use. In the ACAPA's territory the timber extraction has had three different periods. The first (1850s-1950s) characterized by small-scale logging, the second

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[33] According to the National Land Use Planning GIS (SIG-OT http://sigotn.igac.gov.co/sigotn/) ACAPA´s population is 8106 inhabitants and 1453 households for 2011. There is no data of the number of loggers. I use the number of households as a proxy assuming that one person by family derives her income from logging.

[34] UBN stands for Unsatisfied Basic Needs, which is one of the indexes for poverty measurement. The UBN methodology uses several indicators to cover a representative set of basic needs. The index is built throughout a direct multidimensional method (Boltvinik, 1998), meaning that it integrates several dimensions of elements used to define poverty levels. An UBN value in percentages represents the fraction of the population of a place that is below the poverty threshold. According to the National Administrative Department of Statistics (DANE) of Colombia, the index reflects "*The groups that do not reach the minimum threshold are classified as poor. The selected simple indicators are: inadequate housing, housing with critical overcrowding, housing with inadequate services, households with high levels of economic dependence, and households with school-age children not enrolled in schoo*l" (DANE http://www.dane.gov.co)

[35] The UBN values are taken from DANE. The figures correspond to 2005.

(1950s-1970s) by a considerable expansion of the activity, and the latest period (1980s-present) experimented a contraction towards small extraction character again. In the second phase the introduction of new extraction technologies played a central role in the expansion of the activity, which was the introduction of the chain saw. In contrast, the water case has a short history; the aqueduct has 15 years of functioning. The mental models about the resource system functioning in the fisheries case, currently and from the side of environmental authorities is consistent with the model of anarchic nature coined by Gunderson and Holling (2002). In contrast, in the forestry case region traditionally the mental model about the ecosystems of the SES' actors has been closer to the balanced nature. In the water case, the balanced nature is the mental model that has prevailed as well.

In the three cases the leadership has been important for the resource management, but they have different characteristics. The leadership has been developed recently due to scarcity problems and state interventions; therefore the leadership is potentialized of different forms in each case. In the forestry case, the leadership is linked to the Comunitarian Council' political interests. The central topic is not the forest but territorial gobernance, which formally started in 1993 incentivized by the National Government. The entrepreneurship is a different phenomenon, which started to develop in the second phase of the use history, in the 1950s. The entrepreneurs are the sawmill owners. These initiatives have not had a direct connection with the leadership political process mentioned before. In contrast, in the fishery case the leadership is focused in the entrepreneurship. This condition implies more conflicts because leaders' economic interests are highly relevant. This is evident in the organizational situation of the fishermen association. The water case is different because the economic interests are not so strong in the aqueduct users' organization. In this case the indifference regarding collective actions for the resource is dominant. A common characteristic of the three cases is the short organizational history; the formal associations in the three studies have no more than 20 years.

With respect to the norms supporting the resource use, in the forestry case, the rules in used are based on the market, which also is connected with the users' mental model (nature balanced) mentioned above. In the fishery and water case the norms are based in the formal organization for the resource administration. Rule compliance in the three cases is based is linked to social capital levels. However, the water case is different due to the weak economic incentives when users face the decision of follow or not the rules.

Table 13. Users system variables for the three SESs.

USERS (U)			
	FISHERY	**FORESTRY**	**WATER**
Number of users (U1)	200 fishermen	1400 users	600 users (households)
Socioeconomic attributes of users (U2)	UBN: 35.5%	UBN: 68% Land tenure: collective property	UBN: 36.4% Land tenure: private property (average range property area 0,5 to 5 Ha) High emigration rate of youngsters
History of use (U3)	200 years Artisanal fishery	150 years 1850-1950s: small-scale extraction 1960s-1970s: expansion of the activity 1980s-present: small-scale extraction. Technological changes causing important impacts	20 years ago: decision to built an aqueduct by the community 15 years of aqueduct use
Location (U4)	Coastal settlement in the border of the protected marine area	Settlements along the rivers	Disperse farms in the watershed
Leadership/ Entrepreneurship (U5)	Fishermen association Two main leaders usually in conflict	Middlemen: entrepreneurs owners of sawmills Strong political leadership associated with the communitarian council	Community leadership
Norms/ Social capital (U6)	Norms based on fishermen association agreements and formal rules by marine protected zone / High social capital	Norms based on market demand and mental models about forest regeneration /Medium social capital	Norms based on formal Aqueduct Council' rules /Low social capital
Knowledge of SES/ Mental models (U7)	Anarchic nature (Environmental authorities)	Nature balanced	Nature can be controlled Nature balanced
Dependence on resource (U8)	High	High	Not economic dependence
Technology used (U9)	Artisanal fishery gear	Chain saw	Aqueduct facilities

4.4.5 Interactions (I)

In the fishery case there are evidences of resource scarcity due to overharvesting in the fishery spots close to the shore by artisanal fishery and also by industrial fisheries in more depth waters. In the forestry case there is a perception and concern about some species. Also there are evidences of timber extraction below the minimum sizes. In the water case, there is a generalized perception of resource decreasing due to climate variability. The shared information, in this case, is focused in the communitarian infrastructure (aqueduct). This is that the aqueduct association has meetings with all the users each six months where issues about finances, fees and infrastructure maintenance are discussed. In the other two cases the shared information is related with resource extraction conditions. In the forestry the shared information has to do mainly with timber prices. In the fishery the shared information is about fishery spots conditions and species prices.

Deliberation spaces are different in the three cases. In the fishery the deliberation is marked by productive interests, in the forestry they are motivated by territorial governance and in the water case are focused in the infrastructure maintenance. In the water case the conflicts are related with the occasional rule breaking. In the fishery place there are important conflicts among the leaders of the fishermen association about the organization management and financial aspects. The other important conflict is between the fishermen and the marine protected area administration. In the forestry region the conflicts are among leaders, but the motivations have to do with the territorial governance and not specifically around the forest. One of the common conflicting issues is the corruption among leaders. But the most serious conflicts are with the illegal armed groups for territorial governance.

Investment in infrastructure is usually important to maintain the provision and appropriation of a RUC. In the aqueduct case the investment in the communitarian infrastructure is dominant, while in the other two cases the investment is for improving the productive activities. In the forestry case the investment that generates collective benefits is carried out at private level (sawmills). The lobby activities in the fishery case are made mainly with local development NGOs. In the aqueduct case the lobby is predominantly with the State (Municipality). In the forestry case the lobby activities take place in both fields.

The outcomes of the historical and geographical configuration of the three case studies can be classified in social and ecological dimensions. The table 15 shows the principal outcomes identified in the three SESs. The table 16 shows the potential external shocks that each SES

Table 14. Interactions in the three SESs.

INTERACTIONS (I)			
	FISHERY	**FORESTRY**	**WATER**
Harvesting levels of diverse users (I1)	Overharvesting near to the coastal by artisanal fisheries High levels by industrial ships	Overharvesting Harvesting below minimum sizes	Tendency of some users to stock water Waste of water
Information sharing among users (I2)	Conditions of fishery spots, Prices Seasonal species	Prices Extraction zones boundaries	Six month report (infrastructure, fees, resource maintenance issues, financial state)
Deliberation processes (I3)	Administrative meetings of the fishermen association Occasional workshops with marine protected zone officers about rules	Communitarian council meetings (discussions about the etno-delopment planning of the zone)	Aqueduct formal general assembly (six months frequency)
Conflicts among users (I4)	There are conflicts between the two main leaders, due to administrations disagreements of the fishermen association Conflicts with the natural Park administration	Conflicts among communitarian council leaders (intergenerational problems, political perspectives, corruption) Governance conflicts with illegal armed groups	Conflicts with National Regulatory agencies about water property rights Occasional conflicts due to rule braking behavior with some users
Investments activities (I5)	Fishery ship acquiring Gear equipment Fish aggregation devices (payaos)	Personal investments in extraction equipment Personal initiatives of planting some tree species Sawmill facilities (private investments)	Aqueduct infrastructure and maintenance Tree planting in the source zones Fences building in the source zones
Lobbying activities (I6)	With local development and enviuronmental NGOs	With regional environmental agencies Universities With local development and environmental NGOs	With the local state instance (Municipality)

Table 15. Outcomes for the three SESs.

OUTCOMES (O)			
	FISHERY	**FORESTRY**	**WATER**
Social performance measures (O1)	Local cultural model does not favors capital accumulation Perception of extraction decreasing Low rule compliance Low legitimacy of environmental authorities Searching of new territorial governance models (Communitarian council declaration) Difficulties in organizational consolidation	Dominant market oriented logic of timber extraction Low prices of timber Dependency of middlemen Few sawmills in the zone Tendency to extracting timber below minimal allowed sizes Difficulties for organizational and political consolidation	Egoistic behavioral patterns Low level of trust Distribution dependent on the position in the watershed High levels of water waste Organizational strength High adaptive capacity to the regional political trends
Ecological performance measures (O2)	The ecological system is overharvested Predominance of small individuals	Recuperation of some forestry species Loss of some forestry sapecies	Reduction of water production due to climate variability

Table 16. Potential shocks for the three SESs.

POTENTIAL SHOCKS (PS)			
	FISHERY	**FORESTRY**	**WATER**
Socio economic (PS1)	Livelihoods deterioration Increase of the tourism as a potential income source Negative social impacts of tourism	Illegal crops areas advance Illegal armed groups influencing the communitarian council External incentives for agro industries and monoculture implementation	Coal mining activities increasing
Infraestructure (PS2)	Transport infrastructure construction	-	-
Ecologic (PS3)	-	-	Climate change

5 INSTITUTIONAL ANALYSIS

The chapter 4 addressed the question about the definition of each case study SES. To reach such definition it was necessary to understand geographical and historical contexts of the case studies. The conclusion of the contextual chapter, trough out a comparison of the three SESs, remarks the importance of the subsystems and variables that constitute the focus of the chapters 5 and 6 of this dissertation. The focuses of these two chapters are the governance and users subsystems. Consequently, in this chapter, an analysis of the governance systems is done through the IAD framework.

This chapter is divided in five sections. In the first section I make a brief discussion about the outcomes of the action arena in which I will focus of the institutional analysis, which already has discussed in chapter 2, focused on rules and norms typology and outcomes of the action situation. In the following three sections I develop the analysis of each of the case studies done with the data collected in experiments, RPG collective construction and playing, surveys and interviews and the information from the context (chapter 4). Each case study starts with the action situation and its outcomes at the scale of the economic experiment; the next subsection addresses the collective construction of the RPG and the outcomes of the RPG action situation. In the next section the outcomes of the SES are studied in terms of cooperation, trust and general morality conformance. Finally, a summary of the main findings for each case is carried out. In the last section of the chapter I compare the three case studies and synthesize the main findings.

It is important to remark that across the chapter I will refer to three action arenas: experimental, RPG and SES, being the last the one in which fishermen, forest users and aqueduct users are immersed in their daily life. Experiments and RPGs are models of the SES with different levels of complexity. Starting with the experimental structure analysis we can have a controllable reference point, to continue with the role game as an intermediate step to address the social ecological system's structure. This procedure allows us to gradually address and better understand complexity of the commons situation we are analyzing. The process entails a scaling up approach in which each level helps to understand the level above. I use the collectively designed RPG to describe and analyze the action arena of the three case studies. In the first place I summarize the essential problem addressed in each case. I start with the analytical description of the board game, which in the three case studies, presents a fundamental anchoring point for local commons problem. The collective construction of the RPG and implementation works as a talking device uncovering the main problems of the SES. This process is done guided by the elements of the action arena already discussed in chapter 2.

Through the examination of rules I illustrated how they affect each component of the action situation. In order to evaluate the outcomes that these institutional arrangements produce I discuss the criteria for their evaluation, which permits us to define outcome variables. Extraction of resource units accounts for participants' behavior, and it is possible to assess this behavior in experiments and role games. The state of the resource is one of the most important criteria for the sustainability of the socio-ecological system, and it is discussed as an outcome of the experimental and RPG action arena. Economic efficiency is evaluated through payoffs in the experiments and RPG. Trust and cooperation are discussed as outcomes from experiments and RPG and the relation with the SES context. To these traditional evaluative criteria of the outcome variables, I add conformity to general morality. The level of conformity to the general morality is interpreted as the consequence of the dynamics of a given set of institutional arrangements, rather than as an external condition of the action arena´s outcomes. In chapter 2, section 2.4.2, I developed a conceptual framework for the evaluation of this variable. In the next paragraphs I briefly explain the role of the morality dimension in the analysis. In the conceptual chapter I introduced the general morality conformance as an evaluative criterion for action arena's outcomes. As a consequence of the analysis I propose that morality constitutes part of the outcomes themselves that reinforces the action arena working as a dynamic feedback loop. In this sense cooperation and trust are a function of the general morality conformance constructed through time in a community and the different action arenas in which common pool resources users are embedded could constantly reinforce that. A given set of institutional arrangements could promote a moral system in a particular action arena (Ostrom, 2005). But also such moral system will affect decisions in the action arena.

The remaining of the chapter analyses the fishery, forestry and water systems. At the end of each one I discuss the outcomes, in terms of cooperation and trust, and the system's triad law, culture and moral.

5.1 The Fishery System

In this section I discuss the three action arenas (experiment, RPG and SES) and its outcomes.

5.1.1 Outcomes of the experimental action situation

Two can be the extreme reference points that theoretically predicted outcomes of experiments: (1) if players are completely self-interest oriented and opportunistic, the state of both fishery spots moves to low condition in two rounds, and remains in that situation for the rest of the rounds. In 10 rounds, this behavior will result in 200 tokens for the 5 participants of the group. (2) On the other hand, if players manage to coordinate their efforts, the cooperative solution produces 382 tokens by distributing the effort equally over the two fishery spots, where at least two people do not exert the maximum effort (Juan Camilo Cardenas et al., in press). The behavior pattern produced by Baru' participants (Figure 5.1) consists in high levels of effort during the first stage of the experiment that gradually tends to increase, ending at the maximum possible level in the round 10. Before starting the second part of the experiment players have to vote for an externally designed rule to control the resource extraction. They could vote among three rules: rotation of banning fishery spots, quotas and randomly distributing permits to go to fishery spots.

No decrease effort is evidenced in the second part. The tendency is to remain at high levels of effort. It means that, in general, rules did not work in terms of their aim; to reach the sustainability of the resource, meant keeping A and B fishery spots in good condition. The consequence of this decision pattern was that earnings decreased and stayed at low levels during the two stages of the experiment (Figure 5.2). Figure 5.3 illustrates the percentage of groups that managed to keep any of the fishery spots in a high condition. This is the cause of the low earnings of players.

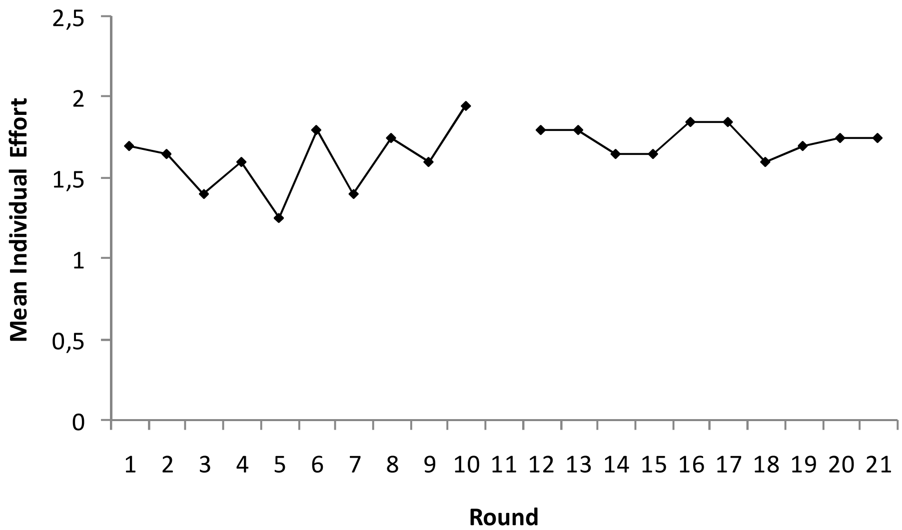

Figure 5.1 Average of individual aggregated effort for fishery spots A and B. First stage: rounds 1 -10. Second stage (with voted rules): rounds 11-20.

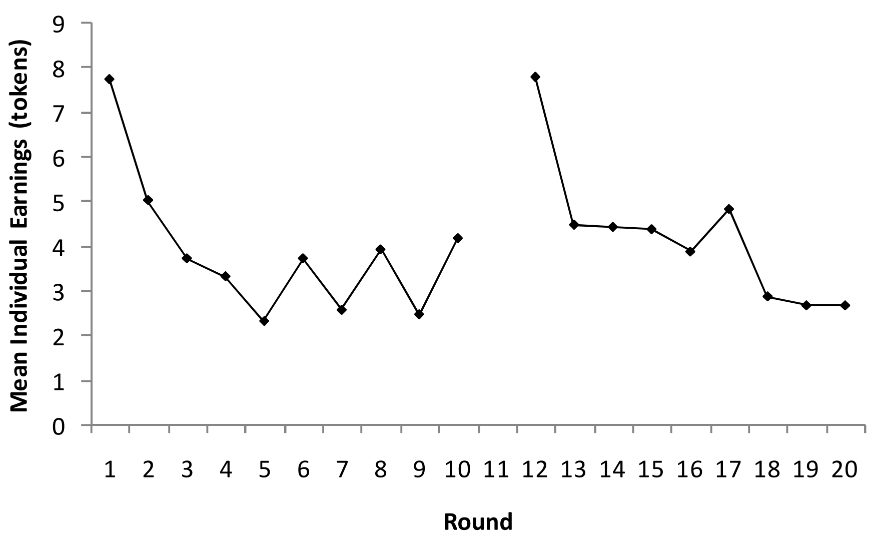

Figure 5.2. Average individual earnings

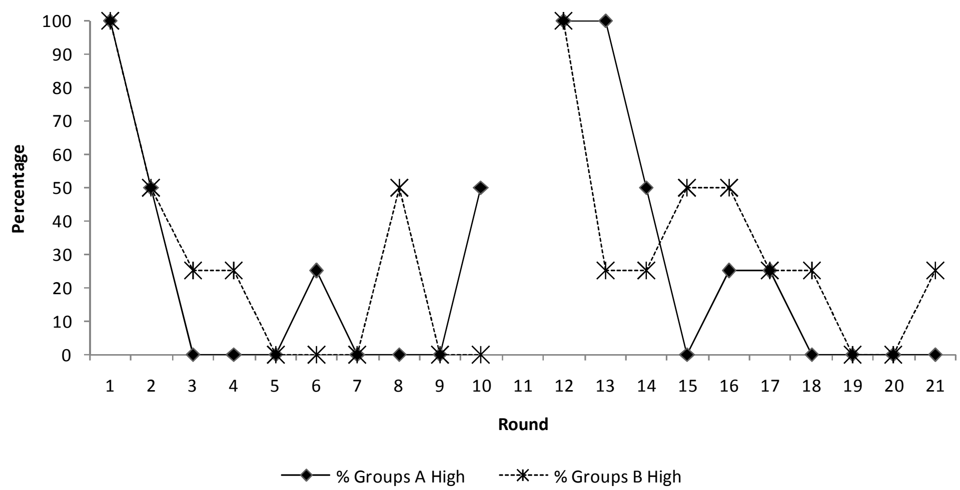

Figure 5.3 Resource sustainability pattern. Percentage of groups that kept A and B spots in high conditions.

In this simplified action situation, these are choice rules, which A*I*M is to influence the actions of the players to lower the fishing effort and sustain A and B places in high condition. Table 5.1 illustrates what happened with the rules. Rule 1 was elected in three of the four groups, but average individual earnings did not improve, and the percentage of rule breaking was 14.7%. The group that elected the rotation rule had a lower rule breaking percentage and the average individual earnings improved slightly. None of the groups elected the quota rule. In general the rules did not improve the earnings during the second part of the experiment.

The preference of this particular rule over the rotation and quota schemes is explained through the exploration of two hypotheses. The random system is perceived as an easier way for rule breaking. Besides, the random banning of fishery grounds and a low probability of inspection is analogous to the way the formal institutions work. The attempt to explain this behavior is important to understand the outcomes of the SES as a result of the institutional arrangements in use. Later in this section I will discuss this outcome in the light of the expanded action situation of the role game and the SES.

Table 5.1 Rules elected and resulting earnings

Rule	Number of times elected	Percentage of rule broken	Average earnings per person (rounds 1-10)	Average earnings per person (rounds 11-20)	Total Average earnings per person (rounds 1-10)	Total Average earnings per person (rounds 11-20)
Random access	3	14.7	41.7	40.7		
Rotation	1	12	33	43.8	39.8	41.5
Quota	0	0	-	-		

5.1.2 Collective construction of the fishery RPG

As I explained in the methodological chapter, the next step was to proceed to a discussion of experimental results with participants, and starting with collective construction of a role game. The protocol followed for that was: (1) to set the objective of the RPG, (2) board game and spatial settings, (3) fishery spots, (4) fishery groups, (5) actors, (6) representation of the fishery activity (effort, condition of the fishery spots), (7) organization of the round, and (8) meaning of one round. In this section I discuss the design of the RPG as a more complex action situation and as a lens to understand the SES action arena.

The purpose of the game

The objective of the game was set after a discussion with participants that brought forward the main fishery problems from their perspective. They stressed the conflicts with the Natural Park and the industrial fishery ships, framing the decreasing of the resource during the last years as a consequence of industrial fisheries practices as well as the use of prejudicial fishery gear by neighboring fishermen villages. Finally everybody agreed that the objective of the role game was to create a space for discussion and negotiation of fishery rules. In contrast, according to the Natural Park official position, the problem is the biodiversity decrease due to fisheries over exploitation by the artisanal fisheries. According to the Natural Park planning document, the fishermen see the main problem in the industrial fishing activity, and the technological limitations for bait extraction (PNNC, 2006).

The game board and the spatial problem

The second step for the construction of the role game was to define the board game. Since the original experimental setting included an explicit spatial configuration with two fishery spots, participants decided to work on a more complex representation of their problem. Therefore, they worked on a map of the island and discussed the location of the most important fishery spots (Figure 5.4).

The excludability characteristic of a common pool resource was the principal issue that arose here; mapping fishery spots "belonging to" or used by Barú fishermen is a claim of their historical rights from their perspective. Testimonies of some of the fishermen led to the idea that their history in this geographic situation gives them rights on the commons *"…the sea belongs to us… well, we have the land, but what are we going to do without the sea?*" (Interview, Barú 2008). Another fishermen explicitly pointed out the property rights issue when asked about who has the right over the fishery spots; "*we have the right to fish on them, who else possibly would have the right?*" (Interview, Barú 2008). On average, fishermen families have lived in the village for 145 years (survey carried out after the field experiments). In the same way they appropriated the land, they also claim their rights over the sea. In other words, for them, to own a territory has not to do with formal property rights, but with living, walking and working on it for many years. In essence it is a claim on the weight they give to their history in the region. From now on I will mention this "marine territoriality", which entails the conceptual definition discussed in chapter 2.

The second issue that emerged during the designing of the game board was the difficulties that fishermen experience for fishing in far places. Therefore, an abstraction of the spatial representation was proposed and endorsed by participants. A central circle represents the land; a contiguous circular region includes three fishery regions that group closer fishery spots. A bigger circular region with three fishery zones represents the far spots. And a zone for industrial fishery was included (Figure 5.5).

During a number of discussions in the workshop participants pointed out that most of the fishermen do not have boats and equipment to go to the far spots; they only can fish in the spots close to the shore; in consequence, the closest fishing places are in bad condition regarding fish abundance. Though there are no historic records about the state of fisheries in the zone, artisanal fishing and tourism activities have increased in recent years as a consequence of loss of land as production mean (PNNC 2006). The generalized fishermen's perception is that the resource is depleting, and that most harvested spots, reported by PNNC (2006), coincide close to the shore. Interviews with fishermen illustrate that, though some fishermen think that rotation experiments could lead to the recuperation of some fishery spots, there is also the continuous risk of defecting by part of them. Fishermen blame industrial fishery ships for entering into park zones and contributing to the resource depletion. According PNNC (2006) industrial fisheries use bottom dragging nets over reproduction zones, which cause serious problems in natural regeneration rates.

In this case constraints in the capacity for mobility and spatial configuration generate a specific spatial structure of the action arena, which affects management arrangements and outputs.

Figure 5.4 Elaboration of a map of Barú and the surrounding fishery spots.

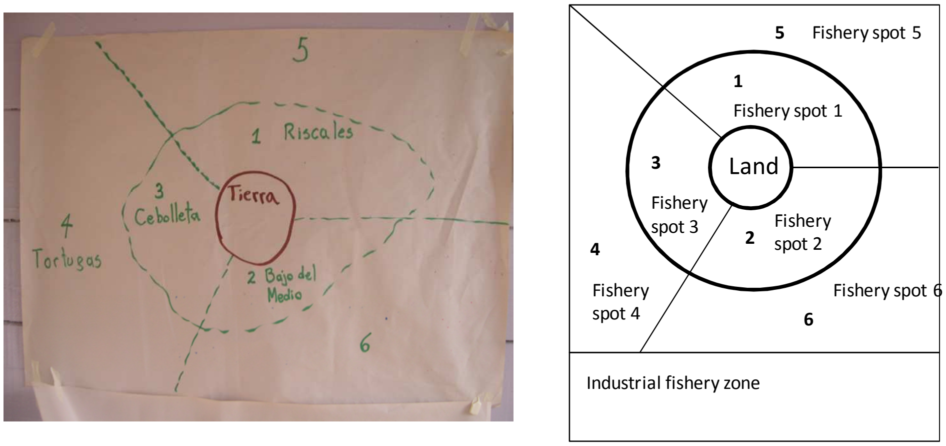

Figure 5.5 Final game board with the essence of the spatial problem.

The action situation

The fishermen participating in the construction of the game defined a set of positions aimed at characterizing the fundamental problem from their perspective, these are: local fisherman, external fisherman, industrial fishery, environmental authority, and governmental development agency representative. The possible actions for the local fisher position were: deciding where to fish, how much effort to allocate, and the fishing gear. The external fisher can make the same type of decisions. The industrial fishery position has the right to fish only in his zone, and also can decide how much effort to allocate. The environmental authority is free to impose and enforce rules, but with limitations such as the creation of monetary taxes. And the governmental development agency position should offer productive options to the fishermen.

The local fisherman position

The fisherman position refers to the fishermen from Barú and Rosario islands, from 100 to 200 individuals, out of a population of nearly 6,240 inhabitants of Afro Colombian origin. In 2002 a group of 24 fishermen formed a fishery organization (PNNC 2006). This organization included in its statutes the fishery rules fostered by the National Park, mainly in terms of technology, minimum sizes of individual fish and species that can be captured. Those were internal rules. The organization managed to obtain, from the government development agency, a fishery boat with higher capacity that allows travel to further fishery grounds. In addition, the organization obtained support for building fish aggregation devices in order to improve harvest and protect coral reef fishery spots.

From the National Park’s perspective, Barú and fishermen from neighboring villages belong to a community relatively homogeneous in terms of socio economical aspects with low incomes and high poverty indexes. Internal heterogeneity starts to be evident by looking at data from the survey applied at the end of the experiments. For example the 30% of participants in the experiments allocate most of their time to agricultural activities while a 60% work mainly in fishery. Regarding the main sources of income, 43% declare that their main economic activity is not form fishing, and it is distributed among handicrafts, small businesses including tourism, and diverse employments, part of them related to tourism activities and agriculture. From interview data and direct field observation it is evident that there are differences in wealth and access to information among members of the fishermen community.

As a consequence of the internal heterogeneity among Baru fishermen, positions and actions in the SES, could include small tourism operators and farmers for example. This diversity of positions has an effect on the outcome of the action situation shown below.

External fishermen position

External fishermen position is aimed to represent fishermen from neighboring villages. Participants who can occupy this position, from Barú fishermen’s perspective, are the fishermen from at least three different villages in the zone and from the city of Cartagena. While role game designers make a clear differentiation between these two positions, the governmental environmental entity has a different point of view in which all the artisanal fishermen from the different villages in the zone, even from Cartagena city, have the same attributes and the same access rights. Therefore, for the National Park authorities the only possible position in this action situation is “artisanal fishermen”. Through the explanation of this position participants expressed their territorial model; which entails a notion of marine territoriality, in contrast with the governmental construction of territory that excludes the sea. For the environmental authority (National Park) the existence of a concept such as marine territoriality is not possible, at least within the limits of the park. Actions attached to this position are of course fishing effort, harvesting and fishing spot choosing. But there are limitations. In the game board they explicitly leave a fishing spots without name because “*these are the places for fishermen from other parts*”, therefore, for them, again the access to the commons is limited. In addition to that they blame neighbor fishermen for using illegal fishing gear.

This difference in the conceptualization of the commons dilemma, far from being superficial, entails one of the dimensions of the cognitive conflict that starts to emerge in this phase. It shapes the institutional problem, which drives most of the outcomes of the action situation.

Industrial fishery position

The industrial fishery position can be filled only by ship captains and operators. Here they conceptualize the problem of territorial invasion and prejudicial fishery practices as dependent upon the ships themselves. Game designers do not up-scale to see a set of participants that are at the level of regional, national and even international companies. For this position the possible actions are to fish out of the Park and far from the artisanal fishing grounds.

According to environmental authority industrial fisheries affect the park ecosystems by harvesting with dragging nets over zones that are important for species reproduction (PNNC 2006). Baru fishermen coincide with this vision, but in addition, they think there is corruption when the environmental authority applies sanctions, and they say that the law is not equal for all. This situation contributes to the level of general morality produced when inequity in rule enforcement is a common practice.

Environmental authority position

Environmental authority is free to impose and enforce rules in the RPG. The Natural Park was created in 1997, and has an area of 120,000 marine Ha. The Park has around 20 officials, including professionals (biologists, social workers) and technicians whose tasks consist of the monitoring of Park’s territory surveillance among other technical duties. Between 2000 and 2004 the Park’s management style was oriented towards participatory approaches trying to build a close relationship with local communities. Many of the rules were established in consensus with the local fishermen (Interview with a Park official, Barú 10/07/2008). Even the internal rules of the local fishermen’s association were designed according to the Park's proposals and the Ministry of Environment's laws (Interview with a fisherman, Barú, 4/07/08). In 2004 the National Parks' central headquarters changed its policy and the director of the Park was replaced by a military one. This new administration changed its policies favoring the top-down style of rule creation, monitoring and enforcement. As a consequence, the relationship with the community deteriorated and the previous administration's work on rule agreements and awareness has been lost. Currently, the general attitude of local inhabitants towards the Park authorities is characterized by hostility, and interference with any of the Park's proposals; a situation that has led to conflicts, with fishermen in general, and especially with the fishermen' organization.

Information available to participants

The role game provided a representation from the game designers' perspective on what information is available for each position in the SES fishing action situation. Available information for fishermen, on the one hand, is the possible harvest according to the type of fishery gear chosen, and on the other hand, the total amount of extracted fish for each fishery spot displayed in the board game each five rounds (Table 5.2 and Figure 5.5). Fishermen know how the resource changes from a good condition spot to a low condition spot, and vice versa, depending on the previous total catch. A spot in good condition changes to low condition, if more than 30 kg of fish are extracted; no matter the number of rounds the spot has lasted with this amount of extraction. If 10 kg or less of fish is extracted from a place in bad condition, it moves to a good condition. Neighboring villages and industrial fishermen have the same information. In contrast with the fishery experiment, participants in the role game can communicate among themselves without any restriction.

In the SES, information can be classified as: the resource system, others' actions, and formal rules. Local knowledge about the state of the resource is passed from generation to generation and updated by self-experience. Environmental and catch indicators are most often mentioned by fishermen, but also young fishermen seem to be very influenced by the opinions of elders. Older fishermen constantly talk about the much better conditions of the fishing in previous generations, this idea is held by young fishermen. It is not clear how the information flows among fishermen. From interviews, one can infer that part of the information about other's actions spread by worth of mouth, mostly information concerning rule breaking and the state of fishing locations. With regard to the formal rules, fishermen who have been closely involved with the management of the fishermen's organization have a general knowledge about them. They are aware of the general restrictions in the Park zone, as well as the rules about minimum allowed catch sizes and fishing gear. Currently, environmental authorities, meaning the Park's officials, do not have mechanisms to establish good communication with local fishermen.

Table 5.2 Returns in kilograms from effort, fish availability in fishery spots, and possible fishery gear (source: Fishing RPG)

RPG Payoff table							
Fishery gear		Good resource conditions			Bad resource conditions		
	Code fishery gear	Effort 0	Effort 1 (4 hours fishing)	Effort 2 (8 hours fishing)	Effort 0	Effort 1 (4 hours fishing)	Effort 2 (8 hours fishing)
Diving	1	0	4	8	0	2	4
Trolling line	2	0	4	8	0	2	4
“Boliche”	3	0	6	12	0	2	4
Net	4	0	5	10	0	2	5
Dynamite	5	0	10	20	0	5	10
Longline	6	0	7	15	0	3	7
Industrial fishery	7	0	15	30	0	7	15

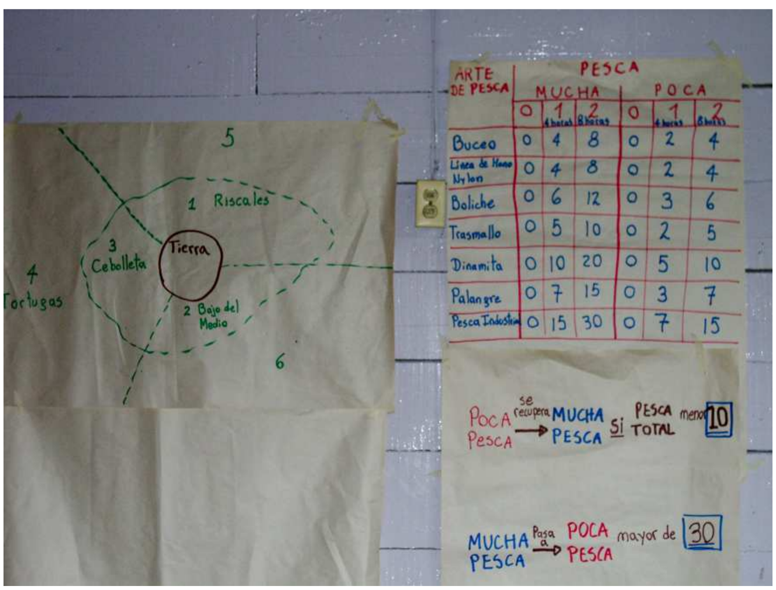

Figure 5.6. Final setting of the Role Game on the fourth day session.

Control over outcomes

Players in the RPG are able to communicate between themselves and with the environmental authority officer. Theoretically, players (fishermen) have complete control over the outcomes, and conditions are given for agreement and rule crafting in order to improve the state of the resource and the benefits. Regarding the SES, the interviewees are in concur, when asked about the ability to change rules, they give answers such as: "we try (to change some things) but it's not possible". They have never thought in organizing to change the rules, and in this way improve some outcomes. One of the fishermen expressed his point of view about this point. He said that the way to change rules and outcomes also involves the fish buyers, middlemen, and touristic operators. Regarding the local leaders, and their role in controlling outcomes of the system, the same interviewee, explains that in order to improve outcomes they should help. What happens in reality is that "once a person catches a public post", he has a stable income and is not a fisherman anymore, he does not care anymore about the community, and the community does not support him. When asked about rule changing the interviewees do not think of changing formal rules as a way to improve outcomes. They insist in a different way of rule enforcement and better rule compliance. The response to the survey question (individual survey applied after experiments) "How much influence do you believe people like you have in making this a better place to live by this course?" could be a proxy of the ideas that people have about controlling outcomes. Sixty percent (60.6%) of the respondents answered that they influence a lot in their community, 23% said they have some influence, and 17% answered that they do not influence much. One can understand these figures as a sign of awareness of the high potential for changing outcomes in the community, but also as the existence of cultural and moral elements that play an important role in the action arena dynamics, and that will be discussed in the outcomes section.

Synthesis of the collective construction of the RPG's action situation

Table 5.3 summarizes a comparison between expected changes and actual changes that occurred during the building of the game. It shows the important contextual dimensions that need to be taken into account to model the social dilemma. Resource diversity, ecological seasonality, and market differences are not core dimensions while the spatial complexity of the resource system is important. Representation of effort does not have to increase in complexity. The technologies became more complex, new roles were introduced and new rules were set as part of the structure of the RPG.

Table 5.3 Expected and actual changes during RPG co-construction.

TOPIC	EXPECTED CHANGES	ACTUAL CHANGES
Changes in resource settings		
Resource diversity	Different kind of target species	NO. Participants did not differentiate between species.
Season to fish	Different seasons or climate restrictions according season	NO. Participants did not include any climate variable or seasonal particularity
Differences due to the context	Differences- Conservation area	YES
Fishery spots	More realistic fishery places (number and names)	YES. Participants began by a realistic map of the region and fishery spots, and then a middle point between experiments representation and the map was used.
Condition of fishery spots	No hypothesis	NO. High and Low conditions were kept from the experiments.
Individual decision making		
Species choice	Possibility to switch from one target speciesspecie to another one.	NO. No differentiation in species to fish
Price	Taking into account the price at market.	NO. Not considered
Fishing spots choice	Different areas to fish which can be grouped into coastal zone or far zone	YES, fishery places were classified in coastal and far zoneszone. Seven fishing locations were defined: 3 coastal, and 4 far zones.
Fishing gear	No hypothesis	YES. Participants differentiated fishing gear. They included 7 types of gear, both legal and illegal, with explicit names and including industrial fishing gearIndustrial fishery.
Incentives structure	No hypothesis	YES. The payoffs were assimilated to kilograms of fish and were defined according to the gear, effort and spot condition.
Effort	No hypothesis	NO. The values of the experiments (0, 1, 2) were kept, but it was necessary to specify their meaning in terms of hours: 1= 4 hours, and 2 = 8 hours.
Collective decisions		

Rules	Rules would be negotiated	YES. They tried to make rotation agreements. Negotiation was about alternative production activities in order to lower the pressure on fishery spots.
Sanctions	Sanctions would be more probable	NO. No sanctions were implemented in the agreements, but the Park authority threatened with the implementing of sanctions.
Roles	Integration of new roles	YES. New roles were defined: Environmental authority (Park official), Incoder official, and fisher from and the other village.

5.1.3 Outcomes of the RPG action situation

Table 5.2 shows the possible effort decisions that each fisher can choose, and the earnings in fish kilograms according to the state of each fishing zone (high or low). The effort could be 0 (no fishing), 1 (4 hours of fishing), or 2 (8 hours of fishing). The catch also depends on the type of fishing gear the player decides to use. Each round of the game represents one real fishing day. The state of fishing zones is updated each five rounds (one simulated week). The representative of the environmental authority; a Park official, receives a report from the facilitator on the state of the game board each five rounds. He announces the new state and can enact/create rules and suggest changes. Players can communicate freely.

Figure 5.7 illustrates the average individual effort for each round of the game. The upper panel shows the dynamics of the fishing zones every five rounds. Initial conditions of the fishing zones were set according to the local conditions; more accessible fishing zones 1, 2 and 3 are in low resource conditions (orange zones in Figure 5.7), while far zones are in good condition (green). During rounds 1 to 10 the average individual effort stayed between 1.4 and 1.9, which led to a worsening of resource conditions. In round 5 the industrial fishery zone became in low condition and in the round 10 zones 4 and 5 felt to low conditions.

The Park official gave a general explanation about the situation of the fishing resource using the state of the fishing zones on the game board as a reference. He warned players that, if they do not decrease the pressure on the fishing zones the authorities would have to take actions. During the second week the Park official asked for the presence of a representative of the governmental agency for rural development and fisheries (INCODER) in order to give productive alternatives to fishermen to diminish the harvesting pressure on the closest fishery spots. Therefore, during the process a new position was created in the RPG's action arena. A representative of the Colombian public agency in charge of rural development policies filled this position. Their possible actions were offering productive alternatives to fishermen different from fishing.

The participant for this position is the Colombian Institute for Rural Development (INCODER), which is the responsible for the implementation of the agrarian, and development policies. Among its functions are the facilitation of access to means of production and the coordination of development efforts among different governmental agencies and communities. Contributing to the amelioration of the livelihoods of rural inhabitants is among its ultimate objectives. The agency also is in charge of fishing regulation and development outside of the protected natural areas (INCODER).

In 2006 the INCODER gave a number of medium capacity fishing boats and equipment to several Colombian small artisanal fisheries, among which was Baru's fishermen' organization (Pesbaru). The new boat allowed them to go to further places, even, out of the Park. Interviewed fishermen say that representatives from this agency visit the village and talk with the fishermen association. They do not see these visits as a monitoring activity in order to enforce rules. It is more a follow up of their fisheries with the new equipment. Despite this perception some of the interviewees said that they should follow the fishing regulation if they go out of the Park. Fishermen see the Incoder as one of the possible actors that could facilitate fishing rule compliance, by providing means to produce additional income, apart from fishing, and to diminish the fishing effort.

The center of the discussion was about the rotation of fishing spots and the need of different productive options. The representative from Incoder gave some options that looked to compensate for the days that people do not go to fish. The Park officer never implemented any specific regulations, he tried to convince them to diminish the harvest, but he always threatened to ban the closest fishing spots (1, 2 and 3). Interestingly enough in the third week all of the fishing spots were in high condition except one close to the shore, and the officer seemed not to recognize the effort of players to recuperate the spots.

The main outcome of the discussion in round 10 was the cooperation agreement for decreasing effort and a rotation scheme of fishing. The agreement was conditioned to an offer of alternative income sources. The role of the development agency (Incoder) was to guarantee that, if a fisher allocates an effort of 1 (half day), he can allocate the rest of his day to another activity, and obtain an equivalent payoff as if he were fishing. The discussion on this point was long and detailed in terms of what could be the economic activities that could be supported by the governmental agency and the type of support needed.

During the last five rounds individual effort decreased, most of the players followed the agreement and as a consequence, in round 15 the state of the fishery zones improved considerably compared to the condition in round 10. All of the far zones were in good condition and two of the three close zones were in a good condition. At the end of the game the Park representative clearly did not recognize the change in behavior of players that led the system to a better state (Figure 5.7). Regarding the fishing gear chosen by players, the trolling line was the most frequently used gear, followed by diving gear (Figure 5.8 lower panel). It is important to remark that, in spite of the fact that designers of the game insisted on including illegal gear in the payoff table (Table 5.2), nobody used them, either in the test of the role game nor in the final game. Effort decisions frequency is concentrated in 2, reflecting the fact that during the first 10 rounds there was no agreement for the decrease in effort (Figure 5.8, upper right panel). The fishing frequency was higher in the close fishing spots, and then started to become balanced with the far spots during the last five rounds (Figure 5.8, upper left panel).

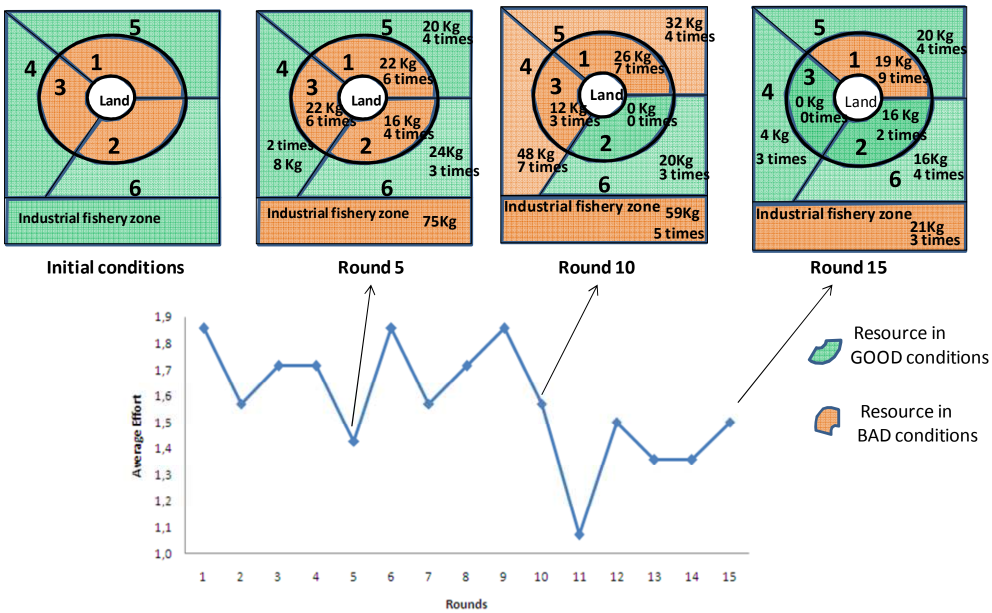

Figure 5.7 Outcomes of the RPG: Average individual effort and state of the resource each five rounds.

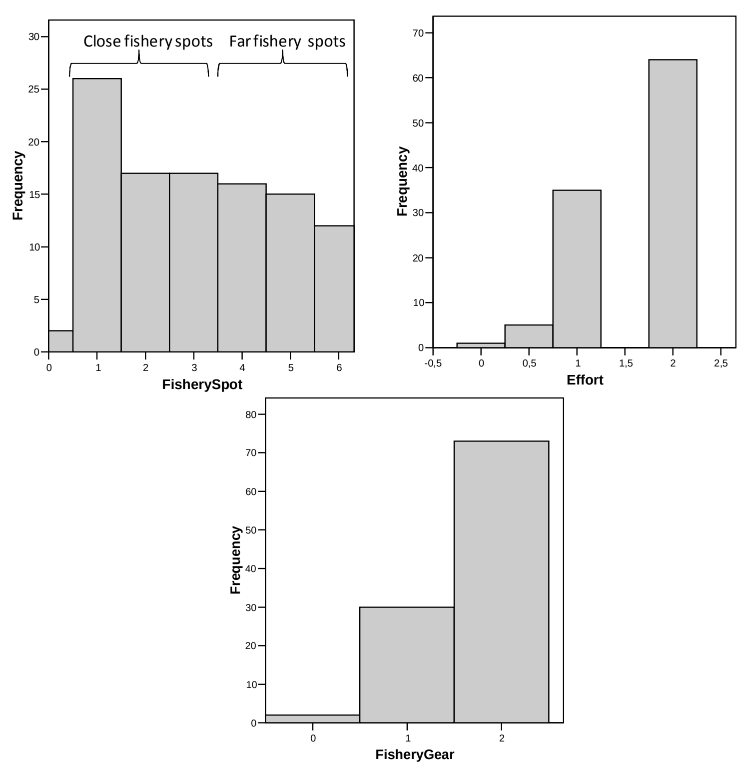

Figure 5.8 Outcomes of the RPG: Frequency of fishing location, effort level and fishing gear used.

5.1.4 The institutional arrangements in the fishery SES

Formal rules

The analysis of the formal rules is based on secondary information collection from the Colombian regulation literature. Tables 5.4 and 5.5 illustrate the formal rules classified according to AD*I*CO rule building blocks, and their A*I*M. As shown in in table 3, there is a complex formal institutional arrangement intended to regulate the fishing activities in Baru's area. A common trait of the laws is that their aim is focus on biodiversity conservation and preservation of ecological equilibrium. Regarding the condition of rules, all, except number 8, are of national scope. This law is the only one specifically addressing the Natural Park, and in consequence, Baru's grounds. The main consequence in terms of rule dynamics is that all of the formal regulation is at the constitutional level, and their change is difficult.

Classification according to rule A*I*M allows better understanding about what part of the action situation they are influencing. For the A*I*M typology I expand the set of rules to specific regulations included in the Decree 622 of 1977 that are important to illustrate how the fishermen' actions are formally constrained by different species restrictions. Table 5.5 shows how 14 out of the 20 laws regulate actions of actors (choice rules), 2 are boundary rules, meaning they define how participants enter in the action arena, 2 are scope rules, which define the for what zones are the rest of the rules and therefore the type of outcomes that zones must have, always with an ecological emphasis. The first boundary rule allows only persons who harvest for subsistence to fish in the protected area. The second boundary rule is also a choice rule, but has been classified as a boundary one because restrictions on fishing gear imply the exclusion of other type of actors such as industrial fishing and autonomous diving fishermen. Most of the rules aim to regulate individual behavior by influencing fishermen' actions including technology, species minimum sizes and species banning. One general rule (number 12) specifies the sanctioning system, which formally would affect the costs and benefits of actors in the action situation; therefore it is classified as a payoff rule. The two scope rules aim to conserve the ecosystem and define the zoning inside the Park. These two rules immediately place Baru fishing zones under the effect of the rest.

Table 5.4 Formal statements AD*I*CO syntax components

STATEMENT	ATTRIBUTE	DEONTIC	AIM	CONDITION	OR ELSE	TYPE
1.Creation of the Natural Park Corales del Rosario y San Bernardo (Law 2811/74)	Colombian and alien citizens	Definition of permitted and prohibited actions	Conservation of biodiversity and maintaining of ecological equilibrium	All National Natural Park areas		Rule
2. Marine geographical zoning definition for National Natural Parks System. (Decree 622/1977)	Colombian and alien citizens	Generic prohibited and allowed activities in each zone	Definition of use zones	All National Natural Park areas	Specifies Specify sanctions for the previous rule	Rule
3. Every activity that the competent environmental authority considers to cause significant modifications of the environment or the natural values of the different zones of the National Natural Parks System is prohibited (Decree 622/1977).	Colombian and alien citizens	Prohibition of every activity considered to harm the Natural Parks by authorities	To conserve the ecological equilibrium	All National Natural Park areas	The violation of any rule implies a fine, that ranges between USD $50 and USD$ 250, or the fine is defined by the local environmenta l authority according the economic capacity of the violator. (Decree 622/1977)	Rule
4. It is prohibited to exercise any fishing action, except fishing with scientific purposes authorized by the environmental authority, sportive fishing and, subsistence fishing. These allowed activities must not threaten the ecological stability of the Park (Decree 622/1977).	Colombian and alien citizens	Prohibition of industrial and artisanal fishing, and allowing sportive, scientific and subsistence fishing	To conserve the ecological stability	All National Natural Park areas		Rule
5. It is forbidden to extract resources in banned or from reserved areas. (Fisheries General Law 13 /1990)	Colombian and alien citizens	Prohibition of any fishing in banned and reserved areas	To assure the sustainable development of the fishery resource	All the Colombian territory	Offenders to this law (Law 13/90) and other norms on the same topic will be punished, according the gravity of the offence, with the following sanctions: 1) Written advertence, 2) Fine, 3) Confiscation	Rule
6. Aquatic species declared threatened and in danger of extinction will be protected by the government. The competent governmental agency will implement the necessary measures in order to avoid extinction according international treaties (Fisheries General Law 13 /1990)	Colombian and alien citizens	Prohibited to harvest endangered species	Endangered aquatic species protection	Colombian territory		Rule

7. It is prohibited to fish with illicit methods such as explosive, toxic, or other means which nature be dangerous for human life or fisheries resources, as well as to carry on board such materials. (Fisheries General Law 13 /1990)	Colombian and alien citizens	Prohibited to fish with certain fishery methods	Protection of fishery resources and human life	Colombian territory	of boats/ships, gear or products. (Fisheries General Law 13 /1990)	Rule
8. Specific definition of permitted and forbidden activities according Marine geographical zonning : A)- Intangible zones: No fishing allowed. B) Other zones: Only subsistence and scientific fishing is allowed. (Management Plan of the Natural National Park Corales del Rosario Y San Bernardo (PNN CRSB) 2005 - 2009)	Colombian and alien citizens	Allowed and prohibited activities for each zone	Integral management of the Park.	National Natural Park Corales and Islas de San Bernardo	The violation of any rule implies a fine, that ranges between USD $50 and USD$ 250, or is defined by the local environmental authority according the economic capacity of the violator. (Decree 622/1977)	Rule
9. The minimum allowable lobster size to catch is 25 cm. (Threatened species declaration: Resolution 584/2002)	Colombian and alien citizens	Allowed and prohibited lobster catch sizes	Protection of a species	Colombian territory		Rule
10. The hunting of turtles is forbidden. (Threatened species declaration: Resolution 584/2002)	Colombian and alien citizens	Prohibited turtle harvest	Protection of a species	Colombian territory		Rule
11. The Mero guasa (Epinephelus itajara) fish species harvest is forbidden (Threatened species declaration: Resolution 584/2002)	Colombian and alien citizens	Prohibited the harvest of a particular fish species	Protection of a species	Colombian territory		Rule
12. The minimum octopus individual weight that can be harvested is 400 grams.	Colombian and alien citizens	Allowed and prohibited octopus catch sizes	Protection of a species	Colombian territory		Rule

Table 5.5 Formal institutional statements classified according their purpose (A*I*M)

INSTITUTIONAL STATEMENT	SCALE	CREATO R/YEAR	A*I*M	TYPE Position: 1, Boundary: 2, Choice: 3, Aggregation: 4, Information: 5, Payoff: 6, Scope: 7.						
				1	2	3	4	5	6	7
1. Creation of the Natural Park corales del Rosario y San Bernardo (Law 2811/74)	Local	Central gov/ 1974	Conserve ecosystem							X
2. Marine geographical zoning definition for National Natural Parks System. (Decree 622/1977)	National	Central governme nt/ 1977	Define boundaries							X
3.Prohibits every activity that the environmental competent authority considers that causes significant modifications of the environment or the natural values of the different zones of the National Natural Parks System (Decree 622/1977).	National	Central governme nt/ 1977	Conserve ecosystem stability			X				
4. It is prohibited to exercise any fishing action, except fishing with scientific purposes authorized by the environmental authority, sportive fishing and, subsistence fishing. These allowed activities must not threaten the ecological stability (Decree 622/1977).	National	Central governme nt/ 1977	Limit extraction			X				
5. The environmental authority will designate the persons and agencies that must exercise control and surveillance in the areas of the National Natural Parks System. These officers will have police functions. (Decree 622/1977)	National	Central governme nt/ 1977	Define monitoring	X						
6. Every person that usually allocates effort to the extraction of fishery resources, using any licit method, is considered a fisherman. The competent authority will establish the classification of fishermen, rights and duties that correspond. (Decree 622/1977)	National	Central governme nt/ 1977	Assign fishing rights	X						
7. Definition of Subsistence fisheries: Nonprofit activity carried out only for fishermen and his family for their livelihood. This type of activity is free in all the national territory. (Fisheries General Law 13 /1990)	National	Central governme nt/ 1990			X	X				
8. It is forbidden to extract resources in banned status and, from reserved areas. (Fisheries General Law 13 /1990)	National	Central governme nt/ 1990				X				

11. Aquatic species declared threatened and in danger of extinction will be protected by the government. The competent governmental agency will implement the necessary measures in order to avoid extinction according international treaties (Fisheries General Law 13 /1990)	National	Central government/ 1990			X				
12. It is prohibited to fish with illicit methods such as explosive, toxic, and others which nature be dangerous for human life or fiheries resources, as well as to carry on board such materials. (Fisheries General Law 13 /1990)	National	Central government/ 1990			X				
13. Offenders of this law (Law 13/90) and other norms on the same topic will be punished, according the gravity of the offence, with the following sanctions: 1) Written advertence, 2) Fine, 3) Confiscation of boats/ships, gear or products. (Fisheries General Law 13 /1990)	National	Central government/ 1990						X	
14. Specific definition of permitted and forbidden activities according Marine geographical zoning : A)-Intangible zones: No fishing allowed. B) Other zones: Only subsistence and scientific fishing is allowed. (Management Plan of the Natural National Park Corales del Rosario Y San Bernardo (PNN CRSB) 2005 - 2009)	Local	Natural Park/ 2005			X				
15. The minimum allowable lobster size to catch is 25 cm. (Threatened species declaration: Resolution 584/2002)	Local	Central Government/ 2002			X				
16. The hunting of turtles is forbidden. (Threatened species declaration: Resolution 584/2002)	National	Central government/ 2002			X				
17. The Mero guasa (Epinephelus itajara) fish species harvest is forbidden (Threatened species declaration: Resolution 584/2002)	National	Central government/ 2002			X				
18. The minimum octopus individual weight that can be harvested is 400 grams.	National	Central government/			X				
19. Prohibited fishing gear: Dynamite, net, dragnet, harpoon, hook.	National	Central government/		X	X				
20. Harvesting of ornamental coral reef fish species is prohibited.	National	Central government/			X				

Rules in use

In order to understand the operative rules in the system, I describe what interviewees express about formal rules and actual behavior in local fisheries. Regulations on minimum extraction sizes of certain species, banning of endangered or high ecosystem importance species, fishing gear restrictions and zone banning are the rules mentioned by fishermen and park representatives.

The lobster (Panulirus argus)

Lobster catch size restriction started to be implemented in 2002. The minimum size for harvesting is 21 cm in length. This was achieved through the very close work of the Park officers with fishermen and touristic operators that buy lobster. The role played by the fisher's association (Pesbaru) was important because the association adopted the formal rule. The monitoring of the rule was carried out by Park workers and fishermen. Fishermen interviewed agree that, at that time, there were good relations with Park authorities and it was possible to make agreements. Nowadays the rule seems not to be enforced due to "lack of information" as expressed in one of the interviews; now Park authorities are trying to organize fishermen to collect data on captures. One of the Park functionaries explained that, at that time, the sanction was the seizing of the product. Park functionaries used to plan monitoring trips specifically for lobster monitoring. They used to make the trips around 9 am where almost all the fishermen were harvesting. Pesbaru used to carry out their own monitoring, but as a consequence the organization paid a toll; at the beginning the fishermen association had 38 members, but due to the adoption of the lobster rule 13 members quit Pesbaru. Most of the fishermen express that the rule does not benefit the community because the resource is currently in bad condition and they have to work. When a fisherman sees another one harvesting lobsters under the permitted size they do not speak, otherwise their own reputation will be harmed and they will be known as an informer.

The queen conch (Eustrombus gigas), mero guaso (Epinephelus itajara) and marine turtle (several species)

This conch species is in danger of extinction and its harvesting is completely prohibited. The interviewed Park representative explained that when they catch a fisher with conchs in the boat they put the small ones in the sea again, but not the bigger ones. There is an NGO in the zone that buys the adult conch from the fishermen in order to return them to the sea. The Park employee acknowledged/observed that they never have done a monitoring trip explicitly for conch monitoring. This species is one of the most valued by the local community, they catch them, not for selling but for their own consumption. Though the local community knows the banning rule for this species "they take all they can" (Interview with a local fisher). When a fisherman sees fisher see a peer catching conch, it is not a big deal, they just chat about it. Clearly, this rule does not reflect the preferences of the community, and it is not perceived as a rule that benefits the community. The same situation was reported for mero (Epinephelus itajara) and marine turtles.

Reef or ornamental fishes

The fishing of these species is formally forbidden. Interviewees agree that the existence of these species in the reefs attracts tourists. But people acknowledge that they fish these species for household consumption and selling them to the some local hotels. One of the Park representatives interviewed expressed that this rule does not reflect the preferences of the community. Fishermen from neighboring villages usually fish these species, and the common behavior of Baru fishermen is to denounce them.

Fishing gear

The use of dynamite and gunpowder for fishing is formally prohibited since 1990 (Fisheries General Law 13/1990). All of the interviewed fishermen agree that this fishing practice has diminished through time and that very few of Barú fishermen currently do that. Fishing gear such as harpoons and all types of fishing nets are prohibited. Sanctions for dynamite use include imprisonment and for nets use is the confiscation of equipment.

Interviewees agree that fishermen do not denounce the use of prohibited gear; they only denounce the prohibited gear when fishermen from other villages use them. The dynamite use is generally denounced by people who are working on the land and hear the explosions. The only gear allowed in the entire Park zone are nylon fishing lines, except in the core conservation zone, which is a permanent banned area that allows no fishing. Interviewed fishermen gave ambiguous answers to the question about the compliance of these rules.

Rule compliance

Though interviewed fishermen are well informed about formal rules, their compliance level seems to be low. For example, prohibited species such as sea turtles and conch are harvested and the reason given is that they belong to their cultural preferences, therefore, mostly with conch, when they spot them they just catch them. The case of marine turtle species is less common but in general they speak openly about it. Regarding minimum sizes of other species such as octopus and lobster the common position is that they try to fulfill the rule but in the face of present scarcity they have to catch it. Park authorities recognize that their monitoring capacity is extremely low, and that current relations with Pesbaru and the community are not in good shape. Nowadays the popularity of Park authorities among the local community is low and there is no clear strategy for working with the community. In general fishermen express directly that there is a low level of rule compliance. One of the questions asked was: From each ten fishermen, how many follow the rules? For example the answer by one person who specialized in lobster and octopus catching: "I think very few, that's why I'm telling you we are in a very *critical* situation regarding the resource, it is totally depleted, but we have *harvest* because there isn't another way of living" (Interview, Baru, July 23, 2007). There is a general consensus among interviewed fishermen on this point.

Fishing gear rules seem to show a higher compliance level. Dynamite and powder gun use is clearly seen as bad practice. Nets and harpoon are less used, and local fishermen particularly blame other villages for the use of net gear.

Rule enforcement is characterized by all the interviewees as a very unequal situation. This feeling is clearly expressed by one of the fishermen: "The wider side for him, the narrower side for me", meaning that the rules apply for small fishermen without money and power, but not for others such as sportive fishermen, wealthy persons and industrial fishery.

The purpose of the rules

Looking at the A*I*M classification of the rules in use it is possible to describe the current situation.

Position rules: I include this type of rule as a rule in use because the actual status of one of the positions is different to the formal one, and it determines the possible actions linked to it. Fishermen from Barú are artisanal fishermen and not only self-consumption fishermen, this clarification is important because according the formal institution (Table 4) the only fishing allowed in the area for locals is subsistence fishing, which is defined as a nonprofit activity only for individual or household consumption, and it is allowed in all the Colombian territory. But what Barú fishermen practice includes what the law calls artisanal fishery. This type of fishing includes individual or collective fishing in cooperatives or associations, with personal work, and personal fishing gear constituting a small scale productive activity (Fisheries General Law 13/1990). This is illustrated by one of the fishermen: "they say that here we do subsistence *fishing*, well, for example, I have to feed four kids, my wife, I pay electricity, gas… and how am I going to live from subsistence *fishing*? Simply to catch what I'm going to eat, and so what with the other stuff? (Interview with a fisher 2008). This is the general situation of locals. Therefore, members are artisanal fishermen from Barú, Park authorities, touristic operators and a NGO (Ceiner).

Boundary rules. The issue that these types of rules are addressing in this SES is fundamental to understanding the system dynamics. Boundary rules or entry and exit rules are defined by three points: "(1) who is eligible to enter a position, (2) the process that determines which eligible participants may enter (or must enter) positions, and (3) how an individual may leave (or must leave) a position." (Ostrom 2005: 194). Formally speaking any person is allowed to practice subsistence and sportive fishing in the Park areas, according to rule 4 (Table 4). Local marine territorial sense plays a key role in the definition of first-order boundary rules in use, which define the eligibility to occupy a position. Being Afro-Colombian traditionally settled in the area is a characteristic that entitles any local to use the fishing grounds. This is clearly expressed by Baru fishermen as already discussed above in the board game definition. The following extract from one of the interviews illustrates this point:

> Interviewer: "Who has rights on the *fishing* grounds?"
> Fisher: "We, the natives"
> I: "What kind of rights?"
> F: "like fishing in them"
> I: "Have you ever felt that you are doing something illegal while fishing in these places?"
> F:" No, never. I would ban other places different from ours."
> (Interview with a fisherman, 2008)

Being part of ancestral Afro-Colombians communities is the first condition for accessing to the fishery commons. Surrounding villages also have this condition; therefore, a second-order entry rule is in use, which establishes a subset of position-holders based on belonging to the Barú community territory, including the Rosario Islands. The islands and the adjacent marine areas are traditionally conceived as the rural zones of Baru. This entry-exit rule for using the commons fishing grounds is evidenced in the role game design process, several interviews and field observations.

Choice rules. This type of rules "specify what a particular occupying position must, must not, or may do at a particular point in a decision process in light of conditions that have, or have not, been met at that point in the process." (Ostrom 2005: 200). Extracting decisions of fishermen are constrained by choice rules, therefore the above discussed rules for harvesting certain species and the use of determined fishing equipment fall in this category. Table 4 illustrates the formal choice rules that aim to prescribe the actions of participants in Baru's action situation. Though the understanding of choice rules in use is a challenging task, it is possible to explain what could have been happening. The park management style at the beginning of 2000 was trying to work together with local fishermen communities, and they managed to build close relations and encouraging fishermen association development. One of the main results was that the fisher's organization Pesbaru adopted formal choice rules for their practices as it is confirmed by fishermen in interviews. The fisher's organization and the Park administration were moving together into a consensus for institutional arrangements that even included self monitoring among Pesbaru members. Pesbaru also managed to raise funds for an experimental project placing fish aggregation devices in and outside of the Park (Interview with Pesbaru leader, 2008). Though members of the organization are 25 out of 200 fishermen in the community, the association was gaining momentum and sound fishing practices were spreading among other local fishermen. In 2004 the Park's director changed, as well as the management style. The new administration abandoned the close work with the community, and the emphasis was on enforcing formal choice rules. This process negatively affected the levels of trust that the Park and fishermen built. In order to enforce the formal choice rules it was necessary to contradict a fundamental boundary rule in use: local fishermen are not holders of an ancestral right to the marine territory. In this process the formal rule about subsistence fishing began to be brought up signaling that daily fishermen' behavior was illegal. One of the consequences of this enforcement affected the fish aggregation device experiment. Formal choice rules do not allow these types of activities inside the park. Internal organizational conflicts led to divisions among Pesbaru fishermen (2007-2008). Interviewed fishermen recognized the existence of choice formal rules, the benefits of some of them, but expressed the lack of monitoring, and the lack of compliance was implicitly suggested. The inequalities in rule enforcement and sanctioning are permanently expressed in interviews and role game. The general understanding is that authorities apply rules unequally depending on the type of actor; industrial fishery boats and wealthy sportive fishermen have different treatment compared to Baru fishermen. In this respect, choice rules in use distribute the power of actions in a high unequal manner. Choice rules in use widen the range of actions for some actors and narrow them for Baru fishermen, in this way they are affecting the basic rights, duties, liberties of actors and their relative distribution.

Information and payoff rules. Interviewees agree that when a fisher catches a person breaking a formal choice rule he does not denounce this person, otherwise his own reputation is seriously damaged. Since information rules

> "…authorize channels of information flow among participants, assign the obligation, permission, or prohibition to communicate to participants at particular decision nodes… Information rules are particularly important in generating information about past actions of participants so that other participants can know who is, or is not, trustworthy" (Ostrom 2005: 206).

This type of behavior is a social norm, which works, first as an information rule in use, and secondly as a payoff rule in use. The social norm directly affects the costs and benefits of actions of participants in the sense that sanctions are not applied.

Payoff rules in use are concentrated in the sanction system. Before the internal problems, the fishermen' association implemented graduated sanctions. Some interviewees said that first the rule breaker was warned verbally, then the second time there was a low monetary fine, and if the person breaks the rule again a higher fine is applied. At the same time they accept that the organization was not capable of monitoring fishermen, mainly when they sold their product to middle men and hotels before landing in the village. It is important to note that none scope and aggregation rules were not identified as rules in use.

In table 5.6 I synthesize the rules in use in Baru's fishery system. Although the term "rule" implies an institutional statement with a complete AD*I*CO structure, in this case prescriptions have the first four components; AD*I*C, therefore we are dealing with "norms", they lack a clear OR ELSE component. These norms directly affect the components of the action arena and shape its outcomes discussed in the next section. Table 5.6 also displays/shows/gives the main source of observation for each rule; interviews (I) and role game (RG).

Table 5.6 Rules in use.

RG: Observed in the Role game. I: Interviews

Position	There are 5 positions: 1) Baru artisanal fishermen, 2) other villages' artisanal fishermen, 3) industrial fishery boats, 4) touristic operators, and 5) environmental Park officials.	RG, I
Boundary	1) All Afro Colombian inhabitants from Baru are permitted to fish in the zone or else those fishermen from other villagers are suspects of using illegal fishing gear and may be denounced. 2) Environmental authorities permit any participant who has more power and money than local artisanal fishermen to fish in the zone.	I, RG I
Choice	1) Baru fishermen are permitted to fish any species and any size if they need it. 2) Destructive fishing gear is not permitted	I RG, I
Information	1) It is not permitted to denounce a fisher that is breaking a formal rule or else one’s own reputation will be negative affected	I
Payoff rules	1) If breaking a formal rule, graduated verbal and monetary sanctions are applied to artisanal fisheries. Rarely enforced.	I, RG

5.1.5 Outcomes of the SES’ action situation

So far I have discussed the fishing action situation using the RPG as a lens and intermediate tool for simplifying the SES, starting with the simplistic representation of the experimental setting. In this section I discuss the outcomes of the SES action situation focusing on cooperation, trust and the level of conformance to general morality as the more relevant results.

Cooperation and trust

The average behavior at the group level of the field experiments indicates lower levels of cooperation than optimal in the two stages: with and without external rules, most groups over-extracted the resource leading both sites A and B towards low stock levels. Considering effort as an indicator of cooperation, there are no significant differences in effort between the first and second stages of the experiment. As another indicator of cooperation, we can also measure how frequently a fishing place is in a low or high state, and we observe that the groups had difficulties in getting the fishing sites back to the high state (Figure 7). Group earnings could not be sustained at high levels after the third round both before and after the rules were applied. For the second stage higher earnings were sustained for an extra round or two but such improvement did not last. The reason is that the group efforts on both sites A and B were sufficiently high to bring both sites to the low level of stocks as with the consequent lower payoffs, and recovering back from low to high stocks of fisheries was very difficult. Surveys carried out after the field experiments show an interesting perception about the community of the participants: 61% of respondents answered that people would be very likely to cooperate if there were a problem related to natural resources, and 30% responded that people would be somewhat likely to cooperate.

When it comes to the RPG, the players introduced the role of the National Park and the settings of the game gave an important role to the Park. There were no direct interactions among the fishermen to manage the resource. The cooperation goes through the authority of the National Park. In the RPG session cooperation exhibits an increasing trend when environmental authorities hear their concerns and discuss about collaboration between fishermen and the Natural Park. A second factor leading to an increase in cooperation was the existence of alternative income generating options.

Three three remarkable points from interviews carried with local fishermen. 1) Local leaders and authorities are an obstacle instead of support for cooperation. 2) Interviewees, outside the arena of experiments and RPG, express that there is short and long term cooperation. Short term cooperation is focused on a household's daily needs, and it destroys long term cooperation, which is identified as collective actions for the conservation of the resources. 3) Long term cooperation would be affected by coordination difficulties and free riding behavior.

The information obtained through the surveys, interviews and during the RPG shed some light on cooperation during the experiments. The context pushes the players towards individualistic behavior. Baru's fishermen consider the governance of the fishery to be in the hands of local leaders or a governmental body, which are considered to be obstacles. If we link this context to the field experiment action arena we can understand the uncooperative behavior. In this simplified arena participants are in an individual short-term situation where incentives for cooperation are not straightforward, and they need high levels of coordination without communication. The short-term monetary incentives are perceived as a mean to fulfill daily needs, and in the absence of communication, coordination is hard to achieve.

Rules and general morality conformance

I identified four types of normative beliefs inferred from the interviews and role game construction and discussions, which constitute the first level of morality conformance discussed in the conceptual framework. To fish in order to feed the household is acceptable, no matter what the state of the resource is. Household needs are an imperative that justifies any behavior that does not fulfill formal rules about size fish restrictions. This normative belief does not seem to extend to the use of illegal fishing gear, which is constantly mentioned but not accepted morally. The second widespread normative belief is that denouncing a fisher when breaking a formal rule is not accepted. Interviewees concur without a doubt that this type of behavior is socially punished by the community through a stigmatization of such person as a stoolie. The third normative belief is that bribing authorities regarding natural resources is not acceptable from the point of view of Baru fishermen.

Main findings regarding generalized beliefs can be synthesized as follows: To bribe authorities is easy for players with power. Bribing authorities is necessary to avoid formal punishment. If formal authorities do not consult with local fishermen about the design of Park rules, these rules are not legitimate. Enforcement of formal rules is applied according to the socioeconomic status of each actor; this is, the law is not for all, artisanal fishermen have to follow the rules but industrial fishing boats, rich and non-local people have different treatment.

Second level of morality conformance. The normative beliefs can be classified in terms of morally, culturally and legally valid behaviors. As morally valid behavior I include: To fish in order to feed the household is acceptable, no matter what is the state of the resource. Since formal authorities do not take into account local fishermen for rule design, then non-compliance with rules is accepted. Bribing authorities is not accepted. To keep one portion of the fishing product to give it to their neighbors that could not work or to poorer families is a moral norm. In terms of culturally valid behavior, the non-compliance with formal rules is accepted when there is no recognition of local community in its design. As an example, harvesting species such as turtles and reef fishes for household consumption is accepted.

Table 5.7 Conformance to general morality as outcome of the SES' action arena.

First level

Normative beliefs: links an action and a value judgment

n1: To fish in order to feed the household is acceptable, no matter what the state of the resource is.

n2: Denouncing a fisher who is breaking a formal rule is not accepted.

n3: Bribing authorities regarding natural resources is not acceptable from the point of view of Baru fishermen.

Generalized beliefs: links an action with an effect without value judgment.

g1: To bribe authorities is easy for players with power.

g2: Bribing authorities is necessary for avoid formal punishment.

g3: If formal authorities do not consult with local fishermen for the design of Park rules, these rules are not legitimate.

g4: Enforcement of formal rules is applied according to the socioeconomic status of each actor

Second level

Moral valid behavior

m1: To fish in order to feed the household is acceptable, no matter what the state of the resource is.

m2: If G3 is true, then non-compliance with rules is accepted.

m3: Bribing authorities is not accepted.

m4: To keep one portion of the fishing product to give to neighbors that could not work or to poorer families is a moral norm

Cultural valid behavior

c1: If G3 is true, then non-compliance with rules is accepted.

c2: To capture, for household consumption, species such as turtles and some reef fishes is accepted.

Legally valid behavior

l1: To fish only for subsistence purposes.

l2: To capture species allowable by law and at permitted sizes

l3: To use only permitted gear.

l4: Not to bribe authorities or accept bribing.

l5: Authorities must treat all the actors homogeneously, irrespective of their economic and social status.

How big is the gap between moral, *cultural* and legal *behavior*?

Figure 5.9 shows a simple exercise for visualizing the behavior typified in the second level of conformance to general morality (Table 5.7). Sets named M, C and L stand for the morally, culturally and legally valid behaviors respectively. The elements of each set are named m, c and l, and stand for each of the types in Table 7.

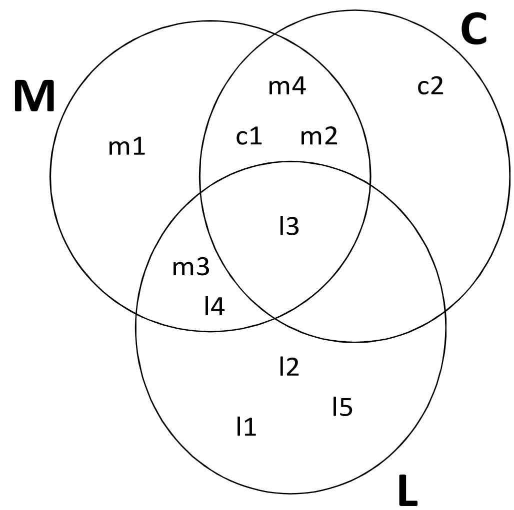

Figure 5.9 Illustration of the gap among morality, culture and law.

When a rule is located in the intersection of the three sets of the figure 5.9 there are more probabilities of rule compliance. Therefore, when all the rules belonging to each category, are in the interception of the three sets, sustainability outcomes have more opportunity to improve. This would be when:

$$M \cap C \cap L = M \cup C \cup L \quad (1)$$

In our case study the intersections are:

$$M \cap C = m2, m4, c1, l3 \quad (2)$$

$$M \cap L = m3, l4, l3 \quad (3)$$

$$C \cap L = l3 \quad (4)$$

and,

$$M \cap C \cap L = l3 \qquad (5)$$

the result of (5) is an indication of the gap among the three categories we are dealing with. From this perspective one could say that the management system cannot be effective if it is based on the already existent formal institutions, but in another kind of management agreement capable of conciliating law, morality and culture. These three dimensions shape human behavior in the action arena. Behavior of actors is linked to the beliefs and behavioral types illustrated in the Table 5.7. A relevant question when studying behavior from this perspective is about the reasons of participants to break the rules. The Table 5.8 illustrates a set of actors' motivations for rule breaking related with the elements discussed above (Table 5.7). Baru fishermen could be classified as rule breakers by conviction and necessity depending if certain conditions are met, which are n1 and/or g3 (Table 5.7). Fishermen from other villages could be rule breakers by necessity if n1 is met. Baru's fishermen behave as cheating players when c2 condition is meet; in essence they know the rules of the game, respect the game in a loose manner, and on occasions have moral justifications, but they are aware that others have better moral claims. The same rationale applies for: (1) industrial fisheries' ship captains when entering to Park zones, (2) touristic operators since they demand illegal fishing products for their businesses, (3) local leaders when they "catch" a formal public position that can offer them economic stability. These players usually make alliances with wealthy and political participants and contribute to the unequal rule enforcement. Park officials seem to behave differently regarding rule enforcement when facing participants different from Baru's fishermen, meaning wealthy players and political power holders.

Table 5.8 Type of players according to Mockus (1994) proposal

Type	Actor	Condition
Rule breaker by conviction	Baru's fishermen	If n1 and/or g3 are/is meet
Rule breaker by necessity or convenience	Baru's fishermen	If n1 and/or g3 are/is meet
	Other villages' fishermen	If n1 is meet
Cheating player	Baru's fishermen	If c2 is meet
	Local leaders	When they hold a formal public position that assures economic stability.
	Industrial fisheries	Entering Park areas
	Touristic operators	Buy illegal species and sizes.
	Formal authorities in some occasions	When rule breaker is different from artisanal fishermen

5.1.6 Summary of main findings of fishery system's institutional analysis

Through the institutional analysis I discussed how this situation is perceived currently and its consequences in terms of outcomes. It is important to remind some of the conclusions from chapter 4 (Geographical and historical context): (1) The local population has historically been immersed in situations where the rule is illegality, and have beneficiated from this state of affairs. In addition the perception of the Colombian government is strongly linked with corruption. This fact has contributed to consolidate culturally and morally valid behaviors, as well as to shape the types of players described in Table 5.8. (2) The priority of formal institutions is the conservation of marine resources without taking into account the local population and its ecological knowledge as part of the system. The rules in use presented in Table 5.6 are one of the consequences of a regulation focused on the ecosystem and not on the SES, which in turn reflects the deep differences of understanding of the commons problem between local fishermen and central environmental authorities. (3) Park authorities see natives as intruders, systematically denying their population history. And, locals in turn, do not perceive the Park as a natural authority. Table 5.7 shows how the consequence of the above three points is the generation of a generalized belief (g3), that has produced a set of moral and valid behaviors, and a typology of players (Table 5.8) with clear consequences for the outcomes of the action situation.

In the experimental action arena most of participants chose the random access rule for the second part of the experiment. I propose two hypotheses that I discuss next. The random system is perceived as an easier way for rule braking. Assuming that the condition of Table 5.8 is met; g1 and g3 in Table 5.7, the formal rule breaking is justified by the convenience or necessity, and also they can be rule breakers by conviction (Table 5.8), given the fact that the potential benefits of the experiments are changing their well being. The random banning of fishery grounds and a low probability of inspection is analogous to the way the formal institutions work. The big gap between morality, culture and law that characterizes the system (formulation (5)), as well as the lack of legitimacy of formal rules, transform the action arena in to a game in which the moral and cultural behaviors are valid. As a consequence, rule enforcement and monitoring are only rare and external events that fishermen must avoid.

Low levels of cooperation (defined as high levels of effort) exhibited in the experiments and the first part of the role game are related with the fulfillment of daily household needs, and are a consequence of the strong focus on formal rules in the ecological system, instead of the SES. One of the key findings is that understanding of the action arena by Baru's fishermen entails a difference in the conceptualization of the commons dilemma, comparing with environmental authorities and the generalized aim of the formal institutions. This fact is one of the dimensions of the cognitive conflict that starts to emerge in this phase. It shapes the institutional problem, which drives most of the outcomes of the action situation.

5.2 The Forestry System

5.2.1 Outcomes of the forestry experimental action situation

The theoretically predicted outcomes of the forestry experiment when players extract the maximum possible in each round is that the stock collapses in round 5, and the group accumulated tokens are 119. But if on the contrary all the players cooperate by extracting fewer trees maximizing the collective benefits, the resource lasts 10 rounds and the group earnings increase to 165 tokens (Cardenas et al. 2008). In the second part of the experiment, rounds 11 to 20, participants vote one rule to be applied during these rounds. The rules that participants can vote for are lottery (Rule 1), rotation (Rule 2), and property rights (Rule 3). With the first rule, in each round two players are chosen randomly to extract trees from the forest. In the second rule a fixed arrange is given for harvesting the forest in which two players are allowed each round. With the third rule, each player can harvest a maximum fixed amount of trees of 2 units. For all of the rules the inspection for rule compliance is done throughout a dice, which is thrown by the facilitator at the end of each round, and if it gives 6 all the players are inspected. If a player has broken the rule she has to return the harvested units in addition to 3 tokens.

Figure 5.10a illustrates the resource's behavioral pattern. The forest decreases rapidly; in the first round the average extraction is of 20 units, close to the maximum possible of 25 trees. However, in average, the forest does not finish in the ten rounds in contrast with the theoretical prediction. When the rules are introduced the average number of trees remained higher than in the first part, but far from the theoretical prediction in case that all players would follow the rule. The average extraction (Figure 5.10b) shows a decreasing behavior with a slight increase in round 4, and continues the decreasing until one tree remains in the board in the round 10. In the second part the average individual effort is considerably higher, starting, at round 11, in 3 trees, and remaining around this number reaching its lower value in the round 20 close to 2 trees harvested. Individual earnings, in average (Figure 5.10d), decrease at the same pace of the resource during the first 10 rounds. In the second part the average individual earnings exhibit more variation due to the effect of the fines when players break the rules and they are inspected.

In figure 5.11 it’s possible to observe the tendency of the average individual effort in the rounds 11 to 20, for each session, which tends to maintain between 2 and 3 trees in the sessions 2 and 10. In session 12 the variability is high while in session 6 the mean remains slightly above 3 in rounds 11 to 19. This variability in contrast with the decreasing trend in the first part is due to the inspection probability of rules. The players tend to keep high extraction levels and when there is inspection they tend to decrease the effort in the next round.

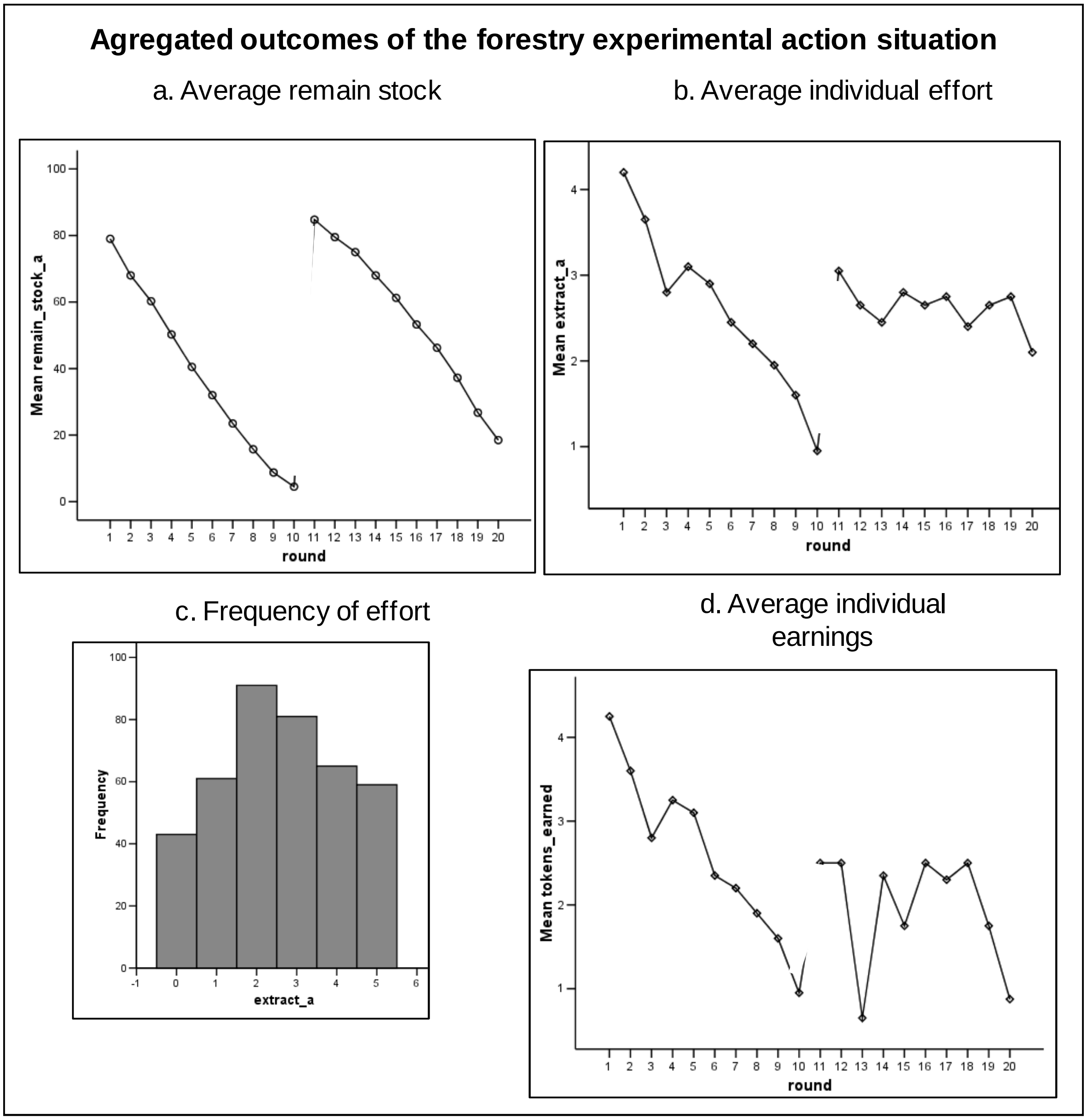

Figure 5.10 Average of collective results in the 4 sessions of the forestry experiments during both parts of the experiments. (5.10a) Average of remaining trees in the board in each round of the experiment. (5.10b) Average individual effort. (5.10c) Frequency of the individual extraction. (5.10d) Individual earnings average.

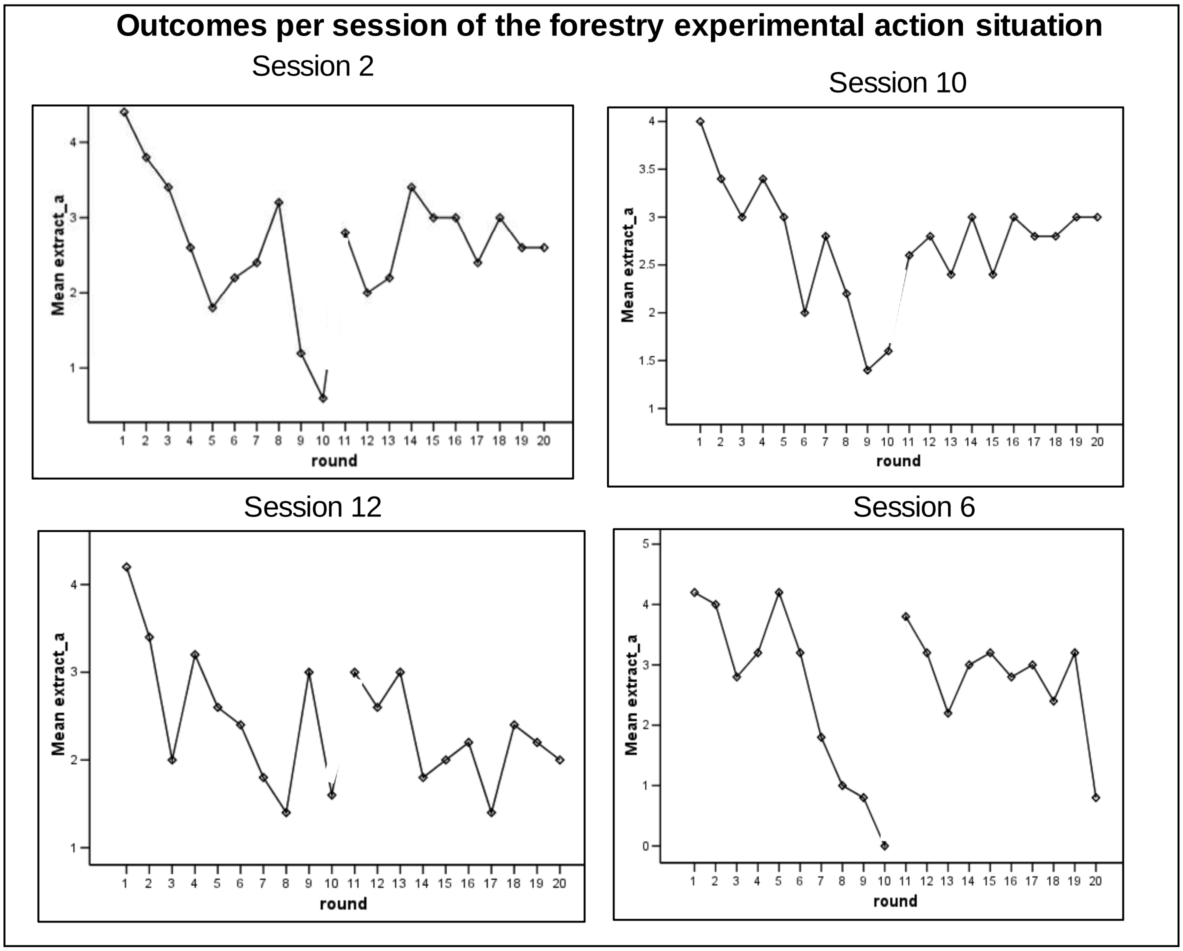

Figure 5.11. Average individual extraction for each session for the forestry experiment. Each session has 5 players, each one making one decision in each round of the experiment, therefore, in each session there are 100 observations.

The main difference between the first and second part of the experiment is that in the first ten rounds, the effort and earnings decrease, but in the second part they remain in a high variability range. This fact can be observed in figures 5.10b and 5.10d, and also in the average of each session (Figure 5.11). The rules introduced in the second part seems not have effects in cooperation, earnings and resource maintenance. Table 5.9 compares the results of both parts of the experiment. Only one of the groups chose the rule number one (random access). In spite of the high rule breaking (42%), the individual earnings average slightly increased 1.4 points. The other three groups played with the rotation rule and the increment in earnings was only 0.3 points and the rule breaking was 53.3%, higher than the session with random access rule. In general the earnings did not increased significatively, the improvement was only in 0.5 points from first to the second part of the game, however the extraction patterns were different. Results show a positive relation between resource growth decreasing and extraction level, this is, the faster the resource decreases, the more trees are extracted in each round (Janssen et al. WP).

During the workshop of experimental results the participants proposed possible solutions to the game. There were 6 different ideas about possible solutions to the game: (1) To implement a seed nursery and to extract each one between 2 and 3 trees each round. (2) To play with rule 3 (property rights rule: maximum 2 trees harvested each round per player) “because in this way there is more chance to the forest to regenerate”. (3) To extract between 3 and 4 trees each round per player and alternate with fisheries. (4) To cut just 1 tree per person each round but the government must compensate loggers for the wood they do not harvest. (5) To combine timber harvest with other economic activities. (6) To extract 3 trees per person each round. Most of the proposals were around extraction of 2 and 3 trees, nobody proposed to extract 5 trees, neither 0 “because we need to eat” they said.

To test the proposals we did two demonstrations with the board and the magnetic trees, harvesting 3 and 2 trees each round per person. As a conclusion, people agreed that cutting always two trees allows to conserve the forest, “if we extract more we´ll get more money but the forest ends faster” but the question was: is it possible to live extracting only 2 trees? Participants permanently tried to relate the game with their real situation, and one of the participants expressed a general preoccupation: “it is possible that everybody in this room harvests only 2 trees, but not everybody understands, people outside this room cut everything at once”. In this moment the discussion was oriented towards the rules of forest use, and one of the “Communitarian council” (ACAPA) pointed that “ we make our own rules and one part of the people in the territory inform to the other part, we need to build a communication network … the forest management plan must be articulated to the municipal development plan”. Regarding the activities of the loggers she said: “people here extract timber, fish and they do agriculture also”. At the end of the session one of the participants said. “I think, this game needs a change in the rules because it is out of focus”, this comment served as the necessary step linking the discussion about the experiments with the improvement of forestry game and the co-construction of a role game of the forest.

Finally, the experimental forestry action arena analyzed here shows an inverse relation between the level of trust of the community and rule compliance, but also the higher the belonging feeling to the community, the lower the extraction level. The rule preferred by participants in experiments was the rotation, but at the same time the percentage of rule breaking was 53%.

Table 5.9: Rules elected and resulting earnings

Rule	Number of times elected	Percentage rule broken	Average earnings per person (rounds 1-10)	Average earnings per person (rounds 11-20)	Total Average earnings per person (rounds 1-10)	Total Average earnings per person (rounds 11-20)
Random access	1	42	25,6	27		
Rotation	3	53,3	25,7	26	25,8	26,3
Quota	0	0	-	-		

5.2.2 Collective construction of the forestry RPG

The co-construction of the role game with the participation of resource users and researchers was carried out following a protocol with the following points: (1) setting the objective of the game, (2) players/Actors, (3) game board, (4) resource dynamics/resource regeneration, (5) resource representation (diversity), (6) players' actions/decisions, (7) incentives, (8) meaning of one round, and (9) organization of the round. Next a discussion of the results of this process is carried out. This activity constituted a progression towards a more complex action situation. The starting point was the experimental action situation described above.

Setting the objective of the game

Participants defined the objective of the new game as “A game for the sustainable use of timber, fisheries and other activities”. The general comment around the objective was that the sustainable use of the forest was possible only if a rotation scheme among activities is practiced, for example “three months timber, and the rest fish and agriculture”. When we mentioned the word “veda” (ban), they said that a better word to use was “rest” because a “ban” is understood as a punishment. Other comments were about the meaning of “sustainable use”, in the sense that the direct meaning of that was “to be careful with the size of the trees we cut”.

The game board

The next step was the design of the game board. The question we posed to start thinking in the game board was if the board used for the forestry experiment was suitable to reach the objective set at the beginning of the workshop. The first general comment was that the forest in ACAPA’s territory had to include small and big trees, different species as well as resource regeneration. Next they started to put hands on the board reorganizing the trees. They drew the small trees, “in regeneration”, the river, channels, paths to houses and paths used to transport the wood (Figure 12). When they were discussing how to represent places left by cut trees, they decided that the space should be a blank patch but it depends on the form the tree was cut down; “if I sell this piece of land the new owner don’t have any belonging sense, then he won’t take care on how this tree is falling down damaging small trees in the sides” (RPG collective construction workshop. June, 2008), then the discussion was about the difference of behavior between a person who uses a chain-saw and the one who uses only manual saw. The first gain money only for cutting down the tree, he does not care about the forest, but the second is different because he is generally the owner of the land and he cares about his property. Participants express that many persons take care of the forest and cut trees only of certain diameters and well distributed in the plot in a way that after two or three years they have again their forest. Finally, they divided the board for the game in 8 patches; 7 are plots for individual loggers and a public sector that represents the mangroves sector and the coast. They stated that mangroves harvesting is not allowed, but when a person needs wood to build a house he cuts some mangroves trees, therefore they put 5 trees marked with an x representing the mangroves (Figure 12) difficult to see

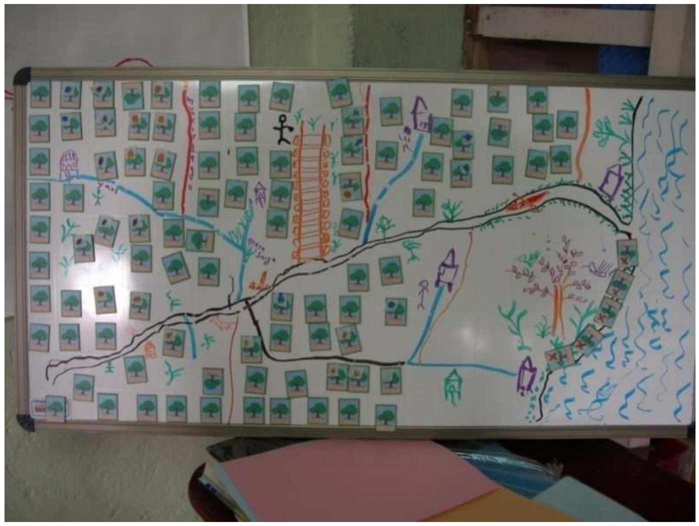

Figure 5.12 Board game constructed by participants

The game board discussion and final design illustrates the relation of locals with the territory and the forest in terms of property rights. This point is relevant due to the formal rules, the Law 70 or Black Communities Law, created in 1993, that declare the Pacific region ("Chocó Biogeográfico") as collective lands for Afro Colombian population. The Comunitarian Council (CC) is the main instrument established by the law for the collective management of these lands. The CCs are the entities entitled with the collective lands. Seventeen years after the creation of the Law 70, Colombian government has given 4'770.407 hectares formalized in more than 130 collective titles (Cardenas, 2009) to the CCs. Each CC groups a number of communities and constitutes the territorial authority for land use planning and natural resource management. CCs are aimed to recognize and formalize the traditional land and natural resources managing to Afro Colombian population. Formally the members of each CC are all the inhabitants of Afro Colombian origin of its territory, and its maximum governance instance is the Assembly formed by representatives of each region or "vereda"[36] , and the Board of directors (Junta del Consejo Comunitario). As mentioned in chapter 3 (geographical and historical context), our forestry case study is located in the CC ACAPA (Figure 3.4 in chapter 3).

[36] The "vereda" is a rural territorial division of administrative character of Colombian municipalities. "Veredas" include human settlements that can be sprawl or concentrated in some areas.

The representation of the forest for the RPG, shows the main traits of the territory: the river as the central element connecting the territory, the smaller channels, the forest with different species, the mangrove zone, the beach and the sea. The forest is divided in individual properties which boundaries are market by red lines (Figure 5.12). The only portion of the territory represented as a common good is the coastal mangrove zone. Ospina (2008) carried out a study on the history of forest use in ACAPA's territory and interviewed locals on several topics related with forest use. One of the issues was the property rights of the forest. Ospina found that people have property rights de facto which have been in use before the Law 70 establishment. The mechanism for acquiring property rights on a forest patch consists in going to unexplored forest and start a channel for transporting the timber towards the nearest river. In this way they assign areas to individuals as a system of property rights. Most of the interviewed coincide in the idea that, at the beginning ACAPA was useful for conflict solving between neighbors in the forest, but now the people, in general, prefer individual entitlement because now the formal owner of the land is ACAPA, they say. Another finding is that people's perception about the Law 70 is that it did not change anything in terms of timber extraction. Some of the interviewees said that the collective title is useful because it makes easier to obtain support from different organizations. Survey data illustrates the individual perceptions about property rights: 80% of the respondents said they own the land where they live. People claimed the need of the local police in mediating individual property rights conflicts.

The action situation

Participants in the construction of the game defined the relevant positions for the game and their functions shown in table 5.10. They included loggers, chain-saw men, timber buyers who are mainly the local sawmill owners, a representative of the directive committee of the CC (ACAPA), and a representative of the governmental regional environmental agency (Corponariño). The actions that the logger can perform are tree harvesting, fishing or agricultural activities. Chain-saw men can cut trees or allocate their time or their activities such as fishing or agriculture like loggers. The difference is that the first ones own a patch of forest. The possible action for the sawmill owner position is to buy timber to loggers or chain-saw men. The role of ACAPA's representative is to build awareness on each individual that the territory is a collective property in benefit of the community. The actions of the environmental authority is to issue exploitation and mobilization licenses. The forest harvesting licenses have a monetary cost, people has to pay in order to get the permit.

The logger (tuquero) position

This position represents all the inhabitants of ACAPA's territory that use the forest as an important source of income through timber extraction. Population of ACAPA's territory is about 12.000 persons living in an area of 95.000 hectares (Ospina 2008). We could say that the level of heterogeneity is lower than the fishery system case discussed in previous section regarding its economic activities. According to the survey 71% of the participants in the experiments said that their main economic activity is to extract products from the forest, 20% to fishing, and 5% to agriculture. As the rest of the Colombian Pacific Coast, this population is among the poorest in the country, in contrast with the immense biodiversity richness. In spite of the declining in timber market since the 1980s, still there is a high percentage of the population that depends mainly on wood extraction; being the Sajo (Campnosperma panamensis) the principal exploited species (Ospina 2008).

During the RPG construction the chain-saw men position was discussed and it was concluded that they were people characterized by two factors: they do not own a part of the forest and many of them come from other regions. Frequently they are hired by locals to extract timber. Participants made emphasis that people who use this technology to harvest trees do not take care where the tree falls and they cause big environmental negative effects, also they cut any type of tree. They stated: “it is necessary to teach to the power saw men and loggers to take care of the forest because they live from that”. They said that they are focused in doing their work soon in order to increase their income. However, Ospina (2008) found that the use of the chain saw has increased among the loggers or "tuqueros" since the early 1980s, and that this has been the only technological change to date. The mechanization not only has facilitated the tree cutting activity but also has widening the commercialization of species by introducing the harder and more expensive wood in the market. These species are found generally in the slopes of the hills and with the traditional tools, axe and "machete" is complicated to bring them down to the river for transporting. Therefore, with the chain saw it is possible to cut and make easier handling the timber on site.

This situation contrasts with the characterization of loggers' position made by participants and the emphasized differences with chain-saw men. I already mentioned that during the RPG this difference was observed in the behavior of some players, which named themselves explicitly as chain-saw men.

Buyers (sawmill owners) position

Participants included the sawmill position as the main buyer of timber, and a figure to represent the intermediaries. In the RPG's action arena this position represents the link with the external timber market. The actions linked to this position are buying and transforming timber as well as lending money to the loggers for their logging activities.

The saw mills appeared in the region towards the ending of the XIX century and their technology has not varied importantly. They are located strategically along the river banks in rural and urban areas (Restrepo 1997). Since the 1980s the number of sawmills in the region started to decrease due to the changes in the wood market, which suffers a contraction; the international wood trade faded and only remained local and national markets. Since the early 1990s the number of sawmills has increased but owned by locals (Ospina 2008). One of the interviewees said: "In the 1970s there were more sawmills in this zone, there were around 10, but today thre are 7" (Interview, 2007). In a participatory cartography exercise carried out with participants in the experiments (2007), people identified no more than eleven sawmills in ACAPA's territory functioning today (Figure 5.13). Restrepo (1997) reports 17 sawmills in the territory of Salahonda municipality, installed between 1963 and 1990.

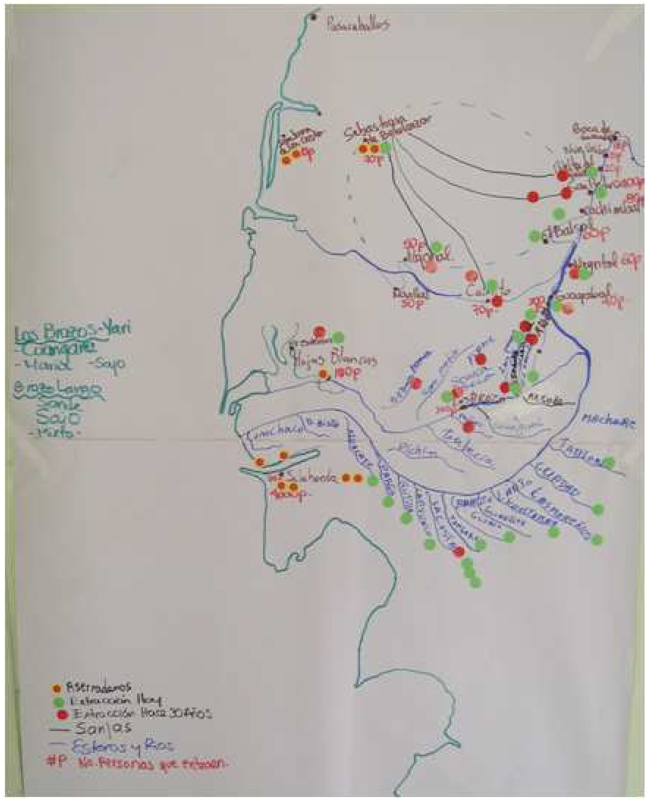

Figure 5.13. Map of ACAPA's territory constructed collectively with participants in experiments. Red dots: timber extraction zones 30 years ago. Green dots: current extraction zones. Red dots with yellow border: actual sawmills. The map illustrates also the main rivers in blue.

Midlemen position

In early stages of the construction of the RPG locals defined a position for the middlemen, who are people that travel in boats through the rivers buying timber to the loggers and from sawmills. They specified that usually they are not from the region. Later all agree that the role of the intermediaries will be performed by the sawmill owner to decrease the complexity of the RPG. The production chain works in the following way. The logger has the direct relation with the forest, him or her, extract and makes the first part of the transportation through the river. They could sell the wood in the river to the contractors, "partidores", which are two different types of intermediaries, or carry it directly to the sawmill (Restrepo 1997). They transform the timber in commercial forms such as blocks, planks or broom sticks. Restrepo (1997) describes in detail the market chain, that continues from the sawmill, which consists in a dense and intricate network of middlemen and product transformers until their last buyers in the big cities.

Communitarian Council position (ACAPA)

The participants in the collective construction of the RPG defined a function and a set of actions for the Communitarian Council (CC). The function defined in the game was:

> "As territorial organization its function is to defend the territory, and contribute to improve life quality of rural communities. To support the community in the formulation of plans and projects, which benefit the communities inside the territory of the Communitarian Council". (RPG collective construction workshop, June 20/2008)

The actions linked to this position were: to build awareness on each individual in the sense, that the territory is a collective property in benefit of the community.

Representatives of the CC's Junta (Board of Directors) present in the workshop, expressed their main concerns which had to do with the Forestry Land Use Plan and its coordination with the Municipal Development Plan. I must remind here two characteristics of the CCs: (1) their competence is in the rural part of the municipalities, but not the urban settlements, and (2) their legal and administrative nature is different from the municipality administration. Therefore, the coordination between municipal land use plans and the CCs planning actions is in many cases difficult and has to go through the filter of local politics and economic interests.

One of the sawmill owners' opinion about ACAPA, it is the organization that is doing something in management and rule enforcement, he said that "people from the "negritudes" control more, this is a phantom village, here there is no law, the village major does not tax anything" (Interview with a sawmill owner, Salahonda 2007). The "negritudes" is a way to refer to all issues related to the Process of Black Communities of the Pacific Coast of Colombia (PCN), which is one of the main drivers of the Law 70 (1993) and the Comunitarian Councils. Even though all the Afro Colombians living in ACAPA's territory are part of the CC, at local level not all the people seem to have a belonging sense to the movement. In general interviewed loggers link their opinions about ACAPA with the land property rights issue. There is also a consensus about the declining in the CC's strength since 2001. Scholars have profusely documented and analyzed the CCs processes in the Pacific Colombian region since the decade of 1980s, even before the Law of Black

Communities (Law 70) in 1993. The research has been done fundamentally from political ecology, geography and anthropology domains, the work of Arturo Escobar (1998 and 2001 among others publications) has largely contributed to the understanding of what I name in this dissertation the socio ecological system of the "Chocó Biogeográfico". Particularly, Rivas (2001) has studied the history of ACAPA, while Ospina (2008) reconstructed the history of forest use since the decade of 1950s.

Regional environmental authority position

The second relevant issue is the licensing for timber harvesting. According the participants, each logger has to ask for a license to the environmental agency (Corponariño) to cut trees. The test of the game was played assuming this procedure and the representative of this entity put a price for each license. During the final game with the real Corponariño officer, the dynamics was quite different; the officer asked for licenses only to sawmills and he explained that the individual loggers do not need license.

Table 5.10 Positions and actions of the RPG's action situation.

Grey rows illustrate the positions mentioned initially by participants but not included in the final design of the RPG.

POSITION	ROLE/ FUNCTION/OBJECTIVE/RULES	ACTIONS
Loggers	ROLE: To cut trees. To control their property. FUNCTION: Sustainability of the forest and territory. OBJECTIVE: To improve life quality with a productive project different to forestry logging (agriculture) and to crop another wood species. RULE: 1) to cut trees minimum of 14 inches of diameter. 2) To control the neighborhood.	To allocate effort to: tree harvesting, fishing or agriculture activities. To sell the timber to the middle men
Timber buyers (sawmill owners)	To buy timber. To Transform the wood. To finance loggers.	To buy timber
Intermediaries - middlemen	To buy timber to the sawmill or logger directly. They do not live in the zone. It was proposed in the beginning, but finally it was not implemented.	
Chain-saw men [1]	To cut trees with the power saw. During the game, some of the loggers were chain- saw men. In contrast with loggers, they do not own land; they are hired to cut trees.	To allocate effort to: tree harvesting, fishing or agriculture activities. To sell the timber to the middle men

ACAPA	FUNCTION: As territorial organization its function is to defend and to watch over the territory, and contribute to improve life quality of rural communities. To support the community in the formulation of plans and projects, which benefit the communities inside the territory of the Communitarian Council.	To build awareness on each individual that the territory is a collective property in benefit of the community.
Governmental Regional environmental agency (Corponariño)	To regulate the use of the forest. To guarantee a good forest exploitation.	To issue exploitation and mobilization licenses. Forest harvesting licenses have a monetary cost, people has to pay in order to get the permit.
Local police	To solve possible conflicts of invasion to forest properties. To enforce the boundaries of properties. To solve fast the conflict with justice. To monitor timber harvesting of endangered species. To support Corponariño. It was proposed in the beginning, but finally it was not implemented.	
Municipal administration	It was proposed in the beginning, but finally it was not implemented in the game.	

[1] This position was explained initially but it was not formally included in the RPG. During the game playing some of the players said that they were playing as chain-saw men.

Resource diversity and growth dynamics

Participants started pointing that the forest in the real life was not homogeneous, then, they said that for the game it was necessary to differentiate trees, as one of the participants explained to the rest: "what we are doing is to translate the former game to the situation we are living here, therefore, if we are living a forest in which there are variety of species, then we must work it like this". Then, they entered in a discussion about the relevant species and their growth rates. They chose four species whose growth rates were set in the following way: Cuangare[37] and Sande[38] species has the fastest growth rates; for each 5 trees in the game board a new tree is born. Garza[39] and Sajo[40] species are slower; for each 10 trees in the forest a new one is born. New trees of each species were located in the zones of the board where there are more trees of this species. When a tree is cut the way trees regenerate is the following: at the end of the round the trees of each species are counted and the cell for the new tree is decided and a dot of the species color are drawn, at

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[37] *Otoba gracilipes*

[38] *Brosimum utile*

[39] *Tabebuia rosea*

[40] *Campnosperma panamensis*

the end of the next round an adult tree is put in the board according to the color dots for each species, then again the counting of the number of trees of each species is done and the new color dots are put, and so on.

It seems to be a consensus about the growth rates of the main species and the forest capacity to regenerates among local loggers interviewed. The Cuángare, most of the interviewees said that a tree will last between 4 and 5 years to reach its harvest size. A tree of 10 inches (diameter) grows up to 16 or 15 inches in 4 years, said another logger. Some of the loggers said that there is overexploitation because there is no re-cropping of species. For one of the interviewees the forest will not last more than 15 years. In contrast, a sawmill owner said that "people say that in 7 years the timber finishes, but this is a lie because always there is more" (Interview, 2007). He said also that, in general, the trees start to grow again after 3 years, and specifically the Sajo species grows in 4 or 5 years from 8 to 12 inches when it is ready to harvest. The same interviewee explain that he does not believe that the trees are declining, but at the same time he has noticed that in the last years people have started to bring smaller pieces, even smaller than the minimum size allowed by the environmental authority (Corponariño). Another logger said that some years before the timber pieces "trozas" had 16 feet long, but now they have in average 12 feet. In other interview is said that when the forest patch is in a very bad condition, they live resting the patch from 8 to 10 years. Several loggers agree that one of the problems is that there is not planting of new trees, this idea was discussed in the experimental results workshop, as well as in some phases of RPG building.

In contrast, Del Valle (1993) reports the results of a research carried out in the region by several forestry scientific studies, which main findings regarding tropical rain forest growth are substantially different to what locals express in our interviews and workshops. For the Sajo species (Campnosperma panamensis), a tree needs 57 years for reach the minimum acceptable harvesting size of 40 cm (15.7 inches), starting from a young individual of 5.2 cm (2 inches) of diameter. The Cuángare (Otoba gracilipes) species lasts 59 years for reaching the same harvest diameter, starting the measure from 1.5 cm (0.6 inches) of diameter. One of the implications of these data is the fastest growth of Cuangare compared to Sajo just like in the RPG dynamics for the natural regeneration of resource set by participants. According to Mergen and Jeffrey (1987 in Del Valle 1993) regeneration cycles in tropical forests has been estimated between 20 and 30 years. A study from the Universidad Nacional de Colombia from 1990 (in Del Valle 1993) found that peasants in this region come back to harvest forest patches after 10 to 15 years or even less after a fallow period. The authors explain that short harvest cycles produce trees with increasingly minor diameter with a low efficiency in the transformation processes, but also the trees are damaged in their fastest phase of growth (Del Valle 1993).

Information available to participants

The information available for each position in the RPG was defined by participants. All the information was public except the decisions and earnings for each participant. Since the RPG simulated a timber market, the prices were negotiated between loggers and sawmill owners in each round individually. There were some public fixed costs such as a minimum amount that each logger had to pay to the game for assuring his permanence in the game. If a logger chose not to extract timber in a round, the game paid him a minimum amount of money, which was public, in order to remain in the game, this represented the effort allocation to other activities such as fishing and agriculture. Players were allowed to communicate freely. The forest natural dynamic was provided for all the players, as well as the way in which each tree species were reproduced and assigned a place in the game board.

Participants started by a discussion about the needs for a forestry management plan and the principal need were to have a forestry inventory, they said. They talked about a forestry inventory for the game, this is, each round to count the percentage of each species and the number of trees by species present in the board. They wanted to go into details such as a sampling plan for counting trees. This idea seemed to be very strong at this stage but at the end they did not include any inventory in the game. They finally said that the forest harvesting in the game was according to each player’s needs.

Actions and control over outcomes

The fundamental RPG's actions were defined when positions were discussed, but the detailed actions were defined during the design of the mechanisms of the round. Due to the insistence of participants in the economic transactions as a key driver of timber extraction, we proposed to include fake money in the game in order to include incentives and give sense to the role of players as sawmills owners given the fact that participants said sawmills were important actors. Another important point was the insistence of people to include in the game other economic activities such as fishing and agriculture as way to achieve a sustainable management of the forest. Therefore, an initial amount of money was given to loggers and the two sawmill owners. The mechanics of each round was defined in the following way:

1- Each logger pays $ 20.000 representing the money for his family's survival.
   If the player decides do not go to harvest timber, it means he allocate his time to other activities like fishing or agriculture and he receives $ 20.000.
2- If he decided to go to the forest then he must pay $20.000 representing transportation and food expenses for the time in the forest.
3- The players go to the forest and cut trees and sell trees to the buyers intermediaries (sawmills).
4- The game (facilitator) buys timber to the sawmills
5- The game (facilitator) count trees of each species and says how many new trees of each one grow and where they grow.

End of the round.

The facilitator played the role of an external market. The money that each logger had to pay in steps 1 and 2 was given to the game, which in turn bought the timber to sawmills. In this way monetary circulation was assured during the game. The temporal meaning of each round was set according to the discussion among participants who agreed that each round represented one journey to the forest to cut trees which could last in average 4 days. They stated that, to simplify the game, always the tide, in the game, was going to be in its highest point that is the ideal condition to transport the wood towards the sawmills.

According to the survey, 45% of people think that they have some influence in the future, regarding making their territory a better place to live. 33.3% think they influence a lot in their future, 13.3% not much, and 8.3% think that they do not influence at all. One of the interviewees said "It is very difficult to change rules with Corponariño" (Logger, Salahonda,April, 2007), in contrast with other two loggers who stated exactly with the same sentence "You change the rules by yourself" (Salahonda, April, 2007), meaning that they have control over the timber extraction in their own forest patches and businesses.

The control over outcomes in the SES action arena from the side of ACAPA's inhabitants has important constraints produced by the armed conflict in the region, especially since 2000 year. The detailed understanding of the armed conflict in this region of Colombia is beyond the scope of this study, but in the understanding of SES' action arena outcomes is important to have into account the essentials. This situation has had consequences mainly in ACAPA's organization influence and action range. In the next paragraphs I synthesize the recent history of the conflict and explain the main resulted conditions for the dynamics of the action arena. During most of the 1990s decade the region was a "peace refuge" as Restrepo (2005) named it. This period characterized by very sporadic incursion of guerrillas but without any concrete actions, the zone was considered as a resting zone for guerrillas. In 1997 occurred the first violent incursion in a village of the region by the FARC guerrillas, but was in 2000 year that paramilitary groups formally announced their presence in the zone. The year 2001 marks a milestone in ACAPA's organization history. Comunitarian councils used to be supported in organizational and project funding fields by several national and international NGOs among others. ACAPA's strength was build with a close collaboration of the regional Catholic Church through the "Pastoral Social”, the social division of the religious institution. In 2001 the director of this organization was assassinated by paramilitary.

This event and the public threats to the communitarian councils by these armed ultra right wing groups generated the displacement and the "strategic invisibility" of local leaders that started and lead the process since the early 1990s (Restrepo 2005). From that year on an armed territorial dispute has been developed between the radical leftist guerrillas, the paramilitary groups and the governmental military forces trying to control these two factions. Analysts and governmental sources coincide that the mentioned territorial dispute was triggered by the coca production. Coca crops and business started to move from the east of the country towards the South Pacific region since the second half of the 1990 decade, driven by governmental coca eradication policies. This process triggered a population migration process of people that worked in other regions in this illegal productive activity. Armed group fought by territorial dominium that implied the business control. Geographically the Pacific region is in a privileged situation: a dense river network and direct access to the sea, which is the main transportation way for product transportation towards Central America and North America (Restrepo 2005).

The coca agriculture came along with an important immigration of small traders, and peasants from the former main coca cultivation regions. This population brought a different culture and economic style, but more important than that, it entailed a modification of the premises of the early 1990s ethnic-territorial black movement. This fundamental idea is that the organization process was being developed with a population ranging between 90 and 95% of Afro-Colombian persons settled in the territory several generations before, which constructed a particular relation with the territory (Restrepo 2010).

During the last ten years a wave of development policies have introduced the agroindustrial development of African Palm mono plantations, and the so called mega projects such as transnational terrestrial communication ways, touristic facilities and mining projects. Scholars (Escobar 1998, 2004, 2008, Agudelo 2002, Villa 2003, Restrepo 2010) link the violence in the region to these projects. They coincide that the attempts of integrate the region to a modern project of nation that have not been achieved since the XIX century, and particularly, failed during the last three decades of the XX century, on the contrary, has been achieved in about ten years through the combination of bullets, coca and money (Restrepo 2010).

The consequences of this context affect directly the control over outcomes of the action situation analyzed here.

Synthesis of the forestry RPG action situation collective construction

Participants in the co-construction of the game gave high importance to the diversity of the resource, for them the homogeneous representation of the forest in the experiment was very limited and simplistic for their reality.

Though during the design of the game the communitarian social organization (ACAPA) participated and clarified some points about the use of the forest and inhabitants responsibilities, it did not play an important role during the game; its role was quite passive.

Perhaps the most relevant issues during the game design, test and final playing, regarding rules, was on one hand, the apparent contradiction between the formal and informal land property regimes, and on the other the harvesting licensing issue. Regarding the land, the formal institution is a collective property, but the informal arrangement evidenced in the game, is an individual private regime. Licenses for timber extraction are issued by the environmental agency (Corponariño). Before the final game people said the loggers should have their licenses, in the test each logger bought their license to the player representing Corponariño. In the final game, with a real representative of Corponariño, licenses were issued only to sawmills, not to individual loggers.

The role game was important to make sawmills visible as important actors in the forest management, which curiously have not been invited to any meeting of the forest use plan. For the community the sawmills are out of the system and make part to the external market, and that they are wealthiest people compared to the rest of the community. During the game loggers could realize the perception and rationality of sawmills.

Participants insisted in the need of other productive options as a condition for the sustainable use of the forest, and it was included in the game according to the objective set the second day, “A game for the sustainable use of timber, fisheries and other activities”. The behavior of players where consistent their idea of sustainability in terms of leaving the forest rest and allocate their effort to fisheries and agriculture. At the end of the game some of the participants, who did not participate in the design, pointed their disagreement in the way the resource regenerates. Their main argument was that it was unfair that a person conserves his forest and the benefits, meaning, growth of new trees take place in all the forest. Then, people who do not leave the forest rest, and harvest every round, benefit and earn more money. They said that the new trees should grow only in the land plots that conserve the forest.

Table 5.11 Expected and actual changes during RPG co-construction.

TOPIC	EXPECTED CHANGES	ACTUAL CHANGES/ADDITIONS
Changes in resource settings		
Resource diversity	Difference kind of target species	YES. Participants represented 4 species of trees.
	Difference in tree species growth rates	YES. Participants did include 2 different growth rates for the 4 tree species.
	They will transform the experiment board in a more realistic representation of the territory	YES. Participants took as a departure point the graphical representation of the experiments.
Resource regeneration	At least two different zones: one close to the river and the other deeper in the forest	NO
	Enlargement of the experiment board in more comprehensive space enough to include extraction zones for the players	YES
	Establishment of different land use units in the forest	NO
Individual units size	Difference in trees size it is possible to cut.	NO. There was no specification about differences in the size of trees to harvest.
Individual decision making		
Species choice	Possibility to switch from one target specie to another one	YES. Differentiation in four species to harvest
Price	Taking into account the price at market. They will convert trees in commercial units they use, which are sections of a tree.	YES. Participants insisted on the monetary meaning of trees, and they referred to each token harvested as “troza” which is the cut unit they use to commercialize timber.
Spatial choice	Enlargement of the experiment board in more comprehensive space enough to include extraction zones for the players	YES, they divided the forest in 7 private patches and 1 public zone.

Incentives structure	No hypothesis	The payoff structure of the experiment was not taken into account at all. Fake money was used to represent the most relevant monetary transactions. Each player negotiated the price of timber with the sawmill owners.
Effort	No maximum level of extraction	YES. Participants defined that each player decided how much timber to harvest according to his/her necessities.
Collective decisions		
Rules	Rules would be negotiated	NO. Not actual negotiation of the rules was observed. Confusion about the licenses to harvest timber which was corrected by the representative of the environmental agency during the game. Regarding property regimes, seems to work a formal collective arrangement at the same time that an informal private regime.
Sanctions	Sanctions would be more strict	NO. No sanctions were implemented.
Roles	Integration of new roles Sawmill owner character and Environmental local agency	YES. New roles were defined: Sawmill owners, environmental local agency (CORPONARIÑO) and ACAPA.

5.2.3 Outcomes of the forestry RPG action situation

In this section I discuss the outcomes of the forestry action situation starting with the simplistic representation of the experimental setting. The section finishes with a discussion on cooperation, trust and the level of conformance to general morality as the more relevant results.

In the RPG the players could make two types of decisions: to go to the forest to cut timber or allocate their turn to fish and agricultural activities. If a participant decided to allocate its effort to fishing, implied do not go to the forest and received from the game (facilitator) the money strictly necessary to survive this round. Population of different tree species had two different growth rates. The place in which each new tree grew up depended of tree, of the same species, abundance. Any tree lasted two rounds in being available for extraction.

Figure 5.14 illustrates the game board during the 6 rounds of the game. In figure 5.15B it´s possible to observe the behavioral pattern of each one of the species of the forest. The resource shows a general trend of decreasing with a slightly recuperation of the most abundant species. Figure 5.14 shows the spatial evolution of the forest in the game board. The forest zone with major changes corresponds to the lower part of the board, in which it is evident an intense extraction. In this area, in round 6, the quantity of trees i slow compared with the initial conditions, and less stable compared with the dynamics of the superior part of the game board.

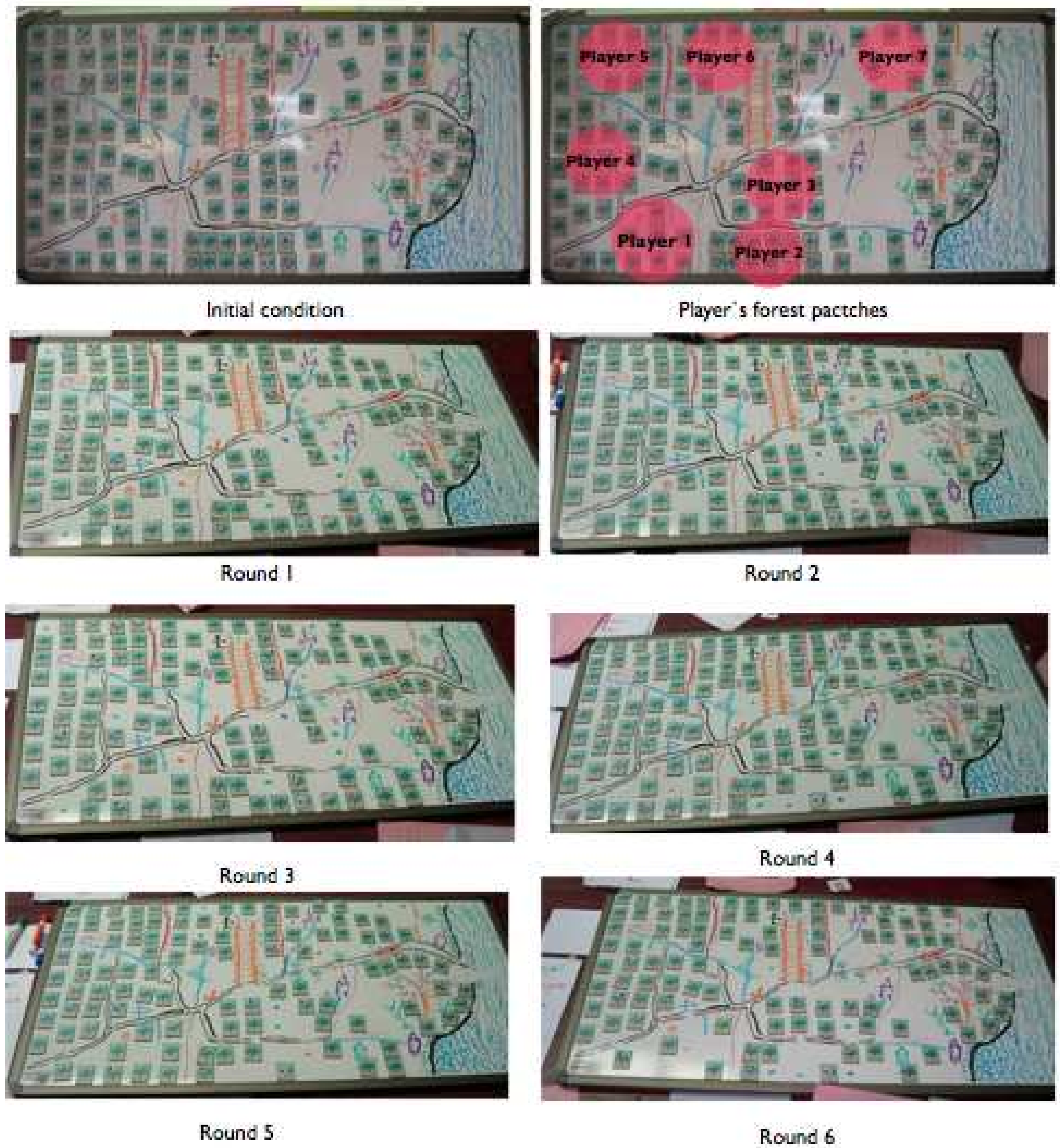

Figure 5.14 State of the forest through the rounds.

The players 4 and 5 decided not extract timber and to allocate their effort in each round to fishing. The player 6 adopted a similar behavior but with a higher extraction level (Figure 5.15F), which allowed the tendency of the remaining forest was of relative stability (Figure 5.15B). In rounds 2 and 5 most of the players allocated their effort to fishing (Figure 5.15C). The player number 2 free ride on the low effort of the others and extracted a high amount of timber (Figure 5.15F). It is important to note that the forest natural regeneration depended on the regrowth rates of each species, but spatially a new tree could grow in any part of the forest. In this way if a player conserved its zone, the benefit was global, meaning that the new individuals (trees) could grow in the zones of other players with higher levels of extraction. The income generated by timber selling depended of the price that the player sold the product to one of the sawmills; therefore the bargaining capacity played an important role. This fact is evident comparing figures 5.15D and 5.15E; the player 3, for example, did not extract the maximum quantity of trees, however, he was the one with a higher income level.

Players 1 and 2 never allocated their effort to other activities (fishing or agriculture) and all players harvested timber at least once during the game. Players 4 and 5 harvested the forest only once, the rest of rounds they allocated their effort to fishing. It is possible to classify players in two groups. Players 3, 4 and 5 in the first characterized by the interest in forest conservation and the allocation of effort to other productive activities such as fishing and agriculture. And the second group, players 1, 2, 6 and 7 interested in the direct earnings of timber extraction.

A real representative of the environmental agency attended the game and managed the issuing of the harvesting licenses. He issued licenses only to the sawmills and it had a high price, equivalent to the real life, as participants said. He hardly had interaction with loggers, except in round 4, when he gave an explanation about the correct way to manage the forest and the need of a technical management plan. His speech was about the real system and not focused in the game board. In figures 5.15A, C and F can be observed the change in behavior of players in round 5 after the speech. Five players allocated their effort to fishing, player 1 decreased his effort and player 7 took advantage and increased his effort. It is important to remark that the environmental agency representative did not live in Salahonda and came for the workshop because he was invited by us.

During the game the owner of one of the sawmills had economic difficulties and could not pay the harvest license, therefore, his strategy was to ask ACAPA for provisional licenses until he could pay the license to Corponariño. Representatives of ACAPA were not so active during the game, only at the end, in the debriefing session, they stated their point of view about forest management.

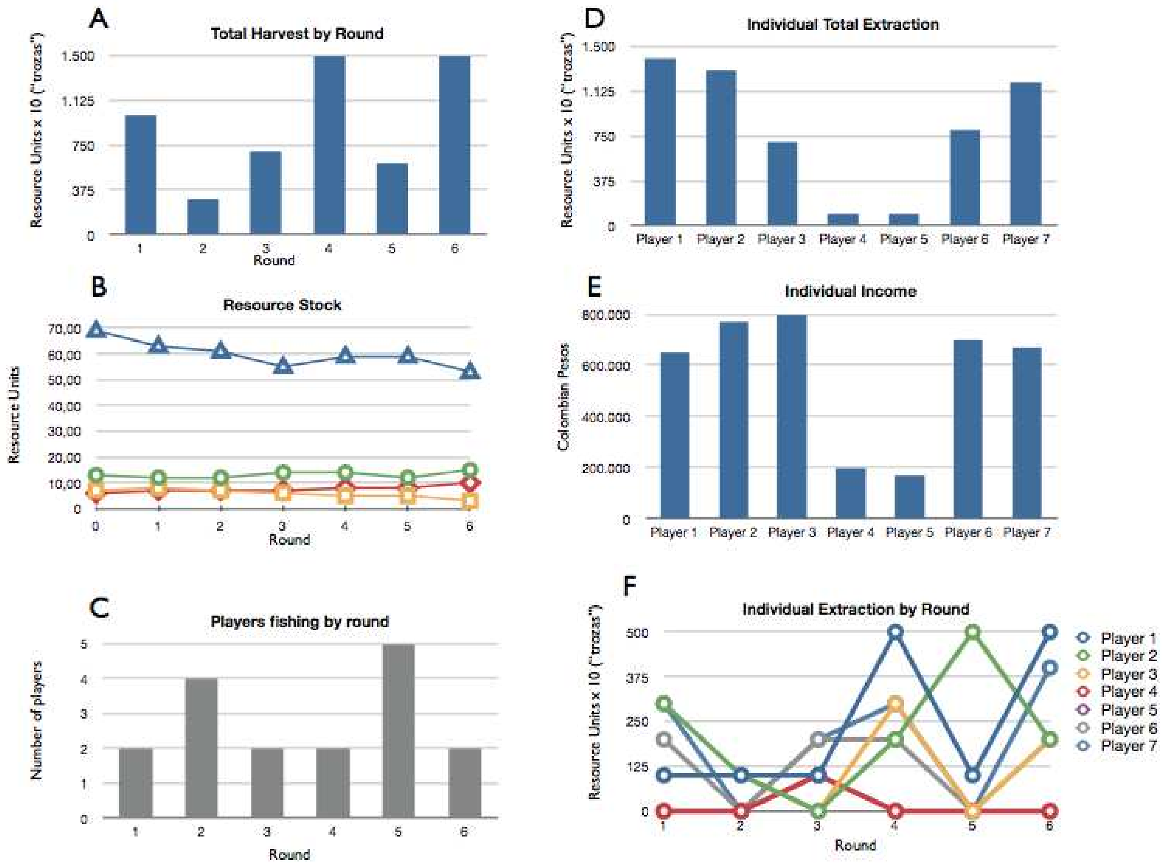

Figura 5.15. Results in the forestry RPG. 5.15A : Total extraction in each round. 5.15B: Forest dynamics trough game rounds. Round 0 indicates the initial conditions for each one of the species in the game board. The graph reports the number of units of each species at the end of each round. 5.15C: Number of players that allocated their effort to fish instead of harvesting the forest in each round. 5.15D: Accumulated extraction of each player. 5.15E: Accumulated income of each player. 5.15F: Individual extraction trough the rounds of the game.

5.2.4 Institutional arrangements in the forestry SES

Formal rules

Sorting the rules through the ADICO (Table 5.12) and A*I*M (Table 5.13) allows observing the tendency of formal institutional arrangements. There are two characteristics of rules according to their aims. On one hand, the regulation is focused on biodiversity conservation, but on the other, the form in which the rules involve people, consists in giving them the responsibility for forest conservation and forest sustainable use. The law itself interprets the region as a social-ecological system, claiming an ancestral development of culture strongly linked to the tropical forest, rivers and seashore. The definition of concrete rules of the game is centralized in the regional governmental environmental agency (Corponariño). This agency has to define monitoring mechanisms, forest use permits and sanctioning systems. This responsibility is given by the national level rules as well as the local communitarian rules.

The rules with local influence (8 and 9 in tables 5.12 and 5.13) are created by the Communitarian Council (ACAPA). They are focused in the control of the sizes of trees harvested and a ban of one of the species (Naidi palm). The sanctions ("or else" element) for violators are left to the governmental environmental local agency (Corponariño).The ban of the palm caused the retirement of 3 veredas from the communitarian council and constituted a new council ("Veredas Unidas por un Bien Común") which was entitled with the common land property title. They organized themselves with the technical advice of a forestry engineer contracted by one of the external companies interested in the exploitation of the palm (Rivas 2001). According this author in the late 1990s, among ACAPA's inhabitants there were a feeling about the Law 70 that the law represented a developmental delay because was generating restrictions on natural resources use. The other relevant rule (rule 8 tables 5.12 and 5.13) recognizes the key role of saw mills in shaping the use and conservation of the forest, by regulating the minimal size of individual logs allowable to purchase to the loggers.

Table 4 shows the classification of the rules according to their AIM of the rules in the action situation. Position rules (1, 2, 3, 6 and 7) define who is to give permits and licenses for timber extraction (rule 1), which is Corponariño, the local environmental agency. Rules 2 and 3 establish that local black communities are the users of the tropical forest, but also they define this position with the role of forest and, in a broader sense, of biodiversity keepers. Rule 6 allocates to the commercial companies the role of monitoring the licenses of loggers and timber transporters. Rule 7 involves police and military members in the role of supporting environmental agencies in monitor and control of rule compliance. Regarding boundary rules, rule number 2 defines the eligibility of local Afro Colombian inhabitants for having the position of users of the forest, as well as its keepers.

Concrete choice rules were created locally by the comunitarian council ACAPA, and are oriented to the people (rule 9) and to the saw mills (rule 8). Rules of national and regional scale regulate in a generic form the direct decisions on timber extraction. The most important choice rule has been the banning of the Naidi palm[41] extraction (rule 9), which has had important consequences to ACAPA. The control through the saw mills and the issuing of licenses is based on the exigence of a forest management plan that must include a detailed forestry inventory and a harvesting plan that ought to be elaborated or advised by a forestry engineer and submited to the local environmental agency, Corponariño. The formal institutional system strongly relies on this management plan as the main source of information for the regulation of forestry use. Therefore, this plan, which is required by the Forestry Use Decree to any actor that intends to harvest the forest, becomes the main information rule of the system. The planning is required for any kind of licensing to extract timber, if no plan is presented, no license is issued. Therefore, a participant of the action situation who extracts timber without compliance of this planning is subject to the sanctions defined by the local environmental authority. Most of the rules are scope rules (3, 4, 5, 8 and 9). Their aims are to protect the tropical rainforest, to warrantee a sustainable use of the forest, and to protect the Naidi palm and allows its natural regeneration.

[41] *Euterpe oleracea*

Table 5.12 Formal statements AD*I*CO syntax components

STATEMENT	ATTRIBUTE	DEONTIC	AIM	CONDITION	OR ELSE	TYPE
1. Regional environmental agencies (i.e. Corponariño) have to issue concessions, permits and authorizations for renewable natural resources use and/or their transportation. (Environmental Law 99/1993)	Public regional and local environmental agencies	Regional and local public environmental agencies must monitor and give permits for the use and mobilization of RNR	To transfer the responsibility to monitor and regulate use to the regional and local scales.	Colombian territory	Investigation and correspondin g sanction, by a governmental agency, for not fulfill a constitutional mandate	Rule
2. The State will allocate to the black communities collective property rights over the lands adjacent to the rivers in the Pacific Basin, which have been occupying through their traditional productive practices (Black Communities Law 70/1993)	Afro Colombian citizens	The State must give collective property rights of lands traditionally occupied	To allocate collective land property rights to Afro Colombian citizens	Colombian Pacific region	Investigation and correspondin g sanction, by a governmental agency, for not fulfill a constitutional mandate	Rule
3. The use of the forest must warrantee the persistence of the resource. The collective land titles have a social and ecological function (Black Communities Law 70/1993)	Afro Colombian citizens	Afro Colombian communities must use in a sustainable form the tropical rain forest, and be responsible for its conservation.	To make responsible the Afro Colombian communities entitled by the collective titles of the conservation of the tropical rainforest ecosystem	Colombian Pacific region	Sanctions are defined by the public local environmenta l agency (Corponariño)	Rule

4. In order to harvest a forest located in public and private lands, the corresponding local environmental agency (Corponariño) will issue a license, concession or association, based on a forestry management plan presented by the beneficiary of the exploitation. (Forestry Use Decree 1791/1996)	Any person who is interested in exploiting forestry resources.	Any person interested in the exploitation of forests must design a forestry management plan in order to obtain a license, concession or association from the local public environmental agency.	To assure a sustainable forestry use.	Colombian territory	The potential beneficiary will not have the authorization for exploiting the forest.	Rule
5. Forestry exploitations intended by black communities are ruled by the Law 70, but the aspects not specified in that law are ruled by the Forestry Use Decree 1791/1996. (Forestry Use Decree 1791/1996)	Afro Colombian population	Forestry use must be ruled by Law 70 or the Forestry Use Decree 1791/1996	To assure a sustainable forestry use.	Colombian territory entitled as collective lands to Afro Colombian people.	Sanctions are defined by the public local environmental agency (Corponariño)	Rule
6. The commercial companies that transform, commercialize and transport forestry products (saw mills and other intermediaries) are obliged to demand to the suppliers (loggers, small saw mills and other timber transporters) a license that warranties the legal transportation (Forestry Use Decree 1791/1996)	Colombian and foreigners citizens	Any company or person that transport timber must have a license issued by the local environmental authority.	To monitor and control the extraction and mobility of timber forest products.	Colombian territory	Seizing of the timber.	Rule
7. Local and regional environmental agencies are to monitor and control the use of the forests. These agencies must coordinate with police and military these activities. (Forestry Use Decree 1791/1996).	Colombian governmental local and regional environmental agencies	All local and regional public environmental agencies must control and monitor the use of forests.	To monitor and control the use of the forests.	Colombian territory	Investigation and corresponding sanction, by a governmental agency.	Rule
8. Limitation to saw mills (ACAPA 1997)	Saw mills working in ACAPA's territory	It is forbidden to buy logs smaller than 4 inches diameter	To facilitate the natural growth of the forest	ACAPA territory	Corresponding sanction applied by the local public environmental angency (Corponariño)	

9. Ban on Naidi palm (ACAPA 1997)	Afro Colombian population member of ACAPA	It is forbidden to harvest Naidi palm	To foster and protect the re-growth of the Naidi palm	ACAPA's territory	Corresponding sanction applied by the local public environmental angency (Corponariño)

Table 5.13 Formal institutional statements classified according their purpose

INSTITUTIONAL STATEMENT	SCALE	CREATOR/YEAR	AIM	TYPE Position: 1, Boundary: 2, Choice: 3, Aggregation: 4, Information: 5, Payoff: 6, Scope: 7.						
				1	2	3	4	5	6	7
1. Regional environmental agencies (i.e. Corponariño) have to issue concessions, permits and authorizations for renewable natural resources use and/or their transportation. (Environmental Law 99/1993)	National/Regional	Central gov/ 1993	To define who must regulate the use of the forest.	X						
2. The State will allocate to the black communities collective property rights over the lands adjacent to the rivers in the Pacific Basin, which have been occupying through their traditional productive practices (Black Communities Law 70/1993)	National	Central gov/ 1993	To allocate collective land property rights to Afro Colombian citizens	X	X					
3. The use of the forest must warrantee the persistence of the resource. The collective land titles have a social and ecological function (Black Communities Law 70/1993)	National	Central gov/ 1993	To protect the tropical rainforest ecosystem	X						X
4. In order to harvest a forest located in public and private lands, the corresponding local environmental agency (Corponariño) will issue a license, concession or association, based on a forestry management plan presented by the beneficiary of the exploitation. (Forestry Use Decree 1791/1996)	National/Regional	Central gov/ 1996	To assure a sustainable forestry use.							X
5. Forestry exploitations intended by black communities are ruled by the Law 70, but the aspects not specified in that law are ruled by the Forestry Use Decree 1791/1996. (Forestry Use Decree 1791/1996)	National/Regional	Central gov/ 1996	To assure a sustainable forestry use.							X
6. The commercial companies that transform, commercialize and transport forestry products (saw mills and other intermediaries) are obliged to demand to the suppliers (loggers, small saw mills and other timber transporters) a license that warranties the legal transportation (Forestry Use Decree 1791/1996)	National/Regional	Central gov/ 1996	To monitor and control the extraction and mobility of timber forest products.	X						

7. Local and regional environmental agencies are to monitor and control the use of the forests. These agencies must coordinate with police and military these activities. (Forestry Use Decree 1791/1996).	National/Regional	Central gov/ 1996	To monitor and control the use of the forests.	X						
8. Limitation to saw mills (ACAPA 1997)	Local	Local communitarian authority/ 1997	To facilitate the natural re growth of the forest			X				X
9. Ban on Naidi palm (ACAPA 1997)	Local	Local communitarian authority/ 1997	To foster and protect the re-growth of the Naidi palm			X				X

Rules in use

Analysis of the interviews, RPG and surveys gave an approximation to the rules in use in the forest use in ACAPA´s territory. Interviews carried out by Ospina (2008) also constitutes a useful source of information for the understanding of rules that participants really use in their daily lives. Relevant fields for the forestry management discussed here are land property rights, licenses and permits, sanctions and monitoring, the management of certain species such as the Naidi palm and mangroves, the role of the saw mills, and forest harvesting.

Land property rights

The ownership of the land is equivalent to the ownership of the forest. Traditionally there were no official land titles in the zone, but the dominion of the land has been individual through de facto titles inherited from generation to generation in some cases, and others through the exploitation of the untouched forest. The law has transformed the possession of the land since 1993, and has given formal collective land titles to these communities. The result is a combination of formal and informal land ownership depending on the interlocutor and the specific situation. During the RPG collective construction, the forest represented in the board game was divided in zones, which represented the forest patch of each player. During the RPG each player harvested timber from its own forest patch in the board game. Only the coastal zone, with mangrove trees symbolized with a red cross, was depicted as common lands. Interviewees expressed the land ownership rules in different ways saying that people respect the borders of the forest patches until the owner dies. Locals explain that the forms of access to the land are basically inheritance, work ("meterle zanja" meaning building a canal in the forest to extract timber), or land buying (Ospina 2008). Most of the interviewees expressed their critics to the collective land title based on the loss of rights to sell their lands. Only few respondents expressed their agreement with the collective title because with this status is easier to obtain financial support from international and national entities for development projects (Ospina 2008 and interviews and informal chats carried out in the context of the field work for this research).

Licenses

During RPG design participants proposed that each logger would need a license each round according to the state of the forest. It implied an assessment of the state of the forest at the end of each round, which was proposed by some participants, but during the final playing of the game this rule was not applied. At the moment of the activity one of the main concerns was the forest management plan that ACAPA was leading, therefore, they made emphasis during the co-construction of the RPG on its usefulness for that purpose. When playing the RPG, the environmental authority issued extraction licenses but for the saw mills. Each saw mill owner bought a license at the beginning of each round. People expressed in the interviews exactly the same mechanism for timber extraction licensing.

The Naidi Palm

During the first years of the communitarian council, the extraction was completely free and was one stable source of income for most of the population. This situation led the species almost to its extinction. During the 1990s the extraction was driven by the quality of the palm, which is a function of the size of the inner core of the plant. The price was set according to the product´s size. The extraction was completely free, and the principal rule was the differential price with the consequences already mentioned. In 1999 ACAPA managed to make the environmental authority to ban drastically the Naidi palm extraction. The prohibition lasted during six years, and was one of the actions that affirmed the rights over the collective territory. In 2006 the exploitation of the palm was reactivated. This time the communitarian council regulated the extraction through out agreements with buyers, in which they only buy the best quality palm. This implied that loggers harvested only the most mature individuals (Ospina 2008).

The mangroves management rules

The rules for the use of the mangroves´ timber were also pushed by ACAPA. Initially the coastal territory with mangroves was not included in the collective title, but the communitarian council managed, using legal and political instruments, to keep this vital space inside its territoriality. They used the argument of their cultural practices and the sustainable management as arguments for claim their right to design their own rules for the mangroves forests (Rivas 2001). As a result, people can use the mangrove only for domestic use such as own house and artisanal boat building (Ospina 2008). The participants in the RPG collective design established a zone with mangroves trees, which symbol was an X. During the game any of the players harvested those trees.

General monitoring and sanctions

Interviewees agreed that the environmental local authority monitors each 2 or 4 years. They coincided in that the minimum harvesting size of timber is 16 inches of diameter, and that when the environmental agency monitors check the size and licenses to the saw mills. Regarding the sanctions, they expressed that when the agency´s officers catch someone breaking the rules, the first time they give a verbal advertence and the second time a fine is imposed. During the RPG it was evident that the negotiation with the middle men, in this case the owner of the saw mills, was shaping the extraction of timber. Most of the time the representative of the environmental agency (Corponariño) was issuing licenses to the two saw mills in the RPG. Only during one of the rounds he discuss with loggers the state of the forest and gave advice about good forest harvesting practices and the forest use plan, using the game board as an illustrative tool.

Timber harvest

The general rules in use for timber extraction can be understood at two scales: individual level and daily use of the forest on one hand, and on the other, the general consequences of the Law 70. Interviewees agreed in 4 basic rules that they followed in their activity: (1) rights to the forest; a forest patch can be appropriated by building infrastructure for harvesting only if the place does not have already an owner, this practice legitimates a person as owner of that piece of land, sometimes there are conflicts because of invasion of others` forest, but in general the rule seems to be the fundamental form of forest appropriation. (2) The places on which they do not harvest are the banks of the rivers and the mangrove zones. (3) The minimum size that people harvest is a range between 12 and 15 inches of diameter. From interviews with saw mills´owners and field visits to some of the facilities, we conclude that, depending on the economic situation they can accept buying, or demand to the loggers smaller diameters of timber. (4) The time to leave resting a patch of forest, called the return time oscillates between 2 to 10 years. At global scale, the Law 70 marked a milestone for the use of the forest. One of the changes due to its implementation was the impossibility of the national and international companies of entering to the zone with licenses of the National government. After the law, in practice, it has been difficult to the National government to facilitate the entrance of logging companies into the zone. In fact, in 2006 the government proposed the "Forestry Law" to the National Congress, which part of the aim was to make possible logging companies to enter in the region. So far the law has been blocked through political lobby of environmentalists and Afro American leaders.

The purpose of the rules

The AIM classification of rules contributes to describe the forestry action arena and the interactions among actors.

Position rules: The direct extractors of timber belong to ACAPA. ACAPA members own the sawmills but they are not direct extractors. Other middlemen not necessarily belong to ACAPA members, they represent the commercial connection of the SES with others systems.

Boundary rules: The entry and exit rules are clearly defined by ACAPA`s Board of directors. But they can issue timber extraction licenses to external companies. This has happened with the extraction of Naidi palm for example. Not always this capacity of this committee has been transparent. The economic interest and the different type of pressures from external companies, illegal armed actors and politicians has led to allowing the big scale timber extraction.

Choice rules: In terms of the rules, which aim is to structure the decision making of the participants in this SES there are two findings that have to be remarked. The extraction decisions of timber loggers are shaped by the middlemen demand. This is most important that what the formal rule could prescribe, meaning that this is the rule in use not the formal one. The second one is that the loggers have wide range span in their conceptions of the time necessary to let trees to regrowth. The range is between two and ten years. According to this notion they leave resting the forest patches to allow natural regeneration.

Payoff rules: This type of rules in this SES are not related with sanctions. The rule works with any species that is allowed to harvest, but the middlemen shape it also. Currently, the harvest of Naidi palm is allowed after several years of prohibition due to overexploitation. The buyers demand the biggest palms, this fact which entails a problem for the maintenance of the species, because the extraction should be done of middle size individuals.

Next table (5.14) summarizes the rules in use in the forestry system. Similarly to the fishery case, they present an AD*I*C structure, therefore we are dealing with "norms", they lack a clear OR ELSE component. These norms directly affect the components of the action arena and shape its outcomes discussed in the next section. Table 5.14 also informs about the main source of observation for each one; interviews (I) and role game (RG).

Table 5.14 Rules in use.

RG: Observed in the Role game. I: Interviews

Position	There are 5 positions: (1) ACAPA´s members (Afro Colombian population of the communitarian council territory), (2) Board of directors of ACAPA, one representative of each vereda, (3) saw mill´s owners, 4) other middlemen, (5) local environmental agency (Corponariño), 6) police and military members	RG, I
Boundary	(1) All Afro Colombian inhabitants from ACAPA´s territory have the right to extract timber from the forest (collective property rights).(2) Individual land/forest property rights are obtained through de facto occupation, familiar inheritance or land buying. (3) The licenses for extraction and transporting timber are issued to the saw mills.	I, RG
Choice	(1) Commercial mangrove harvesting is prohibited. Only it is allowed for domestic use to ACAPA´s members. (3) People do not harvest trees from the river´s banks. (4) The minimum size of trees that people harvest is a range between 12 and 15 inches of diameter. (5) Saw mills´demand determine the size of trees to be harvested. (6) Two to 10 years is the time range that loggers leave a forest patch without harvesting in order to allow natural regeneration.	RG, I
Payoff rules	(1) The extraction of Naidi palm is allowed, but buyers only purchase the best quality individuals (the biggest palms).	I, RG

5.2.5 Outcomes of the forestry SES' action situation

Cooperation and trust

The extraction level in the economic experiments is an indicator of cooperation in this specific action arena. The higher frequencies in extraction in the rounds in which there are 25 or more trees, are efforts of 3 and 4 (Janssen et al., WP), which indicates low levels of cooperation given that the maximum possible effort is 5. Though the resource was over exploited it did not happen as fast as is predicted by the Nash equilibrium. The information trust and perception of the community, from surveys, offers results that contribute to explain cooperation levels in the experiments.

Three important relations were found between the survey and the decisions in the experiments : (i) There is a positive correlation between the perception of community belonging and extracting less trees. This is that the more cooperation level, the higher is the community belonging perception. (ii) When the trust indicator, measured in surveys, is higher the rule compliance is lower. In general, the regulation led to lower levels of over exploitation, but also to high degree of rule breaking. (iii) The higher the resource decrease, the extraction levels are lower[42] (Janssen et al., WP). The results from the RPG offer insights about the current and potential levels of cooperation. It is possible to divide the cooperation levels according two concepts: (1) current and potential cooperation among actors, and (2) cooperation understood as the extraction level. Regarding the first kind of cooperation, it was evident in the RPG construction as well as during the game. In the co-construction of the game were explicit the calls to count with the sawmill owners and middlemen to reach cooperation agreements. During the game was evident the key role of these actors in the extraction and in the forest dynamics.

At the end of the RPG the representatives of the sawmills expressed their willingness to participate and cooperate with the Forestry Management Plan of ACAPA (Communitary Council). The role played by the representative of the public environmental agency (Corponariño) can be defined as moderated willingness to cooperate. The official worker of the agency, during the first rounds of the RPG only sold extraction licenses to the sawmills without doing any intervention in the game board neither a monitoring function. In round number 4 the officer intervened using the board as illustrative tool. He suggested several good practices of forest extraction and sustainable management, and also he stated the official position of the environmental agency regarding the Forestry Management Plan. In his intervention he utilized the board but always spoke about the regional forest. The inference is that there is an important level of willingness to cooperate with the Communitarian Council, and the direct forest users. The participation of the Communitarian Council (ACAPA) was mainly passive and showing low interest. This behavior can be interpreted as a signal of the internal problems and conflicts of the directive committee of the organization. An important fact is that the communitarian organization ACAPA has a very recent history that has been strongly influenced by the armed conflict. It is evident, and it was verified in the fields work that still there are no clear conflict resolution in the organization.

The behavior of the forest direct users in the RPG can be typified in three classes: high, moderated, and low cooperation. Two of the players (players 4 and 5, Figure 8) made extraction decisions aiming to conserve the forest. In addition to their

[42] Two types of analysis were used: i) Multi-level linear regression with the dependent variable the relative resource extraction and independent variables: the level of trust, the level of feeling being part of the community. And ii) a multinomial logistic regression (Janssen et al. WP)

decisions, in the discourse, they tried to induce the same behavior to the other participants. The player 3 exhibited an intermediate level of cooperation, who extracted timber moderately and negotiated efficiently with the saw mills, in this way he did not generated a big impact in the forest and obtained the higher accumulated earnings in the game (Figure 5.15E). The players 1, 2, 6 and 7 had the higher level of extraction and exhibited free rider behavior in rounds 4, 5, and 6 (Figure 5.15F).

According to one of the sawmill owners interviewed, the tendency during recent years is that the extractors bring from the forest timber smaller than permitted by the environmental authority. This fact indicates low levels of cooperation from the extraction and market perspective, because the sawmill buys this timber. Though there is no concrete information about the policies of other saw mills regarding this practice, from informal conversations with timber extractors, is generalized the idea according that small sizes of timber is the one that can be sold always. This implies a systematic breaking of formal rules of timber extraction and buying. For timber extractors the cooperation with the sawmill is vital because the sawmill provides the economic resources in advance to the extractor to go to the forest. In turn the sawmill depends on the extractors to obtain the material for its business. According to some of the interviewees (Ospina, 2008), when a sawmill is closed or moved to other zone it is perceived by the extractors as a type of betrayal to the trust and to the relationship that has been built during a considerable time period.

The interviewees speak about a generalized tendency to the cooperation decrease. A young timber extractor woman states, "*here people is going to continue extracting the same quantities, but if they could, they would extract even more*" (Interview, Salahonda, April 13, 2007). The cooperation practices among the direct users like the "cambio de mano"[43] are not so common nowadays in contrast with previous generations as expressed by one of the interviewees: "*the people is driven mainly for the money*", and says that people of 30 and younger do not like the "cambio de mano", but people that started to work before the 80s still practice this kind of cooperation organization (Ospina, 2008). Another interviewee talks about the "minga"[44], but he says that it is very rare nowadays because "*currently the business is*

[43] Practice that consists in a gathering of a extractors group to help to harvest the forest patch owned by one person. Afterwards, the same group gathers to help in each member´s forest.
[44] The "minga" is a cooperation form where the owner of the forest patch offers food and drinks to a group of people, and people helps in the timber extraction. The difference with the "cambio de mano" is

becoming so hard, there is no means to leave money to the wife, to the sons to eat, therefore, each one asks for his payment (…) before was better, the work was done faster" (Ospina, 2008).

The trust in community leaders, this is the members of the Directive Committee of ACAPA, has been eroding since 2001, when illegal armed groups killed the leader of an external organization that supported the process. Several interviewees say that do not have information about the Communitarian Council and that they do not feel themselves as part of the organization. They coincide in that the resources are poorly managed without following commitments and agreements, but overall they feel that do not participate in decisions. Escobar (Escobar, 2005) analyzes the organizational process of afro Colombian communities in the South Pacific Coast and finds that the generation of new leaders which is replacing the people from the 90s, the so called "new leaders", are adopting an adaptive strategy to the armed conflict that has triggered a considerable effect in the trust decrease from the community, and the consequence has been the internal corruption.

Rules and general morality conformance

The individual and collective morality as a result of the action situation and a particular trajectory of institutional arrangements. Table 7 illustrates the components of the first and second level of morality conformance.

that the "minga" does not entails a laboral Exchange, it is only a contribution withouth any obligation to particiapte in another "minga" in the future.

Table 5.15. Conformance to general morality as outcome of the forestry action arena.

First level

Normative beliefs: links an action and a value judgment

n1: To extract timber is acceptable only for afro Colombian citizens belonging to ACAPA´s Communitarian Council.

n2: If a person works in a virgin forest patch, that forest belongs to this person.

n3: It is acceptable for a person to change the rules when she wants, according to your needs.

Generalized beliefs: links an action with an effect without value judgment.

g1: Most of the people extract timber as much as they can.

g2: Timber extraction have not changed since the Law 70 implementation.

g3: It is difficult to change rules with the local environmental authority (Corponariño)

g4: Natural regrowth of forest lasts between 2 and 10 years

Second level

Moral valid behavior

m1: To claim individual property rights when dealing to other members of the community.

m2: To extract timber according to the intermediaries demand.

m3: The intermediaries can buy timber smaller than minimum size allowed by the formal rules if needed to sustain his business.

m4: Timber extraction is acceptable only for afro Colombian citizens with ancestral roots on the territory

m5 Private land property rights are acquired by inheritance, buying or by pioneer extraction of timber.

Cultural valid behavior

c1: Private land property rights are acquired by inheritance, buying or by pioneer extraction of timber.

c2: Rotation among fishing, timber extraction and agriculture as household livelihood.

c3 Timber extraction is acceptable only for afro Colombian citizens with ancestral roots on the territory

Legal valid behavior

l1: To claim the collective property rights character of the territory when facing external actors.

l2: No extraction of mangrove timber, but only for self consumption purposes (own house and boats building)

l3: No timber extraction from the rivers´banks.

l4: Timber extraction is acceptable only for afro Colombian citizens belonging to ACAPA´s Communitarian Council.

l5	To extract timber over the minimum sizes.

How big is the gap between moral, culture and legal?

Figure 5.16 shows a simple exercise for visualizing the behavior typified in the second level of conformance to general morality (Table 5.15). Sets named M, C and L stand for the moral, cultural and legal valid behaviors respectively. The elements of each set are named m, c and l, and stand for each of the types in Table 5.15.

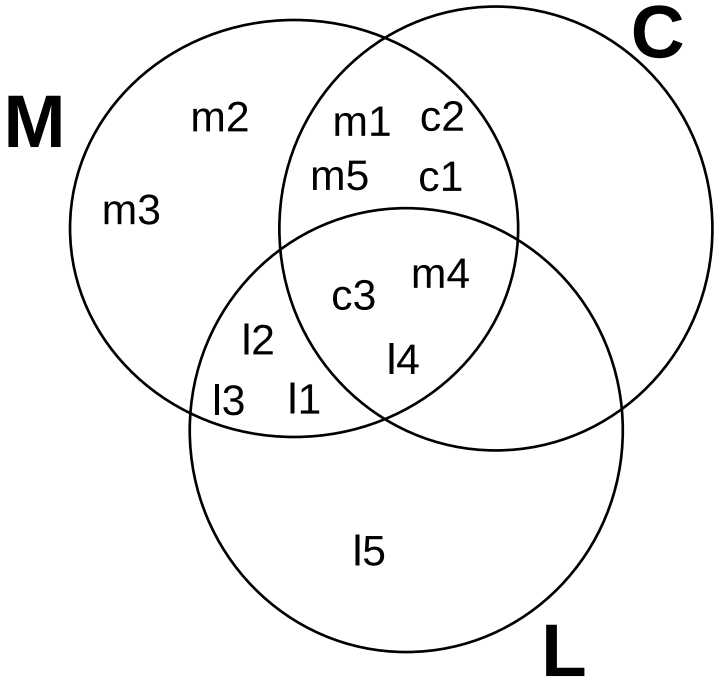

Figure 5.16. Illustration of the gap among morality, culture and law.

The ideal situation for an institutional arrangement, where rules in use coincide with formal ones and therefore sustainability outcomes have more opportunity to improve, would be when:

$$M \cap C \cap L = M \cup C \cup L \qquad (6)$$

In the forestry case study the intersections are:

$$M \cap C = m1, m4, m5, c1, c2, c3 \qquad (7)$$

$$M \cap L = m4, l1, l2, l3, l4 \qquad (8)$$

$$C \cap L = | \qquad (9)$$

and,

$$M \cap C \cap L = c3, m4, I4 \qquad (10)$$

Cultural behavior is included in moral and legal sets. This could be an indicator of a formal set of rules that has been designed carefully, and with a clear intention of interpreting the cultural links between the population and the territory, as was created the Law 70. Nevertheless, there are elements that belong only to the moral and legal valid behavior sets, showing deviations between law and moral. The elements m2, m3 and l5 put the spot light on the role of intermediaries as one of the main drivers that could conciliate or not law, moral and culture.

As a consequence a two types of behavior of actors, regarding rule breaking, in the forestry action arena can be classified (Table 5.16). Direct users of the forest are rule breakers by necessity, because they depend on the intermediaries' demand. Intermediaries are classified as rule breakers by necessity, but also as cheating players. Interviews to some of them indicates a blurry line between the real necessity for sustain their business and their individual benefits maximization character, no matter they really need or not to demand small trees, under the legal sizes. Local leaders are classified as cheating players because there are evidences of a number of internal problems among them that include the use of their positions to generate rules in their individual benefit, and run businesses with external intermediaries (Field observation, 2008).

Table 5.16 Type of players according to Mockus (1994) proposal

Type	Actor	Condition
Rule breaker by necessity or convenience	Direct users	If n3 and/or m2 are/is meet
Cheating player	Owners of saw mills (intermediaries)	If m3 is meet
	Local leaders	Corruption among members of ACAPA´s directive board is a common problem that was observed

5.2.6 Summary of main findings of the forestry system's institutional analysis

I mentioned, in the last section of chapter 4 (Geographical and historical context), a set of problems and potential shocks that entails the context of the forestry action arena and institutional arrangements that I have discussed. (1) Illegal crops (coca) advancement, lead by paramilitars and the subsequent conflict, and control of the territory. It implies a modification of the formal and informal institutions that could affect the forest management and ACAPA's governance of the territory. This situation has influenced the outcomes of the forestry action arena in terms of trust among members of the community, and strategies of ACAPA´s leaders. The new generation of leaders has adopted an adaptive strategy, which has undermined trust towards them, in addition to the corruption accusations. (2) Incentivated by the national government, the implementation of agro industries and monoculture (African Palm plantation projects) by national and international capitals. As Restrepo (2010) and others have pointed, the objective of the current Colombian government is to impose a modern project in the region, which has been delayed for about one century. The way to achieve this goal has focused on these agro industries that have not been completely unlinked from the illegal armed groups incursion in the region. These two factors have changed the labor relations and people´s relation with the monetary incentives of the action situation. The access to fast an easy money brought by the illegal agricultural products, as well as the pressure from agro industries in the sense of offer stable low income jobs has changed the incentives. The consequence in the outcomes is the decrease in cooperation levels, among local inhabitants and the high dependency of the intermediaries to guarantee household income (the disappearing of informal institutions such as "mano de vuelta" and the "minga" is an indicator). Elements of the moral valid behavior (Figure 5.16) that are not included in the sets of cultural and legal valid behavior have their origin in these situations.

And the third point mentioned in chapter 4 is that the territorial-ethnic-environmental discourse of local activists does not reflect the daily life practices of the population, in terms of the pretended ancestral communitarian use of the land. This fact leads to conflicts among leaders of ACAPA, which difficult an effective process of institutional arrangements crafting. This is the partial cause of the deviation of some elements of the culture and moral sets (C and M from figure 5.16) from the legal valid behavior. This point constitutes an important factor affecting the institutions in the utilization of the forest and could be an indicator of the distance between mental models of inhabitants of ACAPA and the formal property regime regarding the territory. The consequence is that the rights on extracting and selling timber are not completely clear. This dynamics gives clues about the problem in this action situation: weakly enforced rights, recent history of new property regimes and weak state institutions.

5.3 The Water Use System

5.3.1 Outcomes of the irrigation experimental action situation

Next I will discuss the outcomes generated by the interactions in the three action situations described above. As in the case of fisheries and forestry cases I orient the discussion towards cooperation, trust and morality as the fundamental outcomes that shape dynamics of the SES.

The experimental action situation

The Nash equilibrium of the game is produced when any of the players invest in the public provision of water units, receiving 10 tokens each one generating a collective payoff for the group of 50 tokens in each round. The other reference scenario is the social optimum or the cooperative solution occurs when each player invest, in each round, 10 tokens in the public good, producing a total amount of water of 100 units. When extracting units of water each individual would take 20 units, therefore in 10 rounds each player would earn 200 tokens and the collective earnings would be 1000 tokens (Juan Camilo Cardenas et al., in press). In the second part of the experiment players were asked to vote for any of the rules explained above to be implemented for the next 10 rounds, but the rest of the mechanics of the game continued as in the first 10 rounds.

The first outcome to evaluate is the contribution of participants to the public good, which is illustrated in figures 5.17 and 5.18. During the first part of the experiment players start to contribute around 25 tokens in average, which represents the 50% of the cooperative equilibrium. During the next rounds contributions tend to decrease, and at the end of this experimental stage, round ten, the average group contribution is around 36% of the cooperative outcome (Figure 5.17a). At individual scale (Figure 5.18a), players in upstream positions, A and B tend to contribute more than the rest located downstream. The average of players B`s contribution is over the 50% of the cooperative equilibrium during the first ten rounds, and players A are slightly under 50% of the social optimum. Players D and E reach the 40% of the cooperative outcome while players C are below this percentage.

In the second stage of the experiment, the overall effect of elected rules (Figure 5.17b) is an important decrease of group contributions. The experimental sessions in which participants elected to continue with the rotation rule (Figure 5.17c) group contribution to public infrastructure decreased. In round 11 contributions started at 36% of the social optimum, 14% less than round 1, in the first stage, and the average finished, at round 20, at 32% of the cooperative equilibrium. With the quota rule (Figure 5.17d) the average decreasing pattern is less dramatic from round 11 to 17, but the last rounds the mean contribution decreased strongly ending in the 28% of the cooperative equilibrium.

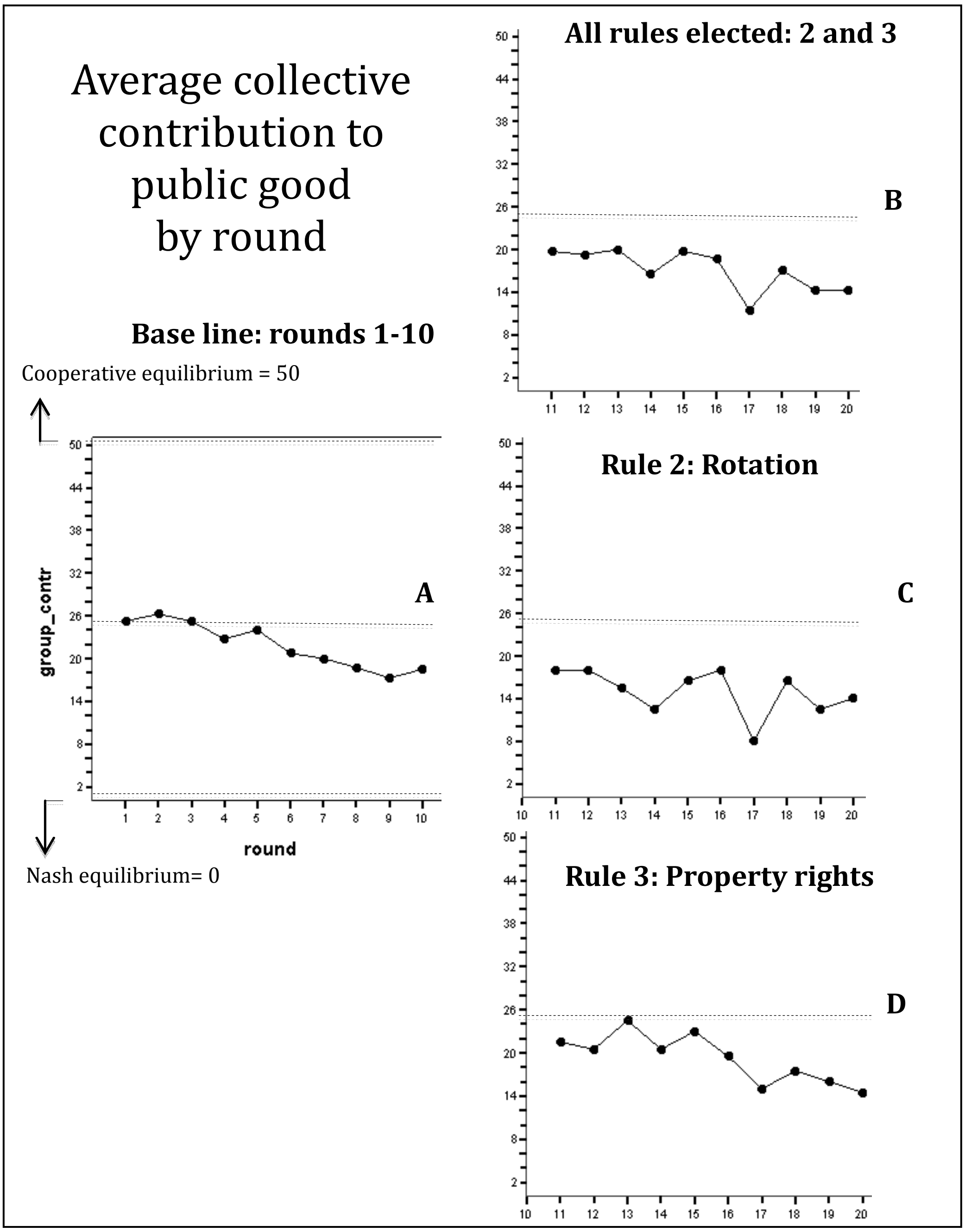

Figure 5.17. Average group contribution to the public fund for water production in the irrigation experiments through rounds.

The total decrease of the accumulated group contribution during all the rounds in each stage is illustrated in table 5.17. The decrease with rotation rule in place is 28.1%, with property rights is 15.5%, and when compared the base line stage with the second part without rule differentiation the decrease is 21.8%.

Table 5.17. Rules elected and accumulated group contribution to the public good

Rule	Total group contribution (rounds 1-10)	Total group contribution (rounds 11-20)	Total Group contribution (rounds 1-10)	Total Group contribution (rounds 11-20)
Random access (1)	-	-		
Rotation (2)	2095	1495	4375	3420
Quota (3)	2280	1925		

When we examine the contribution behavior from the point of view of the positions along the water channel (Figure 5.18) we discover a different history in which the rules have a particular effect mainly in players located at position B and E. During the first stage (Figure 5.18a) players located upstream, positions A and B, tend to contribute more than the rest; average of the B position is close to 60% of the social optimum, and A is close to 50%. Participants in positions C, D and E contribute maximum 40% of the cooperative equilibrium. When rules are in place, rounds 11 to 29, (Figure 5.18b) the first difference with the first stage is the general decrease in contributions. The other observation is the change in the distribution of contributions. Now players in positions B and E increased their cooperation, this is that the main contributions to public infrastructure to produce water are distributed between the upper part of the channel and the tail end. Figure 4c illustrates explicitly the effect of the rotation rule. The symmetry of contributions changed completely; minor contributions are located at upstream and increased downstream. With this rule is remarkable the increase in contributions of players in position E; slightly more than 60% of the cooperation equilibrium.

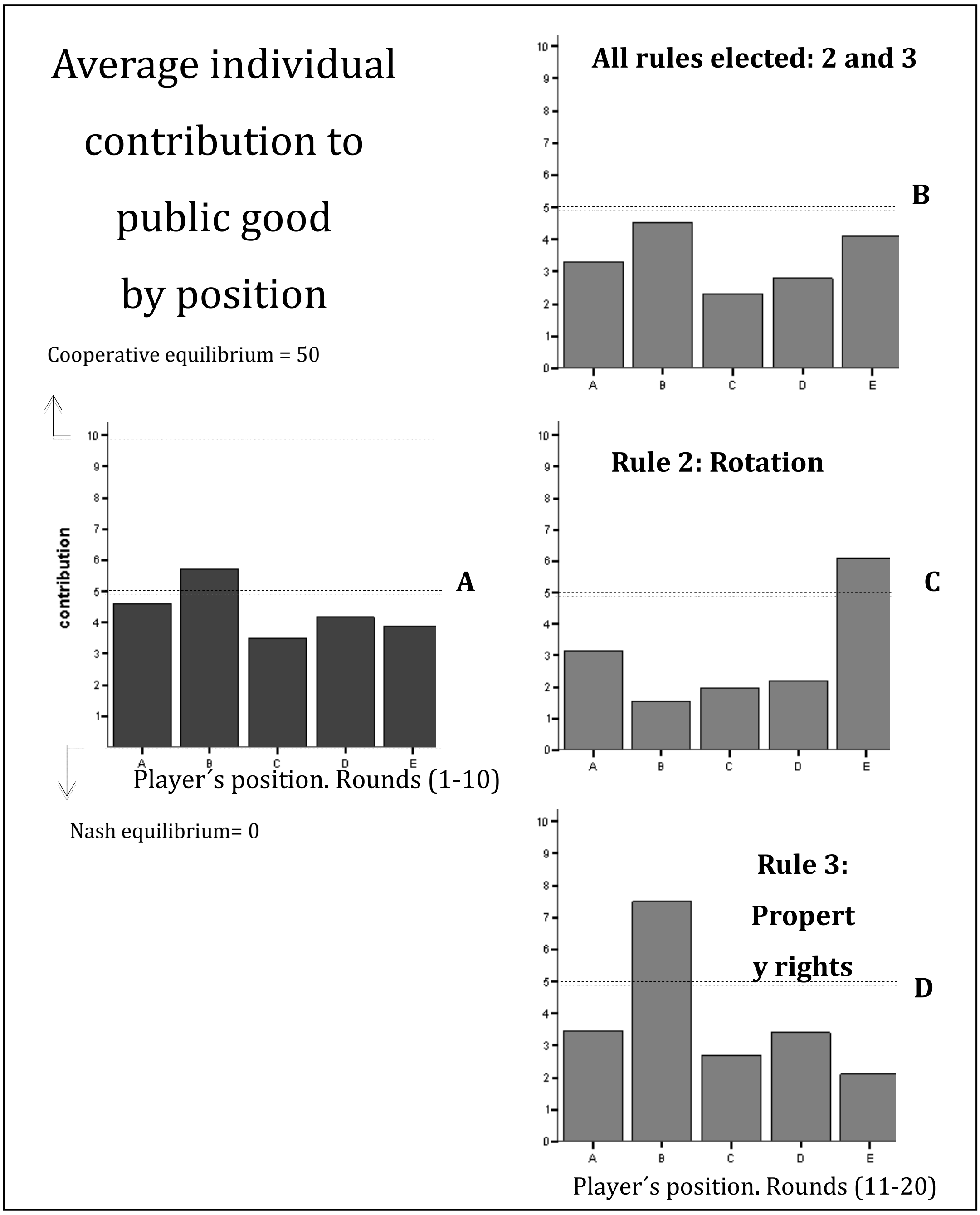

Figure 5.18. Average individual contribution to the public fund for water production in the irrigation experiments according to players' position along the water channel.

In contrast, the groups where the property rights rule was elected (Figure 5.18D) show a complete different pattern to the behavior produced by the rotation rule. Now players in position B improve their contribution reaching almost 80% of the social optimum, while downstream positions tend to decrease their cooperation to lower levels than those of the first stage. In summary what the property rights rule produces is an exacerbation of the pattern of the first part of the experiment, while the rotation rule generates a strong change in contributions symmetry. A general effect of rules is the decrease as shown above.

The second outcome is the level of resource extraction. Due to the experiment structure the availability of water for extraction in each round depending on the previous contribution, and the sequence of extraction decisions (up to downstream), the extraction decision in each position has a complex set of motivations. Figure 5.19A portraits the behavior of participants regarding water extraction in the first part of the experiment. The general pattern is a decrease of extraction from upstream positions to the end of the channel, being players in position A the ones who extract most of the resource. The total extracted by participants in position A is 721 units and the mean is 18 units, while the total sum of resource units extracted by players in positions B, C, D and E from round 1 to 10 is 669 and the average extracted is 4 units. These figures show the high level of inequality generated in this stage of the experiment.

Figure 5.19B portraits the resource extraction pattern produced when rules elected are implemented. The pattern is completely different to the one generated in the first stage. Extraction is evenly distributed among positions A, B, D and E, participants in position C do not display changes regarding the first stage. The rotation rule (Figure 5.19C) caused a significant decrease in resource appropriation, while the property rights rule (Figure 5.19D) reduced the differences in water extraction. Figure 5.20 portraits the pattern of tokens earned during the two stages of the experiment. When comparing the first ten rounds (Figure 5.20A) with the pattern produced with all the rules elected (Figure 5.20B) is evident that the decreasing trend remains, but the level of earnings decreases as it is shown in Table 5.18. The average of earnings in the base line is 12.6; while in the second stage are 10.3 tokens. In synthesis, the rules imply a tradeoff between efficiency and distribution among players along the channel; this is the decrease in efficiency in water production are compensated by earnings more equally distributed. This result is reported also by Janssen et al. (2012) when analyzing experimental of the same experiment but for a bigger sample with Colombian and Thai villagers.

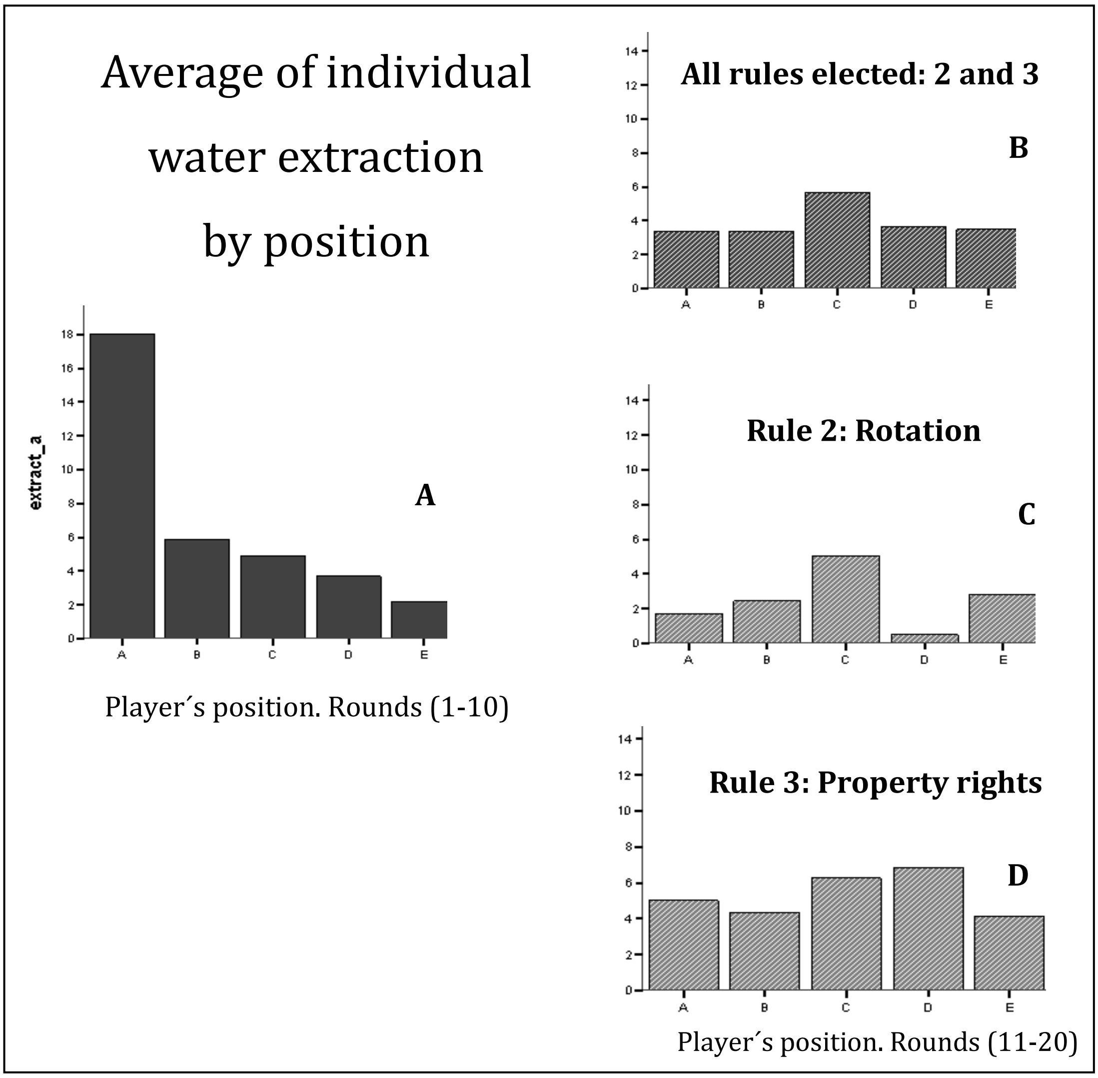

Figure 5.19. Average individual extraction of units of water according to players' positions along the hypothetical water channel in the irrigation experiment.

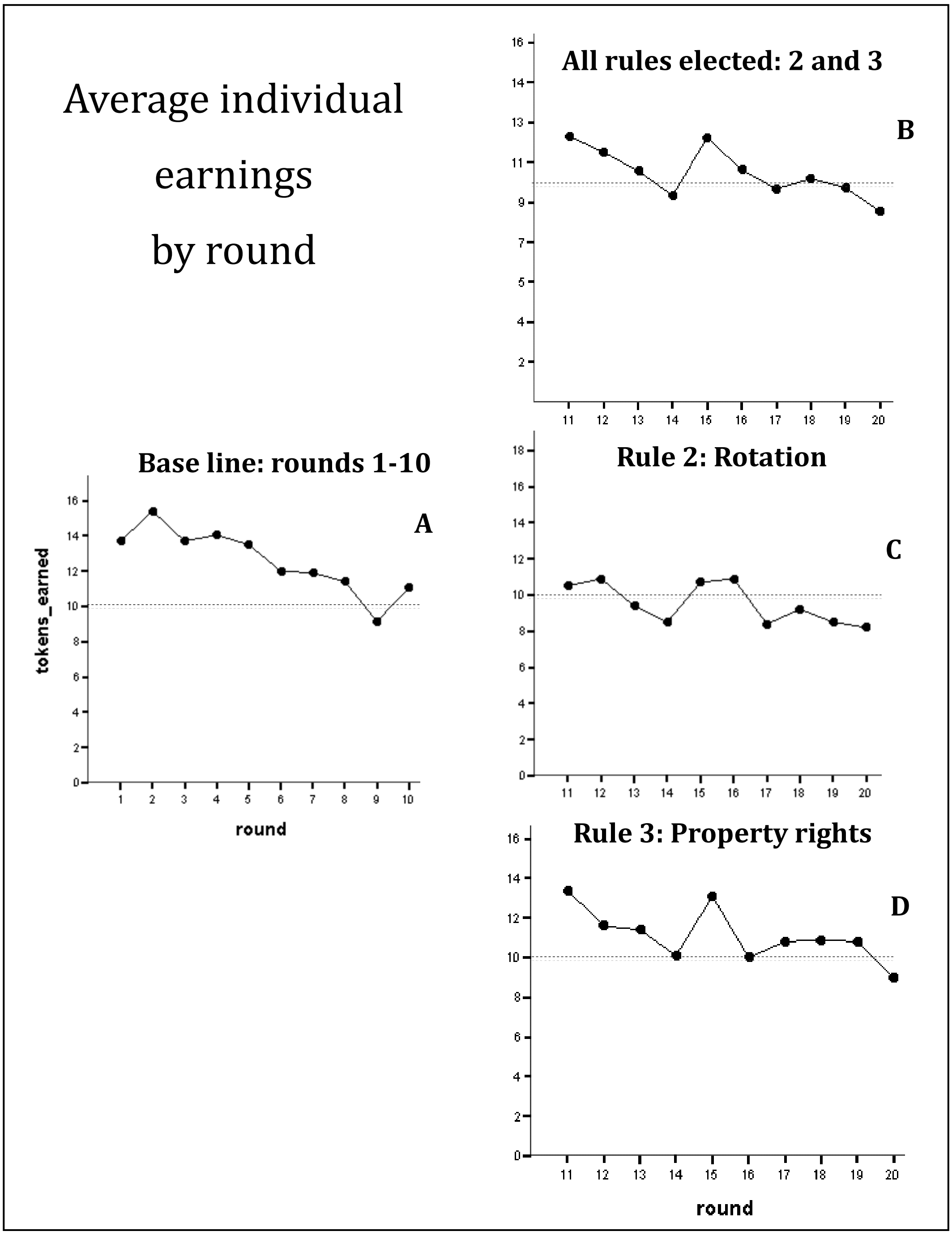

Figure 5.20. Average individual tokens earned in each round of the irrigation experiment.

Table 5.18 illustrates the results of the experimental action situation regarding rule compliance. Any of the groups elected the random access rule. Rotation and quota or property rights rule where evenly elected among groups. As mentioned before the rules did not improve the gains comparing with the outcomes of the base line. Even the groups that played with the rotation rule, which do not have the possibility to cheat, produced a major decrease in the earnings: 24.6%. The groups that played the second stage under property rights rule had a 18% of cheating behavior, but their decrease in gains, with respect to base line, was much less than the other groups: 12.6%. This outcome is due to the relative improvement in contributions of groups under quota rule versus rotation rule (Figure 5.17), that generated a bigger public good facilitating an increase in resource extraction, and the more equal distribution of resource appropriation (Figure 5.18D).

Table 5.18: Rules elected and resulting earnings

Rule	Number of times elected	Percentage rule broken	Average earnings per person (rounds 1-10)	Average earnings per person (rounds 11-20)	Total Average earnings per person (rounds 1-10)	Total Average earnings per person (rounds 11-20)
Random access (1)	0	-	-	-		
Rotation (2)	2	-	12,6	9,5	12,6	10,3
Quota (3)	2	18	12,7	11,1		

Figure 5.21 illustrates the results of the surveys on rules that irrigation village' participants, that played the irrigation experiment, answered. Answers where in a scale from 1 to 5, being 1 the worst qualification and 5 the best for each of the topics: Efficiency, Fairness, Freedom, Self-interest satisfaction and Overall attractiveness. People answered that lottery rule satisfies the self-interest of water users. Results for rotation rule are very similar, but people gave a high rank to the attractiveness of the rule. For the rule 3, which consists in a fix quote of 20% of the total produced water for each of the 5 participants in each round, 50% of the people ranked it as highly efficient, fair and that satisfied the self-interest, and 48% ranked it as highly attractive rule. In figure 5.21, the bar charts compare the answers to overall attractiveness of the three rules. Lottery rule is the less attractive for most of the people, while fix rule is the most

attractive, and rotation rule is also attractive but with lower percentages of answers in ranking 5.

As I already mentioned, the aqueduct “El Granadillo” works based on rules where the rotation scheme is present among the different “veredas” and the fix quota, which is not an explicit rule. From interviews, it is clear that the conduct of people that take more water, stoking in tanks or ponds is one of the more morally sanctioned behavior; in fact, there is an explicit rule that prohibits water stoking. In the speeches of most of the interviewees is the idea that people must be careful with water use and make a rational use of the resource.

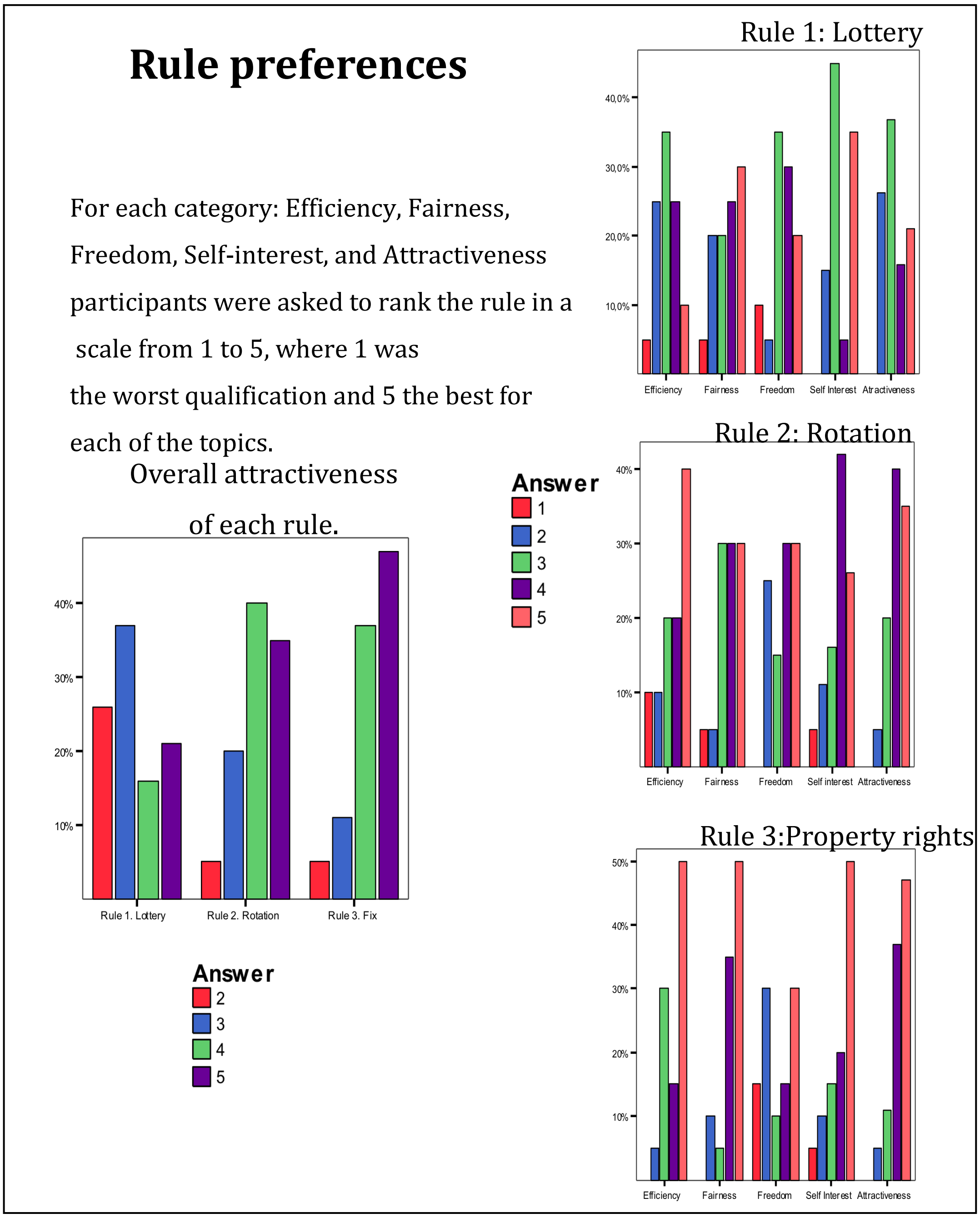

Figure 5.21. Answers on survey on rule preferences.

5.3.2 Towards a more complex action arena: Collective construction of the water RPG

With the experimental setting as a departure point just like in the other two cases, a group of 20 participants attended to a workshop in order to improve the game. The most relevant contribution from participants was the modification of the physical setting of the experiments and the introduction of an explicit zone representing the water source.

The purpose of the game

The discussion about the reasons to build a role game was around individualism and cooperation in the community. The generalized opinion was that people in the community is quite selfish. Participants did not point this characteristic in direct relation with water use or aqueduct problems, they referred to all aspects of the life. It is important to note that people that attended to the workshop were only from the upper veredas. They recognized that they are selfish and the waste of water is a common behavior. Therefore, the objective of the game was set as: "to facilitate learning on water distribution and cooperation for people from the community."

The spatial representation

The smallest formal political and administrative unit in Colombian rural areas is the Municipality, but in practice, the spatial unit with real meaning to people is the vereda. The vereda is a region of variable size where rural human settlements, clustered or disperse, have organized since colonial or even pre Hispanic times in some regions. Usually there is one rural school in each vereda and inhabitants are organizationally gathered in a communal entity called Community Action Council (Junta de Acción Comunal, JAC), which is in charge of the management and lobbing for local development projects. In this case study the most important geographic unit is the vereda. The aqueduct system studied covers six veredas, and the participants in the workshop used this entity as the fundamental spatial unit.

The participants replaced the individual plots of the experiment for the territory of the veredas, grouping the 6 veredas in four, located according to their position in the watershed. The second change consisted in the inclusion of a special zone for water production in the uppermost part of the watershed, which represented a forest. An important element of the structure of the game was, at least initially, that the plumber as a character that was represented in a motorcycle and with capacity to move through out the game board. The veredas were linked by paths that have to be walked by players and the plumber. Figure 5.22 illustrates an initial version of the game board with the spatial organization of the veredas from upper part of the watershed (bottom of the figure) to the lower zone (upper part of the figure). In the figure 5.23 the final board game is showed. In the uppermost part of the board is the forest zone where the water source is located (bottom of the figure), then the veredas, and at the lower part is located the bank representing the urban zone of the municipality (upper part of the figure). The territory was structured with four zones. In the upper part of the watershed the forest was located. In the next zone, still the high part of the watershed, was located the vereda Tibita, and was represented by 2 players. In the intermediate zone of the watershed were located the vereda Espinales, with two players, and Glorieta, with one player. In the lower zone of the watershed was occupied by the vereda La Cuba, which was represented by 1 player.

Figure 5.22. Initial stage of the collective construction of the board game.

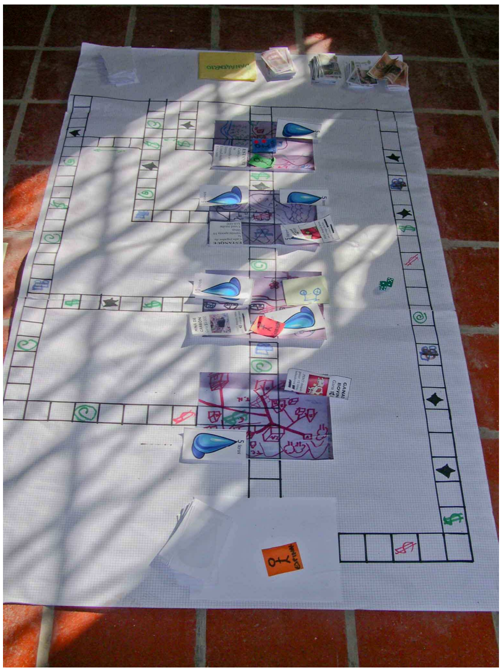

Figure 5.23. Final version of the board game.

The action situation

Participants defined four positions: the vereda player, plumber, bank and aqueduct council.

The vereda.

For this position, a token is used that represent all the inhabitants of each vereda. With this token players move across the board in his turn after throwing the dice that determine how many cells the token can advance in the direction the player wants. When participants defined the vereda positions there is an ambiguity about the meaning of the geographical location of the veredas. This is, on one side, they said that people in the lower veredas have a more difficult access to water, on the other hand, participants said people in the upper veredas experience water shortages when households in the lower parts open de faucet. As expressed by participants people are aware of the difficult situation of others, but at the same time they will not sacrifice anything to improve other´s situation.

The actions available for this position were: to distribute water in any vereda, to pay for planting trees in the upper part of the watershed, to decide wether initiate productive activities such as cattle rising, agriculture or mining, and to use the plumber token to fix broken tubes in his own vereda or others.

The plumber.

The plumber is in charged of fix problems with the tubes in each vereda. Damages in the aqueduct can happen when a player, in his turn, and after throwing the dices, advances through out the board reaches a cell in which he has to withdraw a card that could imply a broken tube. There are other cards that say that the player must pay $1000 COP to the plumber, this payment goes directly to the aqueduct council. There is another card that enables players to send the plumber to any vereda and fix problems according to players' will.

The bank.

Economic transaction in the water management is relevant, therefore in the role game it was necessary a position that regulates monetary earnings. Participants introduced early in the workshop monetary incentives. This fact is an important indication of the main drivers of water management; to conserve the common recourse, it must produce economic benefits. Therefore there is a tendency to perceive the water as a common resource that is worth wile to conserve only if it produces monetary benefits. The actions of the bank included to sell trees for planting in the upper end of the watershed and lend money to participants.

Aqueduct council

The function of the council, in the RPG arena was to solve all the problems of the aqueduct and to invest in improvements, but the council did not do anything, the only role is to receive money from the community. One of the participants in the final debriefing of the RPG expressed his vision of the council: "*the aqueduct council only receives money, and they steal it*". This is probably the expression of the low level of trust in the public organizations. It is important to remark that this perception does not mean that the aqueduct has not improve the well being of the community, it is reflecting the cultural behavior that characterizes the people from this zone: they take advantage of the benefits, but they do not accept the necessity of paying some costs. The perception of inefficiency is reflected in the idea according that the cost they pay for the aqueduct do not reflect benefits, the interpretation could be that they perceive costs higher than benefits.

Information available to participants and control over outcomes

Participants are aware of their role regarding the production of water through the management and conservation of highlands forests, vegetal cover (páramo) and springs. This is expressed in the game: when a player plants a tree in the upper part, a volume of water is produced. Information about the relation among water and production is clear for all participants, but the production is the key part, and its conservation depends on the water use. The low level of council's participation in maintaining aqueduct' structure seems to be a generalized perception among participants. This is reflected in the relevance that participants give to the plumber, but on the other hand, often made jokes about his inefficiency. Regarding the control over outcomes, the role game structure allowed to each player to control water production and allocation, but there was a source of uncertainty given by the dice players had to roll in order to advance in the game board. Additionally, depending on the cards they receive players could affect other´s players outcomes. The players wanted to control their interests for each round, they seemed not to think in long term projects, they did not traced a strategy for the end of the game.

Synthesis of the role game action situation collective construction

Table 5.19 illustrates a synthesis of the modifications that took place on the economic experiments during the co-construction of the role game. The summary shows the expected and actual changes that occurred in the collective construction of the role game. The main change in the resource settings was the explicit representation of water units in the role game. Players introduced the spatial context: they organized the board game with an upper and lower part and the "veredas", as well as a forest zone in the upper part for water production. Individual decisions were modified for choosing productive activities, buying trees to produce water, and the possibility to distribute water among the veredas. The incentives structure was modified; in the role game the payoffs are determined by the type of productive activities each player choose. Also the objective of the players could be to distribute an equal quantity of water in the four veredas of the game board. Participants did not design any rule for water management. They included new roles in addition to the direct water users´ roles; the plumber, the bank and users were divided in groups according their real belonging to the veredas.

Table 5.19. Expected and actual changes during RPG co-construction.

TOPIC	EXPECTED CHANGES	ACTUAL CHANGES
	Changes in resource settings	
Resource	No expected changes	Water units were represented explicitly by water cards in different quantities measured in liters.
Season, water availability	Different seasons or climate restrictions according season	NO. Participants did not include any climate variable or seasonal particularity
Differences due to the context	Differences- Conservation area	YES. Participants included the “veredas” and a zone in the upper part of the board where water is produced as a function of trees planted.
Condition of water sources	No hypothesis	NO.
	Individual decision making	
Possible decisions	Economic contribution to the maintenance of the aqueduct. Water use. Productive activities.	Possibility of distribute the water among the “veredas”. Productive activities. To buy trees for planting in the upper part and produce water. To help or block other participants provoking damages in the tubes, and to use the plumber services to fix problems.
Price	Prices of products yield by productive activities and the monetary contribution to the maintenance of the aqueduct.	Prices of the trees. Costs of implementing productive activities. Payment of the quota for the aqueduct each round.
Water taking choice	A quantity of water to use.	Water distribution among the veredas and use for productive activities.
Incentives structure	No hypothesis	Payoffs depend on the economic activities the players decide to carry out. The game can be win either accumulating money or being able to allocate a quantity of water for each vereda.
	Collective decisions	
Rules	Players would organize the distribution of water among the veredas.	No. They did not established any rule for water use.
Sanctions	Sanctions would be more probable	NO. No sanctions were implemented.
Roles	Integration of new roles	YES. New roles were defined: The plumber, the bank, and the aqueduct council, and players were divided in 4 groups representing different veredas.

5.3.3 Outcomes of the water RPG action situation

As explained above the objective of the role game was to find better ways of water distribution among people from the community. A player (vereda) could win the game reaching any of these two goals: to accumulate 20 liters of water, to accumulate $40.000 COP. If collectively the veredas accumulate 100 liters of water, it is considered that the game is won by all, meaning that the community has cooperated to maintain the aqueduct and distribute the resource with equity.

The forest in the upper part of the board produces water for the veredas. When a player plants 1 tree, it produces water only for the upper vereda (Tibita), if plants 2 then generates water for Tibita and Espinales, if plants 3, the water reaches the vereda La Glorieta, and if the number of trees planted is 4 then La Cuba receives water. Players can plant trees that can be bought in the bank at $200 each. Water in the veredas can be used to irrigation, domestic use and livestock, and each player can decide to implement a productive activity (crop and/or livestock) for which he wins money, but also it needs a certain amount of water to earn money. In each round each player must pay $100 to the plumber in order to maintain the infrastructure and the provision of water. If a player does not pay to the plumber in a given turn, the water is removed from the corresponding vereda. Each player (vereda) starts the game with an endowment of $8.500 COP. They can make any negotiation with other players. In each turn players can move through the game board advancing a number of cells after throwing two dice, and only can make actions when they are in the specific places. For example if they want to purchase trees, they need to go until the bank cell in the lowest part of the board, or if a player wants to plant a tree or distribute water manually among veredas he must move until the corresponding cell.

The outcomes of the game in terms of water distribution and accumulated gains are illustrated in table 5.23. The veredas located in the upper part of the watershed accumulated more water than the downstream ones. The vereda that accumulated more money was La Cuba, located in the lowest part of the watershed, but they couldn’t accumulate the amount needed to win ($40.000). The Aqueduct Council accumulated an important quantity of money and they did not invest in maintenance of the aqueduct or in water provision, this is planting trees in the forest in the uppermost part of the watershed or any other type of negotiation with players trying to induce a better distribution of water among players. The players accumulated money or water but didn´t tried to make a balance. In two of the veredas players constructed water reservoirs that implied that each player of the vereda had to give 10 liters of water and the owner received $10.000. The consequence of this action was that the accumulation of water for the vereda was more difficult but the owner could make profits.

Two insights arise from the interactions among participants during the game. On one hand, the cooperation among participants to distribute water among veredas depends directly on the economic benefits players could have from that. On the other side, the role of the plumber wasn´t played by any person, instead, the character was represented by a token in the game that could be used by the players to fix infrastructure problems. Each time the plumber was needed participants made comments regarding his inefficiency and made fun of him. The plumber was identified as the character that better represented the behavior of the Aqueduct Council. This attitude is interpreted, as the general attitude towards rules of people of the region because finally they do what they think and this is better independently of the formal prescriptions. Also this behavior with the plumber is the result of the idea that the one who cares about the common resource is someone else different to the users.

Table 5.23. Results of the role game

Player	Water (Liters)	Money (COP)
Glorieta	55	1.000
Tibita	40	0
Espinales	25	0
La Cuba	15	29.000
Aqueduct Council	-	21.000

5.3.4 Institutional arrangements in the water SES

Formal rules

Tables 5.20 and 5.21 illustrate the formal rules classified according to AD*I*CO rule building blocks, and their A*I*M. Table 5.20 shows a set of rules at national scale, which aim focus on the conservation of the resource, the declaration of water access as a fundamental right of people, and the inclusion of water use in the planning at regional and municipal scales. The deontic of rules is quite general and involves public instances such as municipalities and the State in general. These prescriptions are classified as rules because they mention sanctions, but without identifying and specifying them. The second group of rules is the regulation of the aqueduct council. The attribute of these rules is constrained to the users of the aqueduct. This regulation focuses in the definition of prescriptions for the aqueduct operation, duties and rights of the users, maintenance and subscription fees, and the positions and possible actions of users and aqueduct council members.

According to the A*I*M of the rules, Table 5.21 shows the type of each rule in terms of the part of the action situation it is affecting. Rules at National scale are scope rules, they attempt to guarantee the outcomes in terms of water conservation, access and resource use planning. The aqueduct association regulation gives prescription that affect all the components of the local action situation. Three prescriptions are position rules defining the actions that must take the participants occupying a given position focused on maintenance, watershed protection, rights and duties of users and monitoring. Two of the prescriptions are boundary rules that define who are the users and household enter or exit conditions to the system. Two prescriptions are choice rules that specify the actions of participants. Aggregation rules define how to control the link between actions and outcomes, establishing the mechanisms for monitoring water use and connect new users to the system. The prescription about monitoring affects the information that users and the council have about water use, therefore this is a information rule. The statutes of the aqueduct association include a set of prescriptions that define the prohibitions and system of sanctions for the aqueduct' users.

Table 5.20. Formal statements AD*I*CO syntax components.

STATEMENT	ATTRIBUTE	DEONTIC	AIM	CONDITION	OR ELSE	TYPE
1. (Law T-379/1995). Water conservation and management is linked to humans 'right to a healthy environment.	Colombian citizens	Water must be protected	To conserve water and to declare the resource as fundamental for human and natural life	National Territory	Sanctions are mentioned but not specified	Rule
2. (T-578/1992). The water is source of life and the lack of provision is threaten the fundamental right to life of humans.		Water must be protected	Declaration of water as a fundamental right for every person in the society			
3. Law 142. (1994) Public services law. State duty to provide water service to every household .		The State must supply water for all the households	To guarantee the access to water			
4. Natural Resources Law (1974)		The State must ensure the efficient use of resources for the well being of the society	To protect water resources from the damages produced by extractive activities and regulating human behavior regarding the environment.			
5. Law 373 (1997). Efficient use of water.		All regional and municipal environmental plans must include a water efficient use program.	To include water use programs in the planning tools at municipal and regional scales.			
6. The rules of the aqueduct association	Users of the aqueduct "El Granadillo"	Establishes the functioning of the association.	To coordinate activities for the maintaining of the aqueduct, and promoting the protection of watershed.	The area of the six veredas that serves the aqueduct.		

7. Article 31 (The rules of the aqueduct association)	The plumber must accomplish maintaining and monitoring tasks of the aqueducy	Maintenance of the aqueduct	Dismissal of the charge	Rule
8. Article 35 (The rules of the aqueduct association)	To pay the contributions for the aqueduct. To contribute with communal works. To pay a bimonthly quota for the maintenance of the aqueduct.	To guarantee resources for the aqueduct functioning	Oral warning, followed by monetary fine, and finally the cutting of the service	Rule
9. Articles 36 - 42 (The rules of the aqueduct association)	Users must pay a fee for the connection of tubes.	To establish the mechanisms for the users´connection to the system.	Suspension of the aqueduct service	Rule
10. Articles 54 - 62 (The rules of the aqueduct association)	Users must maintain in good shape the connections of the aqueduct.	To establish the users´duty to maintain the aqueduct connections	Fine of a daly legal wage	Rule
11. Article 63 (The rules of the aqueduct association)	Users must comply the prohibitions	To define the prohibited actions and the sanctions	Fine and suspension of the service	Rule

Table 5.21. Formal institutional statements classified according their purpose (A*I*M)
Key for TYPE column: Position: 1, Boundary: 2, Choice: 3, Aggregation: 4, Information: 5, Payoff: 6, Scope: 7

INSTITUTIONAL STATEMENT	SCALE	CREATOR/YEAR	AIM	TYPE 1	2	3	4	5	6	7
1. (Law T-379/1995). Water conservation and management is linked to humans´right to a healthy environment.	National	Central gov/ 1995	Conserve water							X
2. (T-578/1992). The water is source of life and the lack of provision is threaten the fundamental right to life of humans.	National Local	Central gov/ 1992	Conserve water							X
3. Law 142. (1994) Public services law. State duty to provide water service to every household .		Central gov/ 1994	To guarantee access to water							X
4. Natural Resources Law (1974)		Central gov/ 1974	Protection of water sources							X
5. Law 373 (1997). Efficient use of water.		Central gov/ 1997	To plan the use of the resource							X
6. The rules of the aqueduct association (the set of rules included in the statutes comprehend the seven type of rules)		Aqueduct association/1993	Infrastructure maintainance and watershed protection.	X	X	X	X	X	X	X
7. Article 31 (The rules of the aqueduct association)	Local	Aqueduct association/1993	Plumber duties	X	X					
8. Article 35 (The rules of the aqueduct association)			Rights and duties of aqueduct users	X	X	X				
9. Articles 36 - 42 (The rules of the aqueduct association)			Functioning and costs				X		X	
10. Articles 54 - 62 (The rules of the aqueduct association)			Connections and monitoring of water use	X		X	X	X		
11. Article 63 (The rules of the aqueduct association)			Prohibitions and sanctions						X	

Operational Rules

Operational rules in the aqueduct system are inferred from interviews and surveys. A first observation is that all the interviewees recognized most of the formal rules of the aqueduct. In this section I summarize the rules they recognized and express that users comply.

The use of water is constrained to households. Irrigation utilization is not permitted, because the type of crops and climate conditions, historically have been managed with the rain. According interviewees when summer is strong they can use water from the aqueduct for livestock. The number of pipes that can be attached to the main tube per user is limited. Accumulation of water from the tubes cannot be stocked in artificial ponds or tanks. Users have to pay a maintenance fee each two months. There is a rotation scheme among "veredas", each two days the water is released to different "veredas".

Persons do not know the aqueduct council formal statutes; they have the perception that this is "a complicated issue that nobody understands". One of the interviewees was the president of the aqueduct council; he said that everybody knows the statutes. Formal rules in use in the aqueduct "El Granadillo" seem to be recognized by all the interviewees. The plumber said that there are no clear rules, but that the only sure thing is that he must control that people do not waste water, using it for irrigation or ponds. As we already mentioned before, the aqueduct "El Granadillo" works based on rules where the rotation scheme is present among the different "veredas" and the fix quota, which is not an explicit rule. From interviews, it is clear that the behavior of people that take more water, stoking in tanks or ponds is one of the more morally sanctioned behavior; in fact, there is an explicit rule that prohibits water stoking. In the speeches of most of the interviewees is the idea that people must be careful with water use and make a rational use of the resource.

Rule compliance

One of the three women interviewed talks about rule compliance in term of how things must be. She says, if she would be the president of the Aqueduct Council, she would make sure "*that the aqueduct would be equal for everybody*", not the way it works today, according her; the rich people get more water than poor people. She illustrated this situation with an example of one of the neighbors, giving the real names of the persons involved in the situation. The same woman said that when someone breaks the rules nobody speaks, they act as if nothing would have happened. She says, people act in this way to avoid problems and having enemies. In contrast with this testimony, the plumber of the aqueduct said that everybody comply the rules, even in summer months. Though his idea of trustworthiness in this community is extremely low, he gave a vision of the aqueduct as a system where everything works almost perfect. Regarding this topic, the president of the aqueduct council said that sometimes people break rules, and that they do not apply strictly the sanctions written in the statutes, he said, “we try to fix the problem talking with people before apply the sanctions”. He said that sometimes it is necessary to call the “personero” of the municipality to make a person to stick to the rules. Clearly they try to applied, informally, the principle of graduated sanctions, the formal rule of the aqueduct regarding rule breaking, is to impose a fine or cutting water supply, instead they call the attention of the offender, first verbal, second they apply a fine, and third the service is suspended. The president says that these sanctions are rarely implemented; they prefer to talk with people first. This was confirmed by the plumber.

The purpose of the rules

Operative rules affect directly the action situation in which aqueduct users are immerse on daily basis. The A*I*M of the rules in use indicates the elements of the action situation they are regulating, and in turn, the behavior of participants. Five rules (7-11 in tables 5.21 and 5.22) types of operational rules are key means of structuring the interactions for aqueduct users in reaching successful outcomes in water allocation. These are position, boundary, choice, aggregation, information and payoff type of rules classified according their objective.

Position rules: There are three main local positions: aqueduct users (households), the plumber in charge of aqueduct maintenance and monitoring, and the president of the aqueduct council. There are two positions that are external to the aqueduct system but they have influence on the aqueduct. The first is the regional environmental authority[45] that formally has the function of protecting water sources, to control de management of

[45] Corporación Autonoma Regional de Cundinamarca (CAR)

watersheds, and issuing water rights to rural local aqueducts. In the case study, and in practice, the agency visits the zone, in average twice a year, and gathers part of the community for planting trees in the upper part of the basing in order to protect water sources. The other position has to do with the technical advice and monitoring of water quality. The municipality fills this position. Usually this function is carried out after political lobbying from the aqueduct council president.

Boundary rules. In this case the operative rules that define who are in the system coincide with the formal prescription of the aqueduct rules. There are three boundary requirements:

1. Membership: Users of the aqueduct have to be part of the aqueduct organization
2. Fee: Payment of an entry fee is necessary to be member of the aqueduct.
3. Geographical: The household must be located in one of the six "veredas" covered by the aqueduct.

Choice rules: These types of rules define the structure of the resource allocation. They define the actions that appropriators can carry out in terms of space, time and technological capabilities. Therefore in the system being analyzed the operational rules of this type are the following:

1. Time: There is a rotation rule for the different "veredas" in water supply. Only in summer season people can use it for livestock.
2. Space: The use of water is constrained to the households. Irrigation of crops is not permitted with water from the aqueduct. The number of tubes for each household is limited. Moreover there is a fixed quantity of water for each household.
3. Technology: Water cannot be stocked in reservoirs.

Information rules: When somebody breaks the rules nobody talks about that. Twice per year the general assembly of the aqueduct, which is composed by all users, gathers and delivers a report on the organization activities, problems and changes in the aqueduct council.

Payoff rules. Two types of rules that affect the costs and benefits of the action situation are present in the aqueduct system: maintenance and sanctions. People must pay a maintenance fee every two months. Sanctions are graduated; the rule breakers are first addressed orally, next time they have to pay a fine, and finally if they break the rule for third time the aqueduct service is suspended.

Table 5.22. Rules in use.

RG: Observed in the Role game. I: Interviews

Position	1) Aqueduct users (households): water appropiation	I, RG
	2) Plumber: aqueduct maintenance	I, RG
	3) President of the aqueduct council: Coordination of users and political lobby towards outside of the system.	I
	4) Municipality: Technical advising and monitoring of water quality	I
	5) Regional environmental authority: Protection of basins and surveillance of watershed management	I
Boundary	1) Membership: Users of the aqueduct have to be part of the aqueduct organization	I, RG
	2) Fee: Payment of an entry fee is necessary to be member of the aqueduct.	I
	3) Geographical: The household must be located in one of the six “veredas” that the aqueduct covers.	I, RG
Choice	1) Rotation scheme among the “veredas”.	I
	2) Water can be used only for households.	I, RG
	3) Crops irrigation is prohibited.	I
	4) Number of tubes per household is limited.	I
	5) Fixed amount of water for each household.	I
Information	1) Offenders to the rules are not denounced	I, RG
	2) The aqueduct council must report twice a year on the activities and relevant issues	I
Payoff rules	1) Maintenance: Every two months users must pay a fee.	I, RG
	2) Sanctioning: Sanctions are graduated.	I

5.3.5 Outcomes of the water system’ action situation

Cooperation and trust

Indicators of cooperation in irrigation experiments are contributions to the public infrastructure and water extraction. As shown in Figure 5.18 group cooperation, in average, starts slightly above 50% of the cooperative equilibrium but decreases with time. Rules didn´t make things better, on the contrary, the levels of cooperation decreased significantly in the second stage of the experiment. At the individual level, the rotation rule improves the cooperation of players in position E, at the end of the channel. But the quota rule improved the cooperation of players located in position B. Regarding the extraction of water, rules changed the pattern of extraction producing less inequality in the appropriation of the resource (Figure 5.19). During the first rounds of the base line, the levels of trust in others explain the average group contributions. But as rounds passed, inequalities in extraction eroded trust in the group leading to lessen the contributions. When rules were implemented the extraction was redistributed but the behavior of contributions followed the same trend, meaning that levels of trust decreased through the rounds.

The surveys showed a low level of trust among the community: 0,53 compared to fishery village: 0.73, and forestry village: 0.63. The findings of the interviews could help to explain the results of the survey regarding low levels of trust in the irrigation village. A recent regulation from the Colombian Public Water Policy, demands that all rural communitarian aqueducts must become a commercial enterprise or a legal cooperative. If this condition is not meet the government will be in charge of the aqueduct administration. The interpretation of the community is that the intention of government is the privatization of water supply, with the consequent increase in prices and a water supply schema similar to urban areas. The Aqueduct Council is trying to face this situation by adjusting the statutes of the aqueduct to become a cooperative. As a consequence, in words of the Aqueduct Council's president, "*people don't want more workshops, researchers and external projects in the zone, because they don't help, they just take what they need*". This situation contributes to reinforce the low levels of trust from community towards outside actors and governmental regulators.

An initial hypothesis to the current institutional setting dynamics, in the irrigation site, could be an action arena resulting of the combination of the following factors: 1) lack of coordination between formal Colombian institutional arrangements at national, regional and local scales. 2) The dominant agenda that feed policies at national scale is the liberalization and privatization solutions, and clearly, it is influencing local scales. 3) Information about local contexts does not flow towards national scale, and possibly interests at each scale are different. There is no dialogue among governmental agencies, at national scale, in charge of policies for the use and conservation of different resources. Policies are punctual and try to address problems very specifically instead of integral approaches. 4) At local scale, trust levels are extremely weak. 5) Trust in governmental institutions is low, but also trust, from the state, in the capacity of local communities to manage by themselves their resources is low. Then, in order to cope with an imposed institutional system, local organizations try to defend their local institutions and their resource management way, by doing poor and shortsighted adaptations.

This scenario produces low levels of cooperation reinforced by the low levels of trust among members of the community and across scales of water management system's governance. Therefore, local participants of the action arena close the doors to external actors as a reaction to the possibility of losing their property rights over water and aqueduct. If the property rights are threatened the long term expectative and certainty is compromised, therefore the action situation moves from a coordination game to a prisoner's dilemma. A possible interpretation of behavior in the second stage of experiments is that participants saw the rules as a proxy of governmental agencies and the level of rule compliance; 18% of rule breaking (Table 5.18) in property rights rule, is an expression of this action situation's equilibrium.

During the RPG, participants made jokes about the aqueduct council, making public the low trust they feel in the council. The plumber was not used in the game, occasionally players made fun of him, showing a direct identification his figure with the aqueduct council. This position has a relevant symbolic value for users of the aqueduct because during the RPG people attributed some characteristics such as inefficiency and negligence; players forget his existence during the game. The organization that they create themselves has a number of problems, which are represented in the plumber character.

From interviews it is possible to have a general picture about the levels of trust in the community of the vereda Tibita Centro. Among the five interviewees there were two persons that have arrived to the community seven years ago and the other three were born in the place (natives). This fact allowed us to have two points of view regarding social dynamics of the community. Natives tend to express their ideas about trustworthiness in terms of water management. When it comes to the issue of controlling the amount of water for each household, a woman, who lives in the upper part of the pipe, said that everybody is responsible of paying its maintenance fee, and that people in general is aware about the importance of fairness in water sharing. In contrast, the plumber of the aqueduct, said, on one hand, that people in the six-monthly meeting of the aqueduct council usually ask about money management, showing a lack of trust in the adequate use of the resources. On the other hand he said that, in general, aqueduct' users do not have many conflicts about sharing water. When we asked if people trust in each other in this community, his answer was clear: *"One can't trust even in one's mother"*.

The interviewees that have arrived to the place seven years ago expressed in a straightforward manner their idea of low trustworthiness in the community. One of them said: "*each one look after of his own business … here one can't trust in anybody, and you can't help anybody…here people is so selfish"*. Interesting enough to be mentioned is the fact that these persons talked about the reputation of the zone for having presence of guerrillas some years ago. They left their home villages due to the lack of employment and the worth of mouth said that in this vereda were more working opportunities, but it would have to be careful due to the guerrilla issue. Regarding the aqueduct, a woman said that few years ago she wanted to be president of the aqueduct council and she postulated her name but she only got five votes from the four women present and her vote. She concludes: "*in this people zone is extremely "machista"* (male chauvinist), *they don't trust in women for the aqueduct management"*.

Rules and general morality conformance

Context, history and institutional arrangements generate a particular action arena that, in turn, produces a specific moral system. As in the previous cases, in this section I Table 5.24 illustrates the first and second level of morality conformance in the aqueduct´s action situation

Table 5.24. Conformance to general morality as outcome of the action arena.

First level
Normative beliefs: link an action and a value judgment n1: To accumulate small quantities of water from the aqueduct is acceptable in summer months n2: To waste water is not acceptable n3: To use aqueduct water for irrigation is not acceptable n4 To denounce people that break rules is not acceptable n5: To adapt behavior to the external power requirements to obtain own objectives is acceptable
Generalized beliefs: link action with an effect without value judgment. g1: If people waste water they have to pay more g2: To plant trees in the upper part of the watershed produces water g3: If the community pays to the regional political leader, it´s possible to make improvements to the aqueduct such as the water treatment plant. g4: If a person is wealthy, she gets more water g5 People is selfish g6 People don´t trust in each other
Second level
Moral valid behavior m1: The household subsistence objective must be reached. m2 and m3 are the main mechanisms to fulfill this principle. m2: Interactions with external actors are driven by reciprocity norms. This behavior is subordinate to m1. m3: Formal rules and agreements are accepted in the discourse, but not always in practice. This is subordinated to m1 and m2.
Cultural valid behavior c1: Humans base natural resource management on the idea of the possibility of control of the nature. c2: To use the paramo for livestock or cropping c3: Actions are not always carried out explicitly: there are differences and often contradictions between the discourse and actions.
Legal valid behavior l1: To pay the aqueduct fee on time l2: To use water of the aqueduct for domestic use, but no for irrigation l3: Not to use water reservoirs l4: To maintain the springs free from livestock l5: Not to use the paramo for livestock or cropping

How big is the gap between moral, culture and legal?

As in previous cases, the second level of conformance to general morality is illustrated in figure 5.24. Sets named M, C and L stand for the moral, cultural and legal valid behaviors respectively. The elements of each set are named m, c and l, and stand for each of the types in table 5.24.

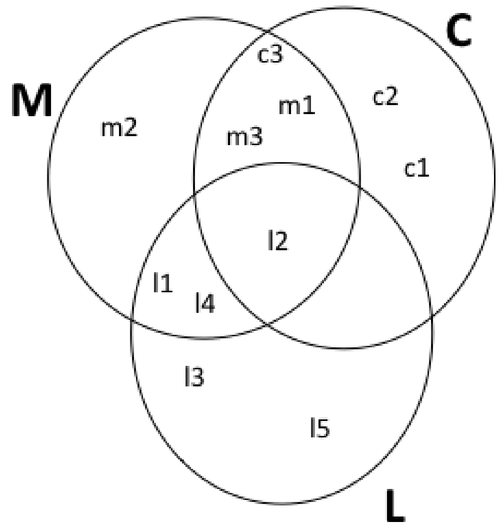

Figure 5.24. Illustration of the gap among morality, culture and law.

The ideal situation for an institutional arrangement, where rules in use coincide with formal ones and therefore sustainability outcomes have more opportunity to improve, would be when:

$$M \cap C \cap L = M \cup C \cup L \qquad (11)$$

In the water case study the intersections are:

$$M \cap C = m1, m3, c3 \qquad (12)$$

$$M \cap L = l1, l4 \qquad (13)$$

$$C \cap L = \emptyset \qquad (14)$$

and,

$$M \cap C \cap L = l2 \qquad (15)$$

the result of (15) is an indication of the gap among the three categories. The I2 (*To use water of the aqueduct for domestic use, but no for irrigation*) belongs to the realms of legal, cultural and moral valid behavior. There are no coincidences between cultural and legal valid behavior in any of the behavioral types, in contrast with the types that belongs to moral and cultural valid behavior at the same time: "*The household subsistence objective must be reached*" (m1), "*Formal rules and agreements are accepted in the discourse, but not always in practice*" (m3) and "*Actions are not always carried out explicitly: there are* *differences and often contradictions between the discourse and actions*" (c3). Regarding the coincidences of moral and legal valid behavior the types are: "*To pay the aqueduct fee on time*" (l1) and "*To maintain the springs free from livestock*" (l4).

Table 5.25 shows the type of players in terms of the reasons for rule breaking for this action arena. All the aqueduct users are considered rule breakers by conviction. This does not implies that all the time they are breaking the rules, the meaning is that people give more weight to their particular moral system than the formal regulation. There are also cheating players that are wealthy people that accumulates water.

Table 5.25. Type of players according to Mockus (1994) proposal

Type	Actor	Condition
Rule breaker by conviction	Aqueduct users	When n5 and/or m3 are met
Cheating player	Some users (wealthier)	When g4 is met

5.3.6 Summary of main findings of aqueduct system's institutional analysis

The institutional analysis carried out in this chapter allows characterizing the outcomes of the action situation of the water system case. In the experiment one of the outcomes is the contributions players make to the maintenance of the CPR. This contribution starts at 50% of the cooperative equilibrium but during the next rounds decreases until the 36% in the tenth round. The outcomes at individual level showed that A and B tend to contribute more than the rest located downstream. When players face rules there is a particular effect mainly in players located at position B and E. During the first stage players located upstream, positions A and B, tend to contribute more than the rest; average of the B position is close to 60% of the social optimum, and A is close to 50%. Participants in positions C, D and E contribute maximum 40% of the cooperative equilibrium. With the rules players in positions B and E increased their cooperation, this is that the main contributions to public infrastructure to produce water are distributed between the upper part of the channel and the tail end. The rotation rule has a specific effect. The symmetry of contributions changed completely; minor contributions are located at upstream and increased downstream. With this rule is remarkable the increase in contributions of players in position E; slightly more than 60% of the cooperation equilibrium. In summary what the property rights rule produces is an exacerbation of the pattern of the first part of the experiment, while the rotation rule generates a strong change in contributions symmetry.

Regarding the water extraction outcomes, the general pattern without rules, is a decrease of extraction from upstream positions to the end of the channel, being players in position A the ones who extract most of the resource. The rotation rule caused a significant decrease in resource appropriation, while the property rights rule reduced the differences in water extraction. In synthesis, the rules imply a tradeoff between efficiency and distribution among players along the channel; this is the decrease in efficiency in water production are compensated by earnings more equally distributed.

Rotation and quota or property rights rule where evenly elected among groups. Even the groups that played with the rotation rule, which do not have the possibility to cheat, produced a major decrease in the earnings: 24.6%. The groups that played the second stage under property rights rule had a 18% of cheating behavior, but their decrease in gains, with respect to base line, was much less than the other groups: 12.6%. This outcome is due to the relative improvement in contributions of groups under quota rule versus rotation rule that generated a bigger public good facilitating an increase in resource extraction, and the more equal distribution of resource appropriation

On the side of the RPG outcomes, there are two main findings from the interactions among participants during the game. First, the cooperation among participants to distribute water among veredas depends directly on the economic benefits players could have from that. Second, the plumber was identified as the character that better represented the behavior of the Aqueduct Council. This attitude is interpreted, as the general attitude towards rules of people of the region because finally they act according a local moral system not always in tune with the formal rules. This behavior in the RPG with the plumber is the result of the idea that the one who cares about the common resource is someone else different to the users.

Regarding the rule compliance in the aqueduct system there are two important insights. When someone is caught breaking a rule they apply an informal scheme of graduated sanctions instead of applying the formal rule. From interviews and RPG seems that the rules are applied differentially depending on the wealth of users. The surveys showed a low level of trust among the community: 0,53 compared to fishery village: 0.73, and forestry village: 0.63. This scenario produces low levels of cooperation reinforced by the low levels of trust among members of the community and across scales of water management system's governance.

In the conclusions of the geographical and historical context (chapter 4) there is one point that is explained by the institutional analysis. It illustrates the relation with the formal rules of the inhabitants of this region: A relation of adaptation, from indigenous and later the peasant *mestizo*, to the dominant power. This adaptive process implied strategies of daily resistance processes in which norms, rules and agreements are accepted in the discourse, but not in the practice. Several authors have documented this behavior in religious and social arenas, where traditional practices are hidden in the externally imposed behavior (Herrera, 2005). This relation has contributed to the construction of the moral system that underlies the action arena interactions and outcomes. That's why the aqueduct users are classified as rule breakers by conviction. This is the expression of a particular moral economy that they practice regarding the use of the resource. This is evidenced in the items belonging to moral and cultural valid behavior, and shared by both, in contrast with the few beliefs and moral valid behavior points shared by the legal valid behavior set.

5.4 Conclusions

I claim that the most important outcome of the action situation is the general level of morality conformance as a result of long-term institutional arrangements. Individual and collective moralities are fundamental for reaching or not high levels of cooperation and trust regarding common resources use and management. Cultural frameworks include morality as one of their elements to select, interpret and present information. Morality offers value judgments about what is morally acceptable or not about specific situations (Pahl-Wostl et al. 2008).

The fisheries case shows the biggest gap among morality, culture and law, which reflects a historic trend of formal illegality and lack of legitimacy of formal rules. This fact transforms the action arena in to a game in which the moral and cultural behaviors are valid, but not the type of behavior that follows the formal law. Therefore, rule enforcement and monitoring are only rare and external events that fishermen must avoid. In the forestry case the discourse of local activists does not coincide with the daily life practices of the population, in terms of the pretended ancestral collective use of the land. This fact makes difficult an effective process of institutional arrangements crafting that leads to conflicts among leaders of ACAPA. This is the partial cause of the deviation of some elements of the culture and moral domains from the legal valid behavior. This point constitutes an important factor affecting the institutions in the utilization of the forest and could be an indicator of the distance between mental models of inhabitants of ACAPA and the formal property regime regarding the territory. This dynamics gives clues about the problem in this action situation: weakly enforced rights, recent history of new property regimes and weak state institutions. In the water case the there are few types of behavior that are shared by the three behavioral domains; moral, cultural and legal. Here, again the historical trend of a colonial relation that ruled the interactions since the Spaniards arrival originated a particular type of interactions in the action arena that produced and continues generating a particular moral system as one of the most important outcomes. Therefore, the aqueduct users are classified as rule breakers by conviction.

Finally, I want to make a brief note on the analysis carried out of the cultural, moral and legal domains regarding the outcomes in each case study. A possible approach to the rule compliance solution is that cultural, moral and legal behaviors coincide and the gap among the three sets is very small. A more realistic vision is that each individual makes decisions as a result of a permanent tension among the three domains. The process could be a conciliating process among the three domains giving more weight to the options according to the particular action arena and interests at stake.

6 MENTAL MODELS

6.1 Introduction

A central issue in natural resource management and evolution of institutions from the perspective of complex adaptive systems is illustrated in what Holling et al. (2002) call the worldviews or myths about nature that people hold, which have implications on policies, institutions and decisions. These perceptions lead "*...to different assumptions about stability, different perceptions of the processes that affect that stability, and different policies that are deemed appropriate*." (Holling et al. 2002). Behavioural patterns of actors in natural resources use reflect values and preferences that drive decisions and levels of cooperation in a SES. The cognitive underlying aspects of values, preferences, objectives and actions associated to natural resources offer a rich perspective about the relation between agents and a SES, as well as relevant insights for policy design (Walker et al. 2006, Jones et al. 2011, Stone-Jovicich et al. 2011).

Walker et al (2006) remark the importance of mental models studies because they "*provide the framework for perceiving and judging the direction and desirability of system change*" (8), they state that "*mental models drive change in social-ecological systems, and adaptability is enhanced through partially overlapping mental models of system structure and function.*" (8). Ostrom (2005) stressed the relation between institutions and mental models regarding common pool resources, she uses an adapted version of the framework proposed by Denzau and North (2000), to explain the relationships between information, decisions and mental models, for explaining the central aspects of institutional analysis.

Research on mental models has focused on eliciting the structure of social constructs that permits access, at least partially, to the underlying reasons for specific problems in natural resource management. The relevance of mental models in SES governance has been linked to the possibilities of communication among stakeholders (Abel et al. 1998), the role of misperceptions of feedback from the ecosystem and regeneration rates of resources (Moxnes 1998, 1998b, 2004), social learning processes (Pahl-Wostl and Hare 2004), the role of heterogeneity of mental models among actors (Ostrom 2005, Poteete et al. 2010), and its importance as drivers of desired change, adaptability and ideas about stability in SESs (Walker et al. 2006).

Experimental economics has contributed to understand what are the important variables and conditions that foster cooperation in common pool resources (CPR) use. CPR experiments have shed light on appropriation and provision problems identifying factors such as communication, endogenous rule crafting, and low and graduated sanctioning among others, as relevant for improve cooperation (Ostrom et al. 1994). Traditional experimental economics and behavioral sciences recognize the need of mental models study: Vernon Smith (2008) remarks the fact that experimentalists interpret decisions of subjects, in experiments, as if they think with the same logic of game theory, in brief that "*the subjects reason like economists*." He urges to study mental models and explanations of experimental economics data assuming that people do not think, represent and process information as economists think. Camerer (2003) calls for new directions in the research on decision making: "*Theorist analyze games in the form of matrices or trees but players presumably construct internal representations that might barely resemble matrices or trees*" and he poses questions for future research "*What do mental representations of games look like?*" While CPR experimental economics field offers generalizations about factors and conditions under which agents could generate patterns of behaviour that favour cooperation, mental models inquiry is contextual and idiosyncratic, and provides explanations for behavioural patterns in specific case studies.

The fundamental problem I intend to address in this research is the cognitive problem underlying common pool resources dilemmas in SESs. The aim is to link local context, institutional arrangements and mental models in order to explain decision making of resource users. The general research question is what are the relations between mental model of resource users and the institutional and ecological landscapes they face. I want to explore the hypothesis that the combination of these bodies of conceptual and practical tools, experimental economics and mental models studies, produces explanations for decision making in SESs.

The concept of mental models is useful in approaching cognitive structures and processes underlying decisions of actors in a SES. Scholars from different fields, such as cognitive sciences, political science and system dynamics, have provided a variety of definitions of mental models (Craik, 1943, Axelrod 1976; Gentner, and Stevens 1983; Johnson-Laird 1983; Senge 1990; Morgan et al. 2002). Sterman and Booth Sweeney (2007) define a mental model as often implicit ideas about the "*networks of causes and effects that describe how a system operates, along with the boundary of the model (which factors are considered endogenous, exogenous, or immaterial) and the time horizon considered relevant*." (Sterman and Sweeney 2007, 215). Holland (1986) recognizes the main characteristics of mental models mentioned by several authors:

> "*A useful general definition of mental models must capture several features inherent in our informal definitions. First, a model must make it possible for the system to generate predictions even though knowledge of the environment is incomplete. Second, it must be easy to refine the model as additional information is acquired without losing useful information already incorporated. Finally, the model must not make requirements on the cognitive system's processing capabilities that are infeasible computationally*." (Holland et al. 1986, 30).

In this research I use the following operational definition: A mental model of a given system is composed by a set of variables and relations among them, that allow people to carry out mental simulations, evaluate outcomes, and make decisions that affect the system, as well as building assumptions about stability of the system. The objective of a mental model is to transform external information into decision outputs. What is in the middle of the two can be seen as a black box, but also as something called "*the processor*" (Kim, 2009). But the representations of mental models are not exactly the processor (Weick, 1990), instead they are constructed from individual or collective observable discourses or behaviours that reflect partially the processor. The assumptions about the nature of the mental model that analysts make, are a function of the elicitation and representation methods (Kim, 2009). It is important to give the definition of collective mental models used in this study as well. Terms like cultural models, shared mental models and collective mental models refer to the degree of shared understanding in a group of people. The organizational researchers use also the term team mental model referring to the same notion (Jones et al., 2011). In this dissertation the term collective mental model is defined as a relatively shared representation of a system by a group of people, which is composed by the individual mental models of the group members. The following quote express accurately the importance of collective mental models in this dissertation: *"The expansion of mental models research from an individual to a collective focus stems from a growing recognition that there is a social component to cognition at the individual level, and that decision making occurs at a range of scales from an individual to group to societal level"* (Jones et al., 2011). I make two assumptions about the collective mental models. The first is that a collective mental model not only is built through a social process, but generates different social processes as well. Second, a collective mental model is a collective phenomenon that differs from individuals' mental models. When the method of collective mental model elicitation is a group workshop, such as the RPG, the resulting mental model structure can be understood as a negotiated belief structure. This resulting structure is the product of and also is used for a political process of negotiation and influence. Negotiation occurs in group, but also there is a considerably influence by individual mental models of powerful participants when negotiated belief structures are constructed (Walsh et al., 1988).

In the realm of natural resources management, the notion of mental models has been used in natural resource management by Moxnes (1998, 1998b, 2004) in the study of reindeer and fisheries decision-making and management in Norway. The author used experiments based on system dynamics models to collect players' decisions, and infer mental models of participants from experimental data. Sterman and Booth Sweeney (2007), and Sterman (2008) studied public understanding of global warming process, eliciting mental models of people from data collected from questionnaires based on future scenarios of global warming gas emissions. Abel et al. (1998) studied the role of mental models in communication among researchers, extension officers and pastoralists about resources management and ecosystem's functioning in Australian rangelands. They used interviews and content analysis to create causal diagrams as representation of mental models. Ozesmi and Ozesmi (2004) proposed a methodology to elicit cognitive maps and build ecological models based on people`s knowledge. With these maps the authors used neural network computation to produce scenarios based on diverse policy options for ecosystems management. Becu (2006) in a research about the local management of watersheds in the north of Thailand used content analysis of interviews and Playable Stories to formalize a collective representation of the watershed system. Dray et al. (2006) presented a methodology to understand and merging stakeholders' mental models to produce a shared representation of the groundwater system in the Atoll of Tarawa in the Republic of Kiribati, in order to build a computer assisted role-playing game. The authors used individual interviews and content analysis to create associative networks of concepts and relations, to produce a common ontology, and finally build a unified modeling language (UML) class diagram to represent a formalized version of the common mental model. Stone-Jovicich et al. (2011) and Mathevet et al. (2011) carried out research on the level of sharing of mental models among relevant stakeholders regarding water management in a watershed in South Africa, and the Camargue Biosphere Reserve in France respectively. These studies combined consensus analysis (Romney et al. 1986) and the ARDI method (Ettiene et al. 2011) to understand mental models and assessing the level of heterogeneity among actors.

The purpose of this section is to understand the structure of mental models of SES' users that participated in the RPG and interviewees. In this way I can build hypotheses regarding their understanding of the cooperation dilemma they face in the experimental setting and daily life. The importance of this question has to do with the question about how the participants conceive their action situation, and what kind of model they utilize to evaluate the potential outcomes, assuming that participants' evaluative criteria are embedded in the individual and collective mental model. Therefore, collective mental models could explain the behavioural patterns produced by their decisions in economic experiments.

Mental models were studied in the following way. After the experiments a series of semi-structured interviews with key informants that participated in the experiments were carried out. Once the recorded audio of interviews were translated into a word processor, I proceeded to an open coding process and the construction of associative networks of concepts and relations that allowed to create causal diagrams that represents the mental models of interviewees. The method was inspired by the following studies: the cognitive mapping from interviews, proposed by Axelrod (1976), Abel et al. (1998), Ozesmi and Ozesmi (2004), and the content analysis and coding method suggested by Dray et al. (2006), applying grounded theory development concepts and techniques (Strauss and Corbin 2007, Coffey and Atkinson 1996).

This chapter starts with a description of the common methodology used in each case study, following by the results and analysis for each one. Next, the results are presented followed by a discussion. First, for each case study, I present the individual mental models and then the collective mental models product of the analysis. Each case is composed by three sections in which I discuss the results of the case studies mental models analysis. For each village, first I show the number of variables and interviews used for the construction of each individual mental model. I continue with an illustration of one of the individual mental models, followed by the explanation of the collective mental model including the role playing game (RPG) activities as one of the sources for the analysis. After that I provide an interpretation of the mental models constructed for each case and its relation with the SES' context. And finally, the relation between mental models and institutional arrangements is discussed.

6.2 Methodology

The modeling of a mental model can be expressed by distinguishing the target system (t), a conceptual model of the system from the researchers' perspective, C(t), and the user's mental model of the target system, M(t). It is fundamental to have into account that the researcher builds a mental model (C) about the mental model of a given individual M(t), therefore the result is C(M(t)) (Norman 1983). A mental model has predictive power, which is rooted in the idea that the objective of any mental model is to permit understanding and anticipation of the behavior of a given system; in other words, it should be possible for people to "run" their models mentally. Norman (1983) gives a methodological important advice for investigating and modeling mental models: getting much more reliable information depends on how researcher elicits information. Generally, when people are asked directly for explanations about actions, decisions and behavior, they give answers according to their mental models about researcher's expectations, therefore is much more reliable to ask persons to describe activities rather than explanations. This suggestion was applied when field interviews were carried out and complemented by Abel et al (1998) guidelines for interviews. It is important to stress the underlying idea of the approach followed in this research. Since a mental model is construct used in decision-making, its complexity goes beyond quantitative data, and its main source of information is the "Mental Data Base" (Forrester 1980) of people, therefore the analytical approach is qualitative and relies in the content analysis. A mental model is theory in itself therefore I used the grounded theory approach (Coffey & Atkinson, 1996; Corbin & Strauss, 2007) to unveil its structure and to capture its complexity.

The methodological approach is composed by six phases: i) elicitation of mental models, ii) the content analysis and coding of transcripts of interviews and different type of workshops, iii) definition of variables and relations, iv) building of the networks of concepts aiming to represent individual and collective mental models, v) formulation of hypothesis, based on mental models, about behavior, and finally, vi) an assessment of the hypothesis through comparison with experimental data.

6.2.1. Elicitation of mental models

The term elicitation is used here to refer to the process of acquiring the information and data for the further construction of mental models. Three instruments were utilized to elicit individual and collective mental models: the collective construction of role games, the implementation of role games, and the semi-structured interviews with natural resource users. The definition of mental models proposed above implies that they always are built and work regarding a specific topic, therefore their study, in this case, was referred to rules, resource dynamics, territory, governmental and NGOs agencies, and social organization. All the activities were recorded with a voice recorder and a video camera.

1. *Workshop 1: Feedback and discussion of experimental results.* The discussion about experimental results with participants in the experiments had also the objective of

eliciting the relevant variables and relations for participants in the experiments as well as their rule preferences.

2. Workshop 2: RPG collective construction. During this activity participants made modifications to the experimental design following an agenda proposed by facilitators. The discussion dealt with the representation of the resource, the decisions that players must make in the role game, the market, the rules of the game and the roles. The discussion about each one of these topics contributed to elicit important variables, relations and dynamics regarding the use of the resource and formal rules as well as rules in use. This activity lasted two days of collective work.

3. Workshop 3: RPG Implementation. The participants in the construction of the role game invited other villagers to run a session of the game. In contrast to the water case that was characterized by the absence of external actors, in fishery and forestry cases, representatives of the local and regional environmental authorities were invited to play in the session. In the RPG communication was possible, therefore players expressed their points of view and discussed key issues of resources use.

The knowledge elicited through these three workshops was used to build the collective mental model of the group of users in each case study. The assumption was that discussions about representations of the natural resource system, and the task of improve such representations worked as effective indirect knowledge elicitation tools. The public discussions on the different aspects of the resources use not only led to consensus about the final representation of each issue, but also contributed to understand their collective beliefs about different aspects of the SES.

4. Individual interviews. Individual semi-structured interviews were carried out with ten key informants in each site. The interviewees were local leaders and lay resource users. These interviews took place in two different moments of the research. The first five were carried out after the experimental sessions, and the rest before the RPG activities. Each interview lasted in average thirty minutes. The first group of interviews was focused in rules, collective action, level of dependence of the resource, and resource maintenance. Another set of interviews were carried out one year later and were focused in ecosystem dynamics, actors involved in natural resource management, social organization and rule dynamics. The questionnaire was carefully designed to elicit relations and variables by asking for descriptions of activities and "what if…" questions following Normand (1983) and Abel et al (1998).

The concrete result of the elicitation process is a data set generated in with the tools described above. This information is converted in word processor files that are imported into the software for content analysis.

6.2.2. Content analysis for mental models construction

The first step was to transcribe the digital voice recordings of: the feedback workshop, the building and the role game testing workshops, and the interviews. The transcriptions were carried out keeping exactly what interviewees said. Next the text was analyzed using software for qualitative data analysis (ATLAS.ti®) (Muhr, 2010). This analysis is the core of the methodology, which consists in the coding process. The analysis is based on the concepts and methods of the grounded theory, defined as a method to develop theory from systematically collected data and analyzed in a research process. The fundamental concept is that the theory emerges from the empirical data; with this approach it is more probable that grounded theories provide knowledge and understanding highly pertinent for guiding action (Corbin and Strauss 2007). The notion of theory used here is that a system of relations and variables allows understanding a phenomenon and making predictions about potential behavior of the system. Therefore, I followed the coding process, the core method of grounded theory, to build theory instead of testing it (Corbin and Strauss 2007) as a mean to construct mental models.

This type of analysis, following Tesch (1990), is a process of de-contextualization and re-contextualization. De-contextualization implies to take data off the context of the field interview in a given environment with certain particularities, these transformations occur when I transcribe the interview and it becomes a text in order to find a new sense by discovering what lies behind that text.

The interview now is a function of a conceptual framework, meaning that the content of the interview is analyzed in the light of the mental models' conceptual framework. This is that the task is the search of variables, causal relations among them, and time delays among cause and effect. In this sense is that the re-contextualization occurs.

The process is carried out to infer the mental model that lies behind the discourse of each individual.

The coding process is a form of making relationships between data and researcher's ideas about them. The codes are links between data and concepts and ideas, and in this sense the codes are heuristics mechanisms (Coffey and Atkinson 1996). Codes are labels to assign meaning units to the descriptive or inferential information collected during a study. The codes are placed besides information chunks of several sizes. These information fragments are words, sentences, or entire paragraphs. Codes can take the form of a direct or complex category (Miles and Huberman 1994). Seidel and Keelle (1995) describe the codification process as an analytical strategy that has three types of operations:

1. To identify relevant phenomena
2. To sample instances of these phenomena
3. To analyze these phenomena in order to find similarities, differences, patterns and structures

The strategy is not the simple data counting process, instead, is a code allocation process to identify and re-organize information, while posing questions and interpreting the data.

The building theory process has three moments that lead to different outcomes: *description*, *conceptual organization*, and *theory formulation*. In order to illustrate the process I use an extract of an interview. The extract is taken from an interview with a fisherman from Baru village (fisheries case study) translated to English from the original carried out in Spanish. The underlined words and phrases in the quote below correspond to the in vivo codes. After the quote I show the different codes that emerged from this extract.

> "*To me there are enough rules, <u>I think the rules, as they are now, are fair</u>, and if people follow the rules, I think tomorrow <u>we could survive</u> better, maybe not us, but <u>our sons will have a better future</u>* […] *I think if there are <u>alternatives</u> for taking them* [fishermen] *out of the Park for extraction or other activities, and give them a better opportunity <u>decreasing the impact that we are causing</u>, I think that the Park could recover. But if there is no that option for decrease that impact, the Park never*

will recover […] <u>*If we, fishermen, are offered with another work opportunity different from fishing*</u>*, then we could contribute to the preservation* ”

The *description* is the basis of more abstract interpretations of data and theory construction. It consists in an inductive procedure that relies on open coding process, which consists in the allocation of concepts to the ideas expressed in the text. The in vivo coding is part of a very first step of open coding. This coding refers to a procedure where the terms are derived from the language of the interviewees (Coffey and Atkinson 1996). This is the first approximation to variables of mental models. Labels taken from the interviewee exact wording are used to assign more abstract concepts to groups of these in vivo codes. The resulting concepts are the first version of variables. The next sentences are examples of in vivo codes:

(1) *I think the rules, as they ere now, are fair*
(2) *we could survive*
(3) *our sons will have a better future*
(4) *If we, fishermen, are offered with another work opportunity different from fishing, then we could contribute to the preservation*
(5) alternatives
(6) decreasing the impact that we are causing
(7) impact

The *conceptual organization* aims to build categories of concepts according to their properties and dimensions. In this stage the data source are the set of codes produced in the description part, as well as the quotes linked to them. Then, a process of axial coding is necessary, which consists in the process of relating each category to its sub-categories. Therefore the exercise occurs along the axis of each category and looks for relationships between them (Corbin and Strauss 2007). Assigning to what type of mental model belongs each group of categories, for example the concept “Rule compliance” is part of the mental model of one individual about resource management rules. This is a category that groups several concepts found in the open coding, and have been conceptualized as variables of the mental model. In the example the “Rule compliance” is a variable that includes the concept of “Legitimacy of rules”, which becomes a variable of the mental model as well.

(1) *I think the rules, as they ere now, are fair* (in vivo)

Legitimacy of rules (sampling of the phenomenon)

Rule compliance (analytical code)

The following example illustrates examples of in vivo codes that help to describe a phenomenon such as “Future quality”, not only in this interview extract but also in several interviews.

(2) *we could survive* (in vivo)

(3) our sons will have a better future (in vivo)

Future quality (phenomenon and analytical code)

The codes (4) and (5) show how in vivo and an instance of a phenomenon leads to a couple of variables or analytical codes. It is important to remark that the code “Extraction” in this extract does not appears explicitly in in vivo codes or in the part of the interview showed above, but it aggregates a number of elements (quotes, and different types of codes) that inform this variable through several interviews of the three case studies.

(4) *If we, fishermen, are offered with another work opportunity different from fishing, then we could contribute to the preservation* (in vivo)

(5) alternatives (in vivo)

Productive alternatives (analytical code)

Extraction (analytical code)

Finally, the codes (6) and (7) illustrates that codes are nested from an abstract concept (Resource) to direct in vivo components.

(6) *decreasing the impact that we are causing* (in vivo)

(7) impact (in vivo)

Park recovery (analytical code)

Preservation (analytical code)

Resource (analytical code)

Next, the analysis focuses on the search of relations among variables that emerge from the open coding as well. This process requires special attention to the sentences, phrases, or paragraphs of interest, which are the ones that express a causal relationship. It implies, while coding, to have permanently in mind the structure: cause concept / link / effect concept. The procedure requires also distinguishing the type of verbs that the interviewee is using in order to determine the type of relation the individual is expressing. Most of them are positive or negative causal relationships, but also could be probability relations. When the person uses verbs like should, must, will have to, and others that express desire, the relation is not a causal assertion, meaning that not necessarily the interviewee thinks there is a cause-effect link (Tucker Wrightson, 1976). The consequence is that not all the interviews produced causal assertions; in fact there are entire interviews that did not produced a mental model in each case study.

The *theory formulation* stage constitutes the final outcome of the process that allows explaining and predicting structures and patterns. The mechanism is the selective coding, which is the process to refine categories, sub-categories and relations among them. This exercise leads to a theoretical saturation point in the category construction in which there are no more emergent properties, dimensions or relations. A causal diagram, using Vensim software, graphically represented each mental model. The figure 6.1 shows a section of an interview with a fisherman from Baru village (fisheries case study). Figure 6.2 illustrates the axial coding process explained above that looks for relationships among analytical codes.

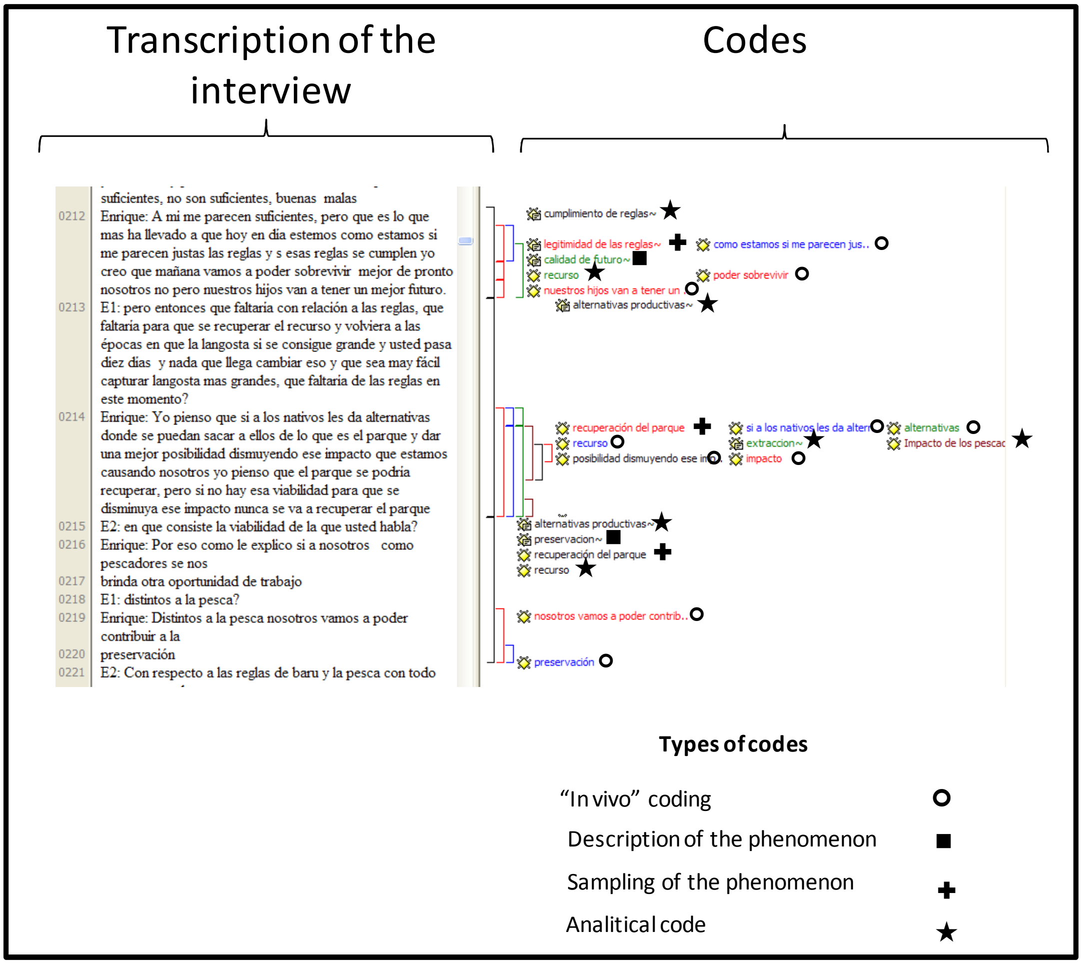

Figure 6.1 Illustration of part of an interview after the coding process in Atlas.ti software. The left part of the figure shows the transcription of the interview. The right side shows the coding that corresponds to specific parts of the text. The result is that each code has a quote. The codes correspond to the three types: description of a phenomenon, sampling of the phenomenon and analysis in order to find differences, patterns and structures. Additionally, some of the codes have comments made by the analyst.

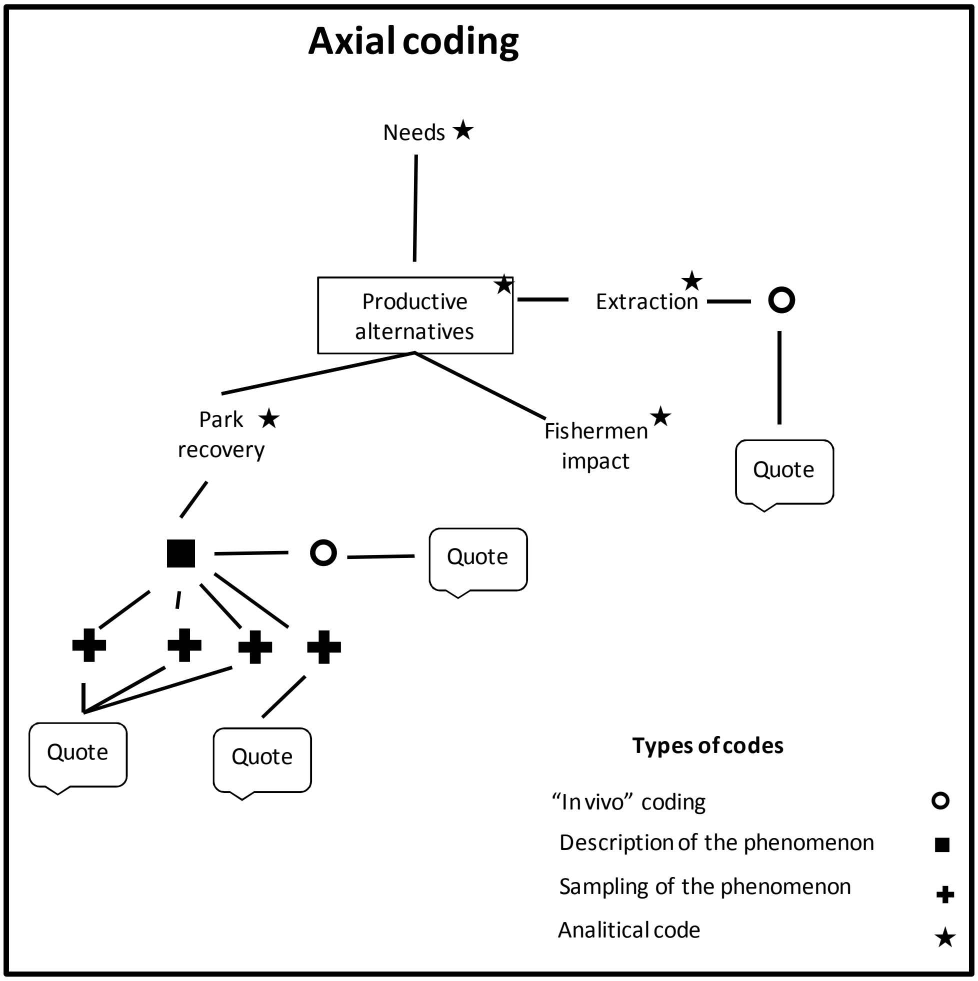

Figure 6.2 Axial coding process. The axial coding is represented in this scheme by using symbols and some codes names. The in vivo codes (circles) are the sources of analytical codes (stars). In vivo codes, in turn, emerge from paragraphs of the interview (Quote). Analytical codes often contain categories or concepts (that could become variables) that describe the phenomenon represented by the code. These are represented by black squares in the figure. These codes could be present in in vivo codes. These analytical codes that represent the description of a phenomenon (Black squares) could be linked to codes that represent instances (ideas, situations etc.) of this phenomenon (Crosses). These codes (Crosses) emerge from quotes of the interview.

The figure 6.3 shows the variables and relationships among them that form an individual mental model and the way that quotations explain the relations among them. For the example of the extract of the interview; the relation among three variables is the more "Productive alternatives", the less "Extraction", which in turn has a negative effect on the

"Resource"; the more "extraction" the less "Resource". The quote that supports this relation in this part of the interview is:

> *"I think if there are alternatives for taking them* [fishermen] *out of the Park for extraction or other activities, and give them a better opportunity decreasing that impact that we are causing, I think that the Park could recover. But if there is no that option for decrease that impact, the Park never will recover* […] *If we, fishermen, are offered with another work opportunity different from fishing, then we could contribute to the preservation "*

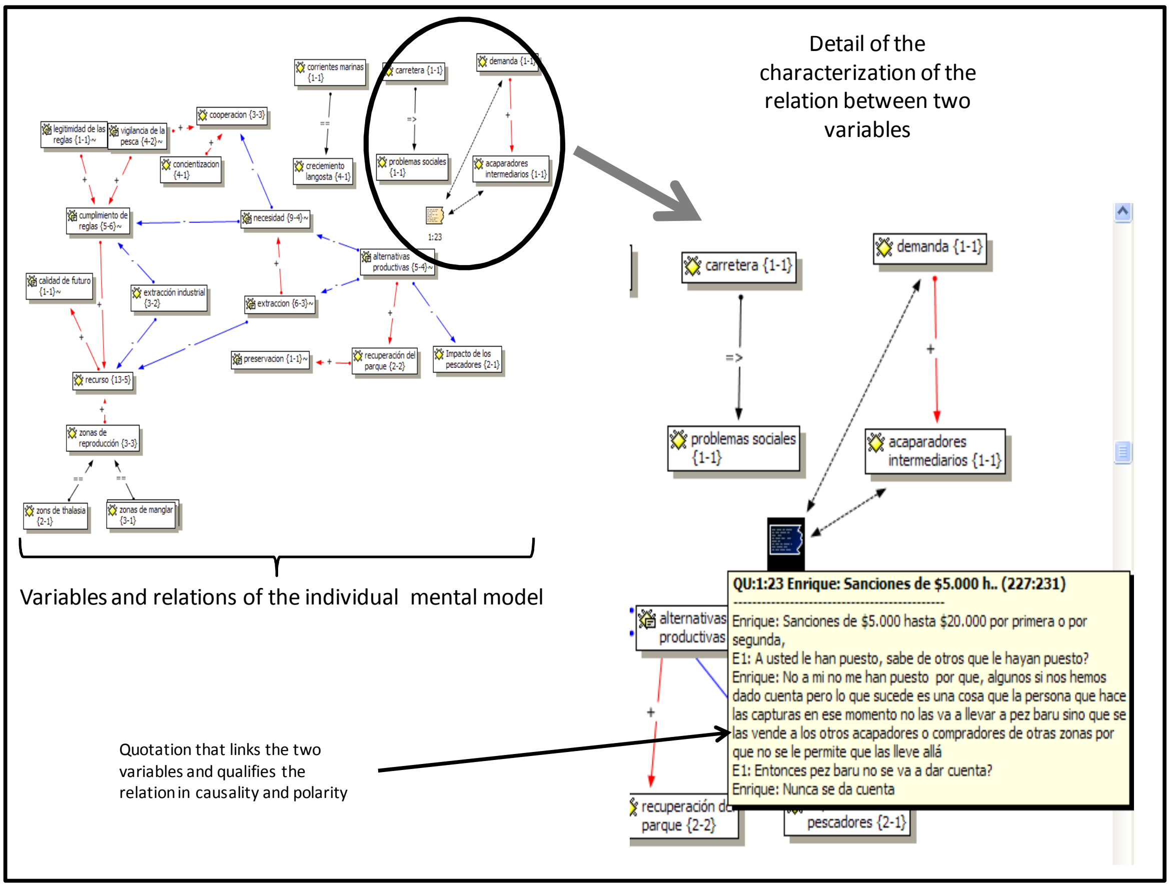

Figure 6.3 Variables and relations that form an individual mental model.

6.2.3. Network analysis and the building of the collective mental model

Once the variables and relationships were defined for individual mental models a symmetric matrix was built for each one with the information of links between variables. These matrixes were analyzed using the network analysis software Ucinet (Borgatti, Everett, & Freeman, 2002). The analysis was performed to have a better understanding of the mental models structure. Two measures were calculated: degree centrality and betweenness centrality (Freeman, 1979). The first is defined by the number of connections a node has. And the second is the operation of weighting the number of pathways that run through a node. This is an indicator of the intermediary position of each node; meaning that the nodes with higher values of betweenness are very important in the network structure because they control the most relevant communication flows (Webb & Bodin, 2008). A graph of the network showing the degree for each variable was produced to know the important regions of the network. In and out degree centrality were calculated to know the influential (out degree) and dependent (in degree) variables of each model. The variables with higher values were selected as the more influential or independent, and dependent ones. Once identified these variables in the causal diagrams, they were used to produce cause and effect trees with a facility of Vensim software (Ventana Systems, Inc., 2010).

The collective mental model for each case study was built by adding the individual models and including a new model for the variables and relations elicited from the transcripts of RPG activities and the feedback workshop. A core structure of the collective model was defined with the variables that had the highest total degree and betweeness values, and relationships that were present in more than one mental model. Finally the variables and links generated in the collective activities were included as part of the collective mental model because they were product of participants consensus in the group activities. The result of this process is a diagram and an explanation about the variables and cause-effect relationships that give an approximation about the logics, motivations and structures behind the decision-making.

6.2.4. Discussion about behavior according mental models, and comparison with behavior in economic experiments

The collective mental model obtained in the previous step was used to qualitatively formulate behavioral hypotheses about the decision patterns in experiments. Decisions during the final implementation of the RPG were used as indicators of the functioning of these mental models in terms of players' decisions.

Experimental data was examined by session and by individual looking for patterns that allowed to define a typology of players in terms of different levels of cooperation using extraction, contributions, and rule compliance decisions. Experimental data also was used to derive other kind of indicators related with perception of the resource, trust, property and others by examining individual survey information.

6.2.5. Relating mental models finding with institutional arrangements and SES' context

The mental models contribute to find relevant variables in terms of intermediation and degree for the decisions of common pool resources users. These findings are related with the action situation outcomes (Chapter 6) and the context of each case study (Chapter 3). For example in a given case study, rule compliance is relevant in terms of degree and intermediation, and extraction decision depends on the opinions about rule compliance, which in turn is shaped by a particular morality system and trust level, product of the action situation. This situation has a more deep explanation in the particular context of colonization and relationships with the government. At the end, the usefulness of the approach points to management strategies, and the lessons are in how to influence or manage those central variables having into account the rest of explanatory elements of collective mental models and the particular relation with institutional arrangements.

The final analysis is a comparison between the collective mental models of each case study looking for regularities, in order to establish patterns in mental models of common pool resource users, and institutional arrangements. For the three cases, only one of the individual mental models is explained and the rest are in annexes. The focus of the Chapter are the collective mental models of each case.

6.3 Fishery case: Fishing is a matter of justice

The mental models of the fishery case study where build from the analysis of five interviews and experimental results' discussion workshop, co construction of the role playing game (RPG) and the RPG playing session.

6.3.1 Fishermen mental models

The content analysis of each individual interview, explained above, produced a number of variables and relations among them about rules and CPR use. The number of variables important for each individual varies due to factors such as personality, synthesis capabilities and knowledge about the topic of the questions. Figure 6.4 illustrates the number of variables defined in each interview. Individual mental models have a range between 16 and 22 variables. In average the emergent variables by interview are 19 with a standard deviation of 2.58, which indicates a relatively low level of variation in the number of variables produced in the content analysis of the interviews. This fact also could indicate a moderate level of homogeneity among interviewees' knowledge about the topics asked. From this information five individual mental models were constructed. In the next section I explain in detail one of them because the most relevant part of the analysis is done with the collective mental model that is illustrated further in the Chapter.

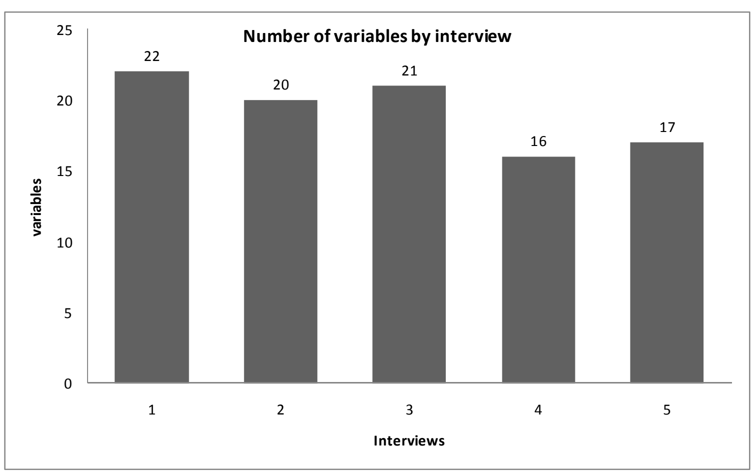

Figure 6.4. Number of variables by interview. The X axis shows each interview labeled from interview 1 to interview number 5. The Y axis represents the number of variables that emerged from each interview.

Mental model 1 (MM1) Productive alternatives oriented

The mental model build from the first interview (Figure 6.5) has 22 variables. Figure 6.5A portraits the causal diagram of the model. The arrows indicate the relation among pairs of variables. The red arrows represent positive causal relations. The arrows have a plus symbol besides in one extreme, meaning that a variation in the cause variable produces a change in the consequence variable in the same direction. This is, an increase in X produces and increase in Y, or a decrease in X produces a decrease in Y. The blue arrows with a minus symbol represent a negative causal relation. This is, if the variable X increases, the Y variable decreases, and also if X decreases, X increases. Black dotted arrows represent relations different than causal. The resource variable is affected positively by rule compliance and the area of reproduction zones. Industrial extraction and artisanal fishing (extraction) affect negatively the resource, which in turn affects positively the quality of the future of the village. The more monitoring, the highest rule compliance. Rule legitimacy affects positively rule compliance. On the other side, the higher the level of needs, and the more industrial extraction imply less rule compliance. The level of cooperation is influenced positively by monitoring and awareness of fishermen, and negatively by the level of needs of fishermen households. These needs affect positively the levels of extraction, meaning that the more needs, the higher extraction. Productive alternatives are a strongly influential variable. The increase in other sources of income represented by this variable generates a decrease in household needs, fishing (extraction) and the impact produced by fishermen on the ecosystem. In turn, this increase contributes with the Park recuperation that generates more conservation of marine resources. The demand of marine products triggers the increase of middlemen. And the transport infrastructure could bring social problems to the village.

As a result of the network analysis (Figure 6.5B) the variable resource has the highest degree followed by rule compliance and productive alternatives. Cooperation, needs, Park recovery and extraction are important variables but their degree is lower. The Table 6.1 shows, on the first column, the influential variables, which are the variables with the highest values in out degree, meaning that they have are more relations that goes out from them towards other variables in the model. The more influential variable in this model is productive alternatives. The central column shows the variables with higher scores of betweeness. This measure indicates the centrality of the variable in the model and its strategic position in terms of being, at the same time, cause and effect in several causal chains. In this case the variable resources has the highest value of betweeness. The right column of the table shows the variables with higher in-degree scores, meaning the variable with more in coming relations. This measure indicates the degree of dependence of a variable in a model. In this case the more dependent variable is resource. Therefore, the most influential variables of the model are productive alternatives, monitoring, needs and rule compliance (Table 6.1). Figure 6.6 illustrates the influence of these the variables in the rest of the model. Variables classified as dependent (Table 6.1) are influenced according to the causal tree illustrated in the figure 6.7.

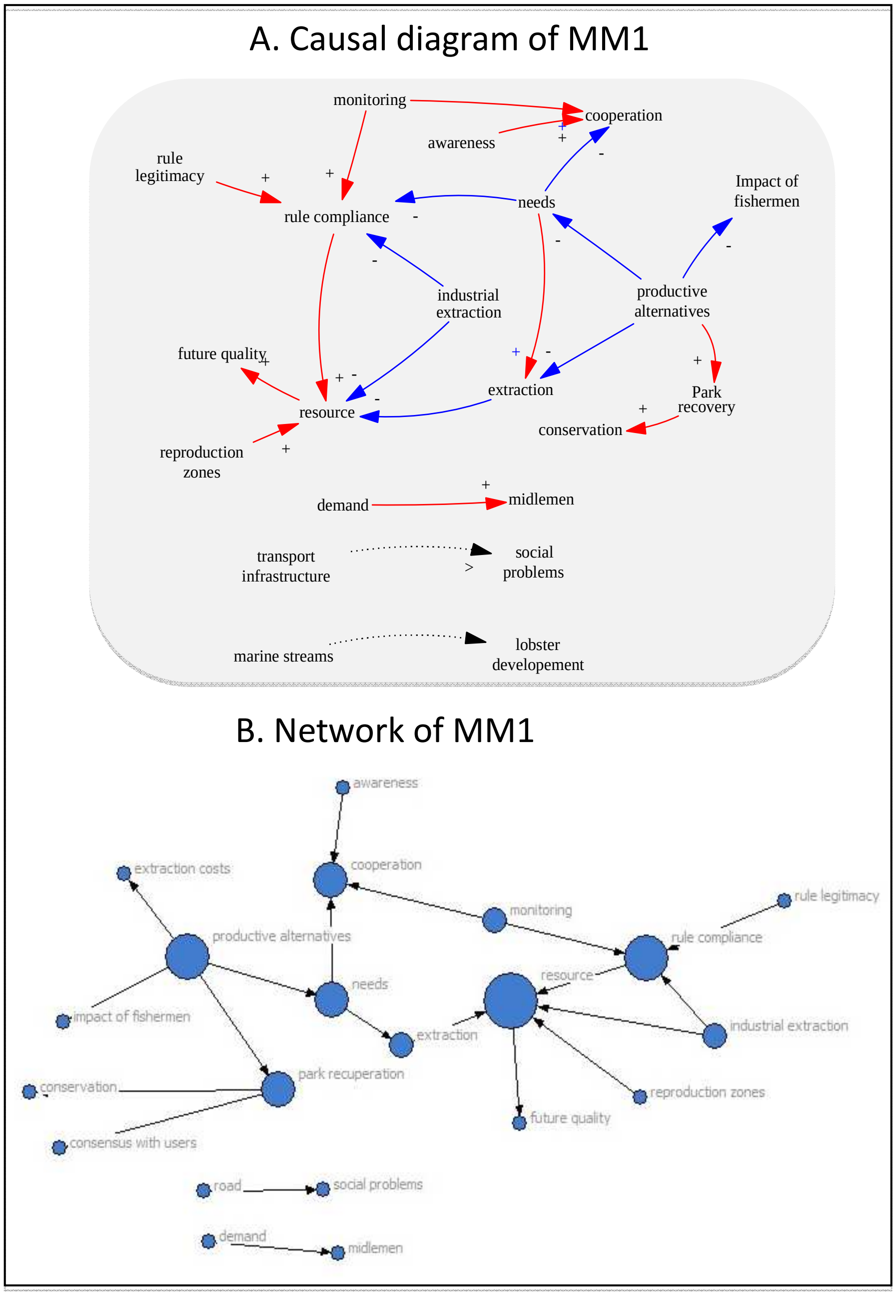

Figure 6.5. Causal diagram of the mental model 1 (MM1)

Table 6.1 Variables ranked according degree and betweenness centrality measures for MM1.

INFLUENTIAL VARIABLES	Out Degree Value	INTERMEDIARY VARIABLES	Betweenness Value	DEPENDENT VARIABLES	In Degree Value
productive alternatives	5	resource	8	resource	6
monitoring	4	rule compliance	4	rule compliance	5
needs	3	extraction	4	cooperation	5
rule compliance	2	needs	4		

With the individual mental models and the information from RPG workshops, an integration of variables and relations was done. This integration constitutes what I call a collective mental model (MMC), which is explained in the following section.

6.3.2 Collective mental model (MMC) of the fishery case

The collective mental model (MMC) has been built including all the variables present in the individual mental models in addition to the variables and relations elicited during the collective workshops. Figure 6.6 and 6.7 shows the variables present in the five interviews and their distribution by interview. Household needs and resource variables are present in the five MMs. Seven variables are present in four interviews, five variables are present in three, ten appeared in two interviews and twenty eight appeared only in one interview. Extraction and rule compliance was mentioned in four interviews. Many of the variables mentioned in individual interviews were confirmed in the workshops, as well as new important variables emerged during the RPG activities such as long and short term cooperation, and rule creation potential. The figure 6.10 shows the complete causal diagram of the collective mental model. Variables and relations in grey color indicate that these elements emerged in the RPG.

Variables of the fishery case mental models

1 Needs
2 Industrial extraction
3 Transport infrastructure
4 Rule compliance
5 Productive alternatives
6 Extraction
7 Tourism
8 Governmental corruption
9 Middlemen
10 Organizative capacity
11 Governmental efficiency
12 Fishermen from other villages
13 Resource
14 Other sources of income
15 Fishermen
16 Awareness
17 Monitoring
18 Park recovery
19 Shore closeness
20 Economic wealth
21 Demand
22 Boats
23 Harmful extraction technologies
24 Over extraction
25 Cultural consumption
26 Cooperation
27 Reproduction zones
28 Long term cooperation
29 Training
30 Physical security of fishermen
31 Bandits
32 Cultural use of technology
33 Age
34 Political influences
35 Differential law enforcement
36 Local leaders corruption
37 Noise
38 Rule legitimacy
39 Employment
40 Community benefits
41 Rule compliance
42 Conservation
43 Level of conflicts
44 Police and surveillance
45 Future quality
46 Consensus with users
47 Income
48 Extraction costs
49 Denounce
50 Local emigration
51 Successful collective action
52 Fishing problems
53 Social problems
54 Rule creation potential
55 Short term cooperation
56 Impact of fishermen
57 Uncertainty of the activity
58 Potential to reach agreements

Figure 6.6 List of variables included in the fishery case study.

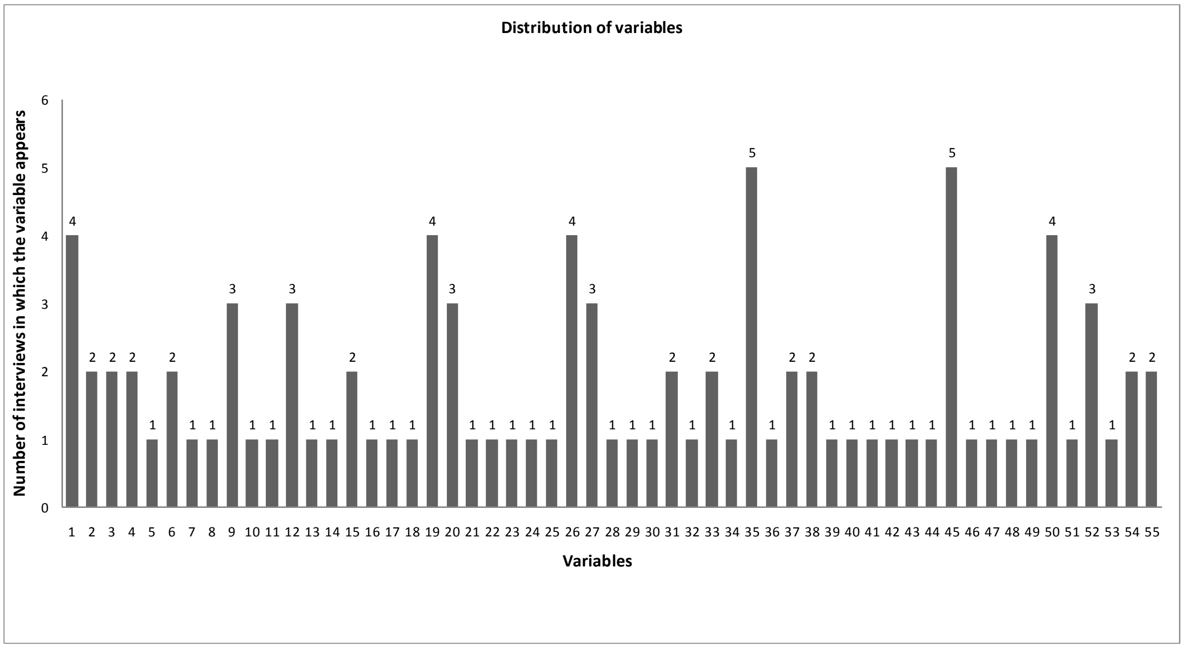

Figure 6.7 Distribution of variables among the individual mental models.

From the network analysis to the MMC it was possible to understand the general structure of the model. The figure 6.9 shows the variables and relations network where the variables are represented according to their total degree value, and the relations are represented by thin and thick lines; where thick lines show the relations common to more than one individual mental model, and thin lines are the relations coming from only one individual mental model. From this diagram is possible to see the central structure of the model, meaning the shared elements by more than one individual model. In this view is possible to appreciate the importance of the variables rule compliance, household needs, resource, and artisanal and industrial extraction, and their interconnections. I call this portion of the model the core structure of the MMC (Figure 6.10).

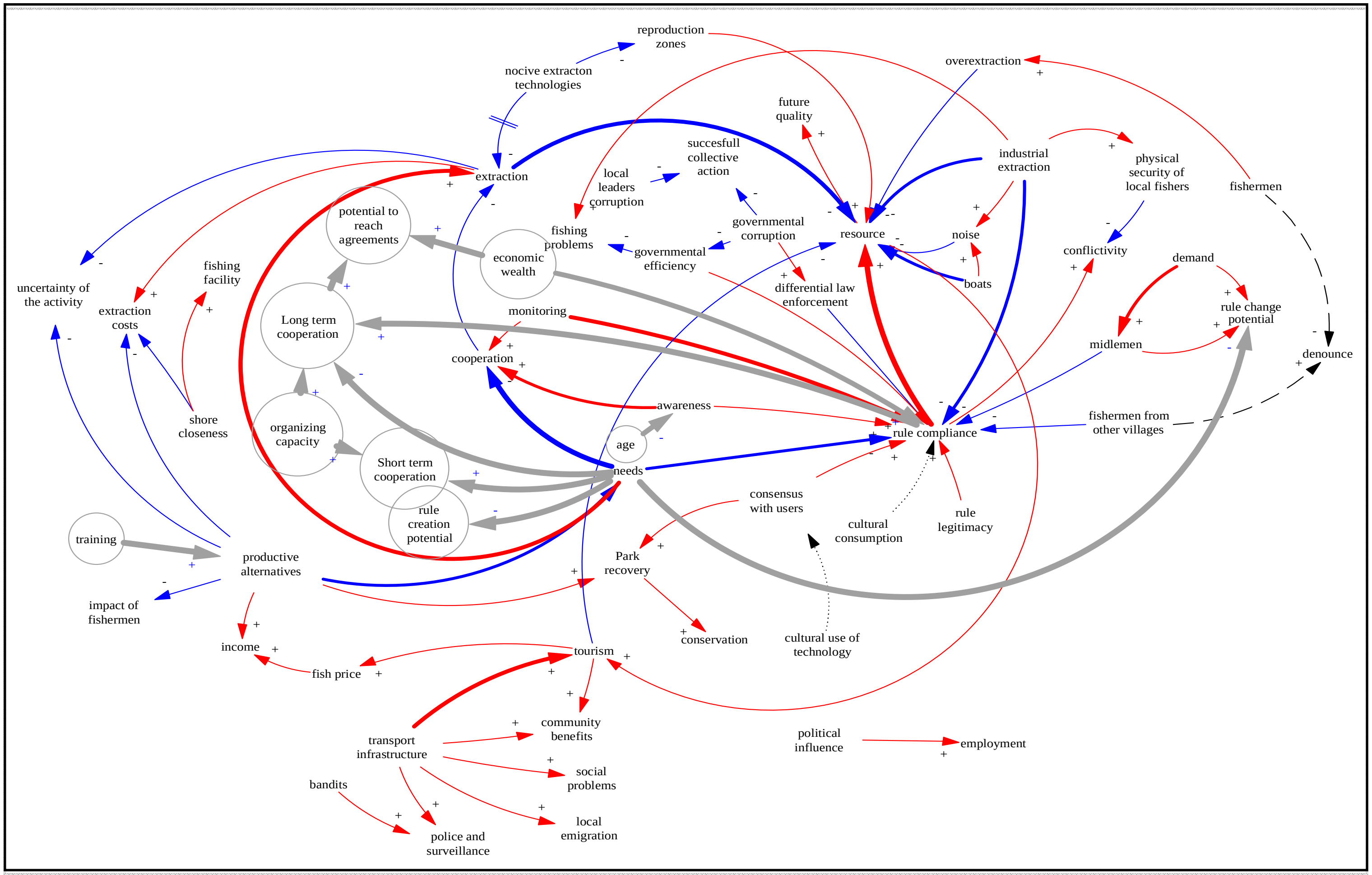

Figure 6.8. Collective mental model (CMM) of the fishery village. Circled variables and grey links indicate that were elicited in collective activities (RPG construction and playing). The thickness of causal relations indicates that they were reported in more than one individual mental model.

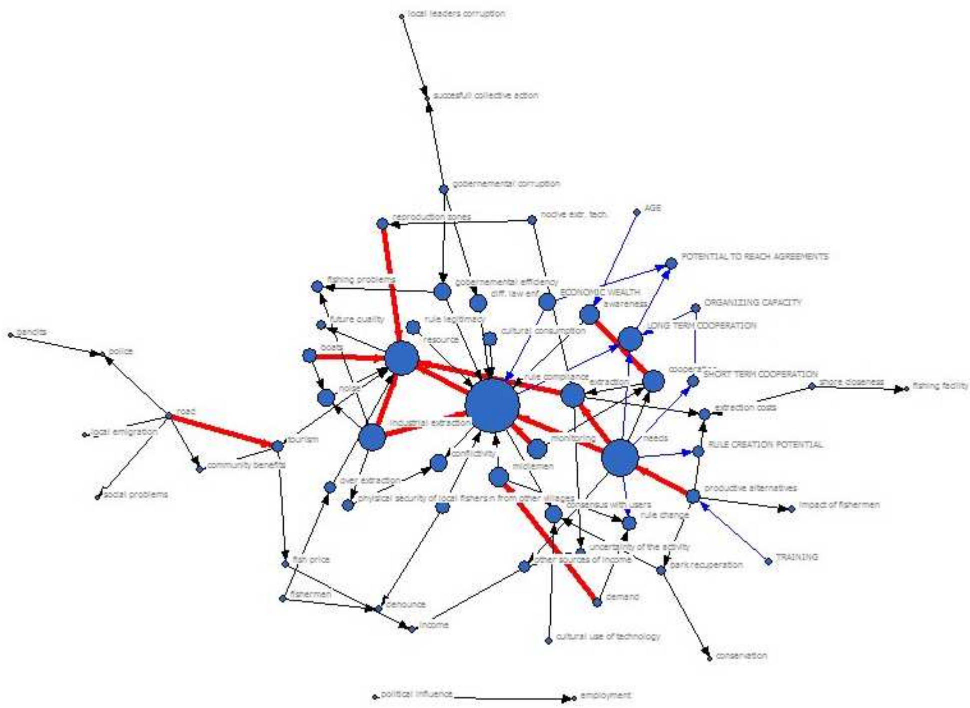

Figure 6.9 Network of the collective mental model (MMC). The size of variables is an indicator of the total degree index. In the same manner, the thickness of links indicates their presence in more than one individual mental model.

According the core structure (Figure 6.10) the resource depends negatively on artisanal extraction; the more extraction the less resource, industrial extraction with a similar relation, and the number of boats in the zone; the more boats the less resource. Rule compliance and reproduction zones generate a positive effect on the resource. Rule compliance depends negatively of household needs and industrial extraction, and positively of monitoring. The increase in productive alternatives causes a lowering in household needs, which in turn affect the rule compliance and extraction; the more needs, the less rule compliance and the more extraction. On the other hand, there are three simple structures that seem to be isolated from the rest of the model, but that appeared in several individual mental models. The more local fishermen' awareness, the more possibilities of cooperation. If there is an improvement in the transport infrastructure, there will be an increase in the flow of tourists to the zone. And, an increase in the demand of marine products generates an increase in middlemen number.

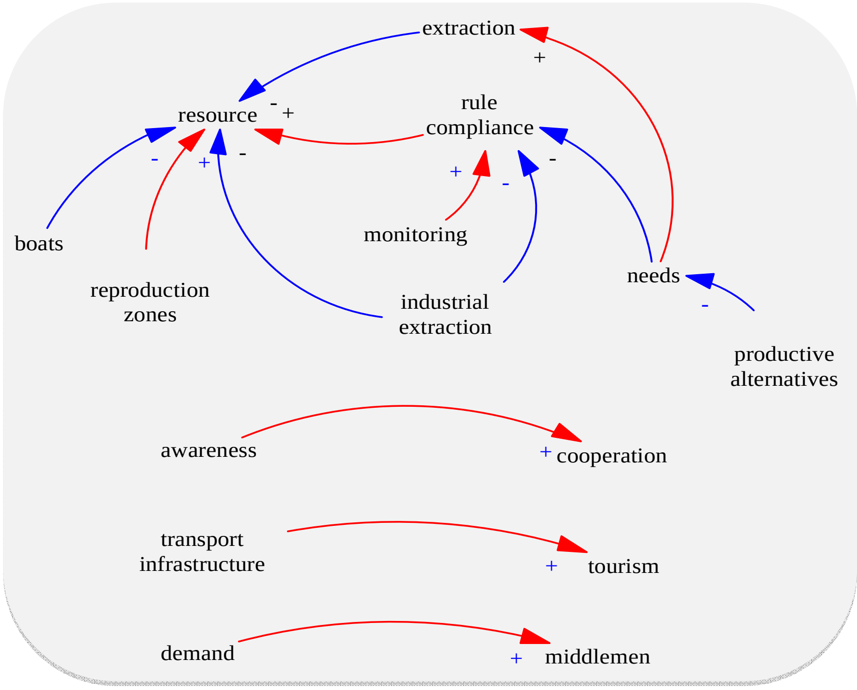

Figure 6.10 Core structure of the MMC. This model is derived from the network analysis, and represents the variables and relations ranked with the highest total degree, reported in more than one individual mental model.

The structured emerged in the feedback workshop and RPG construction and playing is considered a representation of part of the collective mental model. The Figure 6.11 shows the core structure and these variables and relationships. Importantly enough is the emergence of the concepts of short and long-term cooperation as variables of the model. Economic wealth of fishermen influences positively rule compliance and the potential to reach agreements. The level of household needs affects negatively the potential to create rules for local fishery management, but also, if the level of needs is high the possibility of long-term cooperation decreases. On the other hand, if the level of needs is high the short-term cooperation increases. This type of cooperation has the possibility to increase if the organizing capacity of fishers increases as well. If local fishermen receive training and education the probability to find and increase the productive alternatives increases. Finally, the awareness of fishermen regarding the cooperation in the use of the resource depends on the age of each fishermen; the more age, the less awareness, and the less cooperation.

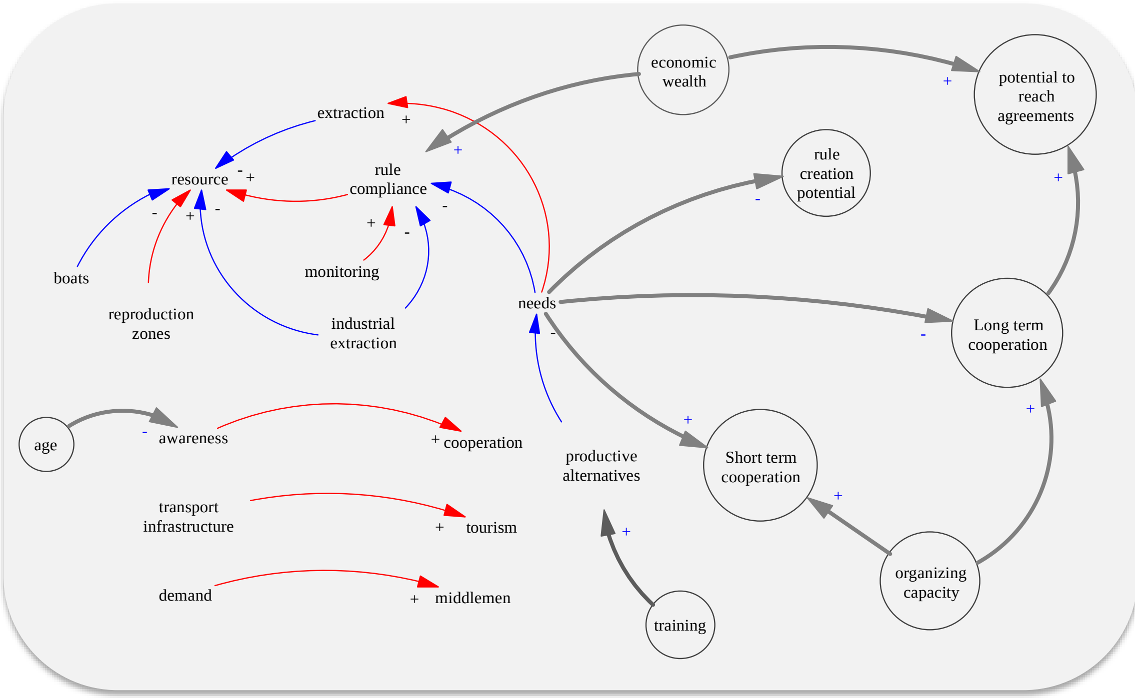

Figure 6.11. Core and collectively consented structure of the MMC. The circled variables and grey relationships emerged from the feedback workshop and RPG sessions. This additional structure is the result of the participants' consensus.

Figures 6.12 and 6.13 show the centrality measures for all the variables of the MMC. The two graphs show that the power of transmitting cause-effect information is focused on few variables in of the MMC. Betweeness centrality (Figure 6.13) is the characteristic that offers information about the most important variables of the model because they are part of the core structure, therefore constitute the "back bone" of the model (Intermediary variables in Table 6.6). The hypothesis is that this cause-effect structure is utilized by fishermen in their decision making all the time, and that the rest of the variables and links are used in specific or individual situations. The key decisions are focused in extraction and rule compliance variables. Figures 6.14 to 6.17 show influential and dependent variables with cause and effect trees, where rule compliance and extraction are consequence of a number of explanatory variables.

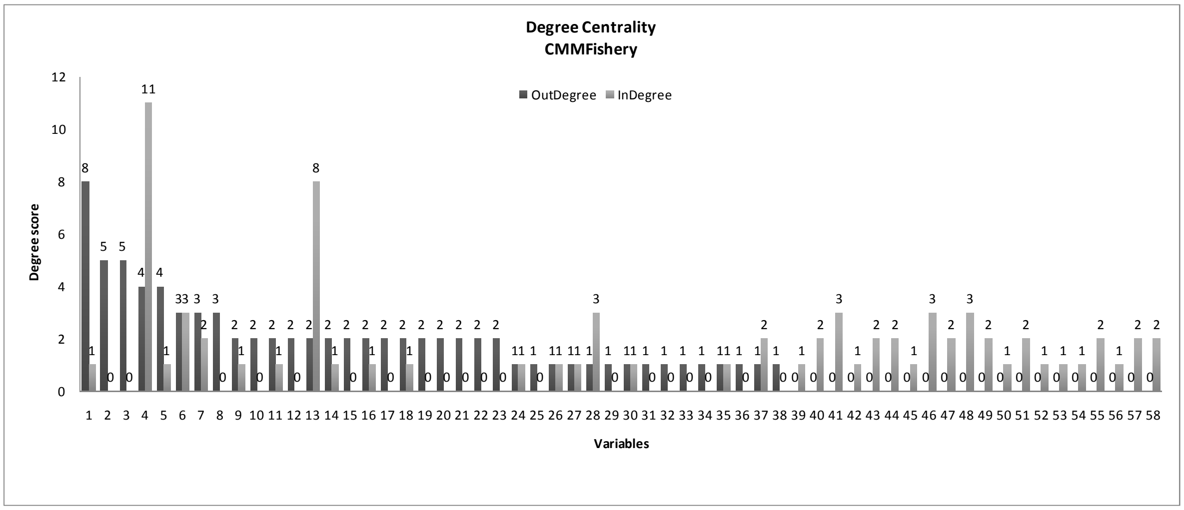

Figure 6.12. Degree centrality ranking for the MMC, showing the relation between influential variables (OutDegree) and dependent variables (InDegree). Rule compliance (variable ID 4) and resource (variable ID 13) have the highest degree of dependence in the model. Household needs (variable ID 1) and productive alternatives (variable ID 2) are the most influential.

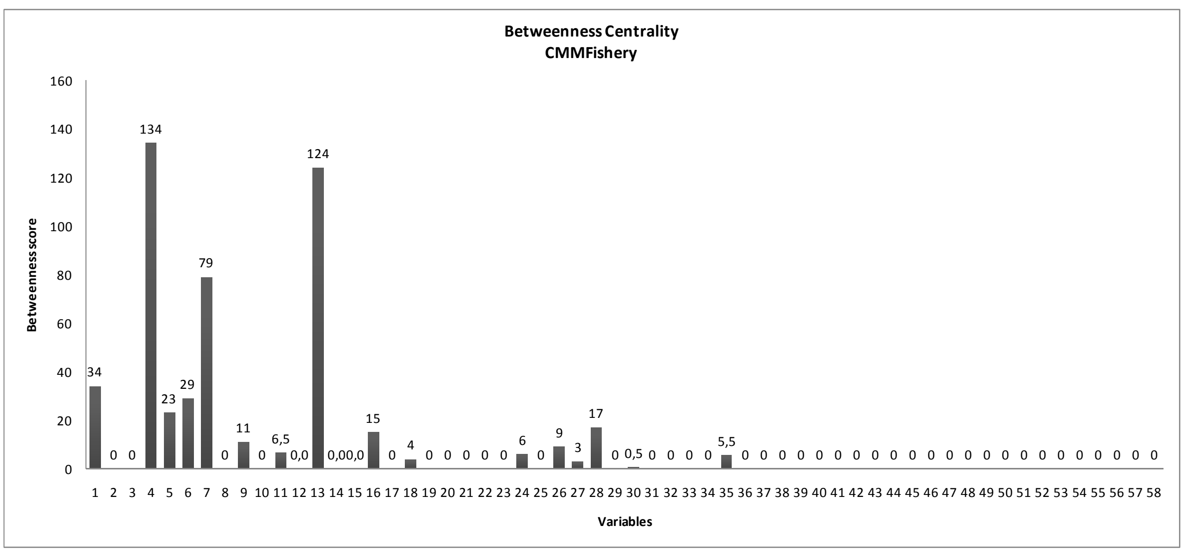

Figure 6.13. Intermediary variables of the MMC. Rule compliance (variable ID 4) and resource (variable ID 13) are the variables with highest degree of intermediation, followed by tourism (variable ID 7), needs (variable ID 1) and extraction (variable ID 6).

Table 6.2 Variables ranked according degree and betweenness centrality measures for MMC.

INFLUENTIAL VARIABLES		**INTERMEDIARY VARIABLES**		**DEPENDENT VARIABLES**	
	Out Degree Value		Betweenness Value		In Degree Value
need	8	rule compliance	134	rule compliance	11
industrial extraction	5	resource	124	resource	8
transport infrastructure	5	tourism	79	extraction	3
rule compliance	4	need	34	long term cooperation	3
productive alternatives	4	extraction	29	consensus with users	3
extraction	3	productive alternatives	23	extraction costs	3
tourism	3	long term cooperation	17		
governmental corruption	3	awareness	15		
		middlemen	11		

cooperation	9

6.3.3 The collective mental model and the fishing socio ecological system

It is important to make a brief synthesis of the SES because the collective mental model is a construct that is built and used in this context. As discussed in the Chapter 4 (Historical and geographical context) the general characteristics of the resource system can be synthetized as follows. The extension of the fishing grounds is about 40.000 of marine Ha, and its boundaries as a CPR has been defined traditionally by a history of use of approximately 200 years. Its productivity can be classified as high in the coral reef zones that coincide with the fishing spots. The units of the resource are highly mobile with a regeneration rate more or less homogeneous during the year. Its predictability can be classified as low due to its mobility and also the difficulty to directly observe the resource. Locals and environmental agencies consider that the resource, currently, is overharvested. These characteristics make the artisanal fishing an activity with high levels of uncertainty. The resource system is at the same time part of a marine protected area (National Natural Park), and also a CPR for the local fishermen. One of the main conflicts characterizing the system is focused in the tension between ecosystem conservation and the artisanal extraction. The first position held by the Natural Park policy and the second by the local fishermen. But also among fishermen there are conflicts between the local fishermen association leaders. This context and the traditional formal vision of environmental authorities has led to a generalized mental model that I name “anarchic nature”, in line with Gunderson and Holling (2001), meaning that the priority must be the conservation and extremely careful use of ecosystems. The collective mental model is a construct that is built and used in the context overviewed above. The next paragraphs illustrate how the mental model explains the outcomes of the different action arenas analyzed in Chapter 5.

Though in figure 6.8 is possible to observe importance of the resource variable, the figure 6.14 illustrates more clearly the position of the variable in a cause and effect tree generated from the CMM. The resource depends on the extraction level, industrial extraction, over extraction by local and external fishermen, the state of what they call the resource reproduction zones, the level of rule compliance and the tourism. Regarding the industrial extraction fishermen were emphatic with the necessity to include the industrial fishery in the role game (Chapter 5). The consequences of industrial fishery not only have to do with the resource, but with the physical security of fishermen; the industrial ships usually cause accidents with the small local fishermen boats. The tourism affects negatively the resource, improves the market and, potentially, raises the social problems, increasing the uncertainty of productive activities and local welfare. The state of the resource determines the community future quality. The tourism structures a causal loop because the tourism has a negative relation with the resource, which in turn affects positively the tourism.

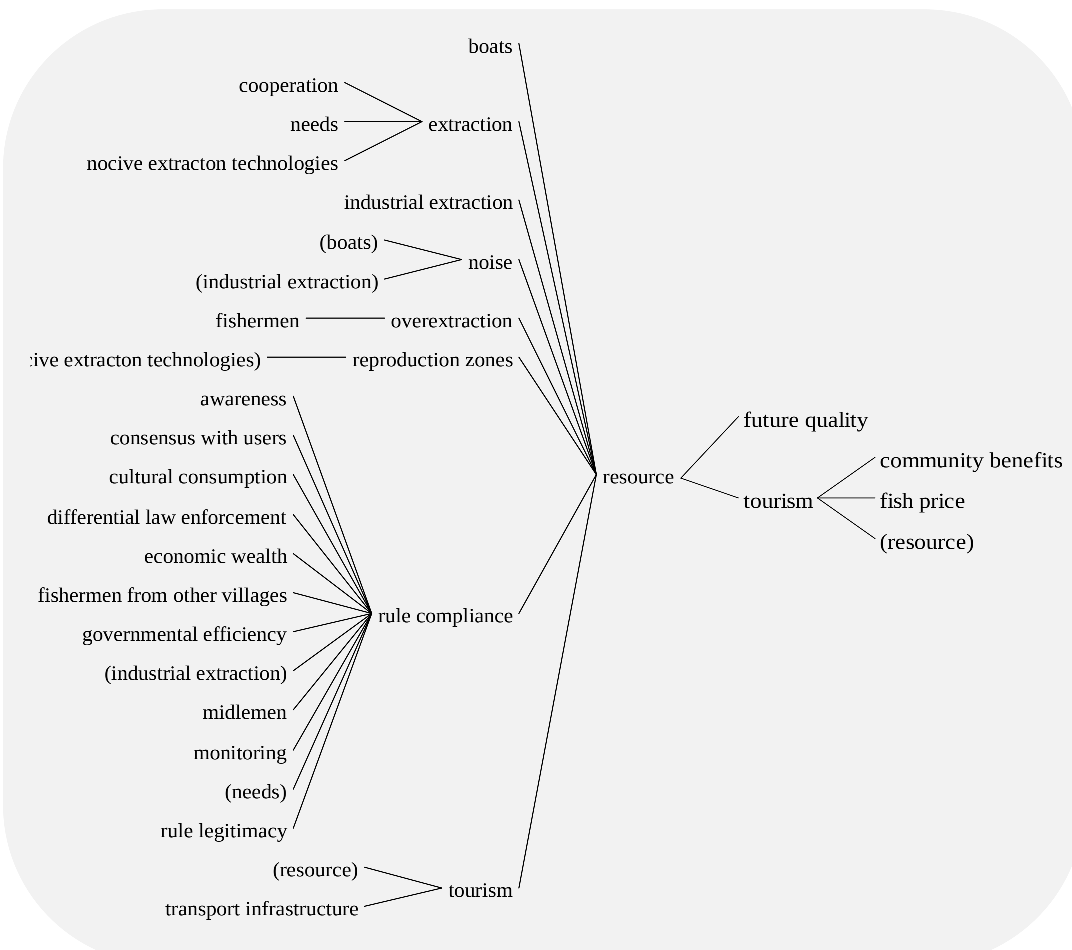

Figure 6.14. Dependent variables of highest degree in MMC: rule compliance and resource.

The levels of extraction depend on cooperation, meaning the effort that fishermen do to extract less (Figure 6.15). The extraction also depends on the needs of fishermen households, and the type of fishery gear used, especially the use of harmful extraction technologies. The extraction affects negatively the state of the resource and positively the extraction costs. If the fishing levels increase the resource diminishes, and, the more extraction, the more costs. The fishermen are aware of the consequences of extraction. They are aware of the costs, the impact of the resource and that the more impact on the resource; the uncertainty increases. The fishermen constantly relate their situation with high levels of uncertainty. In the case of the state of the resource and the extraction is cause by the low predictability due to mobility and impossibility of explicitly seeing the resource as natural characteristics of the resource system.

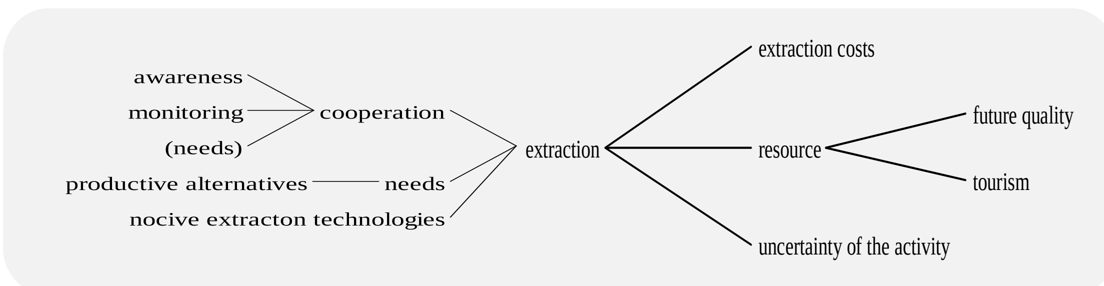

Figure 6.15. Causes and consequences of extraction decisions

The rule compliance depends on a number of variables that could be grouped in four sets (Figure 6.16). The first group of variables includes individual aspects. The first of these variables is fishermen awareness about the fragility of the resource and the importance of its maintenance. Local consumption patterns variable is the second. If traditional and culturally consumption patterns are kept people follow the rules. The fishermen economic welfare and household needs are the third and fourth variables, which are fundamental for rule compliance. In the second group there are variables that have to do with rule justice. These variables are rule legitimacy that they associate with the level of consensus among fishermen and the environmental authorities. The other fundamental variable is the differential law enforcement. For local fishermen the rules are applied only to poor users; the more economic power the less rule enforcement. Therefore, the more this situation happens, the less rule compliance is possible. This topic is directly related with the industrial fishery; for them the environmental authorities do not enforce the rules with these actors. The governmental efficiency and monitoring are included in the third group of variables that influences rule compliance. And the fourth group of variables is related with other actors such as fishermen from other villages and middlemen. This is based on the idea that the external users do not follow the rules. Regarding the middlemen, the logic is that the more middlemen, the less they are paid for fish, and in consequence, fishermen have to break the rules to compensate the economic deficit.

It is important to remark that the rule compliance does not depend on cooperation but depends on a notion of justice. They know that the government is corrupted and that the law is applied in a differential way that it is inefficient. The cooperation depends on rule compliance, the necessity and the organizational capacity. The effects of rule compliance are communitarian not individual. The more rule compliance the less conflicts. If people follow the rules the cooperation in the long term could increase, and in turn will be easy to reach agreements with environmental authorities and among fishermen. When fishermen follow the rules there are benefits for the resource, which improves the future quality and the attractiveness for tourism.

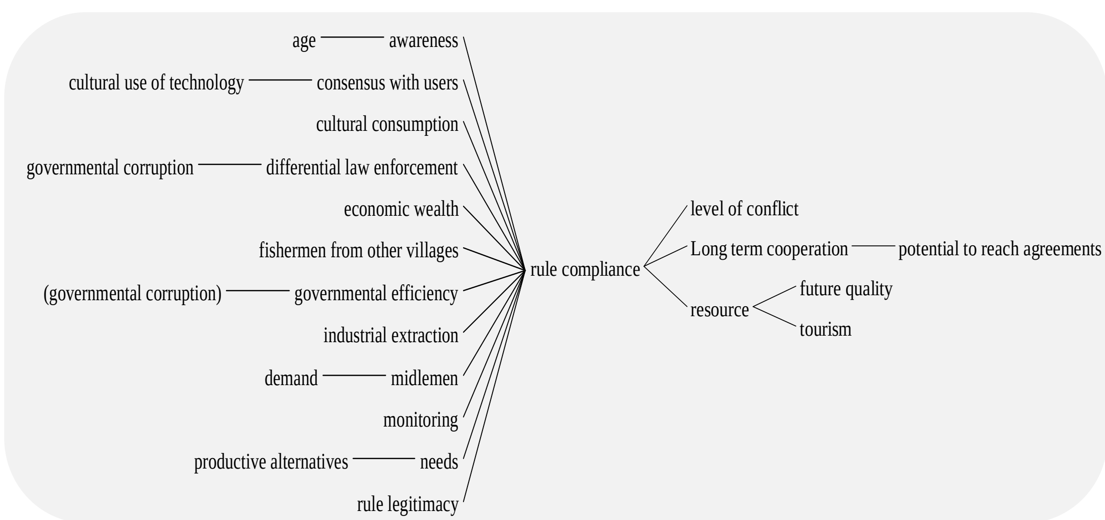

Figure 6.16. Causes and consequences of rule compliance decisions

The fishermen place the household needs at the center of the problem (Figure 6.17). The needs only depend on the productive alternatives, which imply the extraction reduction, income improvement and the Park recovery. In turn, the productive alternatives depend on the level of training they receive for carrying out other productive activities different to fishing. The household necessities are conditions for seven key variables. The first two variables are the cooperation and the reduction of extraction levels. The satisfaction of basic household needs is a condition for the cooperation in the short and long term. Needs satisfaction is also the condition for rule change and creation in the fishing, and rule compliance. The UBN value of the region is 35% (Chapter 4), the average income is over the minimum national wage, and a cultural trait is that the accumulation of capital is not in their rationality, instead, their economic rationality is more short term oriented. The fishing community is far below the National rural UBN average (53,3%), therefore the importance of a variable such as "needs" in the collective mental model must be examined carefully.

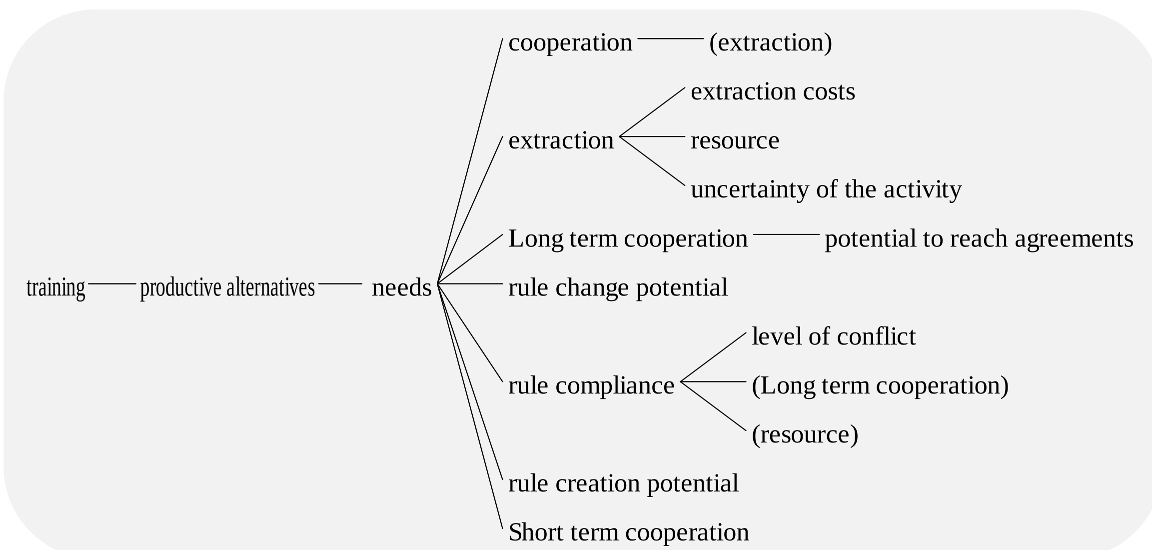

Figure 6.17. Causes and consequences of the level of needs

The state of the resource, cooperation and rule compliance in the experiments

The variables influencing the resource that are present in the experimental arena are extraction, over extraction, reproduction zones and rule compliance. The outcomes of the experiments in terms of resource sustainability showed that all the fishing spots started in good conditions but rapidly felt to a bad state. In the first state of the experiment, without rules, this fall was faster than what happened in the second stage. According to the mental model, the decisions that determine the resource's state and that are included in the experimental setting are extraction, rule compliance and reproduction zones.

In the experimental action arena (Chapter 5) the extraction of the resource is a proxy of cooperation levels of the players. This is the less extraction implies more cooperation. The outcomes of the experimental action arena were dominated by low levels of cooperation in both stages. In the collective mental model there are two types of cooperation: short and long term cooperation. Both variables depend positively on the organizing capacity and also of the needs. When the level of needs increase the short-term cooperation tends to increase but the long-term cooperation tends to decrease. The players in the experimental action arena are in a short-term situation. The economic incentives (game payoffs) could cover approximately one-day real wage that covers the basic household needs. Therefore, they try to increase the short-term cooperation, but the organizing capacity is low because they cannot communicate and this fact makes the cooperation falls. The mental model also includes the monitoring as condition for cooperation; when monitoring increases, cooperation increases and extraction decreases. In the experiments, there was no monitoring in the first stage and the cooperation decreases. In the second stage when rules where in place, the monitoring probability was relatively low but it was different from zero, and cooperation tended to be stable (Figure 5.1 Chapter 5).

The rule compliance in the experiments was measured by the percentage of rule breaking (Table 5.1 Chapter 5) where the random access rule had a 14,7% of rule breaking and the rotation rule 12%. The working variables that condition rule compliance are consensus with users, governmental efficiency, monitoring, needs and rule legitimacy. Consensus with users which value is low, due to the lack of communication. The governmental efficiency and monitoring are represented in this arena by the inspection probability of the game (0,17 that was the probability of a result of six when a dice is thrown), which is low; therefore the effect is that rule compliance is low. The household needs play an important role because of the monetary incentives of the experiment that makes the rule compliance decrease. The rule legitimacy could be understood as moderate because though the players could vote for the rule to be applied in the game, they could not design and discuss among players the rule. Therefore is a rule that is perceived as externally imposed, therefore, the level of rule compliance tends to decrease.

The state of the resource, cooperation and rule compliance in the Role Playing Game (RPG)

The decision variables present in the RPG action arena are the extraction (fishing effort), fishing gear and fishing zone (Table 5.2 Chapter 5). The collective mental model includes three variables that condition the resource extraction; cooperation, household needs and harmful extraction technologies. These three variables are present in the RPG. The fishing technologies included in the game had more harvesting capacity proportional to their resource impact capacity, being the more negative the industrial fishery. In the RPG participants used most of the time the trolling line; the gear that produced less impact. The household needs played a central role in their decisions. According to the mental model the household needs decrease if there are productive alternatives different to fishing, and if the needs decrease, the extraction decreases. In the RPG when productive alternatives were introduced participants effectively decrease their effort and the fishing spots started to recover (see section 5.2.3, Chapter 5). The rule compliance was high in the RPG because the variable consensus with users played a positive role in the increase of rule compliance. The meaning of this variable in the mental model is that the rules have to be negotiated between fishermen and the Park officers. In the RPG that was the situation; a Park officer participated and discussed the options to decrease the pressure on the resource.

The collective mental model and the behavioral spectrum

The mental model is one of the inputs for the behavioral spectrum (see Chapter 2, section 2.6) of the fishermen in this SES. This behavior spectrum provides a typology of players in which each type of behavior is supported by the result of the general morality conformance level (see Chapter 5, section 5.2.5). The first two behavioral types (Table 5.8, Chapter 5) that applies to the local fishermen are "*Rule breaker by conviction*" and "*Rule breaker by necessity or convenience*", which are directly related with the mental model variable: rule compliance. There are three causal relations governing these behavioral types: 1) the more needs, the less rule compliance, 2) the more consensus with users, the more rule compliance, and 3) the higher the legitimacy of rules, higher rule compliance. The third behavioral type: "*Cheating player*" is associated with the causal structure that links cultural consumption with rule compliance. Here the variable cultural consumption refers to the traditional extraction and household consumption of species that are not allowed today like turtles, some gastropods (*Strombus gigas*) and fish reefs.

Finally it is important to stress the idea mentioned above regarding the relative importance of household needs compared with the relevance of the variables related with legitimacy of rules. Having in mind that the average UBN is low compared with the National figure, I propose a hypothesis that could explain how the mental model and the levels of morality conformance interact to produce the behavioral spectrum (see Figure 2.15 Chapter 2) explained in Chapter 5.

According to the CMM satisfaction of basic needs is marked by the uncertainty. Fishermen know that the solution is not in the fishing game but outside of the sea. That is the reason why fishermen focus on productive alternatives. The cooperation is not a problem; they claim that the government must propose another "game", because they know that they will be excluded from the fishing activity. As a consequence locals are exploring different options such as the territorial governance model of collective land titling and communitarian councils, and the touristic productive option. The variables: consensus with users, differential law enforcement, industrial extraction, governmental efficiency and rule legitimacy can be classified as justice variables. Justice variables have an important weight on rule compliance causes, and they are dispersed in different structures of the CMM (Figure 6.16). The variable "needs" is strategically centrally located in the CMM. It is easier to claim that decisions that lead to rule breaking are a function of basic needs satisfaction, than placing on the spot justice issues that imply the reconfiguration of power relations in the SES.

6.4 The forestry case: The territory is negotiated in the forest

The mental models of the forestry case were elicited from twelve individual interviews, from a total of fifteen interviews carried out. Figure 6.18 illustrates the number of elicited variables by interview. In this case the workshops of collective RPG and playing generated new variables and relations for the collective mental model. The average number of variables is 7,5 and the standard deviation is 5,2

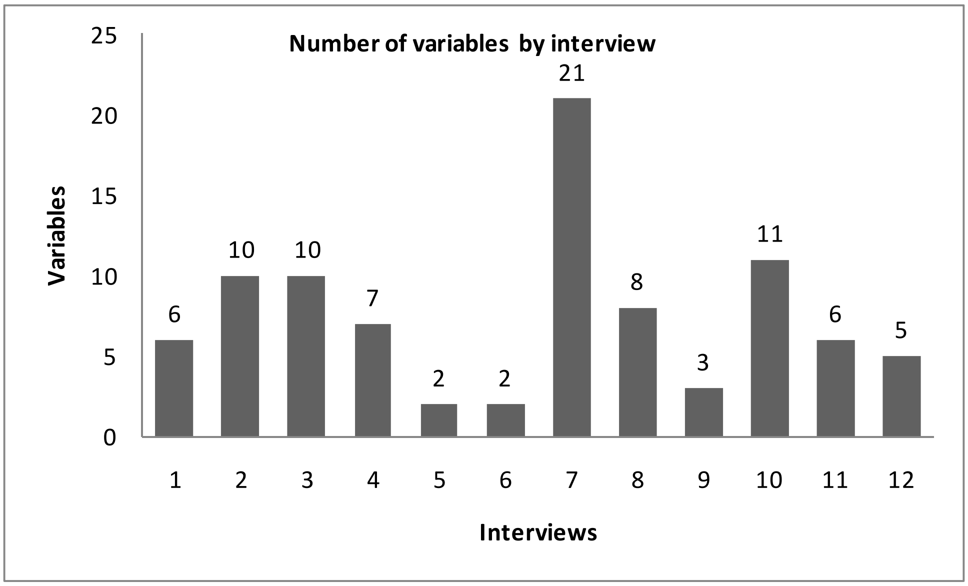

Figure 6.18. Number of variables by interview in the forestry case study.

The next section illustrates the individual mental model corresponding to the interview number 7 of the forestry case.

6.4.1 Mental model 7 (MM7) Extraction oriented

Figure 6.19 portraits the individual mental model structure. The most important variable in this mental model is the timber extraction, which depends positively on the financial resources lent by the middlemen and the level of chainsaw use. The consequences of the extraction are the generation of individual property rights and the increase in sales by the middlemen and in turn the income increase of the logger. The rule compliance is the second most important variable that depends positively of the awareness of the Law 70 and negatively of the licenses for palm extraction. The main consequence of rule compliance is the protection of the territory, which in turn is affected by collective land titling; this is that the collective land property contributes to the protection of the territory. The external timber demand increases the sales to external market, and the local timber demand. In turn these two variables contribute to increase the income of the middlemen. Other dependent variable is the forest regeneration time that depends of the channels that loggers do in the forest, which allow the flooding of forest areas. Finally, there is a relation between the tradition and property rights in the forest. The users that extract timber own the zones of the forest where they harvest. This is the rule that has worked traditionally before the formalization of the collective titling. The Table 6.3 shows the scores of the mental model network structure metrics, illustrating influential, intermediary and dependent variables.

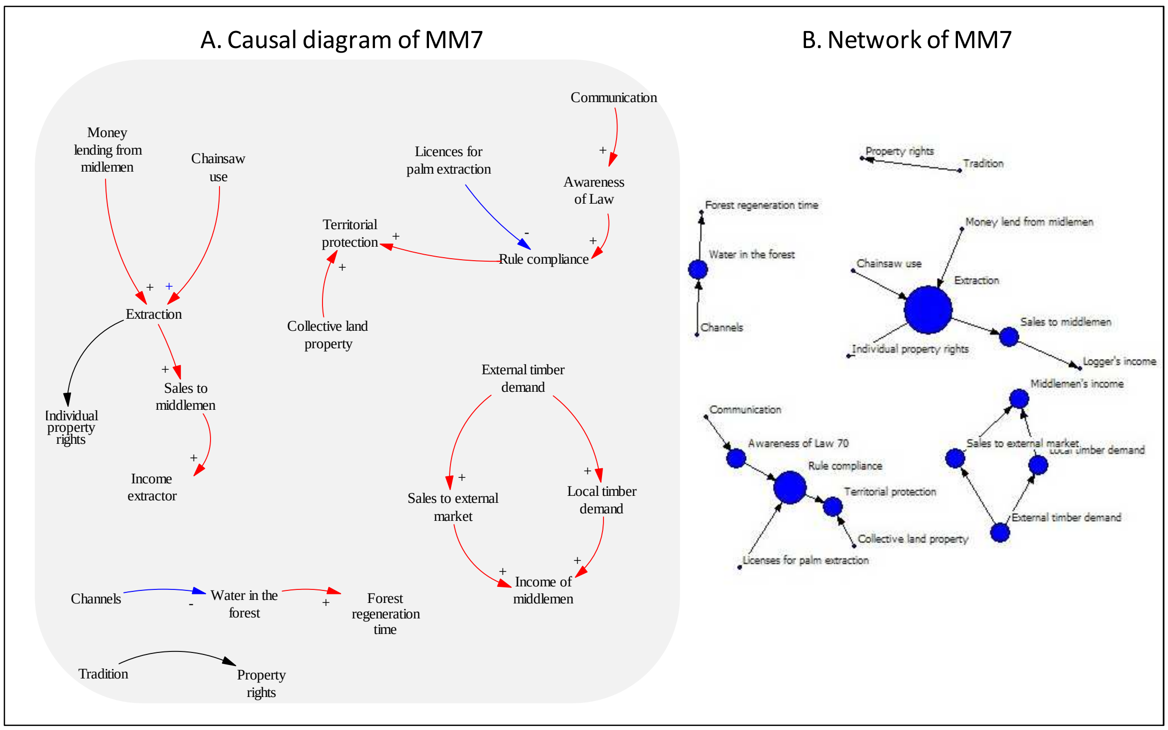

Figure 6.19. Causal diagram and network of an individual mental model

Table 6.3 Variables ranked according degree and betweenness centrality measures for MM 7.

INFLUENTIAL	INTERMEDIARY	DEPENDENT

VARIABLES	Out Degree Value	VARIABLES	Betweenness Value	VARIABLES	In Degree Value
external timber demand	2	extraction	6	extraction	2
extraction	2	rule compliance	3	rule compliance	2
chainsaw use	1	sales to middleman	3		
channels	1	awareness of law	2	middlemen's income	2
collective land property	1	water in the forest	1	territorial protection	2
awareness of law	1	sales to external market	0.5	awareness of law	1

6.4.2 Collective mental model (MMC) of the forestry case

In this section the collective mental model of the forestry case is discussed. Figure 6.20 illustrates the variables and its IDs used in the different charts in this section. The naming of the variables corresponds to the closest English word to the concept expressed by the interviewee. As general rule the concept is expressed with nouns that communicate the idea of a variable that could increase or decrease. The use of singular or plural noun forms responds to the most common interviewees' wording. Exceptions to this rule were made with concepts that interviewees expressed consistently in different forms. There were concepts that did not follow the exact variable meaning. "Organization style" (ID in figure 6.20: 44) is a concept which relation with "Ecological conditions of the forest" (9) does not imply an increase or decrease, but a different relationship; therefore the concept must be understood as "the organization style *determines* the ecological conditions of the forest". Another special case is the concept "Laws (Law 70)" (32) that is related negatively with

“External extraction”. The meaning is that the existence of formal laws similar to Law 70[46] decreases the possibilities of timber extraction by external actors to the Communitarian Council ACAPA. The concept “Tradition” (62) is linked with three variables and its relationship with each one is of different type. With the variable “Individual property rights” (28) must be understood as “the land individual property rights *are associated with* the tradition and vice versa”. Also there is a relation with “Property rights” (48) in a general sense, meaning that the “tradition *determines* the property rights of the forest and the land”. But the general character of the concept (property rights), without specification if they are individual or collective, makes the assertion either open to free interpretation, or meaning that the essence of the relation between these two concepts is that always, in a universal sense, the traditional land and forest utilization determines the type of property rights. A concept and relationship that reinforces this link is “Working in the land” (66), which increases the rights over a specific area of the forest (“Individual property rights” (28). The “Communitary council” (8) concept is linked with “Collective own rules crafting” (6). This relationship must be understood as “the existence of the Communitary Council *is the cause of*, or in this case, *makes possible* the collective own rules crafting”.

[46] National Law that gives autonomy in territorial governance and collective land titling to the Communitarian Councils in the Colombian Pacific region

Variables of the forestry case mental models

1 Awareness of environmental effects of extraction
2 Awareness of Law 70
3 Chainsaw use
4 Channels
5 Collective land property
6 Collective own rules crafting
7 Communication
8 Communitary Council
9 Ecological conditions of the forest
10 Economic activities rotation
11 Economic value of timber
12 Environmental authorities
13 Environmental problems
14 External economic support
15 External timber extraction
16 External rules
17 External timber demand
18 Extraction
19 Fishery bans
20 Forest
21 Forest conservation
22 Forest density
23 Forest inventory
24 Forest management
25 Forest regeneration time
26 Governmental compensation
27 Governmental prohibition rules
28 Individual property rights
29 Individual rule creation
30 Knowledge of the law
31 Land pollution
32 Laws (Law 70)
33 Licenses for palm extraction
34 Local timber demand
35 Logger's income
36 Middlemen's income
37 Mangrove
38 Mangrove extraction
39 Marine fauna
40 Mollusks
41 Money lending from middlemen
42 Monitoring
43 Needs
44 Organization style
45 Over extraction
46 Population
47 Productive activities
48 Property rights
49 Quota rule
50 Rule compliance
51 Rules necessity
52 Sales to external market
53 Sales to middlemen
54 Salinity
55 Sanctions
56 Size of trees
57 Sustainable use of the forest
58 Tall trees
59 Technological advances
60 Territorial protection
61 Timber price
62 Tradition
63 Trees
64 Trees planting
65 Water in the forest
66 Working in the land

Figure 6.20. List of variables included in the forestry case study.

The most mentioned variables in the interviews were Rule compliance, Extraction, Forest regeneration time, and Individual property rights, present in seven, six, five and four interviews respectively. The variables Collective land property, Logger's income, Mangrove, Territorial protection and Tradition appeared in three interviews. Figure 6.21 shows the distribution of all the variables in the interviews. Twenty six variables, out of sixty six, appear in two or more mental models. The collective mental model of the forestry case (MMCForestry) was constructed combining the twelve individual mental models (Figure 6.22). The thickness of the relations indicates that a relationship is present in more than one individual mental model.

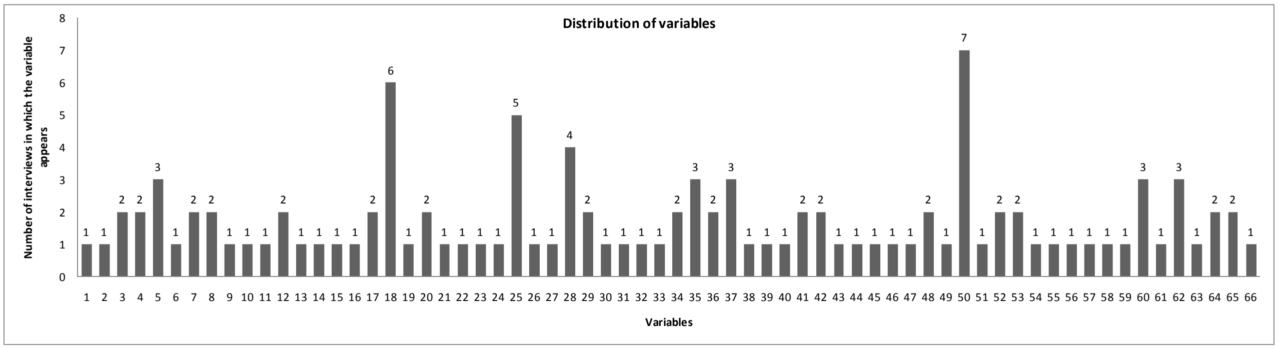

Figure 6.21. Distribution of variables among individual mental models. Variables ID corresponds to the list of variables showed in Figure 6.20.

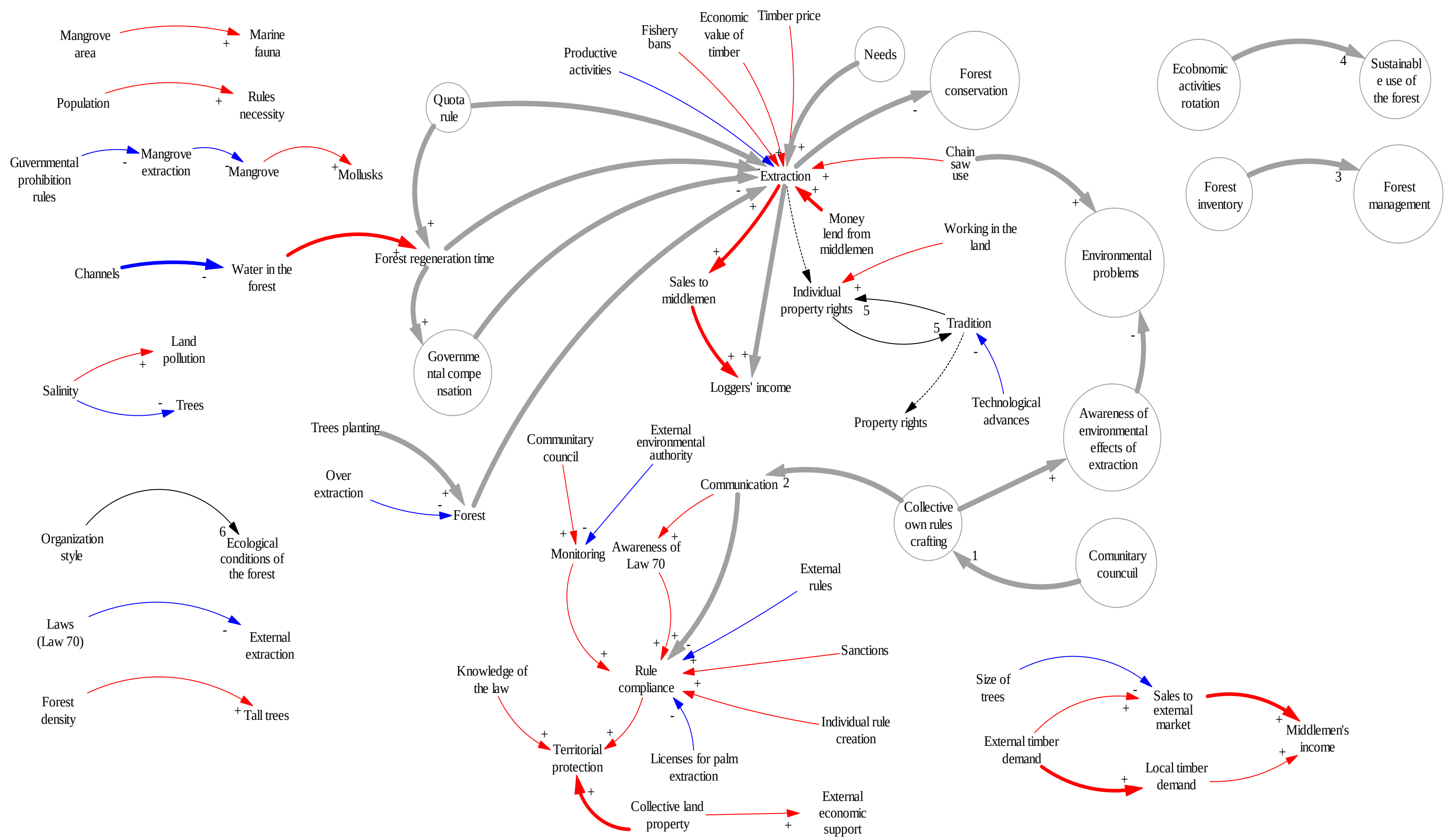

Figure 6.22. Collective mental model (CMMForestry) of the forestry study case. Circled variables and grey links indicate that were elicited in collective activities and not in the individual interviews. The variables connected to the circled ones were elicited in the collective workshops as well (RPG construction and playing). The thickness of causal relations indicates that they were reported in more than one individual mental model. Red arrows represent links with positive polarity and the blue ones with negative polarity. Numbers at the end of the arrow mean: 1: “is cause of”, 2: “needs”, 3: “improves”, 4: “implies”, and 5: “is associated with”.

The network view of the MMCForestry offers a perspective that makes easier the understanding of the model. The relative importance of variables, represented as nodes, is expressed by the size of the circles in figure 6.23. Node colors also provide an indication of the total degree score of variables. The variables with high degree score such as timber extraction and rule compliance are the most active, in the sense that they have the most relations in the network. Therefore, these variables are the more active in the relational process of causalities. Variables with low centrality level have very little effect in the network. Figure 6.24 shows the network in a circular view where is easier to understand the variables according their degree value. The network perspective evidences that the CMMForestry is composed by isolated groups of variables. Timber extraction, rule compliance and sales to external market, and mangrove extraction are central variables in the four main subgroups of variables. The rest of the model is composed mainly by isolated pairs of variables. The major subgroups, extraction and rule compliance clusters, are linked by the variable environmental problems, whose in degree score is 2 and out degree 0, meaning that this is a dependent variable influenced by both subgroups. In addition, this variable emerged during the RPG workshops (Figure 6.22).

From figure 6.22 it is evident that the collective activity around the RPG produced an important number of variables and relations that represent a shared structure of the collective mental model. The causal chain in which these two variables are involved starts with the existence of the Communitary Council that is the cause of the collective own rules crafting, which in turn, needs certain level of communication among members of ACAPA. If the level of communication is enough the awareness of the Law 70 increases among people as well as rule compliance.

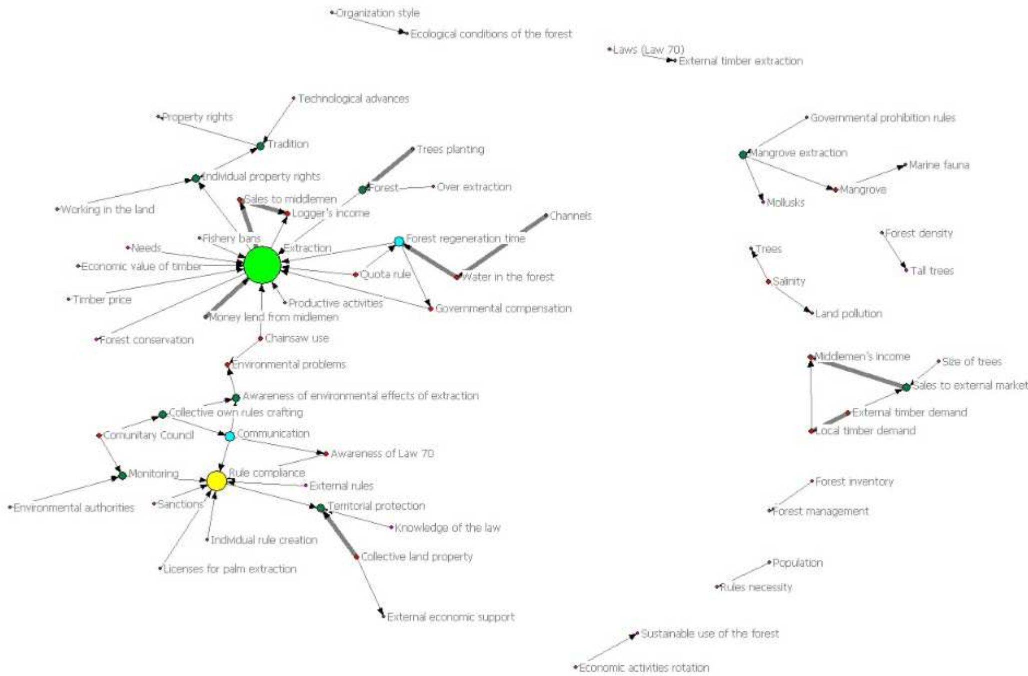

Figure 6.23. Network of the collective mental model (CMMForestry). The size of variables is an indicator of the total degree score. The thickness of links indicates their presence in more than one individual mental model.

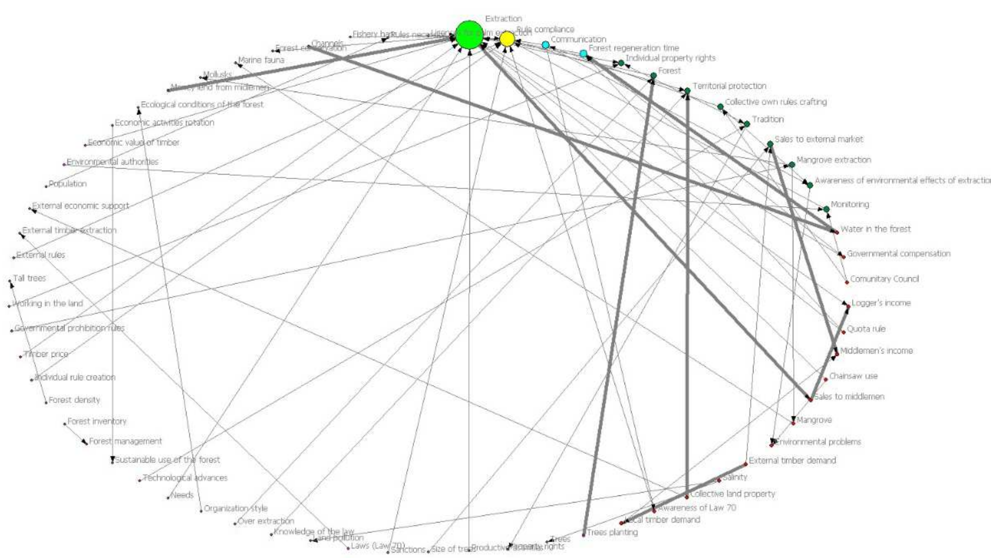

Figure 6.24. Circle network view. Degree centrality of the CMMForestry variables. The node size corresponds to their degree score.

According to centrality measures (Figures 6.25 and 6.26 and Table 6.4) of the network the variable extraction is the most important of the model, having the highest score of degree and betweenness. The structure of the network composed by two main clusters is evidenced in figure 6.23, where the two variables with the highest scores are the center of the subgroups. Interestingly enough is the betweeness score of the variables individual property rights, tradition, forest regeneration time, and forest which is higher than rule compliance, meaning that they are important in the causal network.

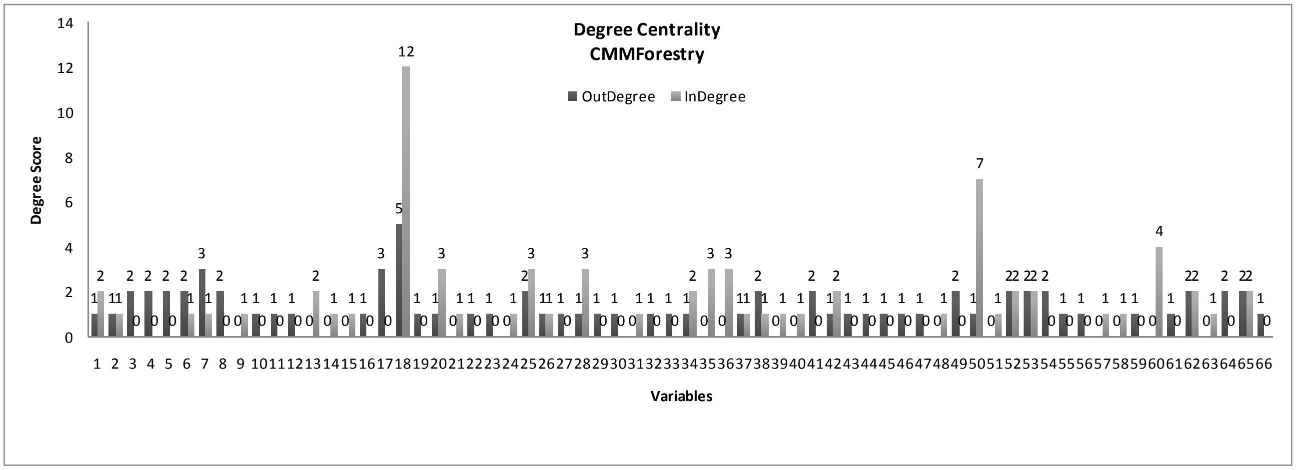

Figure 6.25. Degree centrality ranking for the CMMForestry, showing the relation between influential variables (OutDegree) and dependent variables (InDegree). Extraction (variable ID 18), and rule compliance (variable ID 50) have the highest degree of dependence in the model.

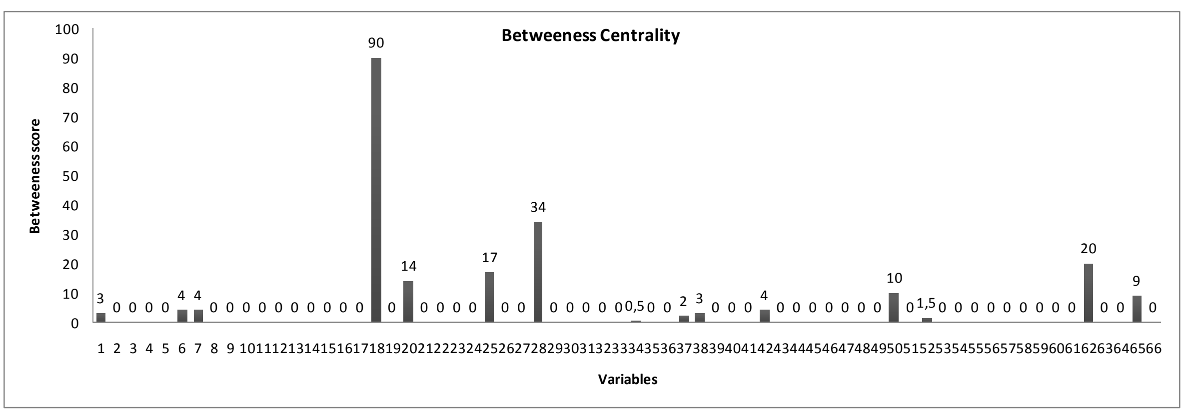

Figure 6.26. Betweeness centrality scores for the variables of the CMMForestry.

Table 6.4. Variables ranked according degree and betweenness centrality measures for MMCI. OutDegree scores reflect the number of causal relations that produce a variable. InDegree scores show the number of causal relations that produce consequences for the variable. Betweenness score express the number of variable pairs that are related through a given node.

INFLUENTIAL VARIABLES		**INTERMEDIARY VARIABLES**		**DEPENDENT VARIABLES**	
	OutDegree Score		Betweenness Score		InDegree Score
Extraction	5	Extraction	90	Extraction	12
External timber demand	3	Individual property rights	34	Rule compliance	7
Communication	3	Tradition	20	Territorial protection	4
Collective land property	2	Forest regeneration time	17	Forest regeneration time	3
Channels	2	Forest	14	Individual property rights	3
Collective own rules crafting	2	Rule compliance	10	Forest	3
Chainsaw use	2	Water in the forest	9	Middlemen's income	3
Communitary council	2	Communication	4	Logger's income	3
Forest regeneration time	2	Monitoring	4	Sales to external market	2
Mangrove extraction	2	Collective own rules crafting	4	Sales to middlemen	2
Sales to external market	2	Mangrove extraction	3	Tradition	2
Sales to	2	Awareness of	3	Water in the forest	2

middlemen		environmental effects of extraction			
Tradition	2	Mangrove	2	Awareness of environmental effects of extraction	2
Quota rule	2	Sales to external market	1,5	Local timber demand	2
Trees planting	2	Local timber demand	0,5	Monitoring	2
Water in the forest	2			Environmental problems	2
Money lend from middlemen	2				
Salinity	2				

6.4.3 The collective mental model and the forestry socio ecological system

The main characteristics of the SES of the forestry case study, as described in the historical and geographical context (Chapter 4) are synthetized in this paragraph. The area of the collective territory is approximately 103.607 Ha. There are about 1400 users that extract timber with a UBN of 68%. The definition of the management regime as CPR was established in 1993 as a product of a communitarian process supported politically by the Colombian central government. The timber extraction has a history of about 150 years with different cycles that imply different intensities of extraction. The productivity is high, typical of a tropical rainforest, with cycles of trees growth between 7 and 20 years. The predictability of resource state is high. In terms of the resource state it depends on the species, there are some of them that have increased in quantity and size of individuals due to bans during the last years, but other species are clearly overharvested. The main characteristic in terms of infrastructure and storage of resource units are the sawmills, which are private and work as middlemen in the productive and commercialization chain. The governance of the resource depends on the Communitarian Council (ACAPA), which has a directive board with representatives of the different regions of the territory. It is important to remark that the forest governance is only a part of the governance role of ACAPA, which is a grass roots organization for the territorial governance with full recognition of the Colombian Government. The use and management rules are collectively defined, in line with the environmental state agency, but with very low monitoring capacity. The main conflicts are of two kinds. On one hand there are internal conflicts among leaders focused on diverse political objectives and corruption issues. On the other hand, there are territorial governance conflicts with illegal armed groups. The region in general has been used and managed traditionally under a mental model of nature balanced; meaning that the ecosystems recover themselves no matter the strength of perturbations and extraction. The collective mental model illustrates the way in which local users make decisions in this context.

The forest depends on individual decisions linked to the extraction level, but also on collective decisions related with trees planting. The communitarian dimension is highly important because the state of the resource is linked to the social organization consolidation. The state of the resource and the regeneration time depends on the existence of a quota rule in order to limit the extraction. This quota rule does not exist currently, but for the participants in the workshops if it would exist, will improve the resource condition. If the density of trees increases, the number of tall trees increases and the regeneration will be better. This allows the possibility to more extraction and also the community could obtain benefits from the government. The collective mental model makes evident the awareness about basic ecological forest dynamics. The mangroves contributes to increase and maintains the marine fauna. If water salinity levels increase there are negative effects on the forest state. Regarding the sustainable use and management of the resource, they depend on the knowledge about the forest, and the possibility of productive activities rotation.

According the CMMForestry timber extraction is a variable that depends of several variables, but only influences at least four relevant variables (Figure 6.27). The extraction depends on the forest conditions, but it is clearly market driven, which is represented in variables such as timber price, other productive activities, and economic agreements with middlemen. Other aspects that influence the extraction are the availability of technology, the periods of fishery bans and the possible governmental compensation for not extracting timber. Personal conditions also affect the timber extraction such as household needs. It is interestingly enough that the extraction does not depend on rule compliance. This is explained by the fact that the environmental authorities interact directly with the sawmill owners and the inspection capacity is low. The extraction affects the forest conservation and the loggers and sawmill's economic interests. The individual property rights of forest patches are consolidated when there is frequent timber harvest. The individual property rights of forest patches are traditionally enforced by the extraction.

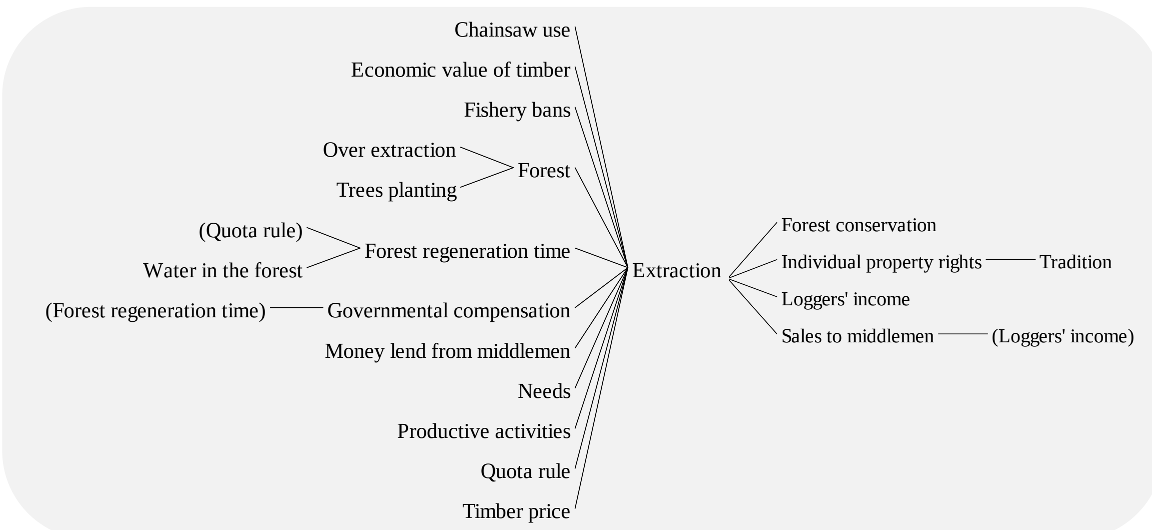

Figure 6.27. The variable extraction is at the same time the most influential and the most dependent variable of the CMMForestry.

The first characteristic of the CMMForestry regarding the variables related with rule compliance (Figure 6.28) is that the extraction is not present. There are three type of rules: external, communitarian and individual. The existence of external rules would decrease the rule compliance, but the possibility to create their own rules makes the contrary effect. Regarding the communitarian rules, the communication among users is fundamental for rule crafting with the consequence of a higher level of rule compliance. But also the communication among users has a positive effect directly on rule compliance. The communication also increases the awareness of the general national law that recognizes the rights to the territory and the collective titling; this awareness among loggers improves the levels of rule compliance. Monitoring and sanctioning are important elements that improve the rule compliance. The monitoring could be strong and have positive effects on rule compliance if the Communitarian Council does it. But if the regional environmental authority does the monitoring the effect on rule compliance is negative. The levels of rule compliance have an effect on the protection of the territory. Therefore, the governance of the territory depends on the awareness of the law and the collective property.

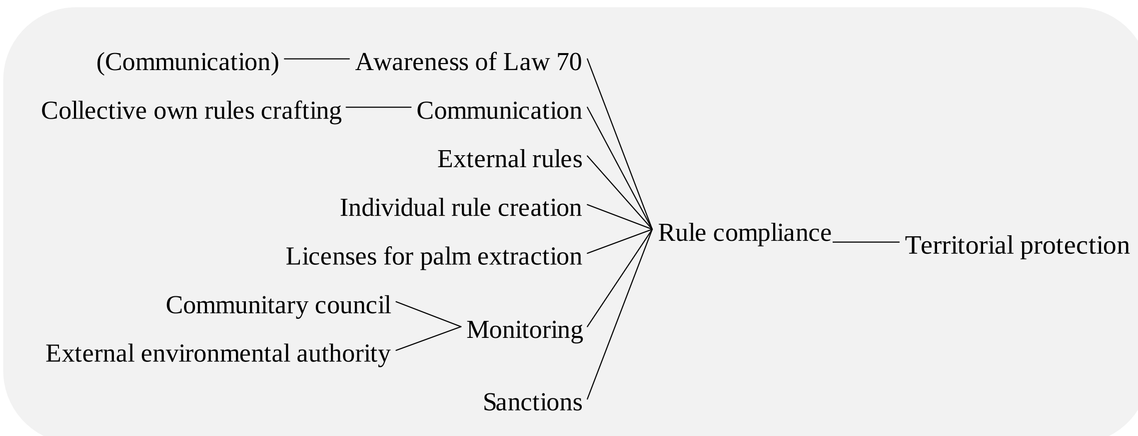

Figure 6.28. One of the main dependent variables in the CMMForestry: Rule compliance, which in turn influences territorial protection.

The state of the resource, cooperation and rule compliance in the experiments

The cooperation in the experiments is interpreted as the inverse of tree harvest, the less harvest, the more cooperation. The variables that are present in the mental model and in the experimental action arena are extraction, forest state, forest regeneration time and household needs and loggers' income. Though household needs variable is not explicitly included in the experimental action arena, it is playing an important role in this setting due to the monetary incentives of the game, which are similar to one day local wage in average. The only variable that implies a direct decision is the extraction. In the first stage of the experiment (Figure 5.10 Chapter 5), and during the first two rounds, the players started to extract close to the maximum because the number of trees in the board (state of the forest) was high and the monetary incentives activated the needs variable, which in turn increased the extraction. The tendency continued, but the maximum allowed was decreased according to the state of the forest that was decreasing rapidly. According to the mental model, the consequences of a high level of extraction are low forest conservation and high level of loggers' income. The forest conservation variable was not privileged due to the simplicity of the experimental action arena and the short time horizon. Instead the household needs variable was stronger than others.

The mental model also includes the variable quota rule, meaning that if a quota rule exists the extraction decreases. In the second stage of the experiment when rules were in place the extraction, in average, remained oscillating between 3 and two threes (Figure 5.10b, Chapter 5). Players could sustain this level of extraction across the ten rounds because the resource state was enough high to allow this, which in turn was possible due to some levels of rule compliance. According the mental model, rule compliance depends on five variables that work in the experimental setting. They are communication, external rules, individual rule creation, monitoring and sanctions. In the experiments the average percentage of rule breaking was 48%. The communication increases the rule compliance, but it was not allowed. The existence of external rules makes rule compliance decrease, in the experiments the rules were externally perceived, therefore the percentage of rule breaking increased. The mental model emphasizes the individual rule creation as a strong cause in rule compliance increase. According to the mental model the monitoring and sanctions increase the rule compliance. In the experiments the probability of monitoring and sanctions was strong enough to increment the rule compliance to a level that allows slowing the rate of resource decrease.

The state of the resource, cooperation and rule compliance in the Role Playing Game (RPG)

In addition to the variables that conditioned the extraction in the experiments, in the RPG (Section 5.3.3. Chapter 5) worked the timber price, the higher the price, and the higher the extraction. The productive activities different from logging, the more possibility of allocating effort to this activities such as agriculture and fishing, the less extraction. The use of mechanized technologies to extract timber, such as the chainsaw, that permits to increase the level of extraction. The existence of a rule that sets an extraction quota is a condition that decreases the extraction. A governmental compensation aiming for not decrease the extraction is also important. The money lending from middlemen to loggers is a definitive condition for timber extraction. These variables were in place during the RPG. The loggers in the RPG were of two types, one group declared that they used chainsaw and the others used manual technologies. The first ones tried to allocate effort to fishing and agriculture and the second allocated the effort to high levels of extraction. The timber price, which was set by middlemen, and negotiated with loggers, played a fundamental role in the extraction decisions. The timber extraction influences the state of the resource, the loggers' income that depends on the sales to the middlemen, and the property rights of the territory. In the RPG was clear the creation of individual property rights of the forest as a function of the level of extraction.

Regarding rule compliance in the RPG, the general regulation that was mentioned has to do with the Law 70[47]. Most of the players discussed continuously about the territorial protection and forest conservation as their main responsibility. One of the concrete rules was about the prohibition of mangrove extraction for commercial use, rule that all the players followed. In the mental model the awareness of Law 70 is one of the variables determining the rule compliance. According the mental model the consequence of high levels of rule compliance is the protection of the territory of the Communitarian Council.

The collective mental model and the behavioral spectrum

In the section 5.3.5 of Chapter 5 the behavioral spectrum of the typology of players is discussed. The two types of players identified in this system are "*Rule breakers by necessity or convenience*" and "*Cheating players*". In the first category are the timber loggers and the owners of sawmills (middlemen). And in the second category are the local leaders. The mental model offers an explanation when some of the causal variables of extraction and rule compliance are examined. When the level of household needs is high for the loggers it is acceptable to change individually the rules (Table 5.16 Chapter 5). One of the variables governing the extraction in the mental model is the need. But also this type of behavior occurs when the middlemen demands timber under the minimum sizes that formal environmental rules permit. In the mental model is explicit the timber price as driver

[47] National Law that gives autonomy in territorial governance and collective land titling to the Communitarian Councils in the Colombian Pacific region

of the extraction, which determines the middlemen demand. Rule compliance variable depends on a variable called individual rule creation in the mental model. This is in tune with one of the conditions of the type of behavior illustrated in Table 5.16 (Chapter 5): it is acceptable for a person to change the rules. Regarding the behavior of the middlemen, which justifies morally rule breaking in order to sustain their business. This is also represented in the mental model in the positive relation between timber price and extraction, and the importance of individual rule creation and the negative relation between external rules and rule compliance. The justification for the rule breaking based on necessity or convenience could be explained by the particular SES context. This is a high level of UBN (68%) and also by the presence of timber price as driver of extraction and rule compliance.

The second type of behavior; "*Cheating player*" is associated to local leaders, in the sense that corruption is a very common problem among the Communitarian Council ACAPA's directive board members. The emphasis on individual rule creation and the importance of the existence of local rules for high rule compliance could be part of the explanation of this behavior.

6.5 Mental models in the water case

Fifteen interviews were used to elicit mental models of the aqueduct users from the upper, middle and low parts of the watershed. Only 12, out of 15, interviewees expressed clearly causal relations and variables. Figure 7.29 shows the number of variables extracted from each interview. The average number of variables is 23 and the standard deviation is 10,6 The feedback, collective RPG construction and RPG playing did not produced new variables or relations for the collective mental model.

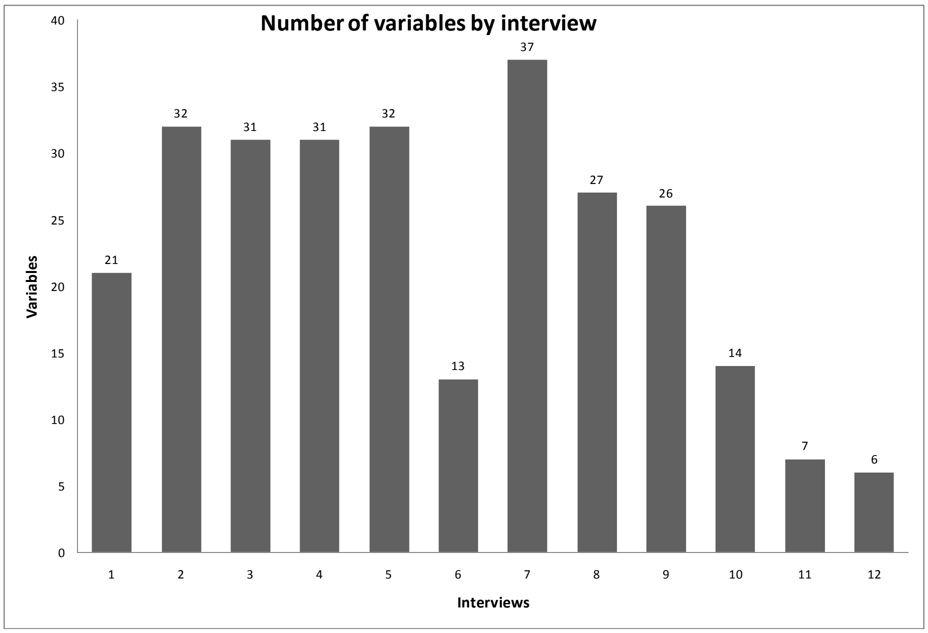

Figure 6.29. Number of variables by interview.

In the next section the individual mental model generated by the interview number 10 (Figure 6.29) is described.

6.5.1 Mental model 10 (MM10). Water production oriented

In this mental model there are three variables of equal importance: water production, paramo area and mining. The causal and network structure is illustrated in the Figure 6.30 and the Table 6.5 portraits the influential, intermediary and dependent variables according the network metrics. Water production depends positively on the area of paramo and the area of forest in the upper part of the basin. But the more area allocated to agriculture in the upper part of the basin decreases the water production. The area of the paramo ecosystem depends on mining, the more area dedicated to mining the less paramo in the upper part of the basin. The coal mining also contributes to the decrease in water provision and increases the chemical pollution. The water provision is negatively affected by the summer season. The high levels of rule compliance produce less sanctions and less denounce by users. External management schemas increase the aqueduct fees for the users.

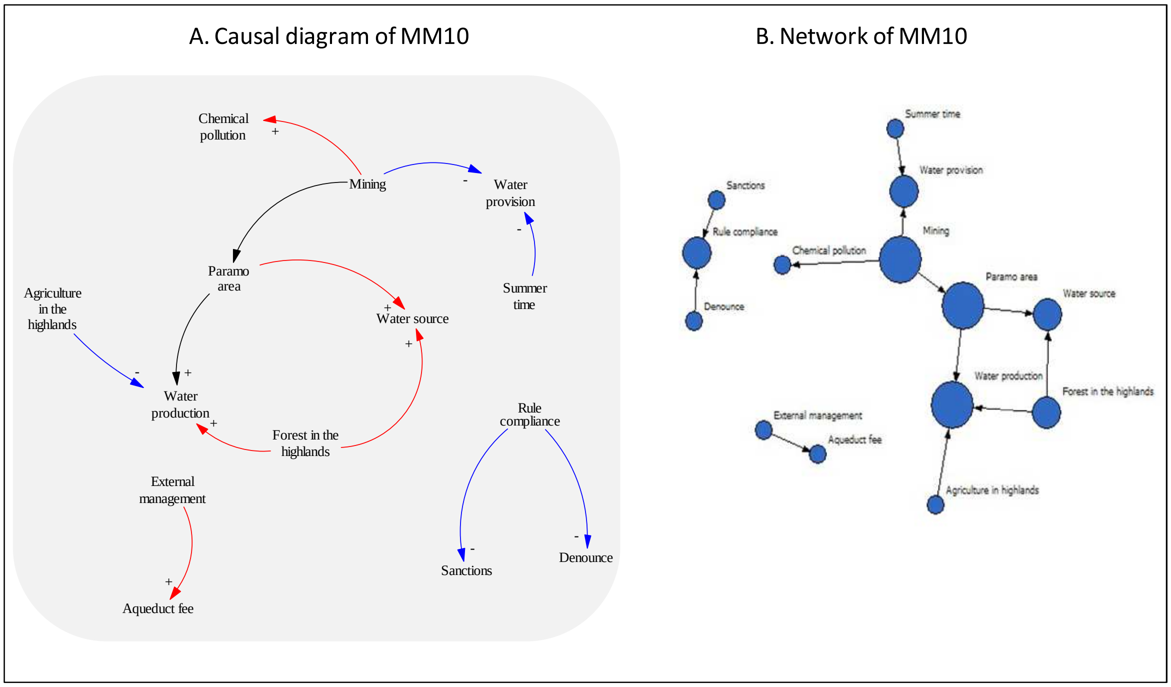

Figure 6.30. Causal diagram and network of an individual mental model

Table 6.5 Variables ranked according degree and betweenness centrality measures for MM10.

INFLUENTIAL VARIABLES	OutDegree Value	INTERMEDIARY VARIABLES	Betweenness Value	DEPENDENT VARIABLES	InDegree Value
mining	3	paramo area	2	water production	3
forest in highlands	2			water provision	2
paramo area	2			water source	2
summer time	1			rule compliance	2
denounce	1			aqueduct fee	1

6.5.2 Collective mental model (MMC) of the water case

Figure 6.31 illustrates the variables and its IDs used in different charts in this section. The naming of the variables corresponds to the closest English word to the concept expressed by the interviewee. As general rule the concept is expressed with nouns that communicate the idea of a variable that could increase or decrease. The use of singular or plural noun forms responds to the most common interviewees' wording. Exceptions to this rule were made with concepts that interviewees expressed consistently in a different forms. This is the case of "Upper part" and "Lower part" referring to the aqueduct users that live in each of the zones of the watershed. Variables that include the word "Conditions" refer to a concept of state or "health" of the ecosystem that can improve or not depending of different causes.

Variables of the irrigation case mental models

1 Agriculture
2 Agriculture in highlands
3 Aqueduct fee
4 Aqueduct maintenance
5 Aqueduct problems
6 Awareness
7 Benefits
8 Cattle rising
9 Cattle rising in the highlands
10 Chemical pollution
11 Conditions of the forest
12 Conditions of the nature
13 Conditions of the Paramo
14 Cooperation
15 Denounce
16 Environmental agency visits
17 Equity in water provision
18 External management
19 External monitoring
20 Forest in the highlands
21 Individual benefits
22 Livestock in the highlands
23 Lower part
24 Mining
25 Monitoring
26 Monitoring by the community
27 Monitoring efficiency
28 Monitoring of water quality
29 Organization of the Aqueduct Council
30 Paramo area
31 Participation in collective choice (Aqueduct)
32 Political influence
33 Rain
34 Rights to use the water
35 Rule compliance
36 Sanctions
37 Solidarity
38 Summer time
39 Trust
40 Unfair situations
41 Upper part
42 Water needs
43 Water production
44 Water provision
45 Water quality
46 Water scarcity conditions
47 Water source
48 Water use
49 Water use measurement
50 Water waste
51 Wealthy users

Figure 6.31. List of variables included in the irrigation case study.

The most mentioned variables in the interviews Rule compliance, Sanctions and Water production, present in ten interviews, followed by Forest in the highlands, Water provision and Water source mentioned in nine interviews, and Denounce appearing in 8. Figure 6.32 portraits this configuration for all the variables. Thirteen variables, out of fifty one, appear in six or more mental models. The collective mental model of the irrigation case (MMCI) was constructed combining the twelve individual mental models and consequently include the relations among them (Figure 6.33). The thickness of the relations indicates that a relationship is present in more than one individual mental model.

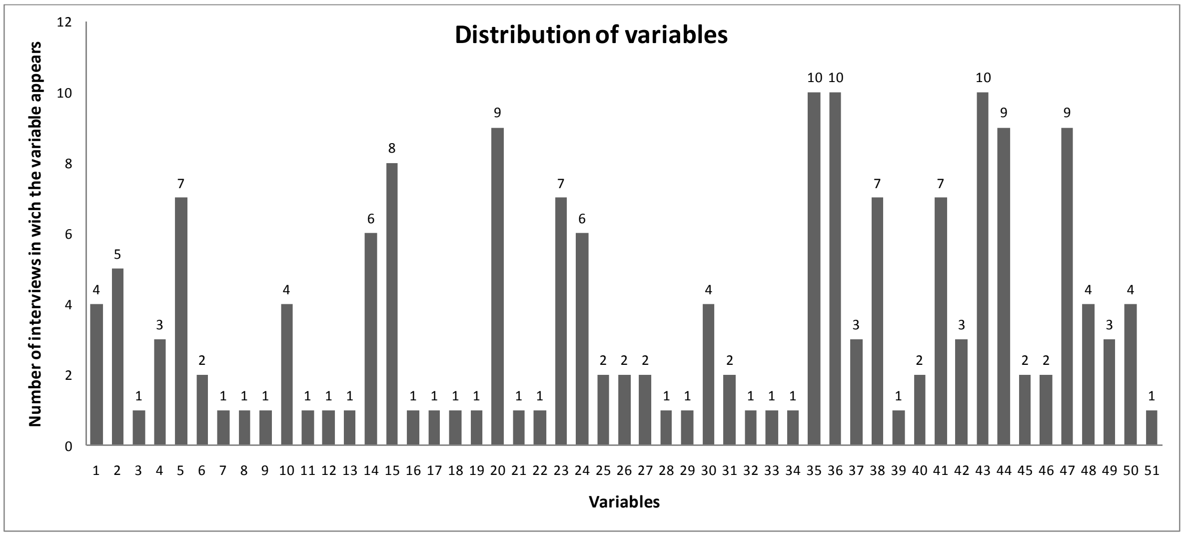

Figure 6.32. Distribution of variables among individual mental models. Variables ID corresponds to the list of variables showed in Figure 6.31.

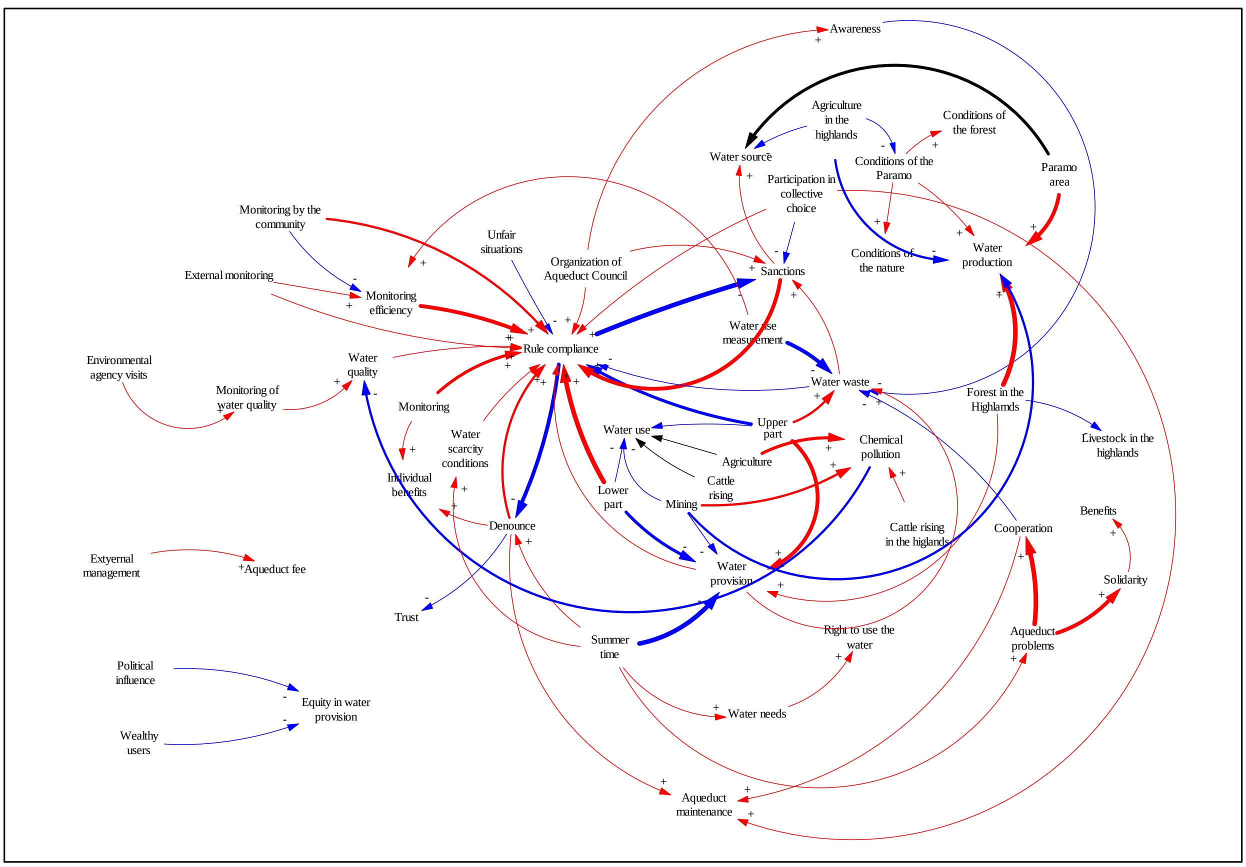

Figure 6.33. Collective mental model of the irrigation case (MMCI). Red arrows represent positive relations, and blue arrows negative relations. Black arrows represent a relation but without a clear polarity, the meaning is that a variable implies the existence of the variable

to which it is linked. The thickness of causal relations indicates that they were reported in more than one individual mental model.

The network view of the MMCI offers a perspective that makes easier the understanding of the model. The relative importance of variables, represented as nodes, is expressed by the size of the circles in figure 6.34. Node colors also provide an indication of the total degree score of variables. The variables with high degree score such as rule compliance, water provision, water waste, and denounce are the most active, in the sense that they have the most relations in the network. Therefore these variables are the more active in the relational process of causalities. Variables with low centrality level, such as blue and grey nodes, have very little effect in the network. Figure 6.35 shows the network in a circular view where is easier to understand the variables according their degree value.

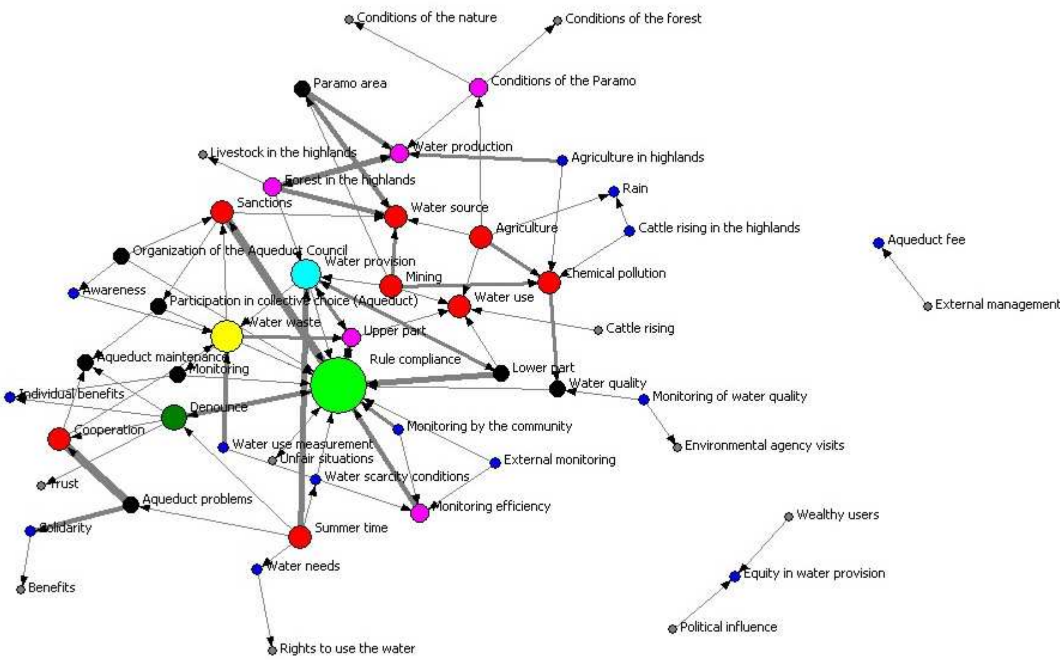

Figure 6.34. Network of the collective mental model (MMCI). The size of variables is an indicator of the total degree score. The thickness of links indicates their presence in more than one individual mental model.

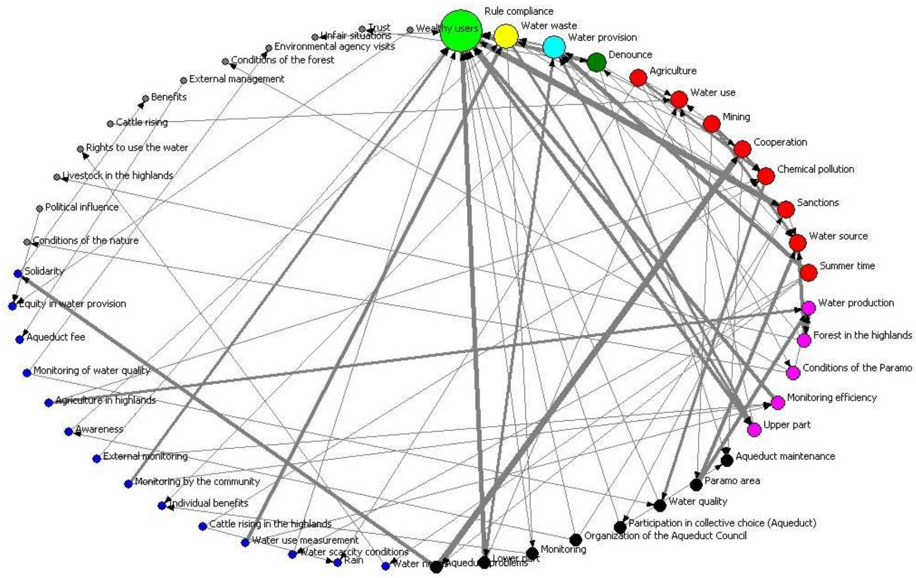

Figure 6.35. Circle network view. Degree centrality of the MMCI variables. The node size correspond to their degree score.

In terms of relations, the strongest relationship in the model is between rule compliance and sanctions, given by the thickness of the links in figure 6.33 and 34. High levels of rule compliance decrease number of sanctions and vice versa. Other strong relationships are summer time increasing decreasing water provision. People living in the lower part of the watershed are more likely to follow the rules, therefore rule compliance levels increase. The more monitoring efficiency, the more rule compliance. The more denounce generates higher levels of rule compliance, but also the other direction of the relation is part of the model; the more rule compliance, the less denounce. Another strong relationship is the presence of aqueduct problems increasing cooperation levels. And forest in the highlands and paramo area increasing water production.

Degree centrality measures also allow understanding the importance of variables regarding the influence and dependence of each one on the rest of the model. In degree index shows the dependence level of the variable rule compliance and its high score of out degree centrality. These values evidence the importance of this variable for this collective mental model (Figure 6.35 and Table 6.6). According the betweeness centrality index (Figure 6.36 and Table 6.6) rule compliance level is the most important variable because most of the causal chains in the model include this node. The meaning of this situation of the variable is that rule compliance level is the more relevant factor that controls the different outcomes of the mental model.

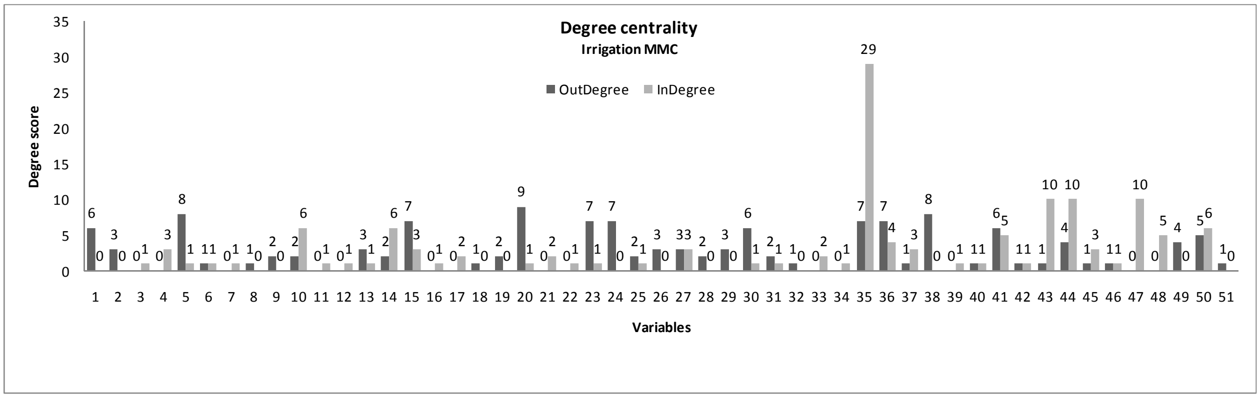

Figure 6.35. Degree centrality ranking for the MMC, showing the relation between influential variables (OutDegree) and dependent variables (InDegree). Rule compliance (variable ID 35), water production (variable ID 42), and water provision (variable ID 43) have the highest degree of dependence in the model.

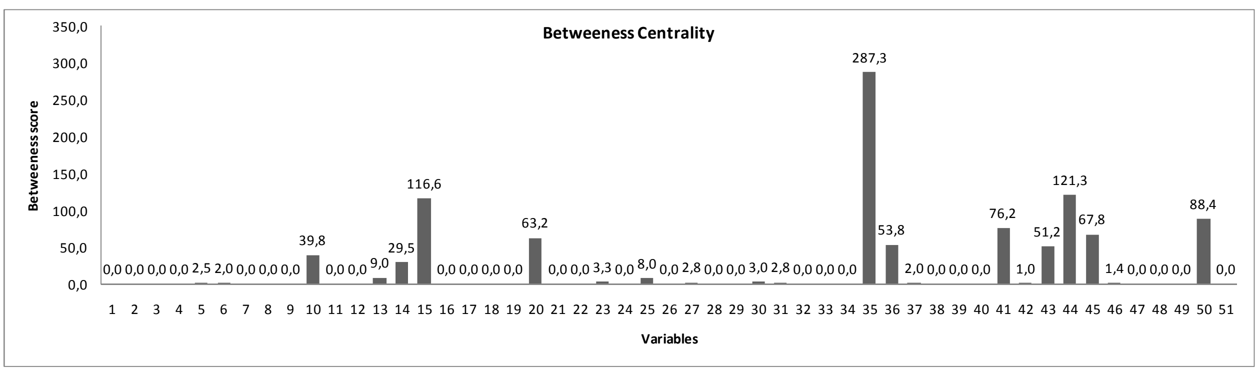

Figure 6.36. Betweeness centrality scores for the variables of the MMCI.

Table 6.6 shows the type of variables forming the structure of the model; influential, intermediary, and dependent. The usefulness of this typology is that it reveals how villagers think about the variables. Most of the people view rule compliance as the main transmitter or intermediary variable. Figures 6.37 – 39 portrait the causal trees of influential and dependent variables. Influential variables identified by the people are: the anmount of forest in the highlands, summer season, aqueduct problems, level of denounce and rule compliance (Figures 6.37 and 6.38). Dependent variables are rule compliance level, water provision, water waste, chemical pollution and cooperation (Figures 6.39 and 6.40).

According to the collective mental model rule compliance depends on a high number of variables. The first inference is that people identify a high number of causes for not fulfilling the rules (Figure 6.39), therefore, aqueduct users condition the rule compliance to specific factors. One of these factors is the scrutiny of others in the community; if there is a high level of social scrutiny, then people is more willing to fulfill rules. An aqueduct user follows the rules if he/she judges the others do their job properly, but if this is not the case is more probably that this individual breaks the rule. Therefore, is others' fault when a person does not follow the rules.

Table 6.6. Variables ranked according degree and betweenness centrality measures for MMCI. OutDegree scores reflect the number of causal relations that produce a variable. InDegree scores show the number of causal relations that produce consequences for the variable. Betweenness score express the number of variable pairs that are related through a given node.

INFLUENTIAL VARIABLES		**INTERMEDIARY VARIABLES**		**DEPENDENT VARIABLES**	
	OutDegree Score		Betweenness Score		InDegree Score
Forest in the highlands	9	Rule compliance	287,6	Rule compliance	29
Summer time	8	Water provision	121,3	Water provision	10
Aqueduct problems	8	Denounce	116,6	Water production	10
Denounce	7	Water waste	88,4	Water source	10
Rule compliance	7	Upper part	76,2	Water waste	6
Mining	7	Water quality	67,8	Chemical pollution	6
Sanctions	7	Forest in the highlands	63.2	Cooperation	6
Lower part	7	Sanctions	53,8	Upper part	5
Agriculture	6	Water production	51,2	Water use	5
Paramo area	6	Chemical	39,8	Sanctions	4

		pollution			
Upper part	6	Cooperation	29,5	Denounce	3
Water waste	5	Conditions of the paramo	9	Monitoring efficiency	3
Water provision	4	Monitoring	8	Solidarity	3
Water use measurement	4	Lower part	3,3	Water quality	3
Monitoring efficiency	3	Paramo area	3	Aqueduct maintenance	3
Agriculture in the highlands	3	Participation in collective choice	2,8	Equity in water provision	2
Monitoring by the community	3	Monitoring efficiency	2,8	Individual benefits	2

6.5.3 The socio ecological system and collective mental model

The water case study socio ecological system has the characteristics described in the following paragraph. The system boundaries are clearly established: the catchment area is the Peñaliza Creek or Granadillo Creek micro basin, the water inlet is in the upper part of the Peñaliza Creek. The source of water for the aqueduct is located in the upper part of the creek where the inlet is installed, which in turn is feed by the water accumulation in the higher "paramo" ecosystem. This ecosystem is highly vulnerable to anthropogenic land use such as cattle rising, carbon mining and agriculture. The first consequence of its alteration is the decrease in water storage and consequently the decrease in creeks and springs caudal. The tubes infrastructure covers six "veredas", serving 600 households, and 2583 inhabitants (Plan de Desarrollo Municipal 1999). There is a main tube that distributes the water in several minor tubes that serve individual households. The water distribution is done throughout a rotation scheme during the week. A plumber conveys and receives information on an almost daily basis during his monitoring and problem solving work. Precipitation has a bimodal behavior, which consists in a seasonal pattern of water availability consisted in scarcity during two months a year and the rest of the year the supply is normal. The precipitation pattern makes the water supply predictability high. There are no storage structures except the tank next to the water inlet in the upper part of the creek. The output of the aqueduct system is not directly related with agricultural or livestock production. The main output is the well being for each household derived from receiving water regularly directly in the house mainly for domestic use. The governing organization of the system is a communal association which members are all the users. The aqueduct infrastructure is owned by the communal association; it is a common resource. The aqueduct has a set of formal rules at the three levels: operational, collective choice and constitutional. Monitoring and sanctioning processes are carried out by members of the General Assembly and the plumber. In the rural zone of the Municipality of Lenguazaque, where the aqueduct system is located, the UBM indicator is 36.4%. Land tenure trend in the rural zone of the Municipality can be an indicator of land property in the zone covered by the aqueduct system. Seventy six percent (76%) of the owners of rural land own areas ranging between 0.5 and 5 Ha. The most probable trend is that properties will be less than 10 hectares in the short term. In terms of stability of the population, there are no data on population mobility, but from interviews, one can conclude that there is a tendency of young people to migrate to bigger cities. Before the aqueduct construction, in 1995, people had to go to the creek and manually transport water to their homes. A milestone in the decision for the organization of the aqueduct was a strong drought about 20 years ago and several episodes of water contamination because of carbon mining. As a consequence, leaders of the "veredas" gathered and decided to manage to build an aqueduct. Users of the aqueduct invest in the system throughout the quota every two months. These contributions are used to maintain infrastructure and pay the salary of the plumber. Conflicts arise occasionally when some users stock water and the aqueduct council does not intervene, or in cases that users try to appropriate water illegally. Lobbying activities with local and regional politics is important because is the form of acquire public resources for infrastructure maintaining or buying small land patches in the upper part of the watershed for springs conservation. The general assembly gathers once per semester, but also, occasionally users gather to plant trees or fix fences of communal land patches bought for springs conservation.

The collective mental model conveys a particular perspective of the important aspects (variables), for the users, and causal mechanisms regarding the water and aqueduct use and management. There are three main influential variables that condition several variables of the SES. The first is the existence and area of forest in the upper parts of the watershed that affects the water production and provision, but also the presence of livestock in these zones. The second influential aspect is the summer season that increases the aqueduct problems; the water needs of users, and diminishes the water provision and cause a generalized condition of water scarcity. Due to these conditions the aqueduct rule breaking increases and also the quantity of denounces by users. The third influential aspect is the aqueduct problems that are perceived as a driver of cooperation and solidarity. The cooperation is a condition for the aqueduct maintenance and the decrease in water waste. Solidarity offers general benefits for all.

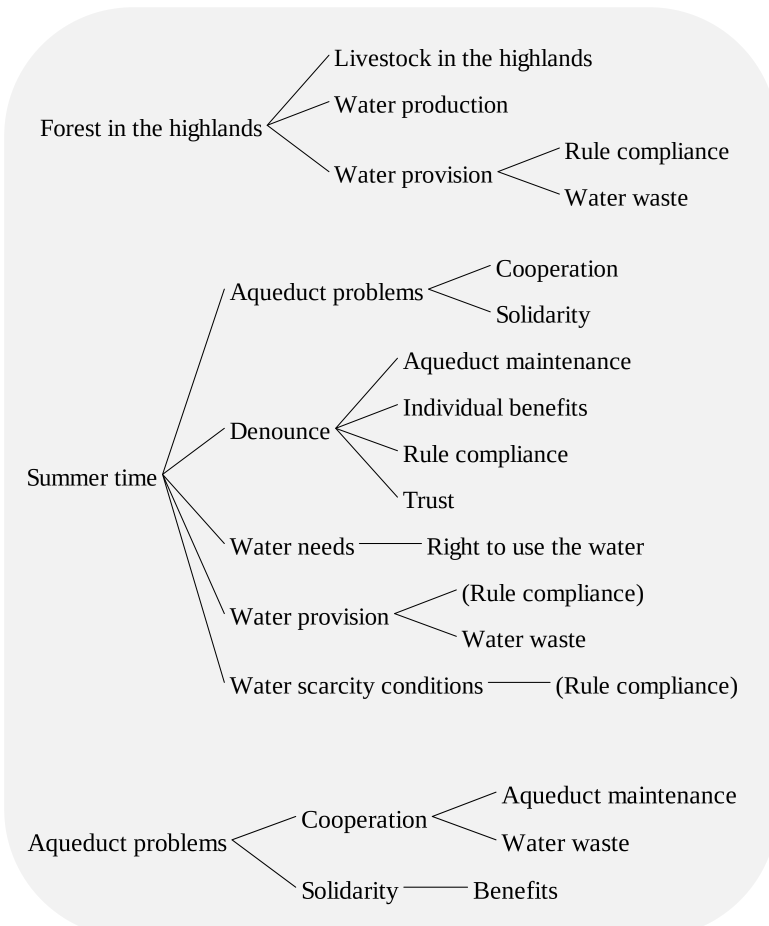

Figure 6.37. Influential variables of highest degree in the MMCI: Forest in the highlands, summer time, and aqueduct problems.

Rule compliance has a high importance in this collective mental model. The variables that condition that people follow the aqueduct rules belong to four types. The first has to do with monitoring and sectioning. In general, the perspective is that any type of monitoring increases the rule compliance, but if the monitoring is done by agencies external to the community, the efficiency is higher than a monitoring carried out by the community. Additionally the existence of sanctions increases the rule compliance. The second set of variables inform about the relation between the geographical location in the watershed and rule compliance. People living in the upper part of the basing tend to follow less the rules, in contrast with the lower part where the rule compliance is higher. This is reflected in the results of the water experiment (Chapter 5). When the rotation rule is used, which is similar to what is happening in the SES for water distribution there was not rule breaking in contrast with the quota rule that produced 18% of rule breaking. The third set of factors affecting the rule compliance is related with the collective choice arena. The more organized the aqueduct council, the higher the levels of rule compliance, and the more opportunities to participate in the administration of the aqueduct, the better the rule compliance. The fourth group of factors is related with the resource. Water quality affects the rule compliance positively, but the scarcity creates incentives to break the rules. The assurance of water provision decreases the possibility that users break the rules. And the water wasting by other users discourages people to follow the rules. When rule compliance improves denounces and sanctions decrease and the conflicts among users also.

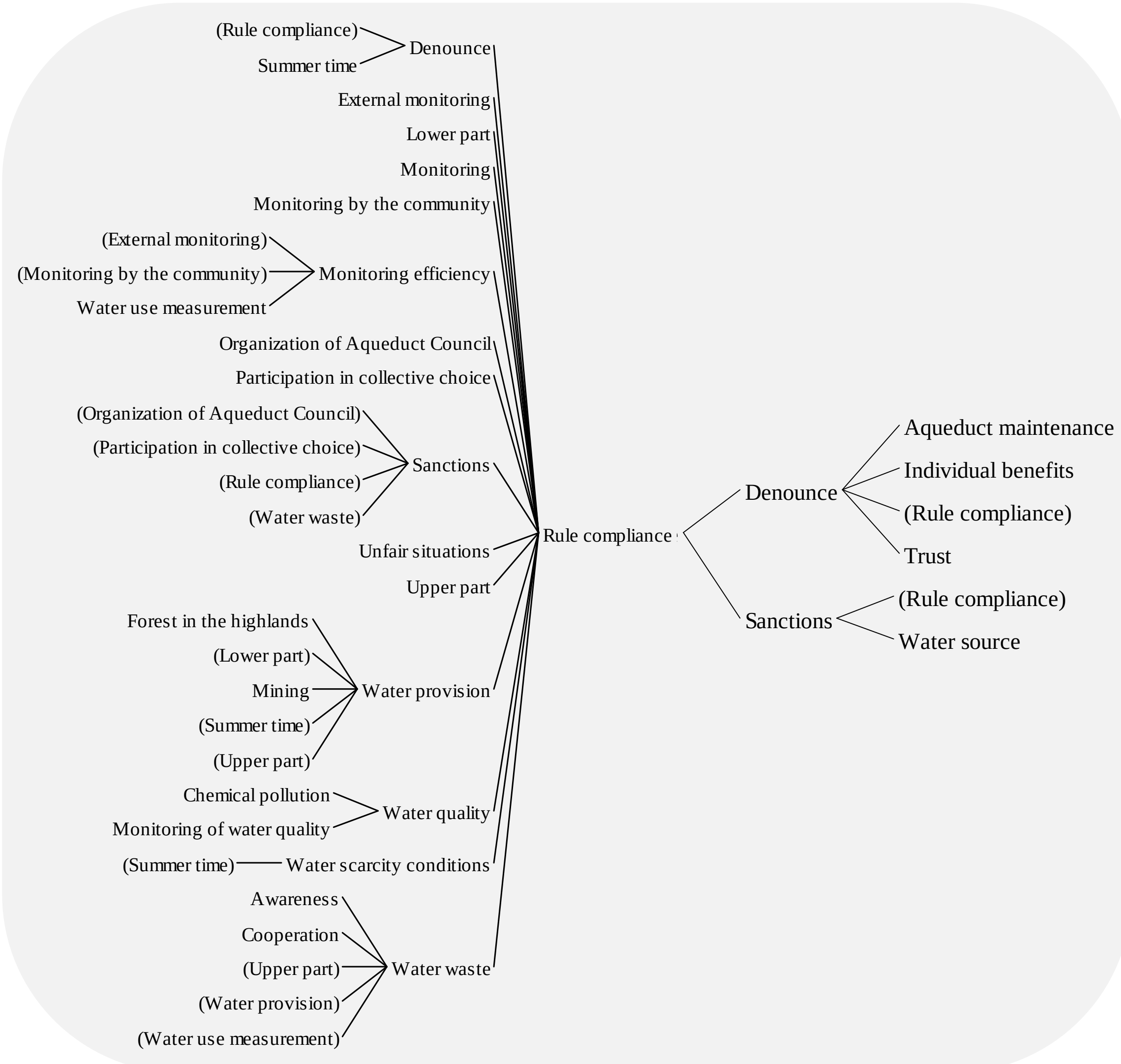

Figure 6.38. Dependent variables of highest degree in MMC: rule compliance.

The variables more dependent in the CMM are water provision, water waste, chemical pollution, and cooperation. The factors that affect positively the water provision are the presence of forest in the upper part of the basin and the behavior of people located in the lower part. In the water experiment (Chapter 5) when rotation rule where in place, the contribution to water provision of players located at the end of the channel (lower part of the basin) increased 60% of the cooperation equilibrium, above contributions of the A and B players. And the negative effects are due to the mining activities, summer seasons and the behavior of people from the upper zones of the watershed. The water waste is something that depends of the awareness level of users, the levels of cooperation and the behavior of upper basin users. The measurement of water utilization is important to decrease the water wasting. The water chemical pollution is affected by the three principal productive activities of the zone: agriculture, mining and cattle rising. These activities also contribute to the generation of land use conflicts in the upper parts of the watershed.

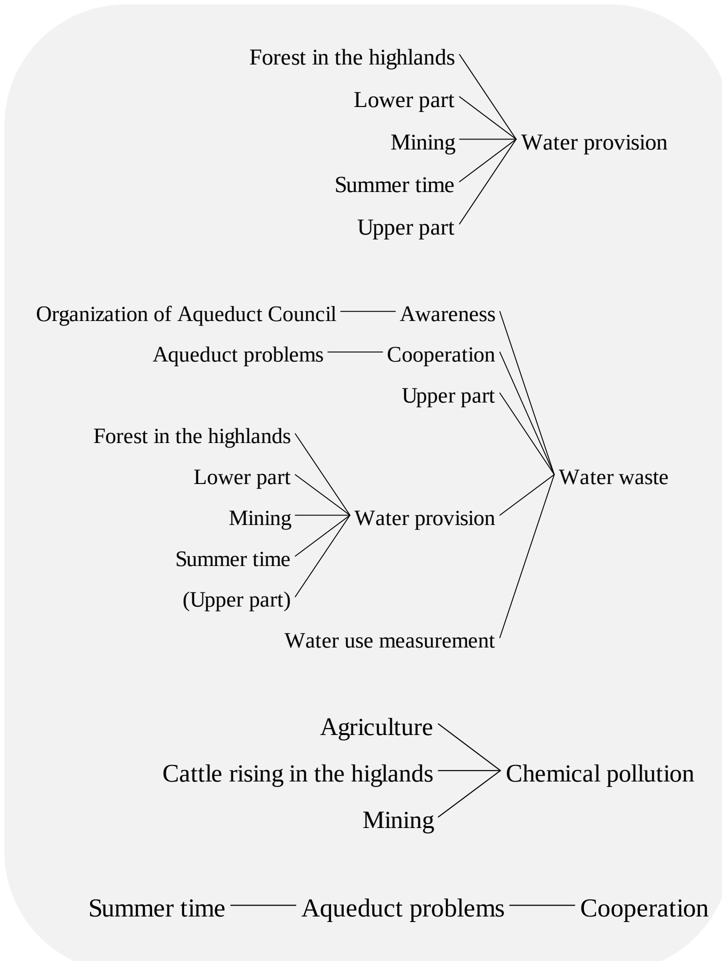

Figure 6.39. Dependent variables of highest degree in MMCI: rule compliance, water waste, chemical pollution, and cooperation.

Cooperation and rule compliance in the experiments

Cooperation in the experimental setting was represented by the contribution to the provision of water but also by the extraction or water use. The variables that affect water provision present in the collective mental model and in the experimental action arena are the location of users. In general users located in the upper part of the aqueduct contribute more to water provision, while users of the lower part contribute less. In the experiments players located in the upper part (players in position A and B) contributed more than the rest during the first stage of the experiments when there were no rules working (Figure 5.18 Chapter 5). The water use depends, in the mental model, of several variables, but in the experimental action arena only the location (upper and lower part location). The effect on water use is contrary to the effect on water provision. Users located in the upper part tend to use more water than users in the lower part. In the experiment (Figure 5.19 Chapter 5) this is the behavior of players across the channel regarding water extraction.

The mental model's variables that affect the rule compliance and that are present in the experimental action arena are location, external monitoring, monitoring by the community, monitoring efficiency, sanctions, unfair situations and water provision. When the rule of property rights was in place the rule breaking was relatively low (18%) (Table 5.18 Chapter 5). The variables sanctions, monitoring and water provision are the most influencing in the rule compliance level that, in turn made the water extraction to be more evenly distributed across the channel (Figure 5.19d Chapter 5).

Water provision, cooperation and rule compliance in the Role Playing Game (RPG

In the RPG of the aqueduct the main outcomes can be synthetized as follows. The players of the upper part of the basin accumulated mainly water, while players in the lower part accumulated money instead of water. The Aqueduct Council accumulated money but did not invested in forest for water provision. All the players were focused on developing their own strategies independently of the formal rules. The variables of the mental model that influences rule compliance such as monitoring, sanctions and organization of the Aqueduct Council have low levels that, in turn produced low levels of rule compliance. Now the water provision, in addition to location in the basin, included the variable forest in the highlands, which was increased only by the players located in the upper part of the basin.

The collective mental model and the behavioral spectrum

The typology of players identified for this case includes "*Rule breakers by conviction*" and "*Cheating players*" (Thable 5.25 Chapter 5). To the first category belong the most part of the aqueduct users, and to the second the wealthier users of the aqueduct. In this case rule breaking by conviction is linked to the adaptation to external power requirements in order to obtain own objectives. These objectives are focused in the satisfaction of household needs. The mechanisms to reach them are several. The historical behavior according what the formal rules and agreements are accepted in the discourse, but in practice the behavior deviates from that. The reciprocity rule for the interactions with external actors is fundamental for reaching their objectives. In the mental model there are elements that permit explaining this behavior in terms of causal structures regarding rule compliance (Section 5.4.5 Chapter 5). Regarding the monitoring and sanctions variables that affect rule compliance it is important to remark variables that have a negative relation with rule compliance. This if the variable level increases the rule compliance decreases. These are the existence of unfair situations in the use of water, monitoring and sanctioning, and external monitoring. Regarding the location, the persons that live in the upper part also have a negative relation with rule compliance. The second category of behavior, "*Cheating player*", is characteristic of wealthier users that gets more water. In the mental model this explicitly represented by the relation between unfair situations and rule compliance, not only by the offender but also the situation generates low rule compliance in the rest o users.

In general it is possible to infer from the mental model that the resource is a public good and a common good. The water is a right and there is not so much emphasis in water scarcity only in the summer season when following the rules is more difficult. The emphasis is more in the water waste as a lack of community awareness. The provision of the resource depends on variables that the users consider external or out of their control such as mining, forest areas and chemical pollution. To follow the rules in this system does not implies a big effort and it has not to do directly with improve or not their monetary income, it is related with the increase in their well being.

6.6 Conclusions

The variables rule compliance; resource state and extraction illustrate relevant findings of the mental models study. Table 6.7 shows the total degree score of each variable for each case. This is the total number of relations that includes the variable, which gives a proxy of the importance of the variable in the collective mental model. Rule compliance has a high value in the water case compared with the other two cases. This could be linked to the successful management of the communitarian aqueduct. For the fishery case, rule compliance has less importance reflecting that the central point is the inequality of rule enforcement. The forestry case shows the lower importance for rule compliance. This is according to the main characteristics of this system: forest use and management subordinated to the market rules, high levels of corruption and unsatisfied basic needs (UBN).

Regarding the resource, in the fishery the variable has the highest value reflecting the importance of the activity and the awareness of its importance. In the forestry and water the resource variable is not as important as in the fishery. The extraction variable is of high importance in the forestry case, users are economically highly dependent on it and it is the driver of the timber market.

The convergence of mental models has been proposed as one of the factors that affect the potential for self-organization in CPR management (Poteete et al, 2010). This is, the higher the level of homogeneity in the mental models in a group of individuals in a CPR situation, the higher the possibilities that they could develop institutional arrangements for a successful CPR management. Inspired by this idea a simple indicator of homogeneity was developed for the three case studies. Based on the interviews that generated the mental models for each case, a comparison between the total numbers of variables present in the collective mental model, and the number of variables included in each individual mental model was done. This calculation gives an indicator of similarity, in number of variables, between the individual and the collective mental model. Therefore, if the indicator has a value of 1, it means that the individual mental model has the same number of variables that the collective one. On the contrary if the value is close to 0 the individual mental model has very few variables. This indicator was calculated for each individual mental model and then the average of this value for each case was calculated.

The value for the fishery case was 0,35; the forestry case gave a figure of 0,11 and the water case a score of 0,45. The interpretation of this indicator is that the in the aqueduct system the level of homogeneity is considerably higher than in the other cases. This could reflect the success of the self-organization of the communitarian aqueduct (15 years), and also can be confirmed by the high importance of the rule compliance variable in the collective mental model (Table 6.7). The forestry case has a low homogeneity score, which could be reflecting the complexity of the political and conflicting context in which this SES has been developed. The high UBN (68%) could be related with the high importance of the market in the use and management of the forest, even having an autonomous governance system formally recognized by the Government. These conditions do not facilitate the successful forest and territorial management. In the middle of the two cases is the fishery case that has internal organizational and collective action difficulties.

Table 6.7 Relative importance of the central variables and homogeneity score of the mental models in each case.

	FISHERY	FORESTRY	WATER
Rule compliance	Degree: 15	Degree: 8	Degree: 36
Resource	Degree: 10	Degree: 3	Degree: 6
Extraction	Degree: 6	Degree: 15	Degree: 5
Homogeneity score	0,35	0,11	0,45

All the variables and relations present in a collective mental model do not work in every situation in which agents make decisions. The specificity of the action arena activates and neutralizes causal structures. A particular action arena provides the conditions for the strength or weakness in terms of structural dominance of causal structures that govern the decision-making. The hypothesis arising from this study is that the dominance of these causal structures is a function of the action arena complexity. A collective mental model shows a wide spectrum of variables and relations forming causal structures, but not the entire model is used in the actors' decisions in a given action arena and in a specific realm, in this case common resources use and management.

7. DISCUSSION

The goal of the dissertation was to study the link between CPR management, mental models and institutions. I intended to address the cognitive problem underlying common pool resources dilemmas in social ecological systems. I developed this research from the perspective according that natural resources management must include the understanding of human systems relations, human values and cultural conceptions. The hypothesis driving this research was that the actors involved in a CPR dilemma could have a different understanding of the commons problem in contrast with the common assumptions according that there is a relative high level of homogeneity among actors in the understanding of CPR dilemmas. This perspective has had consequences in terms of frequent policy failures discussed in the Chapter 1. The definition of problems in natural resources management is fundamental for policy design, but an appropriate problem definition depends on the effort for understanding the different types of knowledge and world visions of actors involved. Heterogeneity of actor's interests, values and priorities are the superficial expressions of deep structured visions of the world. In order to explore this problem I studied three case studies in Colombia, where CPR are central for the communities. The CPR in these cases are fisheries, water and forestry resources. I intended to link the local context, institutional arrangements and mental models in order to explain decision making of resource users. The general research question was: what are the relations between mental model of resource users and the institutional landscape and ecological context they face?

In this final chapter I first offer a brief overview of the results of the conceptual framework discussion of Chapter 2. I start by reviewing the lessons from the institutional analysis. I particularly want to focus on the general morality conformance outcome of the action arena. I make a discussion about the methodological lessons of the research for the study of SES. In the next section I discuss the main lessons of the methodological approach used in this dissertation. Finally I close the chapter with the main insight from the research.

7.1 The behavioral outcomes of the action arena

In the conceptual state of the art (Chapter 2) I developed a conceptual integration of the theoretical elements that constitutes the behavior possibilities of CPR users as outcomes of an action arena (Figure 2.15 Chapter 2). The proposal is that the ultimate behavioral outcomes in an action arena have, on one hand, specific cooperation and trust levels, and on the other hand, a specific behavior of CPR users regarding the level and reasons of rule compliance. This behavioral spectrum includes rule breakers by conviction, by necessity or convenience and cheating players . These ultimate behavioral outcomes are consequence of another type of results: 1) which are the mental models, that are context dependent constructs, and 2) a morality conformance system. In this structure the institutional arrangements are shaped, on one side, by the mental models, and on the other side by the moral system, which in turn is conditioned by cooperation and trust levels and the behavioral spectrum. The institutional arrangements are also affected by this moral system, and more directly the norms, endogenous rules and agreements.

In the next two sections, first I consider the main lessons from the institutional analysis. And secondly, I discuss how the conceptual framework mentioned above worked to study the relation among institutions and mental models. It is important to remark that in the path to study this relation, I found that a fundamental dimension that was missing in the initial approach of this research was the moral system, which I consider that is one of the most important lessons from the study.

7.1.1 Lessons from the institutional analysis

Cooperation and trust levels are important behavioral outcomes of the action arena in CPR dilemmas. The data used to understand cooperation and trust variables were obtained from economic experiments, role playing games (RPG) and surveys and interviews. In the three SESs cooperation has different forms and drivers. The definitions of trust and cooperation are varied in the literature depending on the field and even an author could change his notion depending on the type of problem addressed. For Luhmann (1982) trust is the starting point for rule crafting in order to shape individual behavior. In this sense the trust has the function of diminish the levels of social complexity. For the author trust is the most effective way of diminish social complexity, and in this form appear more action possibilities and less uncertainty regarding the outcomes. For experimentalists trust is conceptualized as the support of cooperation, and trust has been defined as the "*cognitive belief that others will positively reciprocate one`s willingness to take a risk*" (Levi, 2003: 379), or the "*willingness to take some risk in relation to other individuals on the expectation that the others will reciprocate*" (Ostrom & Walker, 2003: 382). Users of the three case studies investigated in this research seem to have similar notions of trust. However the findings of this research are consistent with other studies in the sense that trustworthiness levels have a big variability across cultures and across groups (Henrich et al., 2001; Henrich, 2004). In the three SESs studied trust rests on particular moral systems that produce the variability mentioned by Henrich and colleagues.

Cooperation, as a product of trust, is the final result of behavior. As I have discussed in chapter 2, in line with Nowak (2006) and Nowak & Sigmund (1998), cooperation entails five mechanisms (familiar selection, direct reciprocity, indirect reciprocity, network reciprocity, and group selection) that are explained by the evolution of the moral instinct (Haidt, 2007; Haidt and Kesebir 2010). In the three case studies of this research cooperation has different expressions and levels.

In the fishing case, the cooperation is defined as the level of resource extraction, and also is something that characterizes the relation among users. There are two types: short and long term cooperation, which are in opposition. This is, the high levels of short-term cooperation destroy the possibilities of the long-term cooperative behavior. The first type of cooperation tries to fulfill immediate needs, and implies that users do not try to enforce fishing rules. The long-term cooperation has to do with the resource used to generate sustainability, and this is conditioned by two main factors: the consensus with environmental authorities on one hand, and on the other, the real possibilities of alternative income opportunities. This situation seems to be supported in the high levels of trust that users perceive in their community.

In the forestry case, the cooperation also is defined in two ways; among actors, and by the timber extraction levels. The trust levels in this SESs seems to be not as high as in the fishing case, but still has a moderate level. This system shows a particular negative relation between trust and rule compliance: the more trust among the community, the less rule compliance is possible. One of the main drivers of cooperation in this case is the market; the demand dynamics conditions the levels of cooperation. In this relation the role of middlemen is vital by determining the levels and quality of timber extraction, and also the rule compliance. The highly conflictive context of the SES, which has triggered important levels of violence against the community by external illegal armed actors, has had an important negative effect in the levels of cooperation at least in the last decade.

In the water case, the cooperation is defined by the level of water use, but also by users' contributions to the resource provision. Trust levels in this community are extremely low, not only among the community, but also regarding external actors, public and private. In this case there is a paradox, which consists in that it is the systems that better works in terms of resource appropriation and provision. Therefore, the question is, if trust levels are so low, why the aqueduct has worked for nearly 15 years? The answer can be a combination of three different reasons. First, this system is the only that produce household wellbeing, but it is not related directly with users' income, the character of resource dependence is different from the other two cases. For the second reason I use the hypothesis posed by Hilton (2002) in relation to irrigation systems management: "*The more closely a clearly defined distribution pattern is adhered to, the more effective local resource mobilization for recurrent costs is likely to be*" (157). This covers the two main aspects of water distribution that are volume and timing. The mentioned author states that there is a positive relationship recognized in irrigation systems between the system trustworthiness and the willingness to contribute, paying fees, and willingness to mobilize resources for the system maintenance. The third reason has to do with the historical construction of a particular moral system that has been built on the basis of individualism and low levels of trust among the community, but with a high adaptive capacity and a necessity to develop their own solutions independently from external public or private actors.

In the three case studies the structure of the experimental action arena for the three cases generates strong incentives for individualistic behavior. The lack of communication and the short-term monetary incentives push the system towards low cooperation and trust levels. Rules are seen, in general, as externally imposed (though they are voted, they are not self designed nor discussed or without reached a consensus), and do not increase importantly the levels of cooperation.

Regarding the resulting behavioral spectrum outcome, the three case studies have particular types subordinated to specific conditions (Mockus, 1994, 2002). In two of the cases, fishing and water, *the rule breaker by conviction* type is subordinated to conditions that has to do with the satisfaction of household needs and the legitimacy level, from the perspective of users, of rules. The rule breaker by necessity or convenience, which was found in the fishing and the forestry SESs, in both cases conditioned to the individual needs, but in the forestry case, also to the market demand. In the three SESs studied the *cheating player* is present. And it is conditioned to wealthy actors, local leaders except in the water case. It is associated, in addition to some RPG direct users also to other actors except in the water case.

As I stated in the conclusions of the chapter 2, the action arena's outcomes is characterized by three types of behaviors that can be grouped in moral, legal and cultural domains feed this behavioral spectrum. Following the proposal of Mokus (2002) the explanation of the relation between behavior and rules lies in the gap between law, morality and culture, the analysis offers concrete results for the three case studies (figures 5.9, 5.16 and 5.24 of Chapter 5). In the fishing and water cases the intersection among the three domains is equal to only one type of behavior that belongs to the legally valid behavior in origin, but is accepted and followed morally and culturally. The percentage of shared behaviors by the three domains in these two cases is of 9% with reference to the total number of behavioral types. Things are different with the forestry case where this score increases to the 23% where behaviors from the three domains are present in the common space. This fact explains the low rule compliance level in the fishery and forestry systems. In the water case, however, the low percentage does not give an explanation for the satisfactory outcomes of the aqueduct functioning. Again there is an important difference maybe due to the three reasons mentioned above to explain the low levels of cooperation and the success of the system functioning.

But the percentage of coincidence can be misleading if one do not pay attention to the content and meaning of what falls in the intersection. In the fishing case the confluence of the three domains gives information about the "how to do things", this is the *choice* rule (Ostrom, 2005) in use which is one of the most relevant for resource sustainability: the fishery gear that can be utilized. In the forestry case, what lies on the intersectionof the three domains is a *boundary* rule (Ostrom, 2005), which defines who is the population that can use the resource (Afrocolombian population belonging to the Communitarian Council of ACAPA), but it does not say how to do the actions, how to cut timber, remember that in this case the extraction is driven by the market rules and rule compliance is low. In the water case the intersection is occupied by an element that is substantial for the aqueduct functioning, which is the also, as in the fishing case, a *choice* rule (Ostrom, 2005). That is to use the water only for domestic use, not for irrigation.

7.1.2 Lessons from the mental models study and its relation with institutional arrangements

One of the more important lessons from the mental models study (chapter 6) is that all the variables and relations present in a collective mental model do not work in every situation in which agents make decisions. The specificity of the action arena activates and neutralizes causal structures. A particular action arena provides the conditions for the strength or weakness in terms of structural dominance of causal structures that govern the decision-making. The hypothesis arising from this study is that the dominance of these causal structures is a function of the action arena complexity. A collective mental model shows a wide spectrum of variables and relations forming causal structures, but not the entire model is used in the actors' decisions in a given action arena and in a specific realm, in this case common resources use and management. A word must be said to refer to the relation between individual and collective mental models. A first characteristic of individual mental models is that they are the building blocks of a collective mental model. An individual mental model can be located in the periphery of a collective mental model or in the center, this is, that it can be shared by most of the individuals (centered), or can reflect a completely new set of variables and relations, which could be unique. The interpretation I derive from this research is that even if a mental model is far from the center, the opinions and decisions, collectively seen are fed in specific situations by this structure.

Tables 7.1 to 7.3 illustrate the relation among the operational rules, orientation of relevant mental models structures, and the most relevant insights of the moral, culture and law analysis. The comparison of the three systems shows first interesting difference in the elements located at the intersection among moral, culture and law (Chapter 5) and the influence on a specific type of rules. In the fishing case the coincidence of the three domains evidences a consensus and an acceptance in “how to do things”, which has a clear expression in choice rules. The justice conception is not at stake because there is awareness about over extraction consequences and the compromise of household needs if the resource collapses. In the forestry case the agreement of the three domains evidences a consensus and an acceptance in “who have the rights”, which has its expression in position and boundary rules. And in the water case, the concurrence of the three domains evidences a consensus and acceptance in “the essential”, which has its expression in choice and boundary rules. Regarding the divergences or the elements that are not shared by the three domains, in the fishing SES, the mental models show the specificity of the divergences: rule breaking is accepted when rules are not legitimate, and rule enforcement is differential. This is the reason why in the rest of rules there is a bigger divergence among culture, law and moral. In the forestry case, the divergences in the three domains (culture, law and moral) are dominated by the independence in rule creation, even at individual level. This is that users build their own rules to extract timber in the forest. Market and household need dominates the ethical system. The water case study shows that the divergences are dominated by the adaptive behavior towards the external actors that implies a distance between the communitarian internal norms system and the discourse. The conceptual proposal in the conclusion of chapter 2 was that the conformance to general morality, as outcome of the action arena in a SES, determine the levels of trust and consequently of cooperation. These outcomes feedback the users and governance subsystems in a SES. Cultural, moral and legal behavior domains interplay and, in turn, determine users and governance subsystems. The lesson from the research is that the elements shared by the domains of moral, culture and law in a particular SES determine the more relevant aspects for the users, and in consequence the more relevant operative rules of the system.

A final insight from the mental models study is related with the experimental action arena and rules. Economic experimentalists usually assume that payoff rules are the key to induce and study behavioral changes. In other words, the experimental approach focuses in positive and negative economic incentives to affect the interactions in the action arena and observe the outcomes. What indicates the mental models study is that the payoff rules are not the key element in SESs’ action arenas. These rules can generate behavioral changes but in combination with other factors such as the legitimacy of rules in the fishing case, the market, household needs and high levels of trust allowing the rule breaking in the forestry case, and fairness in rule enforcement in the water case.

Table 7.1 Relation among operational rules, mental models and moral-culture-law systems in the fishing SES

	FISHING SES				
	Position	**Boundary**	**Choice**	**Information**	**Payoff**
Rules	-Local fishermen -External fishermen -Industrial -Governmental authorities -Touristic external operators	- Local fishing rights (traditional supported rights) -Differential rule enforcement according economic and power positions	- Extraction according needs and species - Gear restriction	-Information restriction about rule breaking	-Graduated sanctions Rarely enforced.
Mental Model Orientation	-Territorial conception -Justice conception	-Territorial conception -Fairness of formal rules and enforcement	-Household needs -Local tradition -Awareness of consequences of inappropriate extraction technologies	-Relation between legal and illegal vs. -Knowledge about the ecosystem	-Fairness of formal rules and enforcement -Justice conception
Moral–Culture-Law Gap	The coincidence of the three domains evidences a consensus and a acceptance in "how to do", which has a clear expression in				

choice rules. There is no relation with fairness conception. The justice conception is not at stake because there is awareness about over extraction consequences and the household needs would be compromised.

Mental models show the specificity of the divergences among moral, culture and law: rule breaking is accepted when rules are not legitimate, and rule enforcement is differential. This is the reason why in the rest of rules there are a bigger divergence among moral, culture and law.

Table 7.2 Relation among operational rules, mental models and moral-culture-law systems in the forestry SES

FORESTRY SES					
	Position	**Boundary**	**Choice**	**Information**	**Payoff**
Rules	-Local extractors -Middlemen -Governmental authorities (environmental, and police)	-Local collective property rights (Ancestral and ethnic supported rights) -Traditional individual rights to extract (De facto occupation supported rights) -Middlemen control extraction and transport permits	-Commercial mangrove extraction is not allowed -Spatial and minimum sizes restrictions -Middlemen demand rules the extraction -Respect of forest regeneration time (2-10 years)	-	-Species market price determines monetary incentives
Mental Model Orientation	-Collective land property rights -Timber market	-Collective land property rights -Individual forest management -Timber market	-Timber market vs. -Knowledge about the ecosystem	-	-Timber market
Moral-					

Culture-Law Gap	The coincidence of the three domains evidences a consensus and a acceptance in “who have the rights”, which has its expression in position and boundary rules. The divergences in the moral-culture-law space are dominated by the independence in rule creation, even at individual level. Market and household need dominates the ethical system.

Table 7.3 Relation among operational rules, mental models and moral-culture-law systems in the aqueduct system

	WATER SES				
	Position	**Boundary**	**Choice**	**Information**	**Payoff**
Rules	-Aqueduct users (Households) -Plumber: aqueduct maintenance -President of the aqueduct council -Municipality -Governmental environmental authority	-Membership to the aqueduct -Entry fee -Geographical criterion	-Rotation scheme -Only domestic use of water. -Agricultural irrigation is prohibited. -Fixed amount of water for each household.	-Offenders to the rules are not denounced -The aqueduct council must report twice a year on the activities and relevant issues	-Two months frequency fee. -Graduated sanctions
Mental Model Orientation	-Fairness of formal rules and enforcement -Water provision efficiency	-Collective choice	-Use according location in the system -Social control	-Monitoring and sanctioning -Social control -Collective choice	-Monitoring and sanctioning -Resource state
Moral-Culture-Law Gap	The coincidence of the three domains evidences a consensus and acceptance in “the essential”, which has its expression in choice and boundary rules. The divergences in the moral-culture-law space are dominated by the adaptive behavior towards the external actors that implies a				

	distance between the communitarian internal norms system and the discourse.

7.2 Methodological lessons

The methodological process of this research aimed to model a representation of the SESs in each of the case studies and their explanations in cognitive terms. The starting point using a researcher`s simple model of CPR dilemmas and SESs in the form of economic experiments settings provided a useful initial reference point that allowed to acquire a particular perspective of the problem studied. The collective construction of the RPG using such reference model was effective not only to understand CPR users perspectives, but also to position researchers at the same level of users and establish a productive dialogue. This dialogue produced different versions of the action arena in which interactions occur. Though the RPG action arena complemented by interviews and surveys provided a more complex model, they offer a sort of static picture of the SES. The geographical and historical context research gave the essential dimension to understand and unveil the roots of the so-called cognitive problem in CPR management in the SESs studied. Experiments and RPG provide an action arena model but one that resembles to be on the crest of the wave. The historical and geographic context provides the richness of the *longue durée* in the sense of Fernand Braudel whose metaphor is quite illustrative: the history is like the depth marine streams, but there are also, waves and storms in the sea, they are the present events, the real change occurs when the marine streams change. I do not claim that this study has documented as deep as the stream changes, but I believe that I have studied at least the waves and their crests, and thanks to that I have discovered the importance of moral systems in the dynamics of SESs.

The spirit of the methodological path followed in this research was inspired by the ComMod perspective (Etienne, 2011), and a post-normal vision of science (Funtowitz and Ravetz, 1994). From this perspective, SES management is a post-normal science issue because there is a poor fit with conventional positivistic science that works better when systems are bounded and easily controlled (Berkes and Berkes, 2009). The ultimate aim of this research was to contribute to understand key elements for SES management, therefore the stance adopted was the one mentioned above. The experiences carried out in each of the case studies did not close a process like in a complete ComMod process due to logistics restrictions and contextual conditions. It is fundamental for future research from the same perspective the involvement of a formal process assessment tools in order to understand the effects of these kinds of interventions.

7.3 Commons, management and moral systems

Ostrom (1992) explains that there is no such thing like common pool resources, what happens is that there are different management forms, one of these is their management as a common property. The resource destruction depends on the way in which the property regime faces costs and benefits distribution problems of the resource management. The first level of analysis to address the cognitive problem in CPR management consists in the forms that governmental authorities define the resource and the difference with the direct users understand and define the problem. As a consequence, the situation in the practice is the existence of at least two management styles superimposed. Management styles have assumptions about the right and wrong practices, and about the type of desired SES, and the paths to achieve such system states. The challenge is to understand the underlying logics of these styles, and this led to a deeper level of analysis, which is the ethics, understood as the set of moral principles influencing and governing behavior of human groups in charge of CPR management.

The main insight is that the issue cannot be treated as a simple divergence in representations and variables taken into account by different actors; direct users and governmental policy designers. The expectations at the beginning of this research consisted in finding a sort of patterns of divergences in the understanding of the CPR dilemma across the three case studies. But the research has shown that there are no patterns, at least at simple levels such as more or less variables and relations defining used to define the problem. The problem is more complex because it entails particular moral systems that are the product of particular contexts and histories of the SESs. In terms of the conceptual framework used in this study, there is a constant feedback from the action arena to the moral system as an outcome, but also this moral system is shaping the action arena´s interactions, in order to produce trust and cooperation levels and a behavioral spectrum. Therefore, in order to understand the behavioral outcomes in CPR dilemmas, and designing policy interventions to improve CPR management, it is necessary to understand the particular moral systems that are influencing also the contextual mental models of SES’ actors.

8 CONCLUSIONS

In the introduction of this dissertation I proposed a research problem claiming that it was at the core of the common pool resources management, and that was not enough investigated before. The problem consists in the divergences between the CPR' direct users, policy makers and researchers on the nature of the CPR problems definition. This situation has been called a cognitive conflict, because it implies different forms of understanding commons dilemmas, which have consequences in the decisions, strategies and rules designed to overcome such dilemmas. This problem led me to the central question of this research: What is the relation between mental models and institutional arrangements in CPR management? In order to answer this question I decided to examine three case studies in Colombia that could reflect the problem in three classical CPR management: small scale fishing, water management and forestry. In the process of disentangling the relation between these two (mental models and institutional arrangements) variables I made a conceptual, methodological and empirical journey, which main findings are synthetized in this chapter.

As a result of the revision of the conceptual state of the art regarding CPR dilemmas and management, institutional analysis and Socio Ecological Systems (SESs), a conceptual framework has proposed to guide the research. The SES approach has proved its usefulness to frame and guide the study. Inside this framework the institutional analysis (IAD) has been used to construct a unit of analysis (action arena) and propose a structure for the action arena`s outcomes. This outcomes' structure articulates mental models of resource users, moral systems, institutional arrangements, and trust and cooperation levels that lead to behavioral types. The conceptual revision allowed the definition of the elements that should be studied in each of the relevant concepts mentioned above. For the mental models of the resource users, variables and causal relations among them were the main variables to observe. For the institutional arrangements, the IAD provides the concepts of action arena, interactions, outcomes rules in use and typology of prescriptions (norms and rules). The IAD utilization also needed a decision about the evaluative criteria to observe and discuss the outcomes. During the literature review emerged the idea of the general morality conformance and trust and cooperation levels as evaluative criteria. It was evident the gap in the commons research in examining the general morality conformance. In short, the final analytical and conceptual tool is a proposal for the outcomes structure briefly described above.

The SES approach works well to understand the role of the context in the action arena, which is reflected in the outcomes. The geographic and historical context of the three case studies has provided a clear perspective of the setting of each of the CPR case. The development of this context was fundamental to understand the ecological and social dynamics of the cases as well as the potential shocks that each SES could experience in the future. The use of the diagnostic variables proposed by the SES framework allowed comparing the case studies in spite of the different nature of the resource at stake. The comparison was carried out using the notion of subsystems of a SES. They are resource system, resource units, governance system, interactions, outcomes and potential shocks. Each of these subsystems has a set of second tier variables that helps to compare the three case studies. The users and governance subsystems guided the approach to the institutional analysis.

The institutional analysis showed that the most important outcome of the action situation is the general level of morality conformance as a result of long-term institutional arrangements. Individual and collective moralities are fundamental for reaching or not high levels of cooperation and trust regarding common resources use and management. Cultural frameworks include morality as one of their elements to select, interpret and present information. Morality offers value judgments about what is morally acceptable or not about specific situations. In order to relate morality with the institutional arrangements the different behavior al types of resource users regarding rules and CPR management were interpreted as morally, culturally or legally valid behavior. The development of the IAD showed that CPR users make daily compromises to among the three types of valid behavior. As a reference point, and theoretically, when the behavior of a group is at the same time morally, culturally and legally valid, the formal institutions coincide with the rules in use, and the commons dilemma could be solved. The central proposition is that a possible approach to the rule compliance solution is that cultural, moral and legal behaviors coincide and the gap among the three sets is very small. A more realistic vision is that each individual makes decisions as a result of a permanent tension among the three domains. The process could be a conciliating process among the three domains giving more weight to the options according to the particular action arena and interests at stake. In the three SESs different types of gaps among morality, culture and law were found due to particular historical and geographical contexts. In each of the case studies the findings could be synthetized as follows.

The fisheries case shows the biggest gap among morality, culture and law, which reflects a historic trend of formal illegality and lack of legitimacy of formal rules. This fact transforms the action arena in to a game in which the moral and cultural behaviors are valid, but not the type of behavior that follows the formal law. Therefore, rule enforcement and monitoring are only rare and external events that fishermen must avoid.

In the forestry case the discourse of local activists does not coincide with the daily life practices of the population, in terms of the pretended ancestral collective use of the land. This fact makes difficult an effective process of institutional arrangements crafting that leads to conflicts among leaders of ACAPA. This is the partial cause of the deviation of some elements of the culture and moral domains from the legal valid behavior. This point constitutes an important factor affecting the institutions in the utilization of the forest and could be an indicator of the distance between mental models of inhabitants of ACAPA and the formal property regime regarding the territory. This dynamics gives clues about the problem in this action situation: weakly enforced rights, recent history of new property regimes and weak state institutions.

In the water case the there are few types of behavior that are shared by the three behavioral domains; moral, cultural and legal. Here, again the historical trend of a colonial relation that ruled the interactions since the Spaniards arrival originated a particular type of interactions in the action arena that produced and continues generating a particular moral system as one of the most important outcomes. Therefore, the aqueduct users are classified as rule breakers by conviction.

The lesson is that the elements shared by the domains of moral, culture and law in a particular SES determine the more relevant aspects for the users, and in consequence the more relevant operative rules of the system.

The mental models study illustrated how the variables rule compliance; resource state and extraction are fundamental for CPR users. As one of the results I proposed the notion of a collective mental model, which consists in the aggregation of individual mental models of resources users.

The importance of rule compliance for each case study could be explained as follows. Rule compliance has a high value in the water case compared with the other two cases. This could be linked to the successful management of the communitarian aqueduct. For the fishery case, rule compliance has less importance reflecting that the central point is the inequality of rule enforcement. The forestry case shows the lower importance for rule compliance. This is according to the main characteristics of this system: forest use and management subordinated to the market rules, high levels of corruption and unsatisfied basic needs (UBN). Regarding the resource, in the fishery the variable is highly important reflecting the importance of the activity and the awareness about it. In the forestry and water the resource variable is not as important as in the fishery. The extraction variable is of high importance in the forestry case, users are economically highly dependent on it and it is the driver of the timber market.

The convergence of mental models is one of the factors that affect the potential for self-organization in CPR management. This is, the higher the level of homogeneity in the mental models in a group of individuals in a CPR situation, the higher the possibilities that they could develop institutional arrangements for a successful CPR management. A simple indicator of homogeneity was developed for the three case studies. This calculation gives an indicator of similarity, in number of variables, between the individual and the collective mental model. Therefore, if the indicator has a value of 1, it means that the individual mental model has the same number of variables that the collective one. On the contrary if the value is close to 0 the individual mental model has very few variables. This indicator was calculated for each individual mental model and then the average of this value for each case was calculated. The value for the fishery case was 0,35; the forestry case gave a figure of 0,11 and the water case a score of 0,45. The interpretation of this indicator is that the in the aqueduct system the level of homogeneity is considerably higher than in the other cases. This could reflect the success of the self-organization of the communitarian aqueduct (15 years), and also can be confirmed by the high importance of the rule compliance variable in the collective mental model. The forestry case has a low homogeneity score, which could be reflecting the complexity of the political and conflicting context in which this SES has been developed. The high UBN (68%) could be related with the high importance of the market in the use and management of the forest, even having an autonomous governance system formally recognized by the Government. These conditions do not facilitate the successful forest and territorial management. In the middle of the two cases is the fishery case that has internal organizational and collective action difficulties.

The mental models study gives insight about the experimental action arena and rules. Economic experimentalists usually assume that payoff rules are the key to induce and study behavioral changes. In other words, the experimental approach focuses in positive and negative economic incentives to affect the interactions in the action arena and observe the outcomes. What indicates the mental models study is that the payoff rules are not the key element in SESs' action arenas. These rules can generate behavioral changes but in combination with other factors such as the legitimacy of rules in the fishing case, the market, household needs and high levels of trust allowing the rule breaking in the forestry case, and fairness in rule enforcement in the water case.

All the variables and relations present in a collective mental model do not work in every situation in which agents make decisions. The specificity of the action arena activates and neutralizes causal structures. A particular action arena provides the conditions for the strength or weakness in terms of structural dominance of causal structures that govern the decision-making. The hypothesis arising from this study is that the dominance of these causal structures is a function of the action arena complexity. A collective mental model shows a wide spectrum of variables and relations forming causal structures, but not the entire model is used in the actors' decisions in a given action arena and in a specific realm, in this case common resources use and management.

The mental models are highly contextual, and depend also on the moral system. Cooperation and trust levels of commons users depend on these two systems. These levels depend and also produce, in a feedback relation, different types of behavior called also behavioral spectrum, when interactions are repetitive in time. The methodological framework built for this research included, on one hand, economic experiments and individual surveys that provided patterns of behavior of CPR users, and on the other collective construction of role playing games as well as the role games implementation. These tools (role games) provided contextual, rule crafting, and actor's interactions information that was useful to understand the behavioral patterns in the experimental action arena. In addition to that, in deep interviews were carried out with key informants. The content analysis of the workshops and interviews allowed carrying out the mental models study. The collective construction of the role games used as a starting point the experimental settings, which were modified gradually and finally became a more complex model of each SES. The methodology entailed a process of SES modeling, starting from the experiments, which were designed by the researchers, and continued with a more complex and shared (researchers and CPR users) representation of the SES. The use of experiments and role games as intermediary objects allowed users to express through out these objects instead of answer direct questions. This exercise produced relevant and complementary information to conventional tools (surveys and interviews). But also the use of experiments and role games construction and playing produced also reflection spaces to discuss among the CPR users themselves. Finally, it is important to remark that though the analysis of the collected data is difficult, the results proved to be useful to integrate the context to the micro variables of behavior and mental models, as well as to explain behavioral patterns in experiments with qualitative information.

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APPENDIX I

Experimental Action Arenas

A simplified model of the fishery action arena: the fishery experiment

The fishery economic experiment described in chapter 3 (Methodological framework) constitutes an action arena, which represents a basic CPR problem. The experimental setting is described in detail in (Cardenas et al. in press). The following paragraphs give a description of such action arena. In the experiment there is only one position, players that could be filled by five participants, which are fishermen. Actions assigned to positions include fishing effort allocation and deciding where to go fishing. The effort decision could be 0, 1 or 2, and the fishery spots are A and B, where participants can make their spatial choice. Information available to positions is the total effort put on each fishery place, as well as the payoffs according to the condition of each fishery place. Communication among participants is not allowed and individual actions and payoffs are not public. Information available to players is complete regarding the state of the resource, but there is a considerable level of uncertainty on outcomes predictions in each round of the game due mainly to the private character of the individual decisions.

Relevant variables in this game are state of fishing places A and B; high and low stock, and individual earnings. Therefore the participants have a partial control over the outcomes because the state of variables depends, not only on individual actions, but on the other four participants. The external rewards or payoffs of the experiment (Table 3.3, payoff table on methodological chapter) are a function of fishery spot's condition. In the first stage of the experiment there are no costs associated with the possible actions that produce benefits. But in the second stage there are costs in the form of sanctions for breaking a given rule if a participant is inspected at the end of a round.

As already explained in chapter 3, the second stage of the experiment introduces three different rules that are chosen through voting by players before starting the round eleven. These three rules are aimed to solve the commons problem and improve outcomes of the action arena.

The rules (lottery, rotation and quota) are choice and payoff rules affecting two structural elements of the action arena: actions, and net costs and benefits. With any of the rules each player has a probability of 1/6 of being inspected and if the player is not following the rule he has to return his harvest. In this way the action has a cost caused by the sanction, and the payoffs are affected.

A simplified model of the forestry action arena: the forestry experiment

The forestry experiment constitutes an action situation in which there is only one position: logger, which is filled by five participants. These participants face a repeated game during twenty rounds divided in two stages. Two actions are assigned to positions. In the first stage each participant choose how many trees to harvest from the forest, with a maximum of five trees in each round. At the beginning of the second stage they have to vote for a rule to play 10 more rounds. The resource is constituted by 100 trees of the same species that has a 10% growth rate. The information provided to players includes: the total number of trees harvested by the group in each round, the forest growth rate, tokens earned by each tree harvested and a spatially explicit representation of the forest, in which, each tree is represented by a magnetic token that is removed or added according of the dynamics of the game in each round. In this way players actually see the size of the common resource and its dynamics through the rounds. The number of trees remaining in the forest, besides the graphical information, is announced at the end of each round. Communication among players is not allowed.

The important variables in this game are the state of the resource (number of trees in the forest), and individual earnings. The payoffs or benefits of the experiment are proportional to the tokens earned by harvesting trees; each tree harvested is equivalent to one token, which has a monetary value. In terms of costs, in the first part there are no costs for harvesting decisions. In the second phase, the costs are present in the form of a probable fine (1/6 probability of inspection) if a player is caught breaking a rule at the end of each round. As in the other two experiments, in the second phase players have to choose among three rules: lottery, rotation and property rights, aimed to maximize collective benefits and producing resource sustainability. These are choice and payoff rules affecting actions and costs and benefits of the action situation. This experiment is described in detail in chapter 3 and in Cardenas et al. (2008).

A stylized model of the water action arena: the water experiment

This action situation was conceptualized according to the essence of the dilemma in a typical irrigation system. In this case the dilemma has a particular characteristic that consists in the asymmetric character of the access to the resource. Users in the upper part of the basin have access to the resource first, but also they access a resource in better conditions in terms of quantity and quality. While the access possibilities of downstream users decrease in quantity and potentially in quality when negative externalities such as pollution are produced by upstream users. An experimental action situation was designed for five players (Juan Camilo Cardenas et al., in press), and the interaction was repeated during 20 rounds, divided in two parts of 10 rounds each one. The resource (water) is provided according to the private investments of each participant, once the players have contributed, an amount of water is produced that is available for each player´s plot.

In this experiment there is only one position that is the player that could be filled by five participants. Each participant has a plot and the plots are distributed along a channel that has upper and lower ends, and are named with the letters A, B, C, D and E. The plots receive water in order being first A and the last E. Once the total water produced according the collective contributions, player situated in plot A decides privately the amount of water he wants to take. From the remaining volume of water, the player situated in the plot B decides the volume of water he wants to take, and so on, until the turn of the last player, who is located in the plot E. The actions assigned to positions are two: how much tokens (between 0 and 10) to contribute to the provision of water, and after all the participants have made their contribution, the next decision is what volume of water to take from the available resource.

Public information available to the positions is the total water produced. Each participant, according to his position on the channel, knows privately how much water is available for him. Communication is no allowed among participants and individual decisions and payoffs are private. There is a big uncertainty when trying to predict outcomes, first the quantity of water produced, and the water available to extract. The level of uncertainty increases from upper part of the channel to the lower part, this is the player in the position A has less uncertainty than the rest of the players, until position E whose available water depends on the decisions of the precedent participants. The individual benefits are produced by the addition of the tokens that each participant keep and does not put in the public fund for generation of water, and the units of water each one take, in his turn, from the available water.

The experiment is run during 20 rounds. During the first 10 rounds participants are not allowed to communicate among themselves. This is the base line (first part or first stage). Before starting the round 11 players are asked to vote anonymously for three proposed rules, and the elected rule is implemented in rounds 11 to 20 (second part or stage). The rules are:

> "*Rule 1 (Lottery). Each round the order in which participants can collect from the common resource is randomly drawn after everybody has made their decision how much to invest in the water provision. Rule 2 (Rotation). There is a fixed rotation system of the order in which people can collect from the common resource, starting with ABCDE in round 1, then BCDEA, etc. Rule 3 (Property rights): Each participant receives the right to use 20 percent of the common resource. The order to extract water remains the same for all the rounds: ABCDE. A dice is thrown in each round. When 6 is thrown, participants who collect a higher amount than the share of 20 percent have to pay back the excess water harvested, and also pay a penalty of 6 additional tokens*." (Juan Camilo Cardenas et al., in press).

The important variables in the experimental action situation are the contributions to the public good that is transformed in units of water available for the group, the level of extraction and payoffs. The control each participant has over the outcomes is low because the state of the main variables depends not only of two kinds of decisions of other participants, but also of the position in the channel that generates interdependency among participants. There are no costs such as sanctions for certain type of decision in the first part of the experiment, but in the second stage, one rule, out of three is voted to play another ten rounds. The rules affect actions and net costs and benefits and are aimed to solve the commons dilemma in its provision and appropriation dimensions.

APPENDIX II

Experimental Protocols

Recruitment letter

I am a professor/researcher of Andes University/ French Agricultural Research Centre for International Development. I am conducting a research study to how people govern natural resources collectively. Due to your experience with managing natural resources, your participation is very important for this research. The exercise and the following workshop will give important information for all of us including your community. The funding for this project came from International Organizations and the Andes University/CIRAD.

Your participation in this study is voluntary. You earn 5 dollars by showing up at the exercises, and can earn up to 40 dollars extra in the exercise depending on your decisions and those of the other participants. You may leave the exercise at any time. However, if you decide to leave before the exercise is over you will not receive what you earned. If you have any questions concerning the research study, please contact me at (   ) ___- ____.

Forest game

We would like to thank you for accepting this invitation. We will spend about three hours explaining the activity, playing and answering a short survey at the end. Let's start.

The following exercise is a different and entertaining way to actively participate in a project about individual decisions and natural resources. Besides participating in this exercise and earning money, you will participate in a workshop in the coming days in order to jointly discuss the exercise as well other topics about natural resources. The funds to cover these expenses have been donated by a scientific body.

In this exercise it is intended to recreate a situation in which a group or family must make decisions about the use of a forest. You have been selected to participate in a five person group recruited from a group of people who have been subscribed to be willing to participate.

This exercise is different than exercies in which other persons in this community have played already. Therefore, comments you have heard from other persons do not apply necessarily to this exercise.

You will play several rounds equivalent, for example, to years or wood harvest seasons.
Let's pretend this group has an area of forest with 100 initial resource units. Each round you have to make a decision about how many resource units you want to harvest. You can harvest a maximum of 5 units and minimum of 0 units of the resource.

[Visual explanation; we have a number of magnets on the board which represent the forest units. The instructor shows what happens if a number of units are harvested]

Between the rounds the resource is regrowing. For each ten units of the existing resource, one new unit is added for the next round.

[visual explanation; the monitor shows with the magnets that for each row of 10 magnets one new magnet is added to the forest, use rows of 10 magnets on the board]. The forest cannot grow to more than 100 units.

Each participant makes a harvest decision. Each harvest unit is equivalent to $0.50. For example, if you harvest 50 units during 20 rounds you will receive $25.

When the size of the resource is less than 25 units, the maximum harvest is less than 5 units.

In the MAXIMUM HARVEST LEVEL TABLE, that is green, which will be distributed now [MONITOR distributes the MAXIMUM HARVEST LEVEL TABLE at the same time he shows a poster on the wall of the same table]. I will announce the maximum quantity of units you can harvest according to the size of the resource at the beginning of the round and post it on the wall.

In order to make decisions in each round you must write down your decision on your YELLOW DECISION SHEET, a number between 0 and the MAXIMUM HARVEST LEVEL depending on the current resource level. [MONITOR shows the yellow decision sheet at the same time that shows a poster on the wall with the same card]. Please check your player number on the yellow decision sheet. This will be your player number from now on.

Observe that the sheet has a row with the round number. Next there is a row marked with “my harvest decision”, in this space you will write down the harvest level you decided in this round.

It is very important to know that you must make your decisions privately. Therefore, you need to write down the numbers on the decision sheet in private and you can not show them to the rest of the group members. The MONITOR will collect the YELLOW DECISION SHEETS from all of you and she or he will sum the total of units the group decided to harvest. When the monitor announces the group harvest total I will write on the board the new resource level. You will then get the decision sheets back for the next round.

Let us explain this with an example (Use visual explanation).

Suppose the current size of the resource is 68. Each of you decided to harvest 3 units, and thus a total of 15 units. The resource size reduces to 53 (68-15) and then 10% of 53, which is 5 units, is added, which leads to 58 units. Thus 15 units are harvested, and the size of the resource, after regrowth, is reduced with 10 units. And each participant earned 3 points during this round.

For each 10 units of resource 1 unit is added. If there are no 10 units of resource we do not increase the resource, it means if there are less than 10 units we do not add 1 unit more. If the resource is less than 5 units, no units can be harvested any more. Now let's continue with the next round. Now the current size of the resource is 58 units. It means that the maximum harvest allowed remains 10 units according to the MAXIMUM HARVEST LEVEL TABLE.

Again, each player decides how many units to harvest and again we calculate the resource decreasing and its increase in a 10% for new level of the resource.

Now we are going to explain the YELLOW DECISION SHEET, the sheet the
MONITOR has handed in to you.

[Before we start the monitor will announce one additional rule for this group.]

To start the first round of the game we will organize the seats and desks in a circle where each of you face outwards. The monitor will collect in each round your YELLOW DECISION SHEET. Finally, to get ready to play the game, please let us know if you have difficulties reading or writing numbers and one of the monitors will seat next to you to assist you with these. Also keep in mind that from now on no conversation or statements should be made by you during the game unless you are allowed to.

We will have first a few rounds of practice that will NOT count for the real earnings, just for practicing of the game.

[up to three practice rounds are performed and questions are addressed during the practice]

The initial size of the resource is 100 units

[After the practice rounds announce that the initial size of the resource is again 100 units and that the decisions are now real and affect the earnings]

INSTRUCTIONS FOR THE FOREST GAME

SECOND STAGE

[After 10 real rounds we let the participants vote for one of three rules.]

We give you the opportunity to start over the game with a different rule. I will describe three rules and you write down on your VOTING CARD your favorite rule. The monitor will collect the votes and count them. [If two rules get 2 votes, we do a new voting round with only these to rules]

The rule which derives the most votes will be implemented.

Rule 1. With this rule only two participants can harvest each round. Who is allowed to harvest is determined by drawing two cards with players numbers. The instructor writes down the player numbers who are allowed on the board.

When someone harvest, but is not allowed to, this participant may get a penalty. Every round we throw a dice after the decisions are made and the yellow sheets are turned in. If we throw a six an inspector is in the forest and will catch the rule breakers, the participants who harvested in a turn it was not allowed to. In that case the participant has to payback the harvest plus an extra 3 units. If the dice shows any other number everybody keeps its earnings and we pass to the next round.

Rule 2. With this rule each participant will have its turn to extract forest unit. Only two participants can harvest each round. In this way it will be a rotation scheme to extract forest units. Each participant will be assigned randomly a turn card to extract forest units: The extraction order is:

Round 1: extracts wood the players **A, B**

Round 2 extracts wood the players **C, D**

Round 3: extracts wood the players **E, A**

Round 4: extracts wood the players **B, C**

Round 5: extracts wood the players **D, E**

Round 6: extracts wood the players **A, B**

Round 7: extracts wood the players **C, D**

Round 8 extracts wood the players **E, A**

Round 9: extracts wood the players **B, C**

Round 10: extracts wood the players **D, E**

(explain explicitly that after this rule is chosen, players get randomly a character A, B, C, D or E. player 1 may for example get turn D)

When someone harvest, but is not allowed to, this participant may get a penalty. Every round we throw a dice after the decisions are made and the yellow sheets are turned in. If we throw a six an inspector is in the forest and will catch the rule breakers, the participants who harvested in a turn it was not allowed to. In that case the participant has to payback the harvest plus an extra 3 units. So, if participant whose turn is A is writing down on the decision sheet to harvest 3 units when only the player with turn C is allowed to harvest, we throw a dice, and when we throw a six, participant with turn A do not get the units on its decision sheet, and we subtract an extra 3 from the total collected units of player with turn A. If the dice shows any other number everybody keeps its earnings and we pass to the next round.

Rule 3. Each of you can harvest legally 0, 1 or 2 units per round. If a participant writes a higher amount than 2 on its YELLOW DECISION SHEET, he or she can be caught by the inspector and has to pay a penalty. In every round we throw a dice. And when we throw a six, and the participants who harvest more than 2 units in that round, do not get the units it wrote down on its YELLOW DECISION SHEET, and we subtract an extra 3 units from it's total so far.

Summary:
Rule 1: only 2 persons, randomly determined, allowed to harvest in each round.
Rule 2: only 2 persons, predetermined sequence, allowed to harvest in each round
Rule 3; a maximum of 2 units can be harvested in each round by any person

Do you have any questions about the rules?

Write down your favorite rule on the VOTING CARD, by writing a 1, a 2 or a 3. And turn it in to the monitor

[When we determine the results of the voting the participants fill in the survey on the rules;

When we are determining the voting results, we ask you to fill in this survey about the rules we just described].

INSTRUCTIONS FOR THE IRRIGATION GAME

FIRST STAGE

We would like to thank you for accept this invitation. We will spend about three hours explaining the activity, playing and answering a short survey at the end. Let’s start.

The following exercise is a different and entertaining way to actively participate in a project about individual decisions and natural resources. Besides participating in this exercise and having the chance of earn money, you will participate in a workshop in the coming days in order to jointly discuss the exercise as well other topics about natural resources. The funds to cover these expenses have been donated by a scientific body.

In this exercise it is intended to recreate a situation in which a group or family must make decisions about the use of water to irrigate its plots. You have been selected to participate in five persons group among persons who have been subscribed to participate. This exercise is different to others in which others persons have played already in this community. Therefore, comments you have heard from other persons do not apply necessarily to this exercise. You will play several rounds equivalent, for example, to years or irrigation seasons.

Each round consists of two decisions. First, each of you decide how much to contribute to a public fund in order to maintain irrigation canals. The sum of the contributions will affect the amount of water units available for the five players. The next decision is for each player to take some part of the water units available. Each unit you collect during the game is equivalent to $0.1. For example if you get 250 units during 20 rounds of the game you will receive $25.

We now discuss the first decision in detail. Each round you have 10 units to spend. You can spend some of it in the public fund, and you can keep the rest. You can think of this as the amount of labor you invest in the maintenance of the irrigation system. The level of this effort is between 0 and 10. On the green TABLE OF AVAILABLE WATER QUANTITY and the poster we show how much water will be available for the group of five players depending on the total contributions.

[the MONITOR shows TABLE OF AVAILABLE WATER QUANTITY in the poster and distribute the table to participants].

This table contains the information that you need to calculate the resulting size of the public fund available depending on your contribution and those of the other 4 players. The decision of the contribution is written down on the yellow DECISION SHEET like I will show you right now and provided by the monitor [the Monitor shows the yellow decision sheet on the board].

The monitor calculates the level of the public fund and posts this amount on the board. The Monitor will collect the yellow DECISION SHEETS of 5 participants and he will sum the total units that the group decided to contribute to the public fund. We will write on the board the new current size of the public fund.
[explanation: we may use coins or magnets to explain the allocation of the 10 units. We may use as an illustration a pink pig where subjects put in their coins and the instructor can define the total investment]

For example, everybody invest 2 units in the maintenance of the irrigation system, and keep the 8 other units for themselves. In that case no water is available to be distributed among the players. As a result everybody ends up with 8 units at the end of that round.

Another example is that everybody invests 10 units in the maintenance of the irrigation system, which leads to 100 units of water to be allocated among the 5 players.

Remember decisions are made private and everybody can decide on how much they want to invest in maintenance.

After the first decision is made, the monitor collects the yellow sheets, and calculates the total amount of water available. This amount will be written on the board. Next, all the players get back their yellow decision sheets.

The next decision is to take **a quantity of water for irrigation**. Everybody has the same size of land for irrigation. The money you earn is directly dependent on the water you take from the public pool. Each one of you will receive, FOR EACH OF ALL FUTURE ROUNDS, randomly a card marked with ONE of the following characters: A, B, C, D or E. The player who obtains character A will be the first to decide how much water she/he takes to irrigate her/his plot. It means that characters on the cards define the order in which the properties of each player are situated through an irrigation canal [the monitor shows a draw in the board that represents the situation].

The player who has the card with the letter A decides how much water to take and writes down his/her decision on the YELLOW DECISION SHEET. [Monitor shows the allocation decision spot on the yellow decision card on the poster on the wall]. The Monitor will subtract the collected water from the available water and write the remaining amount of water on a WHITE piece of paper to show this to player B, who has the second option to make a decision. This process continues until player E has made a decision.

[example: given is an amount of water, represented as an amount of coins/magnets. The instructor shows what happens if first player A takes from the pool, then B, etc.]

Then the next round starts with first turning in the contribution to the public fund.

It is very important to remember always that the decisions are absolutely individual, it means, the numbers you write down on the game sheets are private and you must not show them to the others members of the group.
Are there any questions about this? [MONITOR: pause to resolve questions.]
Remember that the units you earn depend on your own decisions and will become money at the end of the exercise.

[Before we start, the monitor will announce one additional rule for this group.] To start the first round of the game we will organize the seats and desks in a circle where each of you face outwards. The monitor will collect in each round your YELLOW DECISION SHEETS. Finally, to get ready to play the game, please let us know if you have difficulties reading or writing numbers and one of the monitors will seat next to you to assist you with these. Also keep in mind that from now on no conversation or statements should be made by you during the game unless you are allowed to.

We will have first a few rounds of practice that will NOT count for the real earnings, just for practicing of the game.

Now we will distribute the cards with the letters from A to E which we draw randomly from a bag.

INSTRUCTIONS FOR THE IRRIGATION GAME

SECOND STAGE

After 10 real rounds we let the participants vote for one of three rules to take water for irrigation. We give you the opportunity to start over the game with a different rule. I will describe three rules and you write down on your VOTING CARD your favorite rule. The monitor will collect the votes and count them. [If two rules get 2 votes, we do a new voting round with only these to rules]

The rule which derives the most votes will be implemented.

Rule 1. In this rule we draw for each round, after you have contributed to the maintenance of the irrigation system, and the monitor has announced the size of the water available, the order in which you can take water for irrigation will be assigned randomly.

[5 color cards with player numbers 1-5 will be drawn from a non-transparent plastic bag]

Rule 2. There will be a fixed rotation in which you can collect water. This order is a 5 round rotation system:

Round 1: ABCDE

Round 2: BCDEA

Round 3: CDEAB

Round 4: DEABC

Round 5: EABCD

Round 6: ABCDE

Round 7: BCDEA

Round 8: CDEAB

Round 9: DEABC

Round 10: EABCD

Rule 3: Each of you has a right of 20% of the water of the irrigation system. This amount is calculated after the available water is announced. The order to extract water remains the same for all the rounds: ABCDE. A dice is thrown in each round. When 6 is thrown, an inspector arrives and will check the water extraction. The subject pays back the extra amount taken, and an extra amount of 6 units if more than 20% is taken.

Summary:
Rule 1: randomly determined turn when to take water
Rule 2: rotating turns to take water
Rule 3: equal water rights

Are there any questions about the rules? [The Monitor pauses to answer questions]
Write down your favorite rule on the voting card, by writing a 1, a 2 or a 3. And turn it in to the monitor.

INSTRUCTIONS FOR THE FISHERY GAME

FIRST STAGE

We would like to thank you for accepting this invitation. We will spend about three hours explaining the activity, playing and answering a short survey at the end. Let’s start.

The following exercise is a different and entertaining way to actively participate in a project about individual decisions and natural resources. Besides participating in this exercise and having the chance of earn money, you will participate in a workshop in the coming days in order to jointly discuss the exercise as well other topics about natural resources. The funds to cover these expenses have been donated by a scientific body.

This exercise is intended to recreate a situation in which a group or family must make decisions about the use of a fishery resource. You have been selected to participate in a group of five persons among those who have been registered to participate. This exercise is different to others in which others persons have played already in this community. Therefore, comments you have heard from other persons do not apply necessarily to this exercise. You will play several rounds equivalent, for example, to years or fishing seasons.

The resource is spread in two locations A and B. Each round you have to make a choice which location to harvest, and whether to put in 0, 1 or 2 levels of effort. The resulting harvest from the effort put in harvesting depends on the condition of the resource. The state of the resource depends on the condition in the previous round and the amount of effort invested in the previous round.

Depending on the condition of the resource the amount of fish is defined by the PAYOFF TABLES for conditions LOW and HIGH. To be able to play you will receive the blue PAYOFF TABLE equal to the one shown in the poster. [MONITOR: show PAYOFF TABLE in poster and distribute PAYOFF TABLE to participants]. This table contains all the information that you need to calculate the amount of resource units available depending on the current resource level and the quantity of units harvested by the 5 participants of the group. Each participant makes a harvest decision. Each harvest unit is equivalent to $0.25. For example, if you harvest 100 units during 20 rounds you will receive $25.

When you chose to put your effort in a location with a high payoff situation, you can harvest 0, 7 or 8 depended whether you put in 0, 1 or 2 units of effort. The resource condition can change in each fishing place. The condition depends on the decisions of others. The HIGH condition can move to a LOW condition when FIVE or more units of effort are invested in a location. A LOW condition can move to a HIGH condition when not more than ONE unit of effort is allocated in the same fishing place for two successive rounds.

For example a HIGH PAYOFF TABLE will be a LOW PAYOFF TABLE in the next round when 6 units of effort are applied in one location. A LOW PAYOFF TABLE will move into a HIGH PAYOFF TABLE when no effort is invested in the location for two rounds.

At the beginning of each round, the monitor will announce the condition of the resource at each of the two fishing locations. To play in each round you must write your decisions, a character A or B , and a number 0, 1 or 2 on the YELLOW DECISION SHEET like the one I am about to show you. [… MONITOR: show **yellow decision sheets** and show in the poster…]

It is very important that we keep in mind that the decisions are absolutely individual, that is, that the numbers we write in the game card are private and that we do not show them to the rest of members of the group. The monitor will collect the 5 sheets from all participants, and will define the harvest for each individual and the condition of the resource in the next round.

When the monitor announces the harvest in each location and the conditions of the resource at each location, we will write these conditions on the boards so that you know which payoff table to use.

Remember that the units you earn depend on your own decisions and will become money at the end of the exercise.

Let us explain this with an example.
[here we run a round with an example]

Are there any questions about this? [MONITOR: pause to resolve questions.]

Before we start, and once all players have understood the game completely, the monitor will announce one additional rule for this group. To start the first round of the game we will organize the seats and desks in a circle where each of you face outwards. The monitor will collect in each round your YELLOW DECISION SHEETS. Finally, to get ready to play the game, please let us know if you have difficulties reading or writing numbers and one of the monitors will seat next to you to assist you with these. Also keep in mind that from now on no conversation or statements should be made by you during the game unless you are allowed to.

We will have first a few rounds of practice that will NOT count for the real earnings, just for practicing of the game.

In the first round you use the HIGH PAYOFF TABLE in each location.

INSTRUCTIONS FOR THE FISHERY GAME

SECOND STAGE

[After 10 real rounds we let the participants vote for one of three rules.]

We give you the opportunity to start over the game with a different rule. I will describe three rules and you write down on your VOTING CARD your favorite rule. The monitor will collect the votes and count them. [If two rules get 2 votes, we do a new voting round with only these to rules]

The rule which derives the most votes will be implemented.

Rule 1. With this rule we draw randomly for each player a location the player is allowed to fish. When we throw a 1, 2 or a 3 you can harvest in A. Otherwise you can harvest in B. Then you can fill in your location and your effort on the yellow DECISION SHEET. We throw a dice each round. When you harvest in a location which you are not allowed to, the result of the dice throwing affect your payoff. When we throw a six an inspector comes to the region and check on your locations. If you are located in a place you are not allowed to, you have to pay back the harvest units. For example if the player harvests in the place A with 2 effort units when the allowed place to fish is B and the dice yield 6, the player pays back the harvest.

Rule 2. Only one location is allowed to be fished in each round. There is a rotation AABBAABBAABBAA of a ban where you are not allowed to harvest. It means that:

Round 1 ban in A

Round 2 ban in A

Round 3 ban in B

Round 4 ban in B

Round 5 ban in A

Round 6 ban in A

Round 7 ban in B

Round 8 ban in B

Round 9 ban in A

Round 10 ban in A

Thus in the fourth round you are not allowed to harvest in location B. When you harvest, but are not allowed to, the throwing of a dice determines whether you need to pay a penalty. If we throw a six, the penalty is to return back the harvest.

Rule 3: Each of you can put an effort of 0 or 1 per round. We throw a dice every round. If we throw a six, an inspector comes to the region to check on your effort levels. If a participant writes 2 units of effort on its YELLOW DECISION SHEET, and the inspector is present, the participant does not get the units it wrote down on its decision sheet.

Summary:

Rule 1: randomly determined location where to fish

Rule 2: rotating turns where to fish

Rule 3: maximum of 1 unit of effort per round.

Do you have any questions about the rules?

Write down your favorite rule on the VOTING CARD, by writing a 1, a 2 or a 3. And turn it in to the monitor

Payoff table			
Fish available in location	Fishing effort		
	0	1	2
High	0	7	8
Low	0	2	3

Voting card		Voting card	
Player number	**1**	Player number	**1**
I vote for the rule number		I vote for the rule number	

Voting card		Voting card	
Player number	**2**	Player number	**2**
I vote for the rule number		I vote for the rule number	

Voting card		Voting card	
Player number	**3**	Player number	**3**
I vote for the rule number		I vote for the rule number	

Voting card		Voting card	
Player number	**4**	Player number	**4**
I vote for the rule number		I vote for the rule number	

Voting card		Voting card	
Player number	**5**	Player number	**5**
I vote for the rule		I vote for the rule	

number	

number	

Player calculation sheet			
Player no:		Time: Place: Date:	
Round	A	B	C
	My Decisions		My points
	Place (A/B)	Effort (0,1,2)	
Practice 1			
Practice 2			
Practice 3			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

<table>
<tr><td colspan="5">Player calculation sheet
Player no: Time:
Place:
Date:</td></tr>
<tr><td rowspan="3">Round</td><td>A</td><td>B</td><td>C</td><td>D</td></tr>
<tr><td colspan="2">My Decisions</td><td rowspan="2">Fine
(Y/N)</td><td rowspan="2">My
points</td></tr>
<tr><td>Place
(A/B)</td><td>Effort
(0,1,2)</td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td></td><td></td><td></td><td></td></tr>
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<tr><td>6</td><td></td><td></td><td></td><td></td></tr>
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<tr><td>9</td><td></td><td></td><td></td><td></td></tr>
<tr><td>10</td><td></td><td></td><td></td><td></td></tr>
</table>

Maximum harvest table	
Current Resource Level	Individual Maximum harvest level
25-100	5
20-24	4
15-19	3
10-14	2
5-9	1
0-4	0

A	B	C	D	E

1	2	3	4	5

Player calculation sheet	
Player no:	Time: Place: Date:
Round	My Harvest Decision
Practice 1	
Practice 2	
Practice 3	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Player calculation sheet			
Player no:	Time: Place: Date:		
Round	A	B	
	My Harvest decision	Fine (0 or A+3)	My points (A-B)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Table of available water quantity	
Total units invested in the public fund by all 5 players	Water available
0-10	0
11-15	5
16-20	20
21-25	40
26-30	60
31-35	75
36-40	85
41-45	95
46-50	100

Player calculation sheet

Player no: Time:

Capital letter: Place:

Date:

Round	My Decisions			
	A	B	C	D
	Contribution	Amount of water extracted	Amount kept = 10-A	Earnings: B+C
Practice 1				
Practice 2				
Practice 3				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Player calculation sheet Player no: Time: Capital letter: Place: Date:				
Round	My Decisions			
	A	B	C	D
	Contribution	Amount of water extracted	Amount kept = 10-A	Earnings: B+C
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Player calculation sheet

Player no: Time:

Capital letter: Place:

Date:

Round	My Decisions				
	A	B	C	D	E
	Contribution	Amount of water extracted	Amount kept = 10-A	Fine (0 or B+6)	Earnings: B+C-D
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Monitor calculation sheet (lottery)

monitor:

Time:

Place:

Date:

Round	Points table A	Points table B	Dice	Randomly drawn locations					Decisions (Place / Effort)					group effort	
				1	2	3	4	5	1	2	3	4	5	A	B
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															

Monitor calculation sheet (rotation of banning)												
monitor:					Time:							
					Place:							
					Date:							
Round	Points table A	Points table B	Dice	Banned location	Decisions (Place / Effort)					Group effort	
					1	2	3	4	5	A	B
1				A							
2				A							
3				B							
4				B							
5				A							
6				A							
7				B							
8				B							
9				A							
10				A							

Monitor calculation sheet (maximum 1 unit of effort)											
monitor:				Time:							
				Place:							
				Date:							
Round	Points table A	Points table B	Dice (6? Yes or no)	Decisions (Place / Effort)					Group effort	
				1	2	3	4	5	A	B
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Monitor calculation sheet				Votes	No. Rule		
monitor:			Time:		1	2	3
			Place:	Round 1			
			Date:	Round 2			

Round	Points table A	Points table B	Decisions (Place / Effort)					C group effort	
			1	2	3	4	5	A	B
Pract 1									
Pract 2									
Pract 3									
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

<table>
<tr><td colspan="5">Monitor calculation sheet</td><td rowspan="2"></td><td colspan="2" rowspan="2">Votes</td><td colspan="3">Rule numbers</td></tr>
<tr><td colspan="3" rowspan="3">monitor:</td><td colspan="2">Time:</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td colspan="2">Place:</td><td></td><td colspan="2">Round 1</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Date:</td><td></td><td colspan="2">Round 2</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Round</td><td rowspan="2">Resource size (A)</td><td rowspan="2">Maximum individual harvest level</td><td colspan="5">Harvest decisions</td><td>B</td><td>C</td><td></td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>Group total forest</td><td>Remaining forest (A-B)</td><td>Regrowth of forest (0.1*C)</td></tr>
<tr><td>Pract 1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Pract 2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Pract 3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>5</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>10</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Monitor calculation sheet (lottery)

monitor:

Time:

Place:

Date:

Round	Resource size (A)	Maximum individual harvest level	Harvest decisions					B	C			
			1	2	3	4	5	Group total forest	Remaining forest (A-B)	Regrowth of forest (0.1 * C)	Allowed players	Dice
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Monitor calculation sheet (rotation)

monitor:

Time:

Place:

Date:

Capital characters for players				
1	2	3	4	5

Round	Resource size (A)	Maximum individual harvest level	Harvest decisions					B	C	D		
			1	2	3	4	5	Group total forest	Remaining forest (A-B)	Regrowth of forest (0.1 * C)	Allowed players	Dice
1											A,B	
2											C,D	
3											E,A	
4											B,C	
5											D,E	
6											A,B	
7											C,D	
8											E,A	
9											B,C	
10											D,E	

Monitor calculation sheet (maximum harvest 2)												
monitor:			Time:									
			Place:									
			Date:									
Round	Resource size (A)	Maximum individual harvest level	Harvest decisions					B	C			
			1	2	3	4	5	Group total forest	Remaining forest (A-B)	Regrowth of forest (0.1 * C)	Dice	
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

							Votes	Rule numbers		
monitor:	Time:	Extraction player no.						1	2	3
	Place:	1	2	3	4	5	Round 1			
	Date:						Round 2			

Round	Contribution decisions					Total Fund	Water available	Extraction decisions				
	1	2	3	4	5			1	2	3	4	5
Pract 1												
Pract 2												
Pract 3												
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Monitor calculation sheet (lottery)

monitor: Time:

Place:

Date:

Round	Contribution decisions					Total Fund	Water available	Extraction order	Extraction decisions				
	1	2	3	4	5				1	2	3	4	5
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													

Monitor calculation sheet (rotation)															Extraction player no.				
monitor:	Time:														1	2	3	4	5
	Place:																		
	Date:																		
Round	Contribution decisions					Total Fund	Water available	Extraction order					Extraction decisions				
	1	2	3	4	5			1	2	3	4	5	1	2	3	4	5
1								A	B	C	D	E					
2								B	C	D	E	A					
3								C	D	E	A	B					
4								D	E	A	B	C					
5								E	A	B	C	D					
6								A	B	C	D	E					
7								B	C	D	E	A					
8								C	D	E	A	B					
9								D	E	A	B	C					
10								E	A	B	C	D					

Monitor calculation sheet (property)														
monitor:	Time:									Extraction player no.				
	Place:									1	2	3	4	5
	Date:													
Round	Contribution decisions					Total Fund	Water available	20% of Water	Dice	Extraction decisions				
	1	2	3	4	5					1	2	3	4	5
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

CONSENT FORM

Participant No.: ___

Place and Date: ___________________ Time of the exercise: ___:___ AM/PM

You have been invited to participate in an exercise that is part of a research about management of natural resources. Due to your experience with managing natural resources, your participation is very important for this research. The exercise and the following workshop will give important information for all of us including your community. The funding for this project came from International Organizations and the Andes University.

This research does not imply exercises with human beings, animals or vegetable material. For that reason your participation will not have any risk for your health.

At the end of the exercise, you will receive an amount of cash depending on your earnings during the exercise. After the exercise is over, you need to answer some questions about the exercise in which you participated today. Also, there will be some questions about your experience as a user of natural resources. What you earned in the exercise and your answers in the survey will be **confidential. This information will be used just for academic purposes.**

In addition to this exercise you may be selected to participate in a workshop to discuss the results of the exercise. The workshop will be held in________ at _________am/pm.

Your participation in the exercise is completely voluntary. You may leave the exercise at any time. However, if you decide to leave before the exercise is over you will not receive what you earned. The amount of money that you earn during the exercise will be given to you, after you finish answering the questions of the survey.

If you want a copy of this consent form, please ask us for it.

AGREEMENT:

I, ____ state that I understand the information given above and my rights and commitments during the exercise. I also understand that I can leave the exercise at any time declining to receive the money earned in the exercise.

Signed, _____________________________, c.c. _____________ of ________________

I, Juan Camilo Cardenas, Professor of the Andes University, certify that this information will be use in a confidential manner and only for academic and community educational purposes. I also certify that we will pay to each participant the amount of money earned during the exercise.

Signed, ________________, c.c. 79.361.300 of Bogotá

APPENDIX IV

Individual Surveys

SURVEY AFTER THE VOTING FOR THE RULES (Fishiheries and Forestry)

You will get questions on 3 types of rules for which you are asked to give your opinion on a scale from 1 to 5.

Rule 1:

At the beginning of each round, for each player a location is drawn randomly where the player may harvest.

How efficient do you think this rule is for managing the fishing grounds / forest?

not at all efficient 1 2 3 4 5 very efficient

How fair do you think this rule is for managing the fishing grounds / forest?

not at all fair 1 2 3 4 5 very fair

How much personal freedom do you think this rule allows you in managing the fishing grounds / forest?

no freedom at all 1 2 3 4 5 complete freedom

How much do you think this rule would advance your own self-interest as measured by your total earning?

not at all 1 2 3 4 5 Very much

All things considered how attractive do you find this rule?

not attractive at all 1 2 3 4 5 Very attractive

Rule 2:

There is a fixed rotation which location the players are allowed to harvest.

How efficient do you think this rule is for managing the fishing grounds?

not at all efficient 1 2 3 4 5 very efficient

How fair do you think this rule is for managing the fishing grounds / forest?

not at all fair 1 2 3 4 5 very fair

How much personal freedom do you think this rule allows you in managing the fishing grounds / forest?

no freedom at all 1 2 3 4 5 complete freedom

How much do you think this rule would advance your own self-interest as measured by your total earning?

not at all 1 2 3 4 5 Very much

All things considered how attractive do you find this rule?

not attractive at all 1 2 3 4 5 Very attractive

Rule 3:

You are only allowed to use a maximum effort of 1 unit of effort fishing of the 2 maximum from the fishing grounds / forest.

How efficient do you think this rule is for managing the fishing grounds / forest?

not at all efficient 1 2 3 4 5 very efficient

How fair do you think this rule is for managing the fishing grounds / forest?

not at all fair 1 2 3 4 5 very fair

How much personal freedom do you think this rule allows you in managing the fishing grounds / forest?

no freedom at all 1 2 3 4 5 complete freedom

How much do you think this rule would advance your own self-interest as measured by your total earning?

not at all 1 2 3 4 5 Very much

All things considered how attractive do you find this rule?

not attractive at all 1 2 3 4 5 Very attractive

SURVEY AFTER THE VOTING FOR THE RULES (Water)

You will get questions on 3 types of rules for which you are asked to give your opinion on a scale from 1 to 5.

Rule 1:

After everyone contributed to the public fund, the order in which the players can take water from the irrigation system will be assigned randomly .

How efficient do you think this rule is for managing the irrigation system?

not at all efficient 1 2 3 4 5 very efficient

How fair do you think this rule is for managing the irrigation system?

not at all fair 1 2 3 4 5 very fair

How much personal freedom do you think this rule allows you in managing the irrigation system?

no freedom at all 1 2 3 4 5 complete freedom

How much do you think this rule would advance your own self-interest as measured by your total earning?

not at all 1 2 3 4 5 Very much

All things considered how attractive do you find this rule?

not attractive at all 1 2 3 4 5 Very attractive

Rule 2:

There is a fixed rotation in which each player can extract water from the irrigation system

How efficient do you think this rule is for managing the irrigation system?

not at all efficient 1 2 3 4 5 very efficient

How fair do you think this rule is for managing the irrigation system?

not at all fair 1 2 3 4 5 very fair

How much personal freedom do you think this rule allows you in managing the irrigation system?

no freedom at all 1 2 3 4 5 complete freedom

How much do you think this rule would advance your own self-interest as measured by your total earning?

not at all 1 2 3 4 5 Very much

All things considered how attractive do you find this rule?

not attractive at all 1 2 3 4 5 Very attractive

Rule 3:

Each player has a right of one fifth of the water. The order to collect units remains the same for all the rounds: ABCDE. A random number between 1 and 6 is drawn, and when a 6 is drawn, players who take more than allowed have to pay this back, plus a penalty of 6 units.

How efficient do you think this rule is for managing the irrigation system?

not at all efficient 1 2 3 4 5 very efficient

How fair do you think this rule is for managing the irrigation system?

not at all fair 1 2 3 4 5 very fair

How much personal freedom do you think this rule allows you in managing the irrigation system?

no freedom at all 1 2 3 4 5 complete freedom

How much do you think this rule would advance your own self-interest as measured by your total earning?

not at all 1 2 3 4 5 Very much

All things considered how attractive do you find this rule?

not attractive at all 1 2 3 4 5 Very attractive

INDIVIDUAL SURVEY

Date (dd/mm/yy) / / Time :

Place Survey number

Surveyor EXP Player number

Village

SECTION I. RESPONDENT CHARACTERISTICS

1. How old are you? years

2. Sex ☐ Male ☐ Female

3. Marital Status

☐	1. Common law	☐	3. Widowed	☐	5. Separated
☐	2. Married	☐	4. Divorced	☐	6. Single

4. What is the highest grade you have completed in school?

YEARS	Level
None	0☐
Some primary school	1☐
Primary school	3☐
Secondary school	4☐
Technical	5☐
University	6☐
Post-university	7☐

5. How long have you lived in this community? YEARS

6. What is your main Economic Activity defined as the activity in which you spent the most **time** during the year? (mark only one)

☐ 1. Extracting products from the forests

☐ 2. Fishery

☐ 3. Farmer

If farmer, do you use irrigation? ☐ Yes ☐ No

☐ 4. other, which one

7. Average number of hours per week for the marked activity? hours

8. What is your main Economic Activity defined as the activity in which you received the most **income** during the year? (mark only one)

☐ 1. Extracting products from the forests

☐ 2. Fishery

☐ 3. Farmer

If farmer, do you use irrigation? ☐ Yes ☐ No

☐ 4. other, which one

9. Average share of your income for the marked activity?

☐ almost nothing of my income

☐ little income

☐ about one quarter of income

☐ about half of income

☐ about three quarters

☐ almost all my income

SECTION II. HOUSEHOLD CHARACTERISTICS

1. Number of people (adults and children) in your household including yourself

2. How long has your family (ancestors) lived in this community? YEARS

3. Have you or any in your household participated in **voluntary work** related to managing, conserving, or monitoring the common pool of natural resources in your village during the last year?

☐ Yes, how many days per year? ☐ No

4. The dwelling that this household occupies is:

☐ 1. Owned and totally paid for
☐ 2. Owned and being paid for
☐ 3. Inheritance or gift
☐ 4. Right of possession
☐ 5. Rented
☐ 6. Transferred or loaned
☐ 7. Other form

5. Are you or anyone from your household the owner of this land you live in?

☐ Yes. How many hectares (acres)?
☐ No

SECTION III. COLLECTIVE ACTION

1. Please tell me whether in general you agree or disagree with the following statements:

1 Strongly Agree 2 Agree 3 Disagree 4 Strongly disagree

1. Most people in this village are basically honest and can be trusted.	1. ☐ 2. ☐ 3. ☐ 4. ☐
2. People in this village are mostly interested in their own well-being	1. ☐ 2. ☐ 3. ☐ 4. ☐
3. Members of this village are always more trustworthy than those in other villages.	1. ☐ 2. ☐ 3. ☐ 4. ☐
4. In this village one has to be alert, or someone will take advantage of you.	1. ☐ 2. ☐ 3. ☐ 4. ☐
5. If I have a problem there is always someone in this village to help you.	1. ☐ 2. ☐ 3. ☐ 4. ☐
6. I do not pay attention to the opinions of others in the village.	1. ☐ 2. ☐ 3. ☐ 4. ☐
7. Most people in this village are willing to help if you need it.	1. ☐ 2. ☐ 3. ☐ 4. ☐
8. This village has prospered in the last five years.	1. ☐ 2. ☐ 3. ☐ 4. ☐
9. I feel accepted as a member of this village	1. ☐ 2. ☐ 3. ☐ 4. ☐
10. If you lose a pig or chicken someone in the village would help look for it or would return it to you.	1. ☐ 2. ☐ 3. ☐ 4. ☐

2. How much influence do you think people like yourself can have in making this village a better place to live?

☐ 1. A lot
☐ 2. Some
☐ 3. Not very much
☐ 4. None

☐ 5. Don’t know/not sure

3. If there was a problem related to natural resource use in this community, how likely is that people will cooperate to try to solve the problem?

☐ 1. Very likely
☐ 2. Somewhat likely
☐ 3. Neither likely nor unlikely
☐ 4. Somewhat unlikely
☐ 5. Very unlikely

4. How often in the past year have you joined others in the village to address a issue related to the use of a common resource, like ?

	Fishery	Water management	Forest
1. Never	☐	☐	☐
2. Once	☐	☐	☐
3. A couple of times	☐	☐	☐
4. Frequently	☐	☐	☐

5. Give examples of these activities?

-
-
-

SECTION IV. QUESTIONS AFTER THE EXERCISES

1. How satisfied were you with the earnings during the exercises?

☐ 1. I was completely dissatisfied

☐ 2. I was not satisfied

☐ 3. I was somewhat satisfied

☐ 4. I was satisfied

☐ 5. I was very satisfied

2. Did you understand the instructions of the exercises?

☐ 1. I did not understood anything

☐ 2. I did understand only a bit of the instructions

☐ 3. I did understood half of the instructions

☐ 4. I did understood most of the instructions

☐ 5. I did understood everything

3. Were you paying attention to the behavior of the other participants?

☐ yes ☐ no

4. Were your decisions influenced by behavior of others?

☐ yes ☐ no

5. If you had the chance to return to the start of the 2nd stage, right before we changed the rules of the game to lottery/rotation/property rights, would you have preferred to maintain the rules unchanged and continue playing the same way as in the 1st stage?

☐ yes, I would have preferred not changing the rules for the 2nd stage.

☐ no, I would have preferred to have the rules changed to the rule we in fact used.

☐ no, I would have preferred to have the rules change to another rule

(Describe here)____

____

6. Does this exercises represent in a simplified form any experiences you have faced in this village?

- ☐ 1. Nothing at all
- ☐ 2. A little bit
- ☐ 3. More or less
- ☐ 4. Yes, in a major way
- ☐ 5. Yes, completely

Do you have some final remarks on the exercises? You can write them here:

APPENDIX V

Interview Guides

Guide 1

1. What is the role of the individual in the community (leader, extraction of the resources, social status, knowledge)?
2. How is the game of similar or different in respect to the dilemmas in real life that the participant experiences? (With a focus on the rules of use)
3. How are the rules changed or modified in this community?
4. Which members take part in the community in addition to resolving problems and conflicts in the community relating to the use of natural resources?
5.What is the community's ability in regards to changing the rules versus imposing rules? Imposed for whom?
6. Is this resource used for self consumption or for monetary profit?
7. How well are the resources maintained?
8. In the last ones 12 months, how frequently have the people of this community met jointly with government officials or political leaders over matters pertaining to the use of natural resources that would benefit the community?
9. How have local government officials and the local leaders taken your concerns into account when making decisions that affect natural resources?
10. Suppose that the members of the community request that a rule imposed by the government be changed. Is it possible?
11. If someone breaks a rule, what is the possibility that the person will be found out and sanctioned?
12. How long does the community use the resource of interest? What has been the history of the resource's regulation and use?
13. What are the challenges and the opportunities for the community in terms of the use of the resource? (Globalization, dams, employment, opportunities in urban areas)

Guide 2

Ecosystem functioning

1. Where do you harvest/collect the resource?

2. How do you hink that the resource is produced?

3. What would happen if the resource zone is replaced with other land uses?

4. What happens if the resource collapses?

5. Which is the function of upper watershed ecosystems? (Water case)

6. How is the dynamics of this ecosystem?

Funcionamiento del acueducto

8. Why the users community built the aqueduct/fishermen association/communitarian council? How was the process?

9. Before the existence of the users organization how was the management and use of the resource?

10. Was it better before or after the users'organization was created?

11. For how long do you think the resource will last?

12. What are the main problems with the resource management?

13. How do you believe these problemas could be solved?

14. Who should solve these problems?

Aactors

15. What is the role of users in the resoiurce mamnagement?

16. What is your opinión about users behavior?

17. In addition to the resource direct users, what other actors are involved in the resource management?

18. Do you think that in addition to the actors you mentioned, there are others that should intervene in the resource management?

Rules

19. What are the rules for resource management?

20. Do your neighbours follow the rules?

25. Does everybody follow the rules?

26. Do you follow the rules?

27 What happens if someone does not follow the rules?

28. Who is in charge of monitoring rules compliance?

29. How is the monitoring working?

30. Do you think rule monitoring must change or not?

31. Is it better that someone from the community monitor sor someone external?

32. What happens if someone does not follow the rules?

33. In case of resource scarcity people would follow the rules that control the extraction?

34. Would you denounce someone that does not follows the rules?

35. Whaqt happens when someone break the rules and other persons know the infraction?

36. Her, usually people trust in the others?

37. Do you trust in the others?

38. Do you think that others trust in you?

39. When there are problems with the resource, people cooperate? How?

40. Who has property rigths of the resource?

41. Is there some relation between productive activities and the resource use?

42. Young people are more likely to stay in the village or they try to leave the zone?

43. How this relation affects the resource maintenance?

APPENDIX VI

Publications

Anderies, J. M., Janssen, M. A., Bousquet, F., Cardenas, J.-C., **Castillo, D**., Lopez, M.-C., Tobias, R., et al. (2011). The challenge of understanding decisions in experimental studies of common pool resource governance. *Ecological Economics*. doi:10.1016/j.ecolecon.2011.01.011

Castillo, D., Bousquet, F., Janssen, M. A., Worrapimphong, K., & Cardenas, J. C. (2011). Context matters to explain field experiments: Results from Colombian and Thai fishing villages. *Ecological Economics, 70*(9), 1609–1620. doi:10.1016/j.ecolecon.2011.05.011

Janssen, M. A., Bousquet, F., Cardenas, J.-C., **Castillo, D**., & Worrapimphong, K. (2012). Field experiments on irrigation dilemmas. *Agricultural Systems*, *109*(0), 65–75. doi:10.1016/j.agsy.2012.03.004

Janssen, M., Bousquet François, Cardenas Juan Camilo, **Castillo D.**, & Worrapimphong Kobchai. (submitted). Breaking the Elected Rules in a Field Experiment on Forestry Resources.

ABSTRACT

The main question that addresses this research is about the role of mental models in the institutional arrangements for common pool resource management. The central idea is that there is a cognitive conflict when different actors define use and management problems of common pool resources. Mental models are used for institutional design. Several actors, to structure commons problems, use different mental models. Mental models influence institutions and policies intended to solve such problems. The conceptual framework of the study included commons dilemmas, neo institutionalism approaches, institutional analysis and development (IAD) socio ecological systems and mental models concepts. Three case studies in Colombia (South America) were chosed to study the above question: an artisanal fishermen place in Caribbean (Barú), a communitarian aqueduct in the Andes (Lenguazque), and a forestry community in the Pacific coast (Salahonda). In order to explore the research question a multimethod framework was designed that included a first phase of economic experiments, surveys and interviews with resource users. The experiments were designed to capture the commons dilemma in each case: fishing, water and forestry. These experiemnts simulated also the dynamic complexity of each of the resources. The experiments also simulated three types of voted rules as solution to the cooperation dilemma. Resource users from the three case studies participated in the experiments. A second field phase was carried out using the companion modeling approach (ComMod) approach. The experimental setting was used to start a co-construction of a role playing game with a group of users in each village. Once the new game was designed a group of users were invited to play the new game. Additionally, a new set of interviews was applied. An institutional analysis and a mental models study was carried out for each of the cases. The evaluative criteria of the action arena were trust and cooperation levels and morality conformance. Among the more relevant findings is the necessity of including the study of morality systems to understand the relation between decision-making, rule design and compliance, and mental models. A conceptual framework for evaluate the outcomes of the action arena is proposed. The central point is the idea that the morality system is at the same time an outcome of interactions, but also it feedsback the interactions in the action arena. This system produces especific levels of trust and cooperation, which are also influenced by contextual mental models of resource users. In order to address commons management is central to understand the gap between morality, culture and legal valid behavior in a community.

RÉSUMÉ