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CHILEAN MODEL OF WATER MANAGEMENT IN CONTEXT OF WATER STRESS

SOCIOCULTURAL CONDITIONS AND VULNERABILITY TO CLIMATE CHANGE

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Zusammenfassung

Chile hat eine privilegierte Frischwasserverfügbarkeit im Vergleich zu anderen Ländern in Lateinamerika aber seine Ressourcen sind ungleich verteilt. Die Hauptstadt Santiago befindet sich fast in der geographischen Mitte des Landes und kann von reichen Wasserreserven schöpfen. Im Norden Chiles ist der Zugang zu frischem Wasser stark begrenzt und es gibt eine offensichtliche Situation von Wasserstress. Im Süden des Landes hingegen gibt es eine reichliche Frischwasserverfügbarkeit. Jedoch sind es der Bergbau und die intensive landwirtschaftlichen Aktivitäten im Norden und im Zentrum des Landes, die zu einem höheren Frischwasserverbrauch führen . Zudem wird Chile aufgrund seiner klimatischen, geographischen und wirtschaftlichen Bedingungen als sehr anfällig für die Auswirkungen des Klimawandels identifiziert. Die mögliche Erhöhung der Temperaturen und der Rückgang der Niederschlagsmenge haben einen wichtigen Einfluss auf die Frischwasserverfügbarkeit..

Der Zugang zu Wasserressourcen in Chile ist durch einen sogenannten Wassermarkt verwaltet. Wasserressourcen wird hier also zur ökonomischen und von Angebot und Nachfrage auf dem freien Markt definiert. Der institutionelle Rahmen für diesen Markt ist das Wassergesetzbuch von 1981, das besagt, dass das Wasser unabhängig vom Besitz eines Stück Landes gehandelt werden kann. Eine Reihe von Schwierigkeiten sind in diesem institutionellen Rahmen identifiziert worden, trotzdem zielte die einzige Reform des Wassergesetzbuches (im Jahr 2005) lediglich darauf, die Bedingungen für das Funktionieren des Marktes zu verbessern. Darüber hinaus gibt es noch Projekte zur Entwicklung von Wassermärkten in anderen Wassereinzugsgebieten, wo dieses Modell nicht aktiv daran arbeitet.

Vor diesem Hintergrund wird deutlich, daß es auch gilt die sozialen und kulturellen Bedingungen des Wassermanagements, die Verwundbarkeit der Bauern und die Anpassungsmöglichkeiten an die Auswirkungen des Klimawandel im Kontext zu verstehen. Meine zentrale Forschungsfrage lautet daher: Welche Voraussetzungenlassen sich im chilenischen Modell des Wassermanagements finden, um Wasserstresssituationen zu bekämpfen? Um diese Frage zu beantworten, wurde die Forschung im sogenannten "Limarí Becken" durchgeführt, einer Region mit einem sehr aktiven Wassermarkt die sich gleichzeitig in einer Wasserstresssituation befindet.

Im Limarí Becken wird das sogenannte "Paloma System" angewandt. Dieses System besteht aus einem Netz von Kanälen und Stauseen, die die Speicherung und Verteilung von Frischwasser ermöglichen, und Bedingungen für einen sehr aktiven Wassermarkt erzeugen. Da die Ressource in

diesem Becken ein knappes Gut ist, erhält sie einen großen wirtschaftlichen Wert, was den Wettbewerb für diese Ressource unter den Nutzern verstärkt. Das Paloma System reguliert den Zugang zu Wasserressourcen der neun Benutzerorganisationen mit einem innovativen Operationssystem. Es verwaltet die Ressource Wasser anhand von drei Stauseen und ermöglicht Transaktionen von Wasserrechten und Wassermengen, Überweisungen, Leasing und Krediten.

Im Rahmen der Forschung wurden wie folgt vorgegangen: semi-strukturierten Interviews (52), Gruppeninterviews (3) und ethnographische Beobachtungen, die mithilfe des Software Atlas.ti analysiert wurden. Die Befragten wurden durch ein „Structural Sampling" ausgewählt, in dem Mitglieder von verschiedene Organisationen (Regierung, Zivilgesellschaft, Experten und Bewässerungsverbände) und Bauern verschiedener Art (kleine, mittlere und große Landwirte und landwirtschaftlichen Unternehmen) identifiziert wurden. Den theoretischen Rahmen der Analyse der empirischen Daten bildet der Sozial-ökologische System Ansatz, der besonders auf Begriffe wie Verletzlichkeit, Resilienz und soziales Lernen eingeht.

Für die Widerstandsfähigkeit des Paloma Systems sind bestimmte Elemente zu identifizieren:

- Flexibilität: Eigentumsrechte und Wasserinfrastruktur ermöglichen große Flexibilität in dem Becken. Jedoch wurde diese Flexibilität aufgrund der Reduzierung der Kulturpflanzenvielfalt und Konzentration des Eigentums auf einige wenige verringert.

- Konnektivität: Nutzerorganisationen sind in der Regel gut angesehen, aber einige Geschäftsführer in Verdacht aufgrund ihrer Aktienanteile ausgewählt worden zu sein. Gleichzeitig gibt es einen allgemeinen Rückgang der horizontalen Kooperationen, so dass fast nur die Unterstützung durch die familiäre Netze bleibt. Die vertikale Kooperation von lokalen, regionalen und nationalen Organisationen birgt gravierende Einschränkungen, vor allem in Bezug auf den Austausch zwischen Gemeinden und regionalen Behörden.

- Sozial-Ökologisches Gedächtnis: Zum einen hat das traditionelle Wissen über Grundwasserneubildung deutlich an Bedeutung verloren, zum anderen gibt es wesentliche Unterschiede zwischen den Bauern in Bezug bei der Identifizierung der Ursache des Wasserstress (Die Ursache wird in entweder dem Becken oder in anderen Teilen des Landes identifiziert).

- Selbstorganisation: Durch den Verlust des sozial-ökologischen Gedächtnisses und aufgrund der fehlenden Konnektivität zwischen lokalen und nationalen Organisationen, scheint die Möglichkeit Änderungen an den Eigentumsverhältnissen oder am Wassermanagement vorzunehmen minimal.

Darüber hinaus wird in Bezug auf die Anpassungsfähigkeit an Wasserstress das Folgende deutlich:

- Identifizierung von Bedrohung: Konstante Dürren werden als Teil des normalen Verhaltens des Beckens identifiziert, und nur sehr wenige erkennen darin den Klimawandel. Von Seiten der Regierung wurden einige Initiativen offiziell gegründet, aber nicht wirklich ernst genommen.

- Steuerungskapazität: Scheint für die ersten drei Jahre der Dürre angepasst dank der Kapazität der Stauseen und Kanäle. Allerdings ist es wahrscheinlich, dass das Becken länger nutzbar ist.

- Wiederherstellungsleistung: Ist sehr begrenzt, weil der Verbrauch von Wasser intensiver und die Plantagen umfangreicher geworden sind. Da es keine Regelungen für diese Probleme gibt, werden sogar nicht so schwerwiegende Dürren schwierige und lang anhaltende Auswirkungen haben.

- Fähigkeit zur Selbstmodifikation: Auf lokaler Ebene besteht hierfür eine große Chance; Bewässerungsverbände haben einige wichtige Vorschriften eingearbeitet. Andererseits sind die landesweiten Möglichkeiten begrenzt; nach 12 Jahren politischer Diskussionen wurden nur kleinere Änderungen im Wassergesetzbuch implementiert und weitergehende Reformen scheinen wenig aussichtsreich.

Dieses Chilenische Modell hat gravierende Auswirkungen auf das soziale Gerechtigkeitsgefüge, weil es den Zugang zu Wasserressourcen für die bäuerliche Landwirtschaft und kleinere Produzenten erschwert, und die Verbesserungen der Lebensbedingungen in ländlichen Armutsgebieten erschwert. Die Beteiligung dieses Sektors am Wassermarkt ist stark eingeschränkt, sowohl in Bezug auf den Zugang zu wirtschaftlichen Ressourcen als auch zu Informationen. In der Regel sind die Möglichkeiten mit Wasserknappheit umzugehen bei den Landwirten sehr ungleich verteilt. Während der Marktmechanismus gut für mittlere und große Bauern funktioniert, weil sie bei Bedarf Wasser kaufen, profitieren Kleinbauern wegen der hohen Preise nur selten oder gar nicht davon. Dennoch ist es möglich, dass sie ihr Wasserrechte verkaufen und auf diese Weise trotz ihrer prekären Situation ein Einkommen in Dürrejahren haben.

Das chilenische Modell des Wassermanagements hat eine begrenzte Anpassungskapazität für Situationen der Wasserknappheit und Klimawandel. Die wichtigste Einschränkung ist die geringe Kapazität für soziales Lernen und somit die Unfähigkeit langfristige Folgen der getroffenen Entscheidungen zu berücksichtigen. Dies beeinflusst die Widerstandsfähigkeit des Systems und damit auch seine Fähigkeit sich anzupassen.

Abstract

Chile has privileged fresh water availability compared with other countries, but its resources are unevenly distributed through the country. The capital, Santiago, is located at the center of the country. While access to fresh water is limited and there is evident water stress from Santiago to the North, the availability of fresh water in southern Chile is abundant. Yet, mainly due to mining and agricultural activities, its use is more intensive in the north and center of the country. At the same time, Chile is highly vulnerable to the effects of climate change due to its climatic, geographical, and economic conditions. Possible increases in temperature and decreases in rainfall can have an important impact on fresh water availability, affecting an important part of the Chilean territory.

Access to water resources in Chile is managed by a so-called water market in which water resources are a commodity subject to the forces of supply and demand, based on a free-market regime that regulates the use and consumption of national resources. The institutional framework for this market is a legal document called the Water Code (*Código de Aguas*, enacted in 1981), which states that water can be traded independently of the ownership of the land. A number of difficulties have been identified with this institutional framework, but the only significant reform to the Water Code (enacted in 2005) was merely intended to improve conditions for the functioning of the market. Moreover, there are ongoing projects to develop water markets in other watersheds where this system is not yet operative.

From this background, it is essential to understand the social and cultural conditions related to water management, the vulnerability of farmers, and possible adaptations to the effects of climate change. The central research question is: what conditions are present in the Chilean model of water management in order to address situations of water stress? To answer this question, I have performed my research in the Limarí basin, where the water market is active and there is an ongoing situation of water stress.

In the Limarí basin, the so-called “Paloma System” is operational. This system consists of a network of canals and reservoirs that allows fresh water to be stored and distributed, generating conditions to maintain a highly active water market. Since water is a scarce commodity in the Limarí basin, it acquires great economic value, generating strong competition among users. The Paloma System regulates the access to water resources of nine user organizations with an innovative operating system that manages resources from three reservoirs and enables transactions involving water rights and volumes, in addition to transfers, leases, and loans of water volumes.

The investigation techniques used in carrying out the research were: semi-structured interviews (52), group interviews (3), ethnographic observation, and analysis using ATLAS.ti. The interviewees were selected through structural sampling, which identifies people representing different organizations (government, civil society, experts, and irrigator associations) and farmers of different types (small, medium and large-scale farmers and agricultural companies). The theoretical tools used to analyze the empirical data are based on socio-ecological systems and their applications to the notions of vulnerability, resilience and social learning.

From the analysis, it is possible to identify elements relevant to the resilience of the system:

- Flexibility: Property rights and water infrastructure allow great plasticity in the basin, meaning resources shift to where their use is more efficient. However, due to the reduction of crop diversity and the concentration of property, this flexibility has decreased.

- Connectivity: User organizations are well evaluated in general. However, there is suspicion of some leaders because the directors are chosen in relation to the proportion of shares. There is generally a parallel decrease of horizontal collaborations, leaving only some family support. Vertical collaboration, which refers to the relationship between local, regional, and national organizations, has serious limitations, especially in the relationship between communities and regional authorities.

- Socio-ecological memory: On one hand, it is possible to identify a significant loss of ancestral knowledge of groundwater recharge. On the other, farmers may face significant differences in addressing the problems of water stress depending on their origin (from the basin or other parts of the country).

- Self-organization: Due to the loss of social-ecological memory and the lack of connectivity between local and national organizations, there appears to be a minimal ability to deal with modifications in ownership structures or water management.

Moreover, in relation to adaptability to water stress, one can state the following:

- Identification of threat: Constant droughts are identified as part of the normal behavior of the basin and only very few informants identified climate change as a threat. At governmental level, a few formal initiatives have been formally established, but the issue has not been taken seriously.

- Control capacity: It seems to be well matched for the first three years of drought, thanks to the capacity of reservoirs. However there is not control capacity in the long term.

- Recovery capacity: This is very limited due to the increasingly intensive use of water and more extensive plantations. There is no regulation on this issue, so the effects of milder droughts are more severe and widespread.

- Self-modification ability: Locally this capacity is relatively good. Irrigator organizations have incorporated some important regulations. Nationally, however, capacity is very low. After 12 years of discussion, only minor modifications have been made to the Water Code and there is no prospect of more in-depth reform.

This model has a serious impact on social equality, because it does not facilitate access to water resources for peasant farmers and small producers, thus hindering the improvement of living conditions in poor rural areas. The participation of this sector in the water market is limited, due to restricted access to economic resources and lack of information. In general, the potential for farmers to deal with water scarcity is very unevenly distributed. The market is useful for medium- and large-scale farmers, but not for small farmers. The former have the ability to buy water when required, while the latter cannot access it due to high prices. Nevertheless, the market allows small farmers to sell their water instead of cultivating and in this manner they can receive some income in drought years, although in a very precarious situation.

The Chilean model has a limited capacity to adapt to situations of water scarcity and to the challenges of climate change. The main limitation is a low capacity for social learning and inability to consider the long-term consequences of decisions. This significantly affects the resilience of the system and therefore also its ability to adapt.

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1. Introduction

Since the Dublin Statement on Water and Sustainable Development (UN, 1992), water has been recognized as an economic good. In this context, the Chilean model of water management (the "Chilean model") has been considered as achieving technical and economic efficiency in the use of water, by regulating water resources through the market. However, many problems have also been identified associated with the management of water resources in this model. At the same time, Chile has been characterized as a country that is highly vulnerable to the effects of climate change. One of its main vulnerabilities is associated with increased water stress in some regions of the country. The present investigation is framed by these two topics: the Chilean model and the context of climate change.

At present, no empirical studies evaluate the social and environmental conditions associated with the Chilean model. With the aim of contributing to the international debate on this subject, this research empirically addresses the problem of water stress for farmers in the context of climate change, analyzing the real capacities of the Chilean model to face situations of water stress. Both its regulations for access to water through the market and its institutional conditions are considered. The research also addresses the vulnerabilities to water stress affecting different types of farmers located at the Limarí watershed. This watershed is innovative in market-based water management and involves the most active rights market and the highest volumes of water at the national level, including an electronic water market. We propose investigating vulnerabilities in drought situations on the basis of descriptions and assessments of the different actors involved, identifying economic, social, institutional, organizational and cultural conditions to deal with water stress problems.

1.1. Background of the Problem and Research Question

Chile is a vulnerable country to climate change: Climate change is one of the greatest challenges faced by society in the 21st century and must be addressed at both global and local levels. Countries must face its consequences developing strategies to adapt to changes associated with global warming, irrespective of their developmental level and their participation in greenhouse gas emissions (IPCC, 2007; ECLAC-CEPAL, 2010). Chile is identified as a country that is highly vulnerable to the effects of climate change due to its climatic, geographical, and economic conditions. A possible increase in temperatures may have an impact on fresh water availability, affecting a significant part of the Chilean territory. A temperature increase of approximately 3°C is predicted in northern and

central Chile, as well as decreases in rainfall on the western slope of the Andes mountain range (ECLAC-CEPAL, 2009; CONAMA, 2008; AGRIMED, 2008; DGA 2007).

Water market in Chile: Access to water resources in Chile is managed by a water market, in which water resources are a commodity subject to the forces of supply and demand, based on a free-market regime that regulates the use and consumption of national resources. The institutional framework for this market is a legal document called the Water Code (1981), which states that water can be traded independently of the ownership of the land. A number of difficulties have been identified in this institutional framework. The main issues are limited market flexibility, high transaction costs, concentration of ownership of water rights, worsening water stress, lack of integrated watershed management and limitations on public control of the resource (Chile Sustentable, 2010; Bauer, 2003; Donoso 2003; Hernández, 2006; Núñez & Soto, 2010; Gentes, 2007; ECLAC-CEPAL, 2003; SAMTAC-CEPAL, 2000; World Bank, 2011). The only significant reform to the Water Code (in 2005) merely sought to improve conditions for the functioning of the market. Moreover, there are ongoing projects to develop water markets in other watersheds where this system is not yet operative.

Inequalities in the water market: The operation of water markets requires that participating farmers must take risks. These risks depend on the type of production in which they are engaged and its degree of sensitivity to water availability. In contexts of greatest scarcity, it has been shown that water prices rise significantly, resulting in substantial difficulties for poor farmers (Hadjigeorgalis, 2004; Zegarra, 2002; Galaz, 2004). At the same time, the model may be defended on the grounds that it favors poor farmers, because it allows them to earn income through the sale of their temporary or permanent rights. Nevertheless, this defense has been widely questioned (Galaz, 2004). Finally, the results of recent research have indicated that the participation of farmers in water market is much lower than expected. This relates to the type of farmer who participates in the market and the fact that not all farmers participate in the same way, since those who have more resources use the market more actively, leveraging their advantages of investment capital and asymmetries in information (Fuster, 2006).

Operation of the water market in the Paloma System: The Paloma System operates in the Limarí basin. This system consists of a network of canals and reservoirs that allows fresh water to be stored and distributed, generating conditions to maintain a highly active water market. Since this resource is a scarce commodity in the Limarí basin, it acquires great economic value, generating strong competition among users. The Paloma System constitutes a unique model in Chile. It regulates the

access to water resources of nine user organizations with an innovative operating system that manages resources from three reservoirs and enables transactions involving water rights and volumes, in addition to transfers, leases, and loans of water volumes (Alvarez & Poncet, 2011; Diaz, 2008; Fuster, 2006; Alevy, et al. 2011; Leon, 2008; Donoso, 2003; Cristi, et al. 2001; Hadjigeorgalis, 2004; Ministerio del Medio Ambiente, 2011).

Status of current research: Several studies in Chile have already identified the productive sectors and geographical areas that would be most affected by the consequences of climate change, as well as the main problems that must be faced. At the same time, state agencies are already making progress in the production of systematic information on this subject. For instance, the Second National Communication on Climate Change (*Segunda Comunicación Nacional sobre Cambio Climático*) has recently been published (Ministerio del Medio Ambiente, 2011). In addition, in recent years several studies and reflections have considered the particular model of water management in Chile, offering criticisms of both the model and water markets in general. However, there are no studies that analyze the performance of this market in the context of climate change, or that specifically examine the water market in the context of water stress and consider cultural aspects, social vulnerabilities, inequalities and risks faced by farmers. Thus, it is key to go beyond the economic dimension of the performance of the market in order to evaluate how it manages water resources. It is also important to consider how the vulnerable population can participate in this market, considering the social conditions of the market and cultural biases. So far, neither the effects of the neoliberal regime on users nor the relevance of organizations and intermediaries in the functioning of the market have been studied. There have been no studies evaluating the uncertainty faced by farmers, the risk tolerance of the most vulnerable people or cultural aspects of water appraisals (Hadjigeorgalis, 2004; Gentes, 2007).

From this background, it is essential to understand the social and cultural conditions related to water management, the vulnerability of farmers, and the possibilities of adapting to the effects of climate change. To properly address these issues, we proposed conducting research in a context of water scarcity regulated by a water market, evaluating the possibilities that the Chilean model offers. In this way, the central research question is: ***What conditions are present in the Chilean model in order to address water stress situations?*** To answer this question, we have studied the Limarí basin, where the market is currently active and there is an ongoing situation of water stress. This will permit reflection on the Chilean model, evaluating the conditions that increase or decrease the vulnerability of farmers and their adaptation capabilities.

To address this research question, the Limarí basin is presented as an especially interesting unit of study. This basin contains the most active water market at a national level, it being possible to observe permanent and temporary water transactions. Moreover, from a climate change perspective, the basin houses the more vulnerable municipalities from the agricultural sector, due to potential reduction in river flows (close to 50%), the socio-economic conditions of its population, and its production system.

At the same time, although water rights were privatized by means of the Water Code in 1981, an informal rights market has existed since the early 1940s. Finally, the basin permits a geographical division that offers a comparative view, between the irrigation sector located above the reservoirs and the area below them. The latter is the sector benefiting from water storage infrastructure and it has an active market (León, 2008; Donoso, 2003; Cristi, et al. 2001; Hadjigeorgalis, 2004; Ministerio del Medio Ambiente, 2011).

1.2. Research Objectives and Conceptual Framework

In the context of the consequences of climate change and the need to observe the possibilities of adapting to this global phenomenon, the main objective of this research is to *identify and explain the conditions that the Chilean model establishes in order to address situations of water stress*. This will then be used to discuss the capability of the Chilean model to deal with the effects of climate change.

In view of this challenge, there is an urgent need to improve our comprehension of water scarcity and the situations of vulnerability that it provokes in rural and urban communities. The relationship between society and the environment has been addressed from systemic tradition, with significant theoretical developments within the framework of the complex adaptive systems approach (Holland, 2006; Gunderson & Holling, 2002) and social-ecological systems (Holling, 2001; Cumming, 2008; Ostrom, 2009; Rappaport, 1977). Our work concentrates on the description of social systems and how they relate to the ecological milieu. In this context, we work with two key concepts: resilience and adaptation. The theoretical discussion is developed in detail in chapter 3, but below we show the specific objectives for each theoretical dimension.

TABLE 1: OBJECTIVE FOR THEORETICAL DIMENSION

Theory	Dimension	Research Objective
Resilience: Flexibility and Diversity	Economic rules	Evaluation of the operation of the water market
	Legal rules	Evaluation of the legal conditions for the management of water resources
	Higher regulators	Description of the institutional and organizational conditions for water management
	Lower regulators	Evaluation of the functioning of user organizations in the

		administration of water resources
Resilience: Connectivity	Cultural evaluations	Ownership of water and their networks of associated meanings
	Vertical collaboration	Influence of state organizations in the management of water resources
	Horizontal collaboration	Cooperative and/or competitive actions in the management of water resources
	Trust	Conditions of trust for collaboration (vertical and horizontal)
Resilience: Socio-ecological Memory	Knowledge	Local knowledge about the water situation in the basin
	Learning	Learning about the management of water resources from previous droughts
Resilience: Self-organization	Capacity for self-transformation	Possibilities to modify the conditions of management of water resources
	Capacity for innovation	Development of new strategies to address the challenges of water stress
Adaptive Capacity	Identifying the threat	Information on water resources and their scarcity conditions (including effects of climate change)
	Control capacity	Difficulties faced by farmers and user organizations in water shortage situations
	Recovery capacity	Recovery capacity of user organizations and farmers in different situations of water scarcity
	Transformation capacity	Capacity of local and national organizations (user and State organizations) to develop strategies for adapting to climate change

1.3. Relevance of the study

Chile is one of the main examples of the application of neoliberal policies in water management. The Chilean model has inspired other countries in the region, such as Bolivia, Peru and some Central American countries (Galaz, 2004), which are already making changes in their legislation to replicate this model. Important international organizations have also highlighted the Chilean model as a reference point for water management (Haughton, 2002). It is therefore especially important to observe the performance of this model in the Limarí basin where it is fully operative.

Finally, it must be considered that water markets are most active when water is scarce, so if climate change increases water stress situations, the performance of water markets will be increasingly important. Therefore, it is essential to study the performance of currently active markets. As such, the Limarí river basin offers a privileged space to research the management of water resources in the context of potential water shortages as a result of climate change.

1.4. Methodological Approach

This research proposes a conceptual and empirical approach to the problem of water stress and water markets in Chile, in the context of climate change, analyzing the operation of the water market

from the perspectives of public institutions involved in its management, users of the resource, and organizations from civil society involved in the issue.

In the existing research on water markets, there is an approach from the economic model or from the legal institutions (top-down). There is no research available including reflection and analysis from users (bottom-up). Thus, in this research, besides considering the background of other studies and official documents on the water market (top-down), the discourses of different stakeholders regarding the water market's performance in the local context will be studied.

This research will adopt a qualitative approach (Mack, et al., 2005), which will observe and describe the operation of the water market through ethnographic work. It will observe different actors' perspectives of the water market in the Limarí basin, taking it as a case study (Flyvbjerg, 2011). The research will also compare (Beckers, et al., 2010) descriptions of the basin area below the reservoirs (where the market is very active) and the geographical sectors located upstream from the reservoirs (where water stored cannot be traded).

Research techniques and analysis:

- Analysis of secondary data and institutional documents: We propose a documentary analysis (Garcia, Ibanez & Alvira, 2000), applied to relevant information in the local print media and to other research on water markets with relevance to the aims of this study.
- Semi-structured interviews: This type of interview (Rubin, H. & Rubin, I., 1995) seeks to address the descriptions of users, professionals, state organizations, civil society members, and experts on the operation of the water market.
- Ethnographic observation: Together with the interviews, during the weeks of fieldwork, ethnographic observation was performed (Geertz, 1994) of the functioning of user organizations and the relationships between officials of government agencies and user associations.
- Content analysis: Semi-structured interviews were transcribed textually, to subsequently carry out a systematic content analysis (Krippendorf, 2004). The results of this analysis were linked to the outcomes from documentary analysis and ethnographic observation.

An information-oriented sampling strategy (Denzin & Lincoln, 2011) was used to select the interviewees, with the aim of identifying distinctions and evaluations made by different stakeholders. It was considered to perform 54 semi-structured interviews.

TABLE 2: INTERVIEW BY TYPE OF INFORMANT

Type of Informant	Interview
Experts	CEAZA expert
	CAZALAC expert
	Climate change expert
	Pro-market expert
	Regional expert
	National expert
Positions with Political Responsibility	Left-wing government politician (2006-2010)
	Right-wing government politician (2010-2014)
Civil Servants	DGA Serena
	DGA Santiago
	DGA Santiago user organization head
	INDAP Ovalle
	DOH Serena
	DOH Santiago
	CNR Santiago
	CNR Santiago user organization head
Market intermediaries	Intermediary lawyer 1
	Intermediary lawyer 2
	Intermediary lawyer 3
	Electronic market administrator
	Informal intermediary 1 (stockbroker)
	Informal intermediary 2 (stockbroker)
Leaders and Administrators, User Organizations	Administrator, Limarí Monitoring Board
	Administrator Paloma System
	Administrator Recoleta
	Administrator Camarico
	Administrator Cogotí
	Administrator Hurtado river
	Leader Cogotí
	Leader Limarí Monitoring Board
	Leader Mostazal Monitoring Board
Civil Society	CS Ovalle
	CS National
	CS South
Farmers	Agriculture company 1
	Agriculture company 2
	Agriculture company 3
	Agriculture company 4
	Large-scale farmer 1
	Large-scale farmer 2
	Large-scale farmer 3
	Mid-size farmer 1
	Mid-size farmer 2
	Mid-size farmer 3
	Mid-size farmer 4
	Mid-size farmer 5

Small farmer 1
Small farmer 2
Small farmer 3
Small farmer 4
Small farmer 5
Small farmer 6
Small farmer 7
Small farmer 8

1.5. Theoretical Context

Certain theoretical points of support, especially the adoption of a strategy based on social systems theory supported by the concept of social-ecological system and the complex adaptive systems approach, have already been explained. Within this perspective and based on the development of the natural and social sciences, our work is methodologically framed by what is known as “radical constructivism”, in which the limits in the process of knowledge are acknowledged but its construction is not relinquished (Maturana and Varela, 1984). To accomplish this, we use the strategy of “second order observation” (Luhmann, 1984) as our support and assume the pertinence of identifying the distinctions and concepts with which knowledge is constructed. Second order observation is carried out concerning the manner in which another observer observes; i.e., the distinctions they employ in order to observe, the means with which they make distinctions, differentiate, and evaluate. Through this methodology, knowledge ultimately emerges from an understanding of how others construct their worlds of reality (Luhmann, 1997). Second order observation constitutes a general methodological framework that sets out the techniques for the production of data and interpretation of results.

In the investigation of complex adaptive systems, work is traditionally done with quantitative data for modeling information. However, in recent years emphasis has also been placed on the importance of qualitative investigation (Chan et al., 2012; Saterfield et al., 2013). This is because the narratives of key informants enable information to be gathered on the descriptions and evaluations of the interviewees, without structuring the responses and allowing greater flexibility for the researcher to adapt to the conditions of different subjects (Chan et al., 2012). The use of narrative and exploratory techniques thus makes it possible to

delve deeper into symbolic and abstract elements related to the ecosystemic services (Saterfield et al., 2013).

An example of qualitative work adopting this perspective has been developed by Roy Rappaport (1977, 1996). He highlights the constructed character of ecological problems and the relationship between social systems and their surroundings, aside from the constructivist nature of the investigation starting from the difference observed by the same author (Rappaport, 1996) between "cognitive models" and "operative models". Operative models encompass those distinctions concerning the ecological environment made by the different stakeholders acting within it, distinctions that circulate in the social system, and in relation to which cultural processes and practices that affect the system's ecological environment are of special significance. Cognitive models, for their part, refer to the abstract components identified through the model that the researcher constructs, thanks to the observation and measuring of empirical elements. To build a cognitive model on the relationship between society and water resources in a specific territory, aside from describing the distinctions that are built over the ecological surroundings, it is also essential to address the formal and informal rules that regulate interaction and coordination (North, 1990) vis-à-vis the access to these resources.

In this study, the analysis of qualitative data is considered for the purpose of gathering information on socio-cultural conditions. Based on semi-structured interviews (Rubin & Rubin, 1995), user descriptions are addressed — professionals in state organs, members of civil society, and experts managing the water resources in the watersheds selected. Based on the analysis of these interviews (Krippendorf, 2004), the meanings and valuations that the different stakeholders assign to water resources are observed, in addition to identifying the formal and informal rules that regulate access to those resources. Furthermore, pertinent information is identified as regards the institutional framework and the situations of water stress from an analysis of secondary data and institutional documents (García, Ibáñez & Alvira, 2000). Finally, through the triangulation of information (Flick, 2008), a "cognitive model" is constructed (Rappaport, 1996) on the different operational models observed in the relationship between society and water stress.

1.6. Dissertation Structure

This document is organized into seven chapters. Chapter 1 corresponds to the present introduction, which reviews the background of the dissertation, its objectives, and methodology. Chapter 2 presents the conditions of water stress and climate change in Chile. Chapter 3 is dedicated to analyzing the concepts of water vulnerability, resilience, and capacity to adapt from the perspective of social-ecological systems. Chapter 4 presents an analysis of the Chilean model of water management, including the Water Code, user associations, institutions participating in water management and the operation of the Limarí basin.

Chapters 5 and 6 present an analysis of the data collected in the Limarí basin, from the theoretical perspective outlined in Chapter 3. Chapter 5 focuses on the resilience of the system and chapter 6 on adaptive capacity faced with the threat of water scarcity in the Limarí basin.

Chapter 7 presents the conclusions of this research, summarizing the problems surrounding the conditions of the Chilean model for dealing with situations of water stress.

2. Water Stress and Climate Change in Chile

Chile contributes only 0.2% of worldwide greenhouse gas emissions (CEPAL/BID, 2010) and emissions per inhabitant are estimated at 3.9 t CO2/capita, close to the world average (PNUD, 2007). But because of its geographical, climatic, and productive characteristics, Chile is considered a country that is highly vulnerable to the effects of climate change.

In recent years a series of studies have been carried out in Chile on the possible consequences of climate change. These studies have predicted a possible rise in temperature (close to 3°C) across a great part of the country, in addition to decreasing rainfall (up to 30% in summer and autumn) in regions with the highest concentration of population (DGF, 2006). They have also identified a significant decrease in the glaciers of the Cordillera de los Andes, which are the main reserves of fresh water in Chile. This is clearly significant for the provision of drinking water in several regions (CONAMA, 2008).

Chile has two critical situations of vulnerability. The first refers to the possibility of desertification in Norte Chico (Region IV) and the second is the reduced availability of water resources for drinking water coverage in the metropolitan area. Both situations are directly related with the probable decline in river flows in these regions, caused by a decrease in rainfall, combined with dwindling stocks of snow due to rising temperatures (CEPAL/BID, 2010).

The risks associated with these critical scenarios must be addressed nationally and locally, creating adaptive strategies. Chile's economy is highly dependent on natural resources, so that adaptation to climate change is essential to move the country towards sustainable economic development (Claro, 2007). However, both the discussion and the development of adaptation strategies to climate change impacts remain incipient in Chile. On the other hand, the socio-economic, institutional, and cultural conditions available to affected localities in order to address declining water resources are very different. These aspects have not yet been investigated.

2.1. The Problem of Water

Compared with other countries, Chile has privileged access to fresh water, due to both the availability of surface water and the presence of water reserves in the Southern Ice Fields. The availability of fresh water in Chile is estimated at 60,614 m^3/capita/yr, with an estimated 9,245 m^3/inhab. (World Water Assessment Programme, 2003).

Despite the abundance of water resources, their distribution is very uneven throughout the country. From Santiago to the north of Chile, access to fresh water is limited (about 639m^3/inhab/yr) and this region faces clear water stress. On the other hand, in southern Chile, available water is plentiful (over 9,000 m^3/capita/yr) (GEO Chile, 2008). This significant difference in the availability of fresh water is largely due to important differences in precipitation by latitude.

Water legislation in Chile distinguishes between "consumptive" and "non-consumptive" uses. Consumptive uses take into account water consumption without being returned to the flow of a river. Non-consumptive use encompasses the use of water that is then returned to the river flow (Bauer, 2003). It is estimated that about 89% of "water rights" are for non-consumptive use and only 11% refer to consumptive uses (GEO Chile, 2008).

Consumptive uses include the following distribution of rights: irrigation 73.8% (average flow of 526m^3/s, used to irrigate about two million hectares), 5.6% potable water (40m^3/s, which supplies 98% of the urban population and nearly 80% of the rural population), 12% for industrial purposes and 9% for mining activities (Nuñez & Soto, 2010). Projections for the year 2030 predict a reduction of 13% in water consumption for irrigation purposes, and a 1% decrease in demand for potable water. A 14% increase in industrial consumption and stability in the percentage of water consumption in the mining sector are also expected (GEO Chile, 2008).

However, this distribution is very different when analyzed for each region of Chile. While mining and industrial water consumption are highly significant for the regions located at the north and south extremes of the country, in the central regions consumption is mainly agricultural (Nuñez & Soto, 2010). In table 3 below, we observe the distribution of consumptive uses by region.
Concerning non-consumptive uses, consumption increases are concentrated in electricity generation. In 2006, an installed capacity of around 8,500 MW was established for the Central Interconnected System (*Sistema Interconectado Central*, or SIC), with 55.6% of power generated from hydroelectric energy and 44.4% corresponding to carbon-based power plants (DGA, 2007).

In recent years, consumptive and non-consumptive use of water in Chile have increased, which has also created a greater pressure in areas where resource availability is limited. In many cases, this has triggered evident water stress (Nuñez & Soto, 2010).

TABLE 3: MODIFICATION OF WATER CONSUMPTION BY SECTOR 1990-2006.

Sector consumption (m^3/s)	1990	1999	2002	2006
Agriculture (consumptive uses)	515.8	611.4	647	526,732
Potable Water (consumptive uses)	27.4	34.1	36.7	40,134
Industrial (consumptive uses)	47.1	68.2	77.2	83,847
Mining (consumptive uses)	43.2	50.5	53.2	62,776
Energy (non-consumptive uses)	1189	2914	3929	3,997,246

Source: National Report (*Informe País*) 2008 (Geo Chile, 2008)

The increased importance of consumption of water in the country has been linked to the particular institutional model regulating the distribution of this resource. The Chilean model, which regulates the use and consumption of fresh water, is unique in the world. It was legally promulgated in 1981 through the Water Code, within the framework of neoliberal reforms enacted under the military regime led by Augusto Pinochet. This Code remains in force today, and was only amended in 2005. On that occasion, certain aspects were established as critical to the normal functioning of the water market, but there was no modification whatsoever concerning the orientation of the market with regard to regulating access to water resources. This process has meant that water policies are dictated by the free market more in Chile than in any other country in the world.

Through the enactment of the Water Code in 1981 Chile established the foundations for the privatization of water rights, reducing state regulatory capacities and stating at the same time that water rights are "private property" and a tradable commodity (Bauer, 2003). In parallel, during the second half of the 1980s and through the 1990s, water services were privatized. Before privatization, the private sector controlled only 2% of water services. By the end of the 1990s, 83% of water service companies were privately owned (Gebauer, 2002). We must emphasize that the great process of privatization took place under the transitional post-military regime governments, in order to encourage investment in the area and expand water service coverage nationwide.

2.1.1. Climate Change and Water Stress in Chile

Current estimates of the effects of climate change on Chile predict a temperature rise of close to 3°C in the northern and central regions of the country, in addition to reduced rainfalls on the western slopes of the Andes mountain range, particularly in the average latitudes and in the summer and fall seasons. The decrease in rainfall may be as high as 50% in the summer months, but in some cases the flow of rivers in winter season could increase as a result of the rise of the 0°C isotherm, thereby reducing solid precipitation in the high peaks and reduction in the Andean area capable of storing

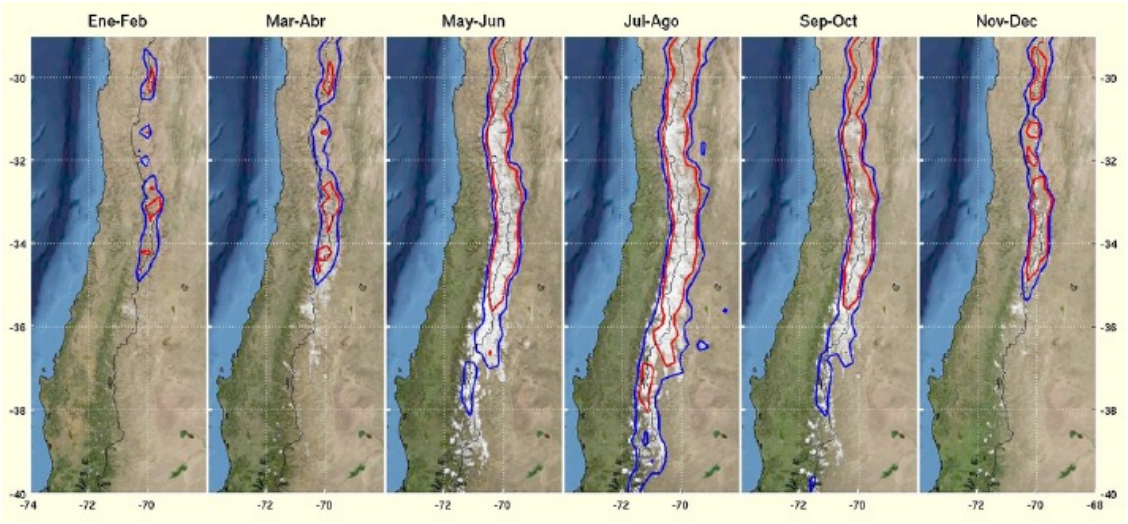
snow (DGF, 2006). Related to this, a significant decrease of the glaciers in Chile has been identified, which reduces freshwater sources (CONAMA, 2008).

Chile has critical situations of vulnerability in some regions due to this probable decline in river flows caused by lower rainfall coupled with dwindling stocks of snow due to increased temperatures. The most critical situations relate to the possibilities of desertification (Norte Chico, Region IV) and the reduced availability of water resources for consumption and potable water (Metropolitan Region) (CEPAL, 2009).

As regards the estimation of climate scenarios for different regions of Chile, two different emission scenarios have been identified for the 21st century (IPCC, 2007), one moderate (B2) and one severe (A2). With respect to projections of precipitation, the B2 scenario estimates a decrease in rainfall of between 10% and 20% in the Norte Chico area (Atacama and Coquimbo regions). For the transition period, both scenarios project a decrease in precipitation for the Antofagasta and Los Lagos regions. This decrease, coupled with the raising of the zero degree isotherm, would result in major water stress from the semi-arid region (Norte Chico) to a significant part of central Chile (CEPAL, 2009). This implies that from the Maipo river basin to the North (between 20° and 33° south latitude), water availability restrictions are projected depending on the scenario (A2 or B2) and the time period considered. For the late period, restrictions may vary between 30% (B2 scenario in the Maipo river basin) and 65% (A2 scenario for the Aconcagua River basin) (DGF, 2006).

Similarly, in the mountainous region between 29° and 40° south latitudes, there are reductions in the zero degree isotherm area for all seasons during the year. This is highly important because these regions provide the greatest productivity from the agro-forestry-livestock standpoint, in addition to the hydro-generated power from the SIC (DGF, 2006).

FIGURE 1: VARIATION OF THE 0°C ISOTHERM AREA BETWEEN PRESENT CLIMATE (BLUE LINE) AND A2 SCENARIO (RED LINE)



Source: Study of climatic variability in Chile for the 21st century (*Estudio de la variabilidad climática en Chile para el siglo XXI*) (DGF, 2006)

In this scenario of significant water stress in Chile resulting from climate change, the Chilean model of water management, based on a water market with property rights, has been evaluated as suffering from serious deficiencies in terms of capacity to address shortages of water resources, to develop programs for improving resource use, and to ensure equity of distribution. To meet these challenges, it will be necessary to implement actions that aim to relax the operation of dams and improve water management at basin level, trying to reduce the impacts associated with a reduction in levels of water availability and changes in the regularity of flows (CEPAL, 2009).

2.2 Vulnerability to Climate Change

In the watersheds located between the regions of Coquimbo and Los Lagos, the most significant flows are expected to decline, in addition to a change in regularity of flows and a decrease in the accumulated ice of the glaciers (CEPAL, 2009). Climate change models indicate that by the end of the century the situation in this geographic area may be completely different from today, dramatically decreasing water availability. These hydrological changes would affect the productivity of industries that depend on the availability and regularity of flows, including irrigated agriculture, hydro-electric power generation, and potable water in the municipal, industrial, and mining sectors (León, 2008).

In this context, aspects that are highly vulnerable to interannual climate variations have been identified in the affected regions, with significant challenges to sanitary, mining and agriculture sectors (CEPAL, 2009):

- Sanitary sector: In the metropolitan area, there would be hydrological changes in the main source of supply for the city (Maipo river), creating a future deficit in the provision of potable water. One possibility is that water companies will buy more water rights to safeguard supply, triggering new costs that would be transferred to users in the city in the form of increased rates.

- Agricultural sector: It is projected that there will be a decline in the water available for irrigation in the districts located to the north of the Maipo river. Coupled with projected changes in the productivity of different types of exploitations, this potentially has considerable effects in agriculture, especially in the fragile ecosystem of Norte Chico.

- Mining: Projections for the next 30 years indicate that in all the basins where mines are located, availability of water will be reduced due to climate change, placing more pressure on the basins that provide the water necessary for this sector.

The geographical areas identified as most vulnerable to these changes are located in arid steppes and semi-arid Norte Chico, due to droughts and increasing desertification (Ferrando, 2002). These processes are present in most water-stressed areas of the sector and aggravate the negative impacts of water scarcity, which in turn hinders the sustainable development and conservation of ecosystems associated with these environments (Unesco, 2010).

2.2.1. Agricultural Vulnerability

In Chile, agriculture has great significance for the national economy. Agriculture and livestock farming are among the main activities in the central and southern regions of the country. The contribution of this sector to national GDP (taking into account production chains) is almost 13%. Over the past 20 years, exports of agricultural and forestry products have grown at an annual average rate of 9.1%. Agriculture is one of the key sectors driving national job growth, with an average of 738,000 people per year (including seasonal work), amounting to 11.2% of the national workforce (Public Accounts of the Government of Chile, (*Cuenta Pública Gobierno de Chile*), 2010).

However, the importance of this activity differs greatly if we compare regions of the country, due mainly to varying climatic conditions and availability of water resources. In regions where agricultural activity is significant, such as the regions of O'Higgins, Maule, and Araucanía, the sector contributes about 15% to regional GDP, while the figure in the regions of Coquimbo and Los Lagos is close to 10% (OECD, 2009). However, in the regions of Tarapacá, Antofagasta, Aisén and Magallanes, the sector contributes only around 1% (*Libertad y Desarrollo*, 2011).

In the per capita evaluation of the existing and projected availability of water resources (Figure 4), the supply of water is very different between regions. From the far north to the metropolitan region, there is critically low water availability (SAMTAC-CEPAL, 2000).

Research on vulnerability to climate change, focusing on the impact on agriculture, has been carried out in this context in Chile. The main problem identified in such research is the potential water stress in major basins of the country. The map in Figure 5 identifies the sectors most affected by changes in flow (red), for which a decrease in wealth of up to 30% could occur as a result of climate change, generating evident water stress. (CONAMA, 1999).

The agricultural sector in Chile is the largest user of water, representing 85% of consumptive rights. The irrigated area is close to 1,100,000 hectares, representing an increase of about 37,000 hectares in the 1990s resulting from irrigation works. The irrigation of orchards and vineyards associated with exports plays a significant role in this increase, especially in the northern and central valleys of the country. Due to the scarcity of surface water, this has led to increased demand for groundwater (Peña, Luraschi & Valenzuela, 2004).

Because a “stock” (share) or right belongs to each of the parties, dividing the amount of water available in the source of supply, whether river, canal, or reservoir, due to water stress on the watersheds, there will be less water granted per share. The effects of water stress in these basins will depend on the ability to regulate flows in each river and the possibility of “moving” water from periods of the year during which is available to the periods during which it is needed (CEPAL, 2009).

3. Water Vulnerability: Conceptual Tools

The comprehension of water scarcity requires an interdisciplinary vision that responds to the problem's complexity, considering the interdependence between the biophysical and socio-cultural conditions. Critical and holistic analysis of these situations demands a redefining of the concepts of scarcity and vulnerability, based on a dialog between the social and geographic disciplines.

In the international literature, the phenomenon of water scarcity is not studied solely as a natural phenomenon; rather it is recognized, identified and analyzed in its social dimension as well. The authors who underscore the socio-cultural factors that influence the configuration of such scarcity refer, for instance, to a "socially constructed" water scarcity (Mehta, 2007). On the other hand, when the focus of study is the degree of vulnerability experienced by various social groups before natural phenomena, it is recognized that a variety of factors exert influence over this aspect. Aside from the external or "natural" factors, which include the availability and distribution of hydrological resources, in reference to biophysical conditions, several socio-cultural conditions are identified that affect the capacity for control and potential for recovery of a specific social group before an external threat (Adger & Kelly, 1999).

In recognition of this complexity and understanding the interdependence and reciprocity between biophysical and socio-cultural dimensions, we likewise sustain in this work that the socio-cultural conditions that configure a social group's vulnerability to water scarcity are, at the same time, contributing factors to the creation of this very threat. This situation presupposes the overlapping of diverse social subsystems, especially the social systems of economy, science, politics, morality and mass media. Economic operations, for example, construct a threat, given the overexploitation of resources. As for morality and politics, they configure possibilities of reaction to this overexploitation through the observation of favorable or unfavorable situations, and the development of collective action strategies to confront situations of water scarcity. The identification of water scarcity is also mediated by the possibilities for scientific observation (for example, ability to measure the aquifers' capacity). Mass media widen the communication on the problems of water shortage as well as the demand for this resource, since the water volumes required to meet the needs of the population differ depending on economic and cultural factors — for example, per capita water consumption in the so-called developed countries is more than double that of countries recognized as belonging to the "third world".

In the context of multiple observations and actions, we consider it fundamental to build a model that will enable interdisciplinary dialog, and engage with the challenge in this document. Our work focuses on the construction of the concept of *hydrological vulnerability* to observe the relationship between a specific social system and its ecological environment, where a threat of water shortage is identified. With this objective in mind and on the basis of a conceptual discussion, we identified the critical elements of the social system that would enable us to identify conditions of vulnerability, as well as the core elements that should be considered in the description of the ecological environment in order to speak of water scarcity. We propose a theoretical model for the observation and comprehension of vulnerability to situations of water scarcity, articulating their socio-cultural and biophysical dimensions.

3.1. The Social Construction of Water Scarcity

The final decades of the 20th century saw a profound questioning in different scientific disciplines of positivism and the claims to objectivity of scientific knowledge. There are multiple possible approaches in this context, some of them the fruit of the development of the "natural sciences" themselves, in which there was a problematization of peoples' processes of perception and the limitations of different senses vis-à-vis accessing "reality", constraining the possibility of resorting to that reality for validation of scientific explanations. Advocates of General Systems Theory such as Heinz Von Foerster, Francisco Varela and Humberto Maturana (Brandao, 2012) have made significant contributions to this line of thought. What is fundamental here is the explanation of the process of knowing and the limits of knowledge, in which it is understood that the observer is central to the construction of the observed (Maturana, 1990). Concurrently, within the framework of the social sciences, Berger and Luckmann's celebrated *The Social Construction of Reality* (1966) founded the current known as social constructionism, which established that knowledge is the product of social interactions. The majority of the social and human sciences developed within this framework in the second half of the 20th century.

The identification of environmental problems — in our case, water scarcity — is likewise framed within this problematization of knowledge (Blaikie et al., 1994). The environment and the properties or problems attributed to it are the result of communications operations carried out in society. When we speak of 'society', we do not refer to individuals or groups, to their thoughts or bodies; rather to the communication produced between people (Luhmann, 1991). Certainly, society could not exist without people, their bodies or thoughts, but society cannot be reduced to its parts, since it is a system of a different sort that reproduces itself autonomously. For this reason, it is through

communication that that which is the environment is defined. Through it, its dangers, risks and natural resources, as well, are identified (Luhmann, 1991).

In a modern society such as ours, the biophysical conditions of the surroundings are primarily identified through the conditions available in the scientific system, and the possibilities for observation of the social group that interacts with it. Modern society is a functionally differentiated society. Each subsystem fulfills a function for society, resolves a problem of reference, and produces a perspective for the observation of society. Thus the economy resolves the problem of material scarcity of resources (doubled as shortage of money in a monetary economy), and perceives the world as a scarce resource that must be distributed (Luhmann, 2013). The function of public policy is to generate collectively binding decisions, and its horizon is the issue of power for such decision making. Morality divides the world between good and bad and reflexively assumes that this distinction can, in turn, be good or bad. The function of mass media function is to disseminate communications far beyond the immediate vicinity of the participants in an interaction, and they perceive the world as an irritant, whether it generates surprises or redundancies (Luhmann, 2007). Science has the function of generating knowledge, and whoever seeks true knowledge that is possible to experience in a generalized manner has scientific communication at their disposal. All of these systems are differentiated communications that exist in society and they do not allow society to be seen in a unified way, but as a horizon of multiple perspectives (Nassehi, 2011).

For this reason, environmental problems that are not communicated do not exist socially. This enables us to comprehend how, nowadays — thanks to scientific advances — we can identify many more problems than those that were themed decades ago (for example, the dioxins that pollute our food or drinking water, gases that affect global climate, etc.). Furthermore, we see that the environmental problem goes hand-in-hand with our modern society's development, since it was born with modern society and therein seeks its solutions. An environmental problem is identified as a threat only when there is communication concerning it (Luhmann, 1986), independently of whether it may have been in existence for much more time in the ecological environment. Unlike other social communications, environmental problems have a special sensitivity to scientific observation and the answers are sought in science. However, these problems are, in turn, also visible as political, legal or economic problems, and even as religious portents. The importance of science resides in its capacity to delve deeper into the “knowledge” of an ecological problem, and not, as in other systems, into the economic, moral, religious, or other advantages or disadvantages inherent in their identification. For this reason, we consider it fundamental to gain knowledge of ecological problems and comprehend their functioning.

On the other hand, vulnerability to environmental problems is also a social construct, not only because it is identified and communicated on the basis of social conditions, but also because the positions of different groups in society (e.g., social class, gender, ethnicity), access to social and natural resources, inhabited spaces, and the strategies that can be implemented to tackle environmental problems influence how such groups are affected by environmental disasters or threats (Blaikie et al., 1994).

Among the implications of this perspective — along with assuming the limits of scientific knowledge itself — we find that identification of situations of water scarcity and vulnerability are influenced by social and cultural conditions within a specific context. Thus, we only speak of this scarcity when it is identified and communicated by those it affects. This does not mean that no relationship exists with the "natural" conditions of water availability, identifiable and comparable through time; however, this relationship is conditioned by society's possibilities of observation as well as by the valuations and expectations existing in it. Scarcity is, in this way, always a scheme of comparison that depends on adopted social perspectives.

The case of water scarcity shows how society is a system that operates autonomously and that uses its own outputs as inputs for its operations. As can be clearly seen in the case of water scarcity, these situations, aside from being conditioned by the possibilities of observation, are provoked by these very social operations. On one hand, the intensive use of water resources has provoked a dramatic shortage in certain regions of the world, but the creation of settlements in areas historically characterized by water scarcity only acquires significance and is problematized as scarcity when there exists a demand for the resource (i.e., the establishment of mining operations, agro-industry or, quite simply, urban settlements requiring sanitary services). On the other hand, the scarcity of this resource is related to its use and consumption, since watersheds that in prior centuries had no shortage of water, today experience it due to intensive use and, in many cases, overexploitation. Thus, it seems appropriate to speak of a scarcity that is socially constructed twice over; i.e., through operation and observation of the resource.

In this context, we understand that hydrological vulnerability is constructed and that the reproduction of its conditions relates to the socio-cultural characteristics of the groups concerned. The increase in threats of natural origin is a product of the relationship between society and the environment; thus, we can speak of socially constructed risks (Beck, 1996; Luhmann, 1991; Douglas, 1996). Assuming these conditions for water scarcity obliges us to build an interdisciplinary focus for comprehension between society and environment.

3.1.1. Interdisciplinary Approach: Society and Environment

The relationship between society and the environment has not been addressed from multiple perspectives; nevertheless, one of the most important of these has been systemic tradition, with significant theoretical developments within the framework of the complex adaptive systems approach (Holland, 2006; Gunderson & Holling, 2002), social-ecological systems (Holling, 2001; Cumming, 2008; Ostrom, 2009; Rappaport, 1977) and social systems (Luhmann, 1998). Moreover, these perspectives offer interesting tools for interdisciplinary work, whether from general systems theory (Ashby, 1984; Wiener, 1979), which proposes the development of an interdisciplinary paradigm, or from second-order cybernetics (Von Bertalanffy, 1976; Von Foerster, 2003), which encompasses complex systems as sets of elements interacting amongst themselves on different levels, with varying degrees of autonomy and self-organizing properties.

From this perspective, upon observing the relationship between system and environment, it is identified that complex systems are capable of perceiving their surroundings and reacting to them; however, the surroundings cannot control or direct changes within the system, and in this sense they are autonomous (Holland, 1994; Cumming, 2011; Luhmann, 1984). Nevertheless, both complex adaptive systems in general, and social systems and social-ecological systems in particular, have the ability to react to their surroundings thanks to mechanisms of self-organization that have to do with preceding conditions of the system, based on which it can modify its own structure. What occurs in the system is a product of the system's own activity and not that of the surroundings; however, precisely due to this last, systems can be “vulnerable” to their milieu.

Changes in systems are observed as emerging states that may respond to different *attractors* or self-organized states of stability, called basins of attraction (Gunderson & Holling, 2002). In this context, the problem of system definition is central: how do we differentiate between system and environment? There are a variety of alternatives in the systemic tradition; for example, identification of a system through its identity (Holland, 2006), by means of the cohesion among its components (Collier & Hooker, 1999), maintaining the relationship between its main components (Cumming & Collier, 2005), or — from the constructivist perspective of the theory of social systems — the identification of a system results from the realization of a distinction, of the application of a difference based on levels of complexity. In other words, a system is always less complex than its environment and, thus, traces a limit with respect to it and self-organizes on its basis (Luhmann, 1984). Considering this work's constructivist basis, we will apply this last perspective of social systems theory, as it encompasses the preceding approaches and grants them coherence. In

addition, it enables us to differentiate between observer systems (psychic and social), biological, biophysical and social-ecological systems, depending on the level of observation and the investigation's scope. It should be noted that our work concentrates on the description of social systems and how they relate to the ecological milieu, the latter also possible to distinguish as a social-ecological system.

The spatial dimension of the observed system must be identified (Cadenas, 2012) in order to address a specific environmental problem such as the one selected. This can be done on different levels. We can observe a small system (for example, an organization) and its various settings –biological, social, physical, etc.; also, a system where social and economical subsystems interact within a delimited geographic space. Or we can even speak of the planet Earth as a world system (Lovelock, 1979), in which multiple subsystems can be identified. This should clearly establish that a system always emerges as an observer's action, and in the case of scientific observation, a system is such depending on the problems to be resolved through the praxis of science.

In this work, and based on the research problems enunciated above, we will identify a specific territory, delimited by watersheds, observing different social and ecological systems that interact within the watersheds, supporting ourselves on the theory of social systems and of social-ecological systems (Gallopin et al., 1989). Given the complexity of the issue and the challenge implied by interdisciplinary work, we have selected the complex adaptive systems perspective to approach the problematic of water scarcity. Within this framework, conceptual tools will be presented to observe what have been named "social-ecological systems", to then address hydrological vulnerability and the system's resilience, based on the relationship between biophysical and socio-cultural conditions.

3.2. Social-ecological Systems

In the context of complex adaptive systems, a social-ecological system[1] refers to the periodic interaction between biophysical and social factors, with emergent properties and self-organizing capacity (Norberg & Cumming, 2008; Folke et al., 2005). The different elements and their interactions generate observable dynamics and adaptive processes arising from their self-organization (Holling & Gunderson, 2002).

[1] Following the proposal of Folke and with the aim of avoiding undervaluation of the pertinence of the social and ecological systems, we will speak of socio-ecological systems (Folke et al., 2005). In this way we emphasize the integrated observation between society and nature, but assuming that the definitions of the limits of these systems are arbitrary and socially constructed.

To comprehend the behavior of social-ecological systems, we must clarify the relationship between the social system and the ecological environment. According to this perspective, social systems are maintained thanks to a constant exchange of matter, energy and information with their ecological environment, therefore a close interrelationship is maintained between society and environment. These relationships and the processes associated to them may lead to modifications in the functioning or structure of the social system due to changes in the ecological milieu (Gallopin, 2006), just as social operations likewise generate changes in the ecological surroundings. This idea comes from the “open systems” concept in general systems theory (Rodríguez & Arnold, 1991), which states that a system's viability consists of an incessant (but selective) flow of inputs of matter, energy and information from the environment. Thanks to these inputs, systems can support themselves, temporarily negating the tendency toward entropy. Systems produce negative entropy to sustain themselves as an order within an environment that tends toward disorder. Since we have indicated the modern theory of social systems within our approach, we should reconstruct this systems approach through the observation that social systems are closed systems vis-à-vis communication (Luhmann, 1991). Of course, this is not to say that they are independent of flows of matter and energy, but it does indeed exclude that the information is something that is, as it were, “given” in the environment, and that the system should introduce it. Information is a value of the system and, thanks to it, communication is constituted, and therefore is self-constructed.

For this reason, so that this relationship may be comprehended, we replace the idea of “interchanges” of information between system and environment and will instead consider Maturana and Varela's (1984) proposal of the concept of “structural coupling”. This concept leaves the conception of matter and energy exchanges between system and environment intact, but excludes the interchange of information. System and environment are in a situation of structural coupling since the system operates in a closed manner with respect to its environment, but is not autarchic in relation to it. In effect, following our theoretical proposal, a system is a distinction — namely, a distinction between system and environment. According to Maturana and Varela, the recurring interactions between a system and its environment are understood as a structural coupling, which means that a co-ontogenic drift is maintained between them, and this allows the mutual triggering of structural changes (Maturana & Varela, 1984). The concept of “structure” is understood when an additional distinction is added to this explanation that refers to the fact that the structure of a system is its variable aspect, while its "organization" is its constant state. “Organization” and “structure” are two properties of any system coupled to an environment (Maturana & Varela, 1984). A system is viable when it is capable of maintaining its organization through changes in its structure.

As a result of these recurrent interactions, a common domain emerges of coordinations, from which units of greater orders are constructed. In our case, a social-ecological system would be a greater unit of order that would be delimited spatially as a result of these recurrent interactions.

Thus, to define a social-ecological system it is necessary to delimit the relationships between the elements, identifying the system's emergent properties, ecosystemic services, governance and memory (Norberg & Cumming, 2008). The spatial or geographic proximity makes it possible to establish relations between elements and, based on these interactions, ascertain the properties of the social-ecological systems as complex adaptive systems. In this regard, the location of the system's elements and their environments and the spatial connectivity among them, including the geography and infrastructure of the spaces where the social and ecological systems interact, are factors of importance. Consequently, aside from spatial delimitation in the identification of a territory for the social-ecological system, it must be considered that the environment of the observed system (major geographic spaces, social systems having regional or world scope, etc.) is also related to the system's behavior.

In this context, for the purpose of observing an environmental problem, we will define a social-ecological system basing ourselves on the delimitation of a territory where it is possible to observe the structural coupling between social and ecological systems, which, on the basis of their emergent properties, can in turn be identified as a complex adaptive system. In the specific case which concerns us, hydrological vulnerability will be observed in a social-ecological system based on the relationship established with the water resource within the confines of a specific territory (such as a defined basin). Stated simply, a social-ecological system describes the regular interaction between a social system and its environment; that is, a domain of recurrent interactions that characterizes a specific and delimited praxis. Certain watersheds constitute a social-ecological system when there exists this type of recurrent and institutionalized, empirically observable relationship. Through these interactions we can then identify the innate characteristics of complex adaptive systems, depending on the type of relationships observed in these interactions (mainly their number, temporality and selectivity),

To comprehend what we understand as hydrological vulnerability, however, we must first explain an important property of complex adaptive systems: resilience; and based on it, the relationship with the system's adaptive capacity.

3.2.1 Resilience

Resilience is often referred to in relation to sustainability, and therefore with a notion of permanence through time (Christmann et al., 2012). In some cases the concepts of resilience and sustainability may even be superimposed, one over the other. However, within the framework of this work, we base this concept on the contributions within the systemic perspectives, considering resilience as a property of the observed system.

The discussion on resilience began in the 1970s with the proposal of Holling (1973), who proposed that, based on this concept, the maintenance of a system be observed, its capacity to absorb the disturbances in its surroundings, including its capacity for change, but also the maintenance of the relationships between its components. Holling and colleagues have subsequently made a few adjustments to the concept, specifying that resiliency refers to the system's capacity to absorb disturbances without changing its basic structure, but modifying variable elements (Holling & Gunderson, 2002). The system's capacity to reorganize itself while maintaining its essential characteristics (function, structure, etc) is related to the maintenance of the system's identity and of its basins of attraction[2] (Walker et al., 2004). However, complex adaptive systems present multiple regimes of stability, and thus there would not be just one point of equilibrium, and it would be possible that the system could change rapidly from one regime of stability to another (Gotts, 2007).

In line with the development of the systemic perspectives we have adopted, resilience is an intrinsic property of the system. The environment cannot be resilient; only a system is resilient, and thus, to speak of environmental resilience, we must refer to the resilience of the social "system" and of the "ecological system", or of the relationship that arises between both as a Social-ecological System. Said resilience is related to the system's sensitivity or irritability, indicating the degree to which affectations are triggered in a system, or modifications originated by external or internal disturbances (Gallopin, 2006); in other words, as the result of its structural coupling. This definition leads us to differentiate between the properties of the system and the exposure to an external threat, despite the fact that it is empirically possible to relate resilience to threats to its adaptive capacity. The concept of resilience renders visible the relationship between a system and a specific environment, from the system's capacity to react to the threats that are identified in the

[2] "A 'basin of attraction' is a region in state space in which the system tends to remain. For systems that tend toward equilibrium, the equilibrium state is defined as an 'attractor,' and the basin of attraction constitutes all initial conditions that will tend toward that equilibrium state. All real-world SESs are, however, continuously buffeted by disturbances, stochasticity, and decisions of actors that tend to move the system off the attractor. Therefore, we think of SESs as moving about within a particular basin of attraction, rather than tending directly toward an attractor" (Walker et al., 2004).

environment. Insofar as social-ecological systems are concerned, the threats that can arise are social disturbances as well as environmental ones, to the extent that they trigger changes in certain subsystems.

According to our proposal, resilience is, above all, a scheme for observing the structural coupling between a system and its environment, which places emphasis on a system's capacity to respond in an adaptive manner to a variety of disturbances in the environment. Thus, the resilience of a system depends on the variables considered and the structural properties that are observable in a system. Resilience is not mere adaptation, but rather a generalized readiness on the part of the system to activate structural changes in diverse internal ambits for the sake of maintaining its viability. All systems that perdure through time are in a certain manner adapted (whether well- or poorly-adapted) and all of them are endowed with structural coupling with the environment (otherwise they would disappear); however, not all systems are resilient. Resilience is observed in a system throughout its history of diverse past structural changes and its general readiness to accept changes in its structure whose result is not as yet foreseeable. For our case study, the external trigger is climate change and the influence exerted by the rise in temperatures and diminished rainfall on water availability in a watershed.

While social systems can be described without difficulty as resilient when observed independently of their ecological environments,[3] this resilience cannot be sustained through time if resilience is not observed in the ecosystems they relate to (Folke, 2006). The same is true, *mutatis mutandi*, in regard to their operative aspects; i.e., the system that operates with resilience that ignores the resiliences of its environment opens itself to danger. For this reason, the observation and assessment of resilience in ecological systems independently of their relationship to social systems is equally insufficient. Due to the above, in the perspective of social-ecological systems, the observation is proposed of resilience, considering both the social and the environmental dimensions.

In sum, and in favor of an integrative approach that can enable us to develop our investigation, we can point out that, thanks to the development of the theory of social-ecological systems, and considering the other theoretic foci adopted, it is possible to establish a set of elements that are key for evaluating the resilience in complex adaptive systems.

[3] As has been pointed out, the application of the concept of resilience in a separate manner to social systems and ecological systems poses no theoretical impediments, given that both are complex adaptive systems and, therefore, if they possess more than one basin of attraction, it would be possible to speak of resilience (Gallopin, 2006).

To observe the resilience of a complex adaptive system, it is necessary to know: 1) the magnitude of the change that is supported by a system while maintaining its state, which refers to the width of its basin of attraction (*latitude*); or said in another way, its capacity for structure change together with maintaining its organization; 2) the system's capacity to modify its self-organization (*resistance*); 3) the system's capacity to learn and improve its possibilities of response (Carpenter et al., 2001); 4) the system's limit or threshold which, upon being crossed, impedes recovery (*precariousness*); that is, when a point of no return is reached; and 5) the possibility of influencing the states desired by the system's dynamic in its various levels (*panarchy*) (Walker et al., 2004). These elements refer to the maintenance of the system's identity or organization, defined on the basis of its components, relations, maintenance in time, and its capacity for innovation (Cumming et al., 2005). All of these properties enable us to delimit observation criteria for resilience.

In addition to these observation criteria, in the case of social-ecological systems and based on the elements identified as pertinent by various authors (Norberg & Cumming, 2008; Adger, 2000; Tompkins & Adger, 2004; Ostrom, 1990; Rappaport, 1977; Olsson et al, 2004; Cumming, 2011), four specific characteristics can be defined that are central for maintaining the system's resilience: 1) diversity, redundancy and flexibility, both in the social ambit and in the ecological ambit; 2) high degree of connectivity among its elements and with their environments, together with the capacity of organizations and communities to collaborate vertically and horizontally; 3) the system's memory linked to its capacity to process information and learn; and 4) the capacity to modify the system's structures and conditions through its self-organization.

We will explain each of these characteristics, which allow us to observe the capacity to maintain resilience in social-ecological systems.

3.2.1.1 Redundancy, Diversity and Flexibility

One of the fundamental aspects for the resilience of a system relates to the diversity of its components. When uncertain situations are faced, the diversity of the components improves the possibilities for successfully engaging with them. We refer to the institutional, technological, productive, biological, institutional diversities, among others, that a social-ecological system is equipped with. When a system possesses this kind of diversity and even redundancy of elements, it has greater flexibility and, therefore, improved possibilities of reaction to disturbances in the environment, since said diversity provides it with more tools to act in front of uncertainty or surprise. This is fundamental, since the strategies of response must be sufficiently flexible to be able to adapt to the changes and disturbances that the system faces (Tompkins & Adger, 2004).

By 1977, Rappaport was already identifying the importance of over-homogenization and over-segregation for the relationship between society and the environment. The growing specialization in agricultural production, for example, would produce a reduction in ecological stability, since monoculture cultivation develops very delicate ecosystems (Rappaport, 1977). Low diversity entails a reduction of the system's self-sufficiency and leaves it at the mercy of disturbances in the environment. In the case of monoculture crops, these form highly vulnerable ecosystems in front of climate changes or —at the social level— changes in trade structures. Therefore, it may be sustained that excessive homogeneity results in loss of flexibility, which hampers the system's response capacity (Cumming, 2011).

Redundancy in institutions (for example, when multiple organizations are focused on the same issue) should not be understood in a negative sense, because this can play an important role in the absorption of the disturbances faced by a system. This is usually seen as the opposite of efficiency, or as an unnecessary duplication of functions. However, this same redundancy entails a diversity of organizations that attend to an issue, providing different perspectives and alternative possibilities for engaging with it. In contexts of uncertainty, this can be an important tool (Folke et al., 2005).

Finally, the variety of knowledge and experience around the relationship with the environment can improve the strategies for facing changes. Also, in this context the system's capacity for innovation (Cumming, 2011) is important, since it allows for increasing internal diversity and, with it, the system's flexibility.

3.2.1.2 Connectivity, Collaboration and Collective Action

In studies about resilience in social-ecological systems, it has been determined that fragmentation in both the ecological and social domains decreases the system's ability to react, as isolated fragments lack connectivity, which decreases access to social and ecological diversity. This explains, for example, why socially excluded groups tend to be more vulnerable to various kinds of disturbances (Cumming, 2011): they lack connectivity and have poor access to diversity in social terms (e.g., access to services, support networks, etc.). Social networks are often built around ecological networks and natural resources; therefore, in many cases, social networks can be linked to spatial patterns (Cumming, 2011). Where social isolation is spatially associated with ecological isolation, the system's resilience would be even poorer.

The connection between different social players and networking –understood as connections that are stable over time– enable the creation of opportunities for new interactions and thus greater

diversity of social and ecological resources. This is central in dealing with uncertainty vis-à-vis threats, as well as in addressing the changes and disturbances affecting the system (Folke et al., 2005). Thus, the growth and consolidation of social networks at the local level, as well as on a national, regional or international scale, contributes to increasing the resilience of the system by increasing connectivity and diversity (Olsson et al., 2004).

Also important in this context is the relationship between local groups and the organizations with broader territorial reach, as this allows for regulations or institutions designed at the national or regional level to be more in line with local conditions (Tompkins & Adger, 2004). Additionally, this makes it possible to make use of the knowledge of the communities that are directly related to the environment. This has been understood through the concept of polycentric institutions, which makes reference to this condition that in some cases might create redundancy but nevertheless makes it possible to face disturbances and changes at different levels (Folke et al, 2005).

Bridges between local organizations and stakeholders, and organizations acting, for example, at the national level, can generate opportunities for accessing new resources or further knowledge. Hence the importance of vertical and horizontal partnerships, that is, the connections and networks that are established to harness common resources and knowledge, both between the stakeholders in a community and with others who are part of a higher level but have some kind of vertical relationship with the community (government agencies, universities, etc.) (Folke et al., 2005).

Finally, it should be noted that the ability to act collectively is one of the aspects around which greatest consensus exists in the environment-society relationship. Collective action refers to coordination between individuals in order to accomplish a common goal (Ostrom, 1990). Access to natural resources requires coordination between individuals, fundamentally to achieve a more sustainable, equitable access. Joint work, support networks, and participation in decision-making are key elements for increasing resilience (Tompkins & Adger, 2004). Specifically, for example, in connection with the possibilities to respond to climate change, the relevance of community resources for responding to the impact of climate change and making collective decisions aiming at improving resilience in the long term has been underscored.

3.2.1.3 Social-ecological Memory and Learning

Another factor that is important for the system's resilience is the system's ability to learn about its relationship with the surroundings and about the relationship between the social and ecological systems. "Ecological memory" is crucial for this purpose (Folke et al, 2005; Olsson et al., 2006). This

concept brings together all the knowledge of a social system about its environment, how the environment has been impacted by changes in the surroundings, and the various adaptation strategies that have been developed.

This capability to store knowledge and keep it available in the system involves shared learning from which perspectives are reformulated to incorporate new knowledge that will be remembered over time (Nykvist, 2012). Both formal and informal contexts –scientific and popular knowledge– are considered in decision-making. In some instances, this knowledge is shared in the community at large, but in other cases, only a portion of the population has access to it (Saterfiel et al., 2013).

The ability to capture experiences on changes, disturbances, or failed/successful adaptation strategies is configured by the possibilities for discussion and incorporation of different levels of knowledge for decision-making purposes (Folke et al., 2005). Ultimately, the social-ecological memory has to do with the social structures that define the possibility to remember and forget specific events and the knowledge around those events (Luhmann, 2007).

The social-ecological memory makes it possible to connect past events to the present, to the expectations, and to future threats (Folke et al., 2005). The diversity in this kind of knowledge is critical for the system's resilience, as it makes it possible to develop innovations to better tackle new threats and changes. The configuration and scope of this memory is also associated with the level of connectivity and vertical/horizontal partnership, since greater connectivity allows for addition of different levels of knowledge to the social-ecological memory of the systems, at the same time as it makes it possible to achieve an increased collective learning during processes of change.

3.2.1.4 Self-organization and Governance of System Changes

A fourth important property for a system to be resilient is its ability to self-organize and modify its own structures; we addressed this earlier in connection with the distinction between structure and organization. This property relates to the ability to preserve the system's original identity when that status is desirable or, otherwise, it refers to the possibility of driving any transformations needed in order to reach more desirable states in the face of threats or when the system's original condition is not as expected (Folke, 2006; Engle, 2011).

This self-modifying ability is, in turn, related to the three properties explained above. (2.1.1) A system can modify its structures when it possesses the diversity and redundancy that provide it with sufficient flexibility, as it requires elements that are available to it and allow it to make the necessary modifications. (2.1.2) Additionally, in order to be able to carry out those modifications, the system

needs high connectivity between its ecological and social elements, based on established networks that make it possible to pass on knowledge and resources in general. (2.1.3) Finally, it is also necessary for the system to learn from past experiences and keep knowledge available in its memory, in order to make innovations and thereby respond to emerging situations.

In the social sphere, this ability to self-organize/govern is critical in modifying the institutions and organizations that set the rules concerning natural resources, so that the system will be better prepared to face unexpected events, crises or uncertainty in general, as well as to deal with any conflicts associated with such changes (Folke et al., 2005). This latter property of resilient systems is fundamental to develop the capacity to adapt to disturbances.

We have briefly summarized those properties conducive to maintaining the resilience of a system. In the next section we will provide elements to specify what we observed based on this adaptive capacity (2.2), and then we will delve into the characteristics of self-organization for adaptive governance (2.3).

3.2.2 Capacity to Adapt: Adaptability/Vulnerability

Capacity to adapt is a cross-cutting concept that is used by both the vulnerability and resilience perspectives. As noted by Engle (2011), it is possible to articulate both paradigms based on the concept of adaptive capacity; therefore, we will use it here to specify the theoretical relationships we are discussing.

Resilience is a property of the system that should not be seen as necessarily positive. A resilient system may be publicly unwanted for moral reasons (e.g., a dictatorial political system) or because it restricts the sustainability of a larger system in the long term (e.g., a capitalist system based on consumption of non-renewable resources), or for other reasons. As mentioned before, what characterizes resilience in purely formal terms is a widespread availability throughout the system to activate structural changes in various internal areas and to accept changes in its structure whose outcome has not yet been anticipated. Resilience describes a history of various structural changes in a system, aimed at maintaining the system's viability. Thus it is clear that a system's resilience is not intrinsically positive for its milieu (for example, the resilience of the capitalist economic system can be very negative when evaluated in terms of its impact on the environment or in terms of its impact on the human environment). However, its adaptive capacity is part of the qualities of resilience as it relates to management and governance of system changes in order to improve the system's relationship to the environment. In this context, it is possible to point out that a system with low

adaptive capacity displays more "vulnerability" to threats and changes, as under this paradigm, both "vulnerability" and "adaptation" refer to relational concepts that describe a system's ability to react to its surroundings in a specific temporal and spatial dimension (Christmann et al., 2012).

While resilience refers solely to a system's internal aspects, adaptation and vulnerability involve an assessment of the specific, unique connection between a system and an observed threat in its surroundings. Based on the concepts of "adaptation" and "vulnerability," we shall describe the observation of the relationship between a social-ecological system and the environmental conditions encountered by said system. This is our observation of a relationship that occurred within a specific period of time, in a limited area, and according to the system's response capacity vis-à-vis identified potential threats. All of these concepts are explained below.

3.2.2.1 Vulnerability: Low Capacity to Adapt

Vulnerability is generally defined as a system's susceptibility to damage. It relates to a possible transformation of the system due to a specific external threat (Gallopin, 2006). Considering the proposals of authors such as Gabi Hufschmidt (2011), Neil Adger & Mick Kelly (1999), and Michael Watts & Hans Bohle (1993), three key elements can be identified when researching vulnerability: 1) exposure to an external threat directly associated with the biophysical conditions of the ecological milieu and the disturbances therein identified; 2) difficulties to control that threat, and 3) problems recovering from damage caused. In this context, the system's sensitivity and response capacity are key to identifying its vulnerability vis-à-vis the threatening conditions identified in the milieu.

It is important to clarify that vulnerability is not the opposite of resilience –although a resilient system might be empirically less vulnerable vis-à-vis a non-resilient one-, since resilience as a property of the system, and its capacity to react to specific disturbances are not two sides of a single phenomenon (Adger, 2000). A system can be non-resilient and non-vulnerable if it is not being submitted to any external threats. On the other hand, a system may be resilient, but vulnerable anyway if faced with an extremely violent threat. That is to say, a "resilient" system can be "vulnerable" if it is exposed to threats from its surroundings. However, as noted earlier, the history of previous exposures to threats, past vulnerabilities which are stored in the system's memory can be important elements in building resilience (Holling, 1973). Moreover, subject to the systems being observed and taking into account what part of the elements that affect vulnerability operate at the individual or collective level (e.g., access to economic resources or water ownership rights), consideration should be given to identifying various vulnerabilities in a single area (Adger & Kelly, 1999; Watts & Bohle, 1993).

3.2.2.2 Adaptability: High Capacity to Adapt

Another important relationship is the one that occurs between "adaptation" and "resilience". As noted above, resilience is a system's capacity to react to disturbances in general; adaptive capacity, on the other hand, has to do with the system's capacity to react vis-à-vis a *specific* disturbance, which allows it to modify its own structures based on learning and self-organization (Walker et al., 2004; Tompkins & Adger, 2004). Due to their conceptual affinities, "adaptation" and "sustainability" have generally been correlated because sustainability can be understood as the system's capacity to maintain adaptation (Holling, 2001). Adaptation makes the system appear as behaving successfully in its ecological milieu because it has to do with the system's capability to deal with environmental contingencies by maintaining or improving its conditions vis-à-vis changes in its milieu and changes in its relationship with its milieu. Unlike resilience, which merely directs the system towards a generalized preparedness for structural change, adaptive capacity makes use of resilience to direct transformations in the system. Thus, albeit with different results, both adaptation and resilience imply: 1) the system's capacity to react vis-à-vis threats; 2) its capacity to face the impacts of external forces; and 3) its capacity to recover. And we add a fourth property: 4) capacity to improve the system's condition in the presence of an equivalent disturbance in the future (Adger, 2000; Gallopin, 2006).

To achieve adaptation, there are elements that have already been identified as critical: learning from previous disturbances, anticipation, preparedness, and planning for new threats (Gunderson, 2000; Hufschmidt, 2011). Also relevant is a system's capacity to modify its own conditions and prospects for change (including creation of new basins of attraction that are more favorable to the system, or reduction of unwanted basins). Ultimately, a system's capability to manage its own resilience is critical to achieve adaptation (Walker et al., 2004; Folke, 2006). In this regard, a system's resilience would be part of its capacity to adapt to disturbances caused by its milieu, since a resilient system is more likely to react to its environment. In other words, resilience is an element of adaptive capacity. These elements are closely connected with the means by which the institutions favor these processes (Adger & Kelly, 1999; Nykvist, 2012); therefore, the evolution of the rules affecting resilience during the self-organization phase is crucial to improving the possibilities of adaptation (Walker et al, 2004).

3.2.2.3 Adaptive Governance: Positive Resilience

We talk about adaptation/vulnerability in the face of a specific threat when we envision four key elements: reaction to a threat, capacity to face the impact produced, recovery from damage caused, and modification of structures in order to be prepared to face new hazards. We can talk about

adaptation (or the positive side of adaptive capacity) when a system manages a transformation into a desirable state so as to remain viable. When this does not occur as expected, we can talk about vulnerability. In this context, when a system is capable of improving its adaptive capacity and manages to transform by self-organizing, we talk about positive resilience in social-ecological systems.

To achieve this kind of governance, stakeholders must be able to reorganize the system within its desirable statuses, thus responding to changing conditions and the disturbances it is subject to (Folke et al., 2005). To achieve adaptive governance it is fundamental that the system be capable of experiencing and learning from different environment change adaptation strategies, maintaining bridges between organizations that generate scientific knowledge, decision-making organizations, and the affected communities. Therefore, it is of the utmost importance to provide spaces that favor involvement of the various stakeholders in the decision-making processes, also to achieve constant communication between the different levels and create forums for conflict resolution, all of this through institutions with flexibility to confront different situations. Also important is the availability of information about the system, its environment and the disturbances that might confront it, as well as the development of infrastructure to deal with a variety of scenarios. Finally, the system's capacity to improve its own conditions by taking advantage of critical situations is fundamental (Dietz et al., 2003; Folke et al., 2005).

Within this same discussion, and for this research in particular, we will understand "hydrologic adaptation" as an attribute of a system that positively responds to a disturbance in the water resource (Gallopin, 2006), and whose processes develop before, during, and after the occurrence of a damage or disaster (Hufschmidt, 2011). At the same time, "hydrological vulnerability" refers both to the system's limitations to confront a threat and to the negative modifications that the system may suffer in the face of a specific disturbance, either during or after the occurrence of the threat or actual damage. Both these concepts make reference to the system's response capacity vis-à-vis a specific disturbance. Both concepts observe the relationship between the system and its milieu, and are intrinsically tied to the resilience of the system. Finally, when the system is able to modify itself, to manage its own resilience and improve its own conditions to be better prepared to confront future disturbances, we speak of "adaptive governance of water".

3.3. Social Sources of Water Vulnerability

Heretofore we have fully explained the concepts coming from the approaches to the complex adaptive systems and social-ecological systems that serve as the basis for our research. For a better

understanding of the social and cultural sources associated with hydrological vulnerability and to explain the factors identified as relevant for the resilience of the social system, in this section we gather a variety of contributions from social sciences that complement the above perspectives. In this context, the theory of social systems is relevant, as it establishes synergy with the above-mentioned perspectives and provides explanatory descriptions of the workings of contemporary society. However, this perspective must be complemented with the theoretical developments of other systemic lines that address social phenomena in the framework of complex adaptive systems and also from other perspectives that have questioned the social conditions associated with vulnerability.

In the next section we present four issues that are central to the observation of social conditions in a social-ecological system's resilience, adaptive capacity and vulnerability: 1) cultural characteristics in the relationship with the environment; 2) fundamental characteristics of contemporary society – functional differentiation and organizational systems; 3) institutional framework and ownership relations; and 4) the collective action associated with natural resource management.

3.3.1 Cultural Characteristics in the Relationship with the Environment

The cultural characteristics of the social groups present in a territory constitute a key factor to the relationship between society and the ecological milieu. The importance of culture to the society-environment relationship has been approached from different perspectives in socio-cultural anthropology. We will focus on the contributions of Mary Douglas (1982) and Roy Rappaport (1977) because of the considerable influence of their proposals, both in general and on the systemic perspectives previously adopted.

Rappaport's work (1977, 1996) was influenced by the systemic theories, and it is one of the primary milestones in ecological anthropology. This perspective considers man to be just another animal species and, as such, intimately connected with his environments or ecological milieus composed of other biological organisms and inorganic substances from which the social systems obtain the resources necessary for their subsistence (matter and energy). The process of adapting to biophysical milieus is considered critical, as the relationship with nature is measured by beliefs, knowledge and imagery of nature which are present in society. According to Rappaport (1996), in order to appropriately describe the relationship between society and the environment it is necessary to consider the socio-cultural elements of this relationship, as well as its symbols and values, because they define the risks and potential impacts involved, as well as the strategies to deal with them.

One of this author's most relevant contributions is his questioning of the relationship between culture and adaptation. From his research on rituals, he explains the relevance of such practices for adaptation as well as for maladaptation to ecological milieus (Rappaport, 1977). By examining these practices it is possible to see that in certain circumstances, the cultural elements (e.g., rituals), respond to the interests of just a sector of society or some institutions, which implies important negative costs to individuals and the ecosystems. In other occasions, the cultural elements favor self-regulation by permitting to maintain the effects in the environment within acceptable ranges, thereby avoiding compromising the continuity of the system (e.g., the famous pig slaughter ritual of the Tsembaga Maring tribe in Papua New Guinea). These self-regulation mechanisms permit to control the system when it approaches dangerous states. Such mechanisms may be cultural components, such as symbolic systems, religious beliefs, behavior patterns, moral codes, etc., capable of making the system return to a state within an optimum range, and thus maintain adaptation (Rappaport, 1977).

In Rappaport's proposal, self-organization is presented as a mechanism that allows the system to remain adapted, as it is thanks to self-organization that the system transforms itself in response to changes in the milieu, but also situations are observed where cultural manifestations are associated with maladaptation processes (Rappaport, 1977). These elements of the relationship between culture and adaptation will be considered in this paper.

Another element that is important in observing the relationship between society and environment is the concept of risk. In understanding risks as socially constructed, culture appears as a determinant of the social perception and construction of threats. Mary Douglas (1987) has addressed this issue from the standpoint of anthropology; she explains that the perception of risk implies recognition and acceptance of the social dimension of risk, considering that risk is related to a society's dominant beliefs and views. From her perspective, risks are loaded with cultural conditionings: the perception of risk depends on the social system; risk generation is a product of social operations; risks are often used socially (in the political, economic, legal, and other spheres), and their acceptance is determined by social and cultural conditions (Douglas & Wildavsky, 1982).

Within the framework of what has been known as cultural theory, Douglas and Wildavsky delve into a theory of risk perception (Douglas & Wildavsky, 1982). Based on risk perception and culture, ways of life associated with manners of perceiving nature are identified: robust, somewhat robust, fragile, and capricious (Douglas, 1992). Thus, different ways of life are identified, which configure the relationships of a social group with its ecological milieu. In the description of the ways of life, a

typology known as “grid-group cultural theory” is used; it contemplates two basic elements: first, an orientation towards the group of individuals, with a sense of belonging and solidarity in their relationships; and second, the social restrictions (grid) for individual actions, considering the setting up of roles and authorities (Douglas, 1978).

In this context, four major ways of life or cultural types are identified: hierarchical, individualistic, egalitarian, and fatalistic, identifying ties with the myths of nature (robust or benign, semi-robust, perverse or capricious, ephemeral or fragile) (Mamadouh, 1999). When nature is benign and robust, you can experiment with it, it is seen as stable, so it is associated with the selfish and individualistic way of life. When nature is capricious and perverse, it is like a lottery, its behavior is unpredictable, you cannot learn from experience. This myth is compatible with the fatalist point of view. When nature is robust, expert knowledge is utterly important, as it is used to assess the security zone. This is equivalent to the hierarchical way of life. Finally, when nature is ephemeral and fragile, any movement might unchain a catastrophe; this vision is associated with an egalitarian standing (Schwarz & Thompson, 1990).

While this typology will not be directly applied in this paper, we will use some of its elements in analyzing the cultural aspects associated with the water resource, like other researches have done in questioning strategies to deal with climate change (Schubert & Gill, 2010). In the model herein presented, the grid considers both the formal and informal structures (institutional and ideological conditions) as they relate to water ownership regulation, while in group orientation we consider social relations, both informal and formalized into organizations (social and organizational conditions).

3.3.2 Functional Differentiation and Organizational Systems

The socio-cultural conditions that are relevant to the relationship with the environment are diverse, and develop at different levels in a society. Although in order to observe the relationship with a specific ecological milieu, we must first define territorial boundaries, a considerable part of the socio-cultural conditions evinced in such space are associated with functional and organizational systems at the global, national, and regional levels. Thus, to comprehend the social, we should first address the basics of the workings of society. To this end, we will focus on the description of a functionally differentiated society and organizational systems, which are central to understanding contemporary society, from the perspective of Niklas Luhmann (1984, 1997).

As briefly pointed out at the beginning, modern society is a functionally differentiated society with dedicated subsystems in charge of resolving specific problems (Luhmann, 1997). Along with these functional systems, organizational systems arise, which operate oriented towards specific objectives, based on decisions. Each subsystem is operatively enclosed and observes its milieu through the distinctions available to it, and is blind to the choices of direction that are not observable with its own codes.

Social systems are oriented to problems identified by their own structure, and do not follow an integrative approach at a global level. This has an impact on environmental issues, which arise from social operations in the ecological milieu and may be described in varying, sometimes conflicting ways. The distinctions of each system create difficulties in addressing environmental issues in a coordinated manner. Additionally, environmental communication is addressed only by systems that are able to observe it from their own structures, i.e., systems that environmental communication can disturb, which limits the chances for greater resonance (Luhmann, 1986).

Social systems presuppose a milieu, as their operations are attached to their surroundings, which may encompass other social subsystems, as well as psychical and ecological contexts. From this perspective, different surroundings can disturb a social system depending on the thresholds of resonance established by the system's structure (Luhmann, 1984). Therefore, both for the sake of understanding the relationship between society and environment and for observing social affairs in the context of social-ecological systems, we need to observe the different social subsystems operating within a given territory and identify the structural constraints of functional and organizational systems (expectations and codes of the functional systems, the organizations and their decisions) and the relationships established with the ecological milieu based on these ascertainments.

3.3.3 Institutional Framework and Ownership Relations

The set of institutional restrictions translates into multiple combinations of formal and informal limitations, which set up the conditions for coordination between stakeholders and configure not only the ownership relations and the chances for trade, but also the regulations of access to ownership, transaction regulatory structures, and the function of the organizations involved in their management (North, 1990). When institutions face hydrological vulnerability conditions, it is possible to identify patterns of social interaction that restrict the chances for action around water resource management (Nykvist, 2012).

An element that is central to the institutional framework in connection with the hydrological issue has to do with ownership of water resources. To address this issue, we consider the proposals of several authors, including Robert Ellikson (1993), Chris Hann (2007), Franz von Benda-Beckmann, Douglas North (1990), Keebet von Benda-Beckmann and Melanie Wiber (2006). Following them, we will understand ownership of water based on a set of rights, where the social unit that holds the property right to the resource or has been granted access to it has to be considered, as well as the valuable defined as a property –in this case, water– and the rights and obligations with regard to that property right or right of use.

The transaction costs are associated with ownership relations and the institutions that lessen uncertainty around this issue (North, 1990). Generally, the role of the institutions consists in reducing uncertainty in human interaction by limiting the choices of the actors and enabling coordination. These institutions act according to formal regulatory frameworks –political-juridical rules (laws), and economic rules (contracts). All of these rules, in their different hierarchies, define restrictions on ownership relations and on the chances for trade. In parallel appear informal rules or restrictions, including beliefs, ideologies, customs, rules of conduct and moral values, which play an important role in decision-making with regard to the ownership and use of water, because the formal rules are often incomplete; additionally, informal restrictions motivate certain choices above others. These informal restrictions also influence the preparation and amendment of formal rules. As amending these rules involves investing resources, this is done only when properly justified and viewed as necessary (North, 1990).

Following the proposal of Rappaport (1977), we will differentiate between higher- and lower-level regulators, considering formal and informal regulations that operate at different levels in society. Lower-level regulators would be closer related to the conditions of the milieu, while higher-level regulators may be more "arbitrary." Rappaport states that the response times of lower-level regulators are shorter than those of higher-level regulators because they are more directly exposed to environmental disturbances, and also because of their possibilities for modification. In contrast, higher-level regulators take longer to respond, but are more likely to react vis-à-vis major disturbances. However, the loss of diversity and self-sufficiency would result in loss of autonomy by institutions, and gain of influence on the part of major regulators (Rappaport, 1977). In situations where local and regional benefits are in conflict, a difference arises in the institutions' management capabilities: the local government may be more responsive, while the regional government may be more capable of ensuring equity and sustainability (Cumming, 2011). The chances of endurance

increase when disturbances occur on smaller scales (Walker et al, 2004), because the system is less likely to react.

Ultimately, to understand the ownership relations around hydrological resources, we need to examine the various levels of social practices where they are expressed -the venues where water ownership rights are defined or discussed, the transactions of water rights, and the formal and informal restrictions that enable this coordination.

3.3.4 Management of Resources at Community Level

A fundamental aspect of the socio-cultural conditions for this society-environment relationship is the ability to act collectively. This aspect was briefly addressed above in connection with collaboration in the context of the resilience of a social-ecological system. Collaborative partnerships are critical in relating to the ecological milieu. To understand this, we have considered the work of two great international icons: Mancur Olson (1971) and Elinor Ostrom (1990).

The theory of collective action sets out the conditions under which cooperation occurs. Olson, with his book *The Logic of Collective Action: Public Goods and the Theory of Groups* (1971), set out a line of work of great influence, which has remained current to date, addressing the potentiality of group action. His work in the framework of the theory of groups, attempts to explain the existence and action of a group, when and how a certain number of people will act jointly with one common goal. This perspective illustrates the fact that when people sharing interests make strategic decisions as a group, there is always a very large proportion of its members for whom the effort invested in protecting those interests is greater than the actuarial expectation of drawing meaningful results from said action. This is because the benefit from the action is common to all group members, while the effort is always individual. Thus, there will be a great temptation to expect others to mobilize and obtain benefits for the group (the so-called “free rider”). Nonetheless, collective actions do occur, and for this to happen, Olson (1971) proposes the use of “selective incentives” (social, cultural, economic, etc.). So, the collective action will occur when, in addition to the expectation of achieving the collective goal –understood as a public good– there is a mechanism that boosts participation in the action, in the form of selective benefits. In this context, selfish motivations oriented towards private (economic, emotional, symbolic, etc.) purposes, work as selective incentives conducive to materializing the collective action (Urquiza, 2006).

Elinor Ostrom, on the other hand, has focused on the issue of access to the commons (Ostrom, 1990). The author proposes key socio-cultural conditions to successful management of these assets,

including: access limits should be clearly defined, that is, there should be explicit rules regarding access to the commons; local conditions should be taken into consideration; the community should be involved in the decision-making process; the community's prospects for self-determination should be respected. Ostrom also emphasizes the relevance of both supervising and tracking the use and consumption of the commons, and providing for penalties against those who do not abide by the standards established for their use and consumption. Also, to successfully manage the commons, reliable, accessible dispute settlement mechanisms should be in place (Ostrom, 2000). To fulfill these requirements, it is fundamental to have a good institutional structure, so as to distribute operating costs, income, or the use of the commons. In order to reduce uncertainties, it is critical for the community to have control over resource use/appropriation decisions, as well as over the information on the resources. In this context, knowledge of the system and the system's learning capacity are of the essence. In parallel, Cardenas and Ostrom (2004) point out some elements that drive individuals to act cooperatively: identity, reciprocity in the group context, and trust. Institutions play a critical role here, since individual values are not enough. In some contexts, the institutions may disfavor sustainable development, particularly where local knowledge and authorities are not respected, or where communities' ability to develop self-regulations is ignored.

Elinor Ostrom (2009) also develops her work in the context of social-ecological systems; here, she identifies multiple, interrelated subsystems, including the social. To Ostrom, the greatest challenge is in understanding why in some cases, social-ecological systems achieve sustainable development and in others, they do not. To make progress in this respect, she highlights the importance of examining the relationships between the stakeholders at different levels (Ostrom, 2009). When individuals expect the benefits gained from the joint management of resources to be greater than the investment made in creating the necessary rules and regulations, they are likely to self-organize. But when users cannot be trusted to respect the rules, these community governance initiatives are discouraged. Ostrom (2009) identifies ten key variables that would affect the governance of the commons and the costs and assets perceived: the clarity of the rules established by the users; coherence and respect for the rules from the national level toward local conditions; information and cooperation at the various levels; compliance monitoring, and user's willingness to monitor the practices associated with the use and distribution of resources.

Other elements that Ostrom and colleagues identify as relevant in promoting collective action to govern access to the commons, are: the individuals should be aware that their contribution will make a difference; there should be some certainty that the contribution made will be returned or recovered; the reputation of the community involved should be positive; the time horizon should be

longer; the individuals should be able to enter and exit the various groups (in order to achieve micro-adjustments). These researchers also emphasize that it should be possible to communicate with all participants, ideally in face-to-face situations; therefore, group size is important. Based on previous research, it has been determined that it is easier to build trust in smaller groups. However, in the case of public goods, large groups are necessary in order to enhance the expectations of success (e.g., for mitigation of climate change), as it is not possible to address these issues on the basis of small groups. This certainly creates a bigger challenge in dealing with problems associated with public goods. They also highlight that if a system is highly productive, there will be no incentive to invest time and effort in community organization, as there is no obvious need for collective action. Thus, self-organization would be likely to occur only where users identify conditions of scarcity (Poteete et al., 2010).

Therefore, we can conclude that collective action in connection with the use and care of the commons is not something that can be taken for granted. Just because a community shares the same interests, you cannot assure that its members will act based on those interests. However, when collective action occurs, it is thanks to selective incentives and to the assumption that others will act collectively too, which is associated with the socio-cultural conditions of the group and how such conditions make it possible to have confidence in the group.

In sum, a number of conditions are necessary in order to facilitate collective action, including promotion and support from institutions, appropriate size of the community involved, and existence of selective incentives (Ostrom, 1990). Only when favorable conditions exist, is it possible to prevent the individual strategic behavior that passes over the good of the community (known as "free-riding"[4]) or the excessive exploitation of the resources (as in the so-called "tragedy of the commons"[5]). Thus, the conditions that favor collective action can increase the resilience of he social system vis-à-vis the threats of the ecological milieu.

In the studies by Elinor Ostrom and colleagues (Attanasio et al., 2009), it is concluded that family members and close friends are more likely to act collectively and generate relations of reciprocity, while relations or reciprocity and collective action are much less common between strangers. These authors stress the importance of risk aversion in unfamiliar contexts, the relevance of the social standards involved, the monitoring of their compliance, and the interactions between the parties

[4] The "free rider" issue has often been used in political and economic theory to refer to situations where individuals benefit from common goods or services without paying or working towards achieving the benefits.
[5] "Tragedy of the Commons" involves a situation where a group of individuals moved by personal interests and acting independently destroy or extinguish a shared asset.

(Poteete et al., 2010). An important aspect of this process involves the historical background, that is, when some individuals develop a successful partnership, others are more likely to act collectively too. The more people engage in collective action, the less are the perceived risks of not receiving the expected collective benefits: trust and reciprocity are mutually reinforcing. But this also means that when the trust is broken and some community members abstain from taking collective action, the rest is likely to follow suit. Therefore, it is of the utmost importance to establish appropriate penalties and oversight capacities to prevent such occurrences.

4. Chilean Model of Water Management

Chile pioneered the installation of a free-market regime for use of national water resources, where water is managed as a commodity subject to the forces of supply and demand in a market without state regulations (Bauer, 2003). Paradoxically, the Water Code argues that the market recognizes water as a national good for public use, but at the same time as a tradable economic good, which has permitted water resources to be governed by rules of private property within the framework of a free market (Donoso, 2003).

4.1. The Water Code in Chile

The main features of the Chilean Water Code are the stating of conditions for managing water resources; that is, regulating the water market in Chile (Donoso, 2003; Hernández, 2006; Nuñez & Soto, 2010):

- The State provides free water rights in perpetuity to anyone that requests them, provided the requesting party complies with the following requirements: a) the application must be "legally appropriate"; b) it must be technically demonstrated that there are available water resources from a natural source, distinguishing whether they emanate from surface or groundwater; and c) the new use must not affect the holders of existing rights. The application must define: a) the amount of water to be extracted (in liters per second); b) the points at which the party wishes to collect the water and the means of such collection; and c) whether the right is consumptive or non-consumptive, to be permanently or temporarily exercised, continuous, discontinuous or alternated with other persons.

- If a dispute occurs between individuals applying for the same rights, the final owner is determined through an auction to the highest bidder, where the person willing to pay the highest amount for the resource is awarded the rights. However, in cases involving the public interest, the President of Chile may cancel the auction and assign the resource for the benefit of a particular party.

- After obtaining the water rights, the owners can trade with them without restriction, paying no taxes or license fees for the maintenance of the resource (except for the 2005 amendment to the Water Code, which establishes a fee for non-use of the resource, aimed at discouraging the accumulation of and speculation in an "idle resource"). Transactions involving water rights can be made on the free market, as once they are granted private rights by the State, individuals can

make use of those rights without State intervention. There is absolute freedom of disposal and acquisition, with the market established as the means to resolve the competition between different uses of the resource.

- Water rights are legally defined as a real right that allows the use of assigned water resources. Therefore, water rights are not subject to a particular use requirement and there are no grounds for their revocation.

- Rights of water use are not linked to land ownership rights, which means that they can be bought and sold irrespective of the owner of the land on which the water flows.

- Water use rights are subject to the "registered property regime", similarly to land ownership. This registry provides legal certainty regarding the ownership of water rights, establishing several constitutional, civil, criminal and special legal actions for parties to defend their water use rights against damage or unlawful interference.

- Water rights must be administered by organized users. The State practically does not interfere at all in the management and control of the effective exercise of these rights. User organizations are responsible for managing and monitoring the implementation of these rights, and also for building, maintaining and improving the headworks, canals and other works necessary for the exploitation of the resource.

The Water Code defines different types of rights, classifying them as consumptive and non-consumptive (Donoso, 2003; Bauer, 2003):

- Consumptive rights (*derechos consuntivos*): right to use the water without a requirement to return the resource post-use. The owner of this right can entirely consume the water in any activity (including irrigation, potable water, industrial and mining use). However, some of these waters do in fact return to the rivers either as ground or surface water, in many cases contaminated.

- Non-consumptive rights (*Derechos no consuntivos*): right to use that forces the owner to restore the water, amounting to use without consumption (an example would be hydroelectric power generation). It is established that this use must not impede or limit the exercise of other current consumptive rights. However, there is no clear regulation on period of accumulation of these waters, which may in practice affect downstream consumptive users.

The manner of exercising both rights (consumptive and non-consumptive) can also vary. This variety of rights was designed with the aim of increasing opportunities for use of water resources. The rights are supported by a special legal framework that protects them and permits their transfer (Donoso, 2003):

- In permanent exercise: rights allowing the use of water resources in an ongoing manner in the amount established by the rights of use, unless the source of supply does not contain enough water, in which case the flow must be divided among the users who have rights over it.
- Possible exercise: right that allows the owner to use water only during periods when the flow maintains a surplus, and only after the owners of continuous exercise rights have been supplied.
- In continuous exercise: right that allows the steady use of water for twenty-four hours a day, throughout the year.
- In discontinuous exercise: right that allows the use of water only during certain periods of the year.
- Alternating exercise: water rights in which the resource is distributed between two or more parties who take turns to make use of the supply.

The Chilean model defines water resources in an overlapping sense as both public and private goods, since it considers that where a river enters into some kind of authorized channeling, it temporarily loses its character as a national good for public use and is considered as a private economic good. When the waters return to the river flow, they are again deemed public goods until channeled back to another owner (Donoso, 2003). Considering that the waters have owners, as a private economic good they can be sold, leased, assigned and used for any production process, such as irrigation, among other possibilities.

One of the benefits identified with regard to the model is that it allows users to internalize the opportunity cost of the resource and provides incentives to adopt new technologies that conserve resources and improve efficiency of use. In this model, efficiency is understood as the use of water by an agent with the highest economic value. From this perspective, a competitive water rights market would permit optimal resource allocation, through the regulation of supply and demand in a "water market". In short, the spirit underpinning the design of the Water Code considers water as an economic good; therefore, the market is the appropriate mechanism to ensure its efficient use, with public authorities interfering as little as possible (Hernandez, 2006).

However, even proponents of the model identify elements that limit the operation of and create many difficulties in achieving a properly functioning market. One of the main difficulties identified is the initial allocation of water use rights for free, which represents a transfer of wealth to individuals from a national good for public use. Since this initial allocation does not reflect the economic value of the resource, coupled with serious deficiencies in transparency and fairness, it favors only those stakeholders who are better informed about the possibilities of resource allocation. Similarly, the ability to accumulate "idle water" has increased market problems, because until recently the lack of legal restriction or payment of license fees would favor monopolistic situations. Finally, it has also been stated that this model poses serious difficulties for the integrated management of watersheds, as the uses of each type of right are subject to change that may affect downstream consumers (Donoso, 2003), while the State has no opportunity to monitor or plan for situations of extreme water scarcity.

4.1.1 Legal Reform of 2005

After years of discussions on the provisions of the Water Code and the need to improve it, due to performance problems in the water market across most of the country, it was decided to partially amend the legislation. This reform was corrective and aimed at strengthening and revitalizing the water market, avoiding accumulation and excessive speculation by users who did not make use of their rights. The main aspects of this reform were (Hernandez, 2006; Nuñez & Soto, 2010):

- A requirement to justify new water rights applications that exceed a certain number of liters per second, clarifying the projected kind of use. Although the kind of use must be previously declared, nothing prevents an owner or successor from changing the destination or use of the water subsequent to its acquisition.

- A requirement to pay for non-use of the resource, through a license fee intended to discourage hoarding and accumulation of idle water. This fee is applied in the case of owners of water flowing at more than 10 or 100 liters per second, depending on the location of the resource and the type of right (consumptive or non-consumptive).

- The President of the Republic of Chile now has the ability to exclude from market competition water resources considered significant for the community, with the aim of protecting the public interest of market competition. It is possible to avoid auctions when there is competition for rights.

- The General Water Office (*Dirección General de Aguas*, or DGA) has the obligation to consider environmental issues when granting new water rights, which permits the establishment of "ecological flows" of up to 20% of average annual flow and may even reach 40% in some cases (Nuñez & Soto, 2010). The DGA also has increased powers to protect the resource, being able to stop works or prevent water extractions of certain rivers when there are problems with legally established rights.

- In order to produce a "public water cadaster", new user requirements and a Water Register, which allows records to be developed of traditionally used rights, are introduced.

- User organizations called Water Communities now include groundwater and can be granted legal status, giving them greater scope for action.

- River Monitoring Boards now have faculties to control groundwater basins.

These modifications may improve the water market in Chile but could also accelerate it, particularly as regards the payment for non-use of the resource, which encourages the growth of transactions and projects to prevent hoarding of "idle water" and to avoid license fees. This may result in the intensification of water stress in certain regions resulting from higher pressure to use water. In addition, due to the delay in implementing the reform (discussions began 1992 and the reform was only adopted in 2005), there are significant difficulties that limit the possibilities of improving the water market. It is hard to implement the new allocation system in rivers that are already legally exhausted and not possible to establish "ecological flows" in most of the rivers that require such a system, because rights already exist over the entire flow (Hernandez, 2006).

4.2. User Associations

Private actors have the important function of distributing water resources according to the rights of each user, in addition to the function of maintaining the water facilities of common use (reservoirs, canals), which must be performed through user associations. The current Water Code recognizes three types of user organization (Donoso, 2003; León, 2008; Chile Sustentable, 2004):

- Water Communities (*Comunidades de Agua*): user organizations that exist by the mere fact that two or more parties have rights to use the waters of a channel or source of groundwater and/or share use of the same headworks, canals or dams. These communities have a responsibility to obtain and distribute the resource among the holders of water rights, and to build, maintain and

improve headworks, dams and canals. They have legal personality, and each community member has the right to vote in relation to the amount of water rights it holds.

- Channel Associations (*Asociación de Canalistas*): user organizations made up of owners of water rights who use artificial channels to control water flows. This organization is designed to facilitate the use of water by its members, taking care of water distribution and its proper use, as well as the construction, maintenance and management of irrigation structures.

- River Monitoring Boards (*Juntas de Vigilancia*): user organizations that exploit, in some manner, the waters of a basin or watershed. These organizations comprise individuals, legal persons and other user organizations (Water Communities and Channel Associations). Their purpose is to manage and distribute water from rivers to members, safeguarding the resources of an entire watershed or a river section. These organizations can exploit, conserve and build works of common use, as well as resolving conflicts over the use of established rights. Their organizational structure consists of a General Assembly, which elects a Director and a President. The President is the legal representative of the organization. The Director must also appoint a manager, who is in charge of technical aspects of water distribution.

In 2004, 21 River Monitoring Boards were registered with the DGA (with a further 30 unregistered). There were 49 registered Channel Associations (with 167 unregistered), in addition to 2,625 Water Communities, all of which were unregistered because prior to 2004, there was no registration obligation for Water Communities (Hernandez, 2006). A total of 2,892 user organizations were estimated to exist throughout the country.

4.3. Institutions Participating in Water Management

Although the Water Code establishes that rights are regulated by the market, it also reserves the following functions to the State (Donoso, 2003):

- The State is responsible for investigating and measuring water, creating the databases necessary to enable informed management of water rights.

- It must analyze the possibilities of conceding new water rights, regulating the use of water resources and preventing harm to third-party rights or inappropriate exploitation of water channels. Therefore, the State should also consider other types of permits such as construction of new works, modifications at the point of extraction of water and discharges into watercourses, among others.

- The State is required to ensure the conservation and protection of national water resources through a system of environmental impact assessment (*Sistema de Evaluación de Impacto Ambiental*, or SEA).

In this context, the most important State institutions that are involved in water management are:

- General Water Office (DGA): an agency under the Ministry of Public Works with responsibility for planning, development and exploitation of natural water sources. Among its main tasks is the management of the National Hydrometric Service (*Servicio Nacional Hidrométrico*), analysis and approval of applications for water rights and hydraulic improvement projects, in addition to supervising the activities of the River Monitoring Boards.

- National Irrigation Commission (*Comisión Nacional de Riego*, or CNR): an agency under the Ministry of Agriculture with responsibility for planning, assessment and approval of investment projects in irrigation infrastructure, through the coordination of public institutions and private organizations. This institution also coordinates the implementation of irrigation law for major and minor works, together with its Irrigation Department.

- Office of Hydraulic Works (*Dirección de Obras Hidráulicas*, or DOH): an agency responsible for implementing technical and economic studies for State-financed irrigation investments that have been previously approved by the CNR.

However, it has been noted that the functions of some of these organizations, especially those associated with planning and management of water resources, are only nominal: the ability to design and implement programs is very limited. On the other hand, control and monitoring functions are limited by the same Water Code, which means that institutions lack appropriate tools to deal with water pollution and water shortages. Finally, a major flaw has been pointed out in the development of an integrated approach to water resources. Separating resource allocation responsibilities from those relating to resource management limits the opportunities to efficiently manage resources and to effectively respond to increasing competition and demand for water (Chile Sustentable, 2004).

Other state agencies linked to the management of water resources in Chile are: the Ministry of Environment, responsible for its protection and conservation; the Environmental Assessment Service (*Servicio de Evaluación de Impacto Ambiental*, or SEA), responsible for environmental assessment processes; Sanitary Services Superintendence (*Superintendencia de Servicios Sanitarios*, or SISS), which oversees the behavior of the sanitary sector and also monitors industrial liquid waste discharges from the industrial sector; the National Energy Commission (*Comisión Nacional de*

Energía, or CNE), responsible for the regulation of electricity services; the Institute of Agricultural Development (*Instituto de Desarrollo Agropecuario*, or INDAP), responsible for supporting agricultural production in the poorest sectors; the Agriculture and Livestock Service (*Servicio Agrícola y Ganadero*, or SAG), responsible for the health of the country's agricultural products; the Ministry of Health (*Ministerio de Salud*, or MINSAL), responsible for monitoring health conditions for the inhabitants of the country; and the National Marine Fisheries Service (*Servicio Nacional de Pesca*, or SERNAPESCA), responsible for overseeing water quality for specific purposes.

It is also necessary to emphasize that the State has invested in more infrastructure for the management of water (dams and canals) and also offers financial aid programs to encourage investment in irrigation works for agriculture (León, 2008):

- Law No. 18,450, Approving rules for the promotion of private investment in minor irrigation and drainage works (*Ley 18.450: Aprueba normas para el fomento de la inversión privada en obras de riego y drenaje*): This legislation came into effect in 1986, with the aim of increasing the irrigated area, improving irrigation efficiency and developing agricultural soils. The promotion of investment under this law has been carried out within the framework of the National Irrigation Commission (CNR).

- Farmers Irrigation Program (*Programa de Riego*, or PRC): this program was implemented by INDAP and aims to support the incorporation of new surface irrigation or drainage for agricultural production and improve irrigation safety through the construction of small irrigation works.

- Solidarity and Social Investment Fund (*Fondo de Solidaridad e Inversión Social*, or FOSIS): Established in 1990, FOSIS subsidizes plans, programs, projects and special development activities that contribute to overcoming poverty in the country, including the full or partial funding of local irrigation projects.

4.4 The Operation of the Limarí Basin

In Limarí, decreasing rainfall is very important because the average annual rainfall in the Coquimbo Region is 180mm and a large part of agricultural production depends on the management of water reservoirs (León, 2008).

In this region, a policy was soon introduced to promote irrigation with the construction of three large dams, which has contributed greatly to the expansion of irrigation technology and increased

planting. Nevertheless, today, due to the expansion of mining activity, the stock price has become largely inaccessible to small farmers and peasants in the area (Leon, 2008).

Between 1980 and 2000, the communities near the dam (including Monte Patria) invested nearly 300,000 dollars to improve infrastructure, offering subsidies and technical assistance. The three dams built in Limarí province have a total storage capacity of about one million cubic meters of water (León, 2008).

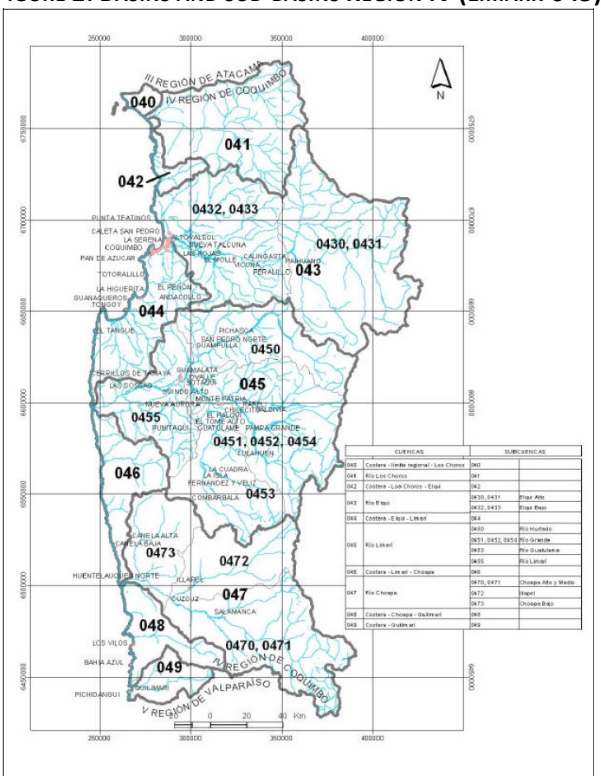
The current estimated flow of the basin and its present uses are set out below.

TABLE 4: FLOW OF LIMARÍ RIVER BASIN

Flow by use [m^3/s]									
Limarí Basin	Farming	Potable Water	Industry	Mining	Electricity	Forestal	Tourism	Waste receptor	Ecological flow
Hurtado river	1.041	0.016		0.064		0.002		0.000	0.250
Grande river	3.343	0.021	0.047	0.001	1.250	0.004		0.017	0.890
Guatulame river	1.222	0.077		0.157		0.003		0.022	
Limarí river	5.274	0.196		0.208		0.001	0.001	0.164	

Source: Ayala, Cabrera y Asociados Ltda. (2007)

FIGURE 2: BASINS AND SUB-BASINS REGION IV (LIMARÍ: 045)



Source: Ayala, Cabrera y Asociados Ltda. (2007)

There are more than 460 canals and three dams in the area:

- La Paloma reservoir: has a capacity of 750 million cubic meters of water and covers an area of 3,000 hectares. The reservoir was built between 1959 and 1966 and was opened in 1968. It contains the waters of the Grande and Huatulame rivers. It is the largest irrigation reservoir in Chile and the second largest in South America.

- Cogotí reservoir: has a maximum capacity of 150 million cubic meters and covers an area of 850 hectares. It was built in 1939 at the confluence of the Pama and Cogotí rivers. It is mainly used for irrigation, but also for tourism, since its banks are camping areas and there is a beach suitable for swimming.

- Recoleta reservoir: has a capacity of 100 million cubic meters, used exclusively for irrigation and covering a total area of 555 hectares. It contains the waters of the Higuerillas and Hurtado rivers. Its construction began in 1929 and was completed in 1934. It is mainly used for irrigation, but is also available for tourist activities.

These dams, added to the system of interconnected canals, are known as the Paloma System. This system regulates the flow of the Grande, Huatulame and Hurtado rivers. Every year the River Monitoring Board for the Paloma System assigns the amount of water that corresponds to each organization, based on its shares, the water reserves and projections. Thus, the distribution system operates according to the availability of water in each dam (León, 2008).

The Paloma System has 7,398 users (irrigators or shareholders), 1,679 of which are organized into three channels and 15 associations of water communities. There are three River Monitoring Boards in the basin, for the Grande, Rapel and Cogotí rivers. The gross and net demand of water for irrigation in the basin are estimated at between 790,840,000 m3/year and 724,402,000 m3/year (CADE IDEPE, 2004)

In evaluations of the water management model in Chile, the Paloma System provides an example of the active operation of the water market. Because water is scarce in this system, it has great economic value and thus generates significant competition among users. One advantage of this system is that the proportionality of rights depends not on a variable flow, but on the volume stored in the dams, which means availability is known in advance of the agricultural season. The regulation capacity of dams gives security about the availability of water supply, clarifies the supply and allows users to make informed decisions regarding how they will use its waters (Donoso, 2003). Thus, the

Paloma System may be conceived of as a "water bank", where users have accounts and can make withdrawals of water or loans (with the corresponding return in the following period), in addition to different users being able to exchange deposits of water.

4.4.1 Agricultural Activity

The most important crops in the basin are artificial grasslands, orchards and cereals. In relation to the area used in the community, farms amount to 433,534 hectares in total, of which 8,969 hectares are used for annual crops, 27,912 are devoted to fallow and rest periods, 32,8420 are grassland and 617 are used for infrastructure (Censo Agropecuario y Forestal, 2007).

In recent years, the sector has seen an accentuated replacement of traditional crops irrigated annually by more intensive (often permanent) crops in the use of labor and higher yield per hectare. The Vine Pisquera represents 37.5% of the surface with permanent crops, as the sector has a suitable climate for growing *pisco* grapes. This industry has incorporated new technological advances over time and is export-oriented. Moreover, the surface area occupied by vegetables and flowers has increased significantly, the most important products being peppers, artichokes, sweet cucumber, peppers and tomatoes. These crops are aimed at satisfying the domestic market and exporting to certain niches of Argentina at certain times of year. Livestock is mainly goats, while cattle stocks are diminshing because the feed resources available for this species are declining. Sheep farming is specialized toward wool production, industrial in character but with low representation in the community.

In this highly commercialized area, most farmers tend to specialize in one or two types of crop. Zegarra has developed a typology of producers in the Limarí valley, identifying four typical activities (Zegarra, 2002):

- Livestock/traditional: This covers an important group of livestock producers and a few farmers who specialize in traditional crops such as corn, beans and potatoes. In the past, cattle were much more important in the Limarí valley. Although this activity is now less important due to declining profitability and the scarcity of water, a presence remains, both as a specialist activity and as a complementary one for some types of farmers.

- Horticulture/greenhouse: These crops mainly include artichokes, sweet cucumber, tomatoes, green peppers and chili. Farmers in this group use greenhouses in small plots, irrigating crops using the drip technique.

- *Pisco* grapes and avocados: These are permanent crops, consisting of trees that live for between 15 and 20 years. Farmers in this group require a high initial investment. Most grapes produced in this sector are processed by local pisco industries: Pisco Capel and Pisco Control. Avocados, on the other hand, are sold at local markets.

- Grape exports: These farmers also work with trees and are oriented almost exclusively toward the export market (mainly U.S. and Asia). The production process is dominated by large commercial enterprises dedicated to both growing and packing and also to the export of grapes. Family farms remain present today in this sector, but they have steadily decreased in terms of area, since large companies have achieved a significant expansion in recent years.

In the valley one can identify the coexistence of the family farm, consisting of medium and small farmers who manage their own land. However, in grape exports the participation of such farmers is very low, since large exporters operate most of the land dedicated to this product. In general, traditional farmers in the valley have the lowest level of education (5.7 years on average) and horticultural producers show significantly fewer years of experience and smaller families than other producers. Among the horticulturists there is also a greater presence of tenants, which is explained by the younger heads of households. Also, some cattle producers are small tenants, since they have little land or no grassland and instead rent on a seasonal basis (Zegarra, 2002).

Recent years have seen sustained growth in fruit exports in the Limarí valley, surpassing the evolution of the rest of the valleys of Norte Chico. Some of this growth has been evaluated as due to the possibilities provided by the water market.

However, this steady increase in planted areas requiring irrigation gives rise to a scenario that comes into conflict with the sustainability of the water market. This adds to increasing erosion and desertification as a result of misuse of resources and the exploitation of vegetation in order to feed goats (Ferrando, 2002). There is hence a tension between economic growth, desertification processes and the use of water resources, which could be reaching their maximum usage capacity due to reduced rainfall.

4.4.2 Paloma System Hydro-Efficiency

The water resources of the Limarí river have been managed through the water and social system known as the Paloma System since the 1970s. This system integrates three reservoirs and multiple irrigation channels and has given rise to a major expansion of agriculture in an area

with low rainfall, with a sustained increase in irrigated area and a changed production structure in the basin (Alvarez, Kretschmer & Oyarzun, 2006). It has also permitted the development of a highly mobile water rights market.

The Limarí basin has been divided into two sections: the irrigation sector above the reservoirs and the area below them, the latter being known as the Paloma System. Water rights are defined in terms of cubic meters of stored water, which can be predicted before the start of the season and is calculated proportionally according to the rights or shares held by each farmer. These shares are distributed simultaneously to the proprietors or with a rotating system of distribution (or in shifts) in case of drought (Cristi, et al. 2001).

Thanks to the secure availability of water generated by the dams, one may describe the Paloma System as a water bank, because users can perform transactions such as water withdrawals, sales, purchases and deposits between different users. Users may even request lending rights, with “repayment” in the following season (Donoso, 2003).

The Monitoring Board of the Paloma System administers the system and is in turn subordinate to the National Irrigation Commission. The organization estimates the annual amount of water stored and establishes the amount of water that corresponds to water user associations in the system. The maximum allowable volume of water is 50% of the total stored, when such total amounts to less than 500 million m3. If this volume is exceeded, the maximum allowable is 320 million m3. Subsequently, each irrigator association assigns the appropriate volume of water to each of its members (Cristi, et al. 2001).

Transaction costs in this system are considerably lower than for other watersheds in the country, thanks to a highly flexible water distribution structure that also allows water availability to be predicted with greater certainty. This not only permits the existence of a permanent trading market where water rights are purchased and sold, but also enables temporary transfers between users, who trade certain volumes of water on what is known as a "spot market". The volumes transferred during periods of scarcity are greater than 10% of the total volume assigned to users (Cristi et al, 2001; Donoso, 2003).

This water market activity may also explain the existence of a significant number of farmers with non-permanent crops. Such farmers have the potential to modify their water consumption by varying the percentage of use of their land to provide water when its spot market price is greater than its cost when used as input in their production.

Multiple benefits have been identified in the functioning of this market, including increasing the gross product of the area as a result of the reallocation of water to activities generating economic value, in addition to the possibility of small and medium farmers obtaining income from the sale of water in lean years (Cristi et al, 2001).

The need to improve market efficiency through more transparent information concerning the reserves of each user, with a reduction in "private" information, is also clear. There is an obvious need to formalize an options market, which would reduce uncertainty about the availability of water on the spot market, and small and medium farmers also require access to a capital market in order to be able to access the water market (Cristi et al, 2001).

Finally, one of the critical issues identified in this market is that its high mobility has changed the production structure of the sector; the water rights that were initially associated with an area have moved elsewhere and become subject to different uses. This movement has also resulted in the expansion of cultivation areas, which may in future require the use of new water sources in times of scarcity (Alvarez, Kretschmer & Oyarzun 2006).

4.4.3 Environmental Problems associated with Water Resources and Agriculture

An analysis of the regulatory plans for each community reveals the environmental problems declared by each municipality[6]. In the case of Limarí province, the following environmental problems have been identified:

- Pollution of rivers, streams and reservoirs: Due to the disposal of mining waste in rivers (including the Hurtado river), intensive farming with agrochemicals (pesticides) polluting streams and production activities related to *pisco* and wine, liquid effluent (vinasse) is generated, the bulk of which joins the waters of the Grande and Rapel rivers. The pollution of streams and rivers flowing into the La Paloma reservoir increases its pollution levels.

- Deterioration in vegetation and fauna: Deterioration in vegetation has been identified due to overgrazing of goats and sheep and the clearing of native vegetation in order to create monocultures in valleys and on the hills, particularly involving the over-harvesting of old carob. This phenomenon is more marked in the towns of Monte Patria, El Palqui, Chañaral de Caren and Huatulame, due to advances in agricultural crops. The loss of native vegetation leads to a loss of habitat for local fauna. In parallel, the demand for firewood and charcoal has generated an over-exploitation of the carob tree, a species becoming endangered within the communal territory.

6 Source: Regulatory Plan, Monte Patria Community (*Plan Regulador Comuna Monte Patria*) (2005)

- Erosion and desertification: Good agricultural soils are being lost due to improper management of industrial aggregate extraction in riverbeds, increased grassland soil erosion due to overgrazing of livestock (especially goats) and the clearing of hills through consumption of vegetation for fuel.

Despite these problems, the Limarí river and its tributaries are classified as good in general, with certain exceptions. The river with the best natural quality is the Comberton, followed by the Moston, Rapel, Hurtado, Cogotí and Huetulame rivers. Finally, the Punitaqui and Limarí rivers are those with the lowest water quality. The main contaminants identified are related to mining, intensive agriculture, logging and goat husbandry (CADEIDEPE, 2004):

- Abundance of manganese in the entire Limarí basin.
- High concentration of metals: boron, copper, selenium and aluminum.
- The Grande, Hurtado, Cogotí, Huatulame, Limarí and Punitaqui rivers have high concentrations of calcium ion, magnesium and sodium.

Finally, climatic studies have shown desertification trends due to reduced rainfall, increased frequency of droughts and rising temperatures. Some studies suggest that the maximum capacity of water resources in the sector has been reached, despite the high-efficiency irrigation system (Ferrando, 2002).

4.5. Problems in the Water Market

The Chilean model of water management has faced a number of difficulties and one can identify important weaknesses in spite of the reform adopted in 2005. Among the main problems identified in this water market are (Chile Sustentable, 2010; Bauer, 2003; Donoso 2003; Hernandez, 2006; Nuñez & Soto, 2010; Gentes, 2007; CEPAL, 2003):

- Limitations of market agility: Because of the geography of the country, it is very costly to transfer resources from one basin to another and the infrastructure is not sufficiently developed for this purpose (resulting in high transaction costs). Moreover, one cannot be certain about the real availability of water due to the poor quality of national registries. There is a significant difference between nominal and real rights, as well as conflicts among users due to customary rights sales and the hoarding of non-consumptive rights.

- High transaction costs: The high costs involved in investing or modifying infrastructure for water distribution limit market flexibility. Basins with a developed water market have a significant infrastructure. This infrastructure has been developed through State investment; an example is the Limarí basin and the highly active market of the Paloma System.

- Lack of an extensive water market: Transactions are relatively few and only more prevalent in certain places, since the accumulation of rights remains a security measure for the dry season and because there is uncertainty about the relationship between supply, demand and profitability. Nor is it possible to find reliable information on actual transactions, since only part of the rights are registered with formalized titles in the public water cadaster. This situation is due to the high cost of regulating rights, resulting from the bureaucratic procedures that are involved.

- Concentration of water right ownership: Because of the free concession of rights and lack of control in the process, some monopolistic situations have arisen, in terms of consumptive rights (mining, major exporters of agricultural products, water companies), and non-consumptive rights (hydroelectrical), violating the assumption of free competition and impeding the optimal allocation of resources.

- Impact on social equity: The water management system in Chile has not promoted access to water for family farming purposes, hindering the improvement of living conditions in poor rural areas. When the Water Code came into effect, a significant proportion of farmers did not register the water rights passing through their lands as they were not sufficiently informed about the process. Today, agribusinesses and mining industries have the rights to channels and the investment capacity to use them. This is the result of marked asymmetry among the various actors in the Chilean water market.

- Concentration of ownership in the sanitary sector: the privatization of sanitary services, together with the monopolization of these services by particular geographical sectors, has led to sanitary service access problems for people with fewer resources, due to frequent rate increases. The water tariff system in Chile is the most expensive in Latin America.

- Worsening of water stress and destruction of watersheds: Most of the basins of northern and central sector of the country are subject to heavy demand, which in many cases results in the depletion of rivers and destruction of numerous ecosystems. Hydroelectric companies monopolize water to produce energy, affecting downstream water users. Similarly, mining and

forestry companies use abundant water for their tasks, returning some of it contaminated to the rivers. Peasant agriculture suffers without sufficient water, with reduced production, food shortages and desertification. In some cases, villages that traditionally had plenty of water must today be supplied using water tank trucks.

- Lack of integrated watershed management: Water management is carried out at sections of rivers and not at river basin level, which limits opportunities to monitor environmental problems and resolve conflicts. The River Monitoring Boards and the DGA do not have sufficient tools to address problems between different types of users (e.g., consumptive/non-consumptive), which becomes even more difficult when users belong to different sections of rivers. Likewise, these organizations fail to address environmental problems that arise in one section of the river but affect another. Many of these conflicts lead to the courts, exacerbating the conflict and/or damaging the weaker party (usually peasant farmers).

- Loss of public control and governance of the resource: the Chilean model presents serious difficulties for managing water resources in the basins, resolving conflicts relating to those resources and protecting river ecosystems. Legal and institutional conditions limit the scope for governments to respond to the growing social and environmental problems of water management. The loss of public control over the ownership and management of water generates a structural problem as regards the democratic governance of water and hence increases local, regional and national conflicts relating to the resource.

However, some aspects have been improved as a result of the Water Code and the privatization process, such as the increase in coverage of sanitary services, sewage treatment and greater efficiency in using the resource. From the perspective of some authors (Bauer, 2003; Donoso, 2003), the "recognition of water as an economic good" has encouraged private investment and has allowed greater flexibility in allocating resources. But we must emphasize that these authors agree that this market works in situations of scarcity and where there is adequate infrastructure to reduce transaction costs.

4.5.1 Performance of the Market and Inequality

The functioning of the water market means that participating farmers will face some uncertainty about water supply, resulting in varying degrees of risk to farmers depending on the type of production in which they are involved and the sensitivity of that production to variations in the availability of water (Hadjigeorgalis, 2004). For example, permanent crop producers face increased

risk due to the significant investment they make in their plantations, as the risks faced not only involve the current season, but may also affect the future of their plantations. On the contrary, annual crop farmers risk losing only with regard to the current production.

It has been identified that the degree to which farmers tolerate risk varies, which may be due to many factors, of which one of the most important is income. Where farmers have higher incomes, their risk tolerance will be higher and they will be more willing to make high-risk and high-reward decisions. In contrast, low-income farmers prefer not to take risks and instead make safe investments, but have less potential for profit. These farmers prefer a low but secure income to a higher but uncertain income (Hadjigeorgalis, 2004).

This reduced willingness to take risks influences their decision to participate in the water market, since a low-income farmer will be willing to sell water or water rights on the spot market, which provides a steady income, rather than taking the risks associated with agricultural production (Hadjigeorgalis, 2004). Thus, low-income farmers sell their water rights, whether permanent or temporary, to higher-income farmers who are willing to invest in agricultural production with increased risk.

Research conducted by Zegarra (2002) identifies that for the period between 1996 and 1997, 9% of respondents were net sellers of water, while 28% were buyers during the season, representing a transfer of 9,632 m3. Price per m3 was 53.2 Chilean pesos and the biggest buyers were the major producers of grapes for export, amounting to 35% of all buyers. Permanent crop farmers tend to participate in these transactions as buyers on the water use rights market, since for them a deficit of water is more risky for production. Meanwhile, participating low-income farmers sell water (on the spot market) or water use rights (on the permanent market), since many of them are only producers of seasonal crops (Hadjigeorgalis, 2004).

The consequences of farmers' tolerance and willingness to take risks for their cultural and economic conditions have not been sufficiently studied. However, it is possible to identify that certain patterns of trade between farmers are not possible to explain considering only economic transactions in the water market (Hadjigeorgalis, 2004). This could be very significant in terms of unequal opportunities for farmers in this market and also in increasing the gap between traditional farmers and export-oriented agribusiness.

Although we have identified that water markets work best in situations of scarcity, in the Paloma System serious limitations were revealed in the drought during the 1996/97 season (Zegarra, 2002).

The water market became less efficient in the allocation of resources due to high demand, which led to an extremely high price of water distribution, limiting the opportunities for small and medium farmers to buy water and hindering opportunities for investment in permanent crops. This issue is important because a greater frequency of droughts has been recorded in the Limarí valley during recent years. Moreover, in the context of drought, farmers must pay the same amount for administration costs, despite receiving a much smaller amount of water; this can be a major problem for poor farmers.

A mechanism to reduce risk to producers is the hoarding of water by maintaining a surplus of rights or additional purchases. Many analysts question this behavior, but it represents a type of insurance for farmers who face high risks in periods of water deficit (Hadjigeorgalis, 2004). This risk-sharing alternative is threatened by the new policy of charging fees for non-use, built into the reform of the Water Code of 2005, which aims to improve the efficiency of the water use rights allocation process. The effects of this new policy on the water market remain to be studied.

Another important factor also plays a part in the inequality of conditions for participation in the market; this is the possibility of water theft. Upstream farmers can take illegally significant amounts of water, affecting the remaining farmers who draw from the same stream. This problem seriously affects the poorest farmers, because there are no adequate tools to protect their rights and the judicial process involves high monetary costs (Zegarra, 2002).

Finally, a defense of the model maintains that the model actually favors farmers with fewer resources, enabling revenue to be generated through the sale of temporary or permanent rights. This defense is strengthened by the scarcity of reports of water theft and violations of the rights of those groups (Galaz, 2004). However, this defense fails to take into account that the water market is not equivalent to other markets. If farmers sell their permanent rights, they lose the ability to recover them, unless they are able to significantly increase their income from other sources. Meanwhile, in the case of spot markets, farmers sell their temporary shares, but at the same time stop investing in their own lands. This distorts the distribution of resources between rich and poor users, gradually increasing differences between the two. At the same time, low numbers of theft and violation complaints are due to the lack of oversight tools and absence of facilities for low-income farmers to make complaints.

In this context, it is possible to assert that the shortcomings of the judicial system and the limited tools for resolving conflicts through user associations are determining factors for unequal participation in the water market. Thus, rich users have a highly advantageous position in the market,

as they enjoy more investment opportunities and can also buy water when required in addition to illegally extracting water without consequences (Galaz, 2004). The condition of the Chilean judicial system is crucial to this weakness. The system is slow and costly for its users. Furthermore, the most vulnerable members of the population have little confidence in it. Moreover, there is no significant presence of other organizations that might support the poor farmers, such as rural NGOs. The user associations operate by representation based on shares or rights, which means that farmers with more water resources can exert more influence. Finally, government agencies offer scant control and support tools for vulnerable farmers.

4.5.2 Water Markets and Water Stress

In a scenario of water stress, the ability to control scarce resources and mitigation planning are essential to address the problems that climate change may trigger. This explains the significance of the Water Code and the performance of the Chilean water market that it has established.

The water market presents significant operational constraints: high transaction costs, lack of public information, variability of resource availability and uncertain definition, and the accumulation of rights and monopolies in some markets. Additionally, it is necessary to note that if the rights market is fully implemented and the expected dynamism created, vulnerable sectors of the population may face greater shortages, because there are significant disparities for the use of water resources and other problems may arise from the scarcity of the resource, such as the transmission of diseases (SAMTAC-CEPAL, 2000).

In this context, the Water Code of 1981 has been shown to be inadequate to address the integrated management of water resources. This is mainly due to the fact that the Water Code does not generate the conditions for the development of tools permitting integrated watershed management, coordination of multiple water uses and the internalization of economic and environmental externalities (Donoso, 2003). At the same time, it has not been possible to develop a single audit body, a transparent and effective public conflict resolution system or appropriate environmental control and conservation mechanisms in Chile (Gentes, 2008).

Despite the 2005 amendment to the Code, whereby the State intended to appropriate higher capacities of intervention and increase control of water resources, the overexploitation of resources in certain sectors of the country has impeded the protection of watersheds (Gentes, 2008). Nor has the reform delivered the tools to address issues of inequality in access to water rights and in conflict resolution.

Finally, from a global perspective, one of the main difficulties in confronting the consequences of climate change is the lack of integrated watershed management, because water resources are managed at the level of river sections, which limits the possibility of addressing the problems of scarcity or pollution at the watershed level since surface water and groundwater are independently administrated. Nor is there integrated management of the quality and quantity of water resources. All this raises serious difficulties in developing action plans on problems resulting from climate change, as well as limitations in dealing with extreme drought situations and developing comprehensive mitigation plans (SAMTAC-CEPAL, 2000).

The watersheds facing critical water stress scenarios require government intervention to resolve conflicts which the market cannot settle satisfactorily. From the progressive evidence of trends toward a substantial reduction in available water resources due to global climate change, one may even predict the need for decentralized agencies (at watershed level) in order to control and coordinate the use of resources (SAMTAC-CEPAL, 2000).

The peculiarities of the water market in Chile have led to it being repeatedly cited as a successful free-market experience in water resources. There has also been criticism of some respects, but mainly related to the corrections that might be made to the model. The 2005 reform attempted to achieve some of these corrections. However, other studies that question the model point to significant weaknesses, in some cases structural and not possible to address through partial reform or corrections to the existing model (Bauer, 2005).

Some key conditions are necessary for a water market to function well: management of water shortages, guaranteed and clearly defined water rights, appropriate regulation of market transactions, an inventory of water resources and mechanisms for conflict resolution. Under these conditions, in the opinion of the experts a water market could work efficiently and sustainably (Donoso, 2006). In the Chilean example, there are important gaps in several of these areas.

Evaluating the performance of the Chilean market and comparing it with other equivalents reveals significant shortcomings, particularly in relation to equity in market access and sustainability of water resources. In the study entitled “An Integrated Assessment of Water Markets” (Grafton et al, 2010), the Chilean market is compared with others in Australia, China, the USA and South Africa. The main deficiencies identified in Chile in terms of equity are weakness in market control, difficulty in accessing the resource benefits and deficiencies in the initial resource allocation (figure 3).

FIGURE 3: EQUITY

Equity

	Beneficial use in extractions	Basic human needs	Controls on market power	Third-party impacts	Initial allocation
Australia	3	3	2	1	2
US	3	3	2	1	2
Chile	1	3	1	1	1
South Africa	2	2	I	2	(pending)
China	X	1	N/A	X	N/A

3 Nearly or fully satisfied

2 Mostly satisfied, some further development required

1 Partly satisfied, substantial further development required

X Not satisfied/Missing/Not operational

I Inadequate info

Source: Grafton et al, 2010

For sustainability, the main shortcomings are lack of scientific data on water resources, appropriate boundaries of environmental flows, adaptation to the needs of the environment and integrated watershed management (figure 4).

FIGURE 4: ENVIRONMENTAL SUSTAINABILITY

Environmental Sustainability

	Adequate scientific data	Adequate provisions for environmental flows	Adaptive management of environmental needs	Water quality considerations in water planning	Basin and catchment-level water planning
Australia	1	(pending)	(pending)	(pending)	(pending)
US	2	1	1	2	1
Chile	1	1	1	1	1
South Africa	1	(pending)	I	I	I
China	X	1	X	1	X

3 Nearly or fully satisfied

2 Mostly satisfied, some further development required

1 Partly satisfied, substantial further development required

X Not satisfied/Missing/Not operational

Source: Grafton et al, 2010

In general, we have identified that the market-based system for allocating water rights considers water as an economic good, recognizing water as a scarce resource and internalizing this scarcity in its price, which has brought many benefits because it permits the use of market incentives for management. In Chile, the legal security of private property rights has promoted private investment in water use and the freedom to buy and sell water rights has allowed water resources to be reallocated in some areas, meaning the resource has been used more efficiently. However, the Chilean legal framework has proven to be rigid and resistant to change (12 years of discussion only achieved a partial modification of the Water Code) and presents serious deficiencies in the

management of water conflicts, in the protection and sustainability of the resource and in the protection of poor farmers. This model demonstrates that institutional reinforcement is required to improve its efficiency, sustainability and equity and to safeguard the public interest (Bauer, 2005).

To adequately address situations of scarcity it is necessary to develop integrated watershed management, coordinating the different uses of water, internalizing environmental externalities, resolving conflicts and facilitating the participation of the most vulnerable. Otherwise, the Chilean model does not have the tools to address long-term problems and cannot cope with the challenges of climate change.

Ultimately, in light of the facts regarding the consequences of climate change in Chile, the current problems in the management of water will worsen while competition for water increases, putting increasing pressure on the existing institutional framework. Recognizing the need to regulate the water market, improvement in institutional conditions is essential in order to meet the challenges of climate change.

5. Resilience of the Socio-Ecological System in Limarí Basin

As set out in the previous chapter, resilience in a socio-ecological system is related to two main aspects: the flexibility of its elements and the inter-connectivity of those elements. When observing the social dimension, we establish central components that must be addressed in considering this flexibility and connectivity, in order to analyse the system with regard to access to hydrological resources.

The legal and economical regulations that affect such access to these resources are key to understanding the flexibility of the system. At the same time, the manner in which the organizations operate at a national level (major regulators) and at a local level (minor regulators) is fundamental to the flexibility of the system when facing scarcity problems.

Finally, taking into account the theoretical approach outlined in the previous chapter, it is also important to observe the relation between different elements of the system, a connectivity that is reflected in terms of the social dimension by collaborative relationships, both vertical and horizontal, and the trust that these kinds of relationship allow.

Below, we describe the analysis of the empirical material obtained as a result of the interviews carried out, addressing each of the previously identified theoretical dimensions.

5.1 Flexibility: Legal Regulations

The main legal regulations relating to access to hydrological resources in Chile are set forth in the Water Code (*Código de Aguas*) that was approved by the military regime and has been in force since 1981. Accordingly, and also taking into account the analysis of speech of the different interviewees, the Water Code is clearly identified as the most important regulation for hydrological resources, defining what is possible in this field and the limitations faced by the different parties involved in the distribution of and access to water. Thus, various questions, criticisms and positive aspects of water management relate directly or indirectly to the conditions established under the Code (for detail, see chapter 3).

The various stakeholder evaluations place their hopes in a change to the model, describing the reforms that are required in the Code. Concurrently, the model is seen as inflexible, with direct reference made to the Water Code and to the practical difficulties in amending it..

The local media also confronts and identifies this as an issue. Below is an example of how important this topic is among local public opinion, which differs from the national press, where this kind of treatment does not appear with respect to the same issue.

IMAGE 1: "LOCAL LEADERS WILL FIGHT FOR CHANGES IN THE WATER CODE"

Source: *El Ovallino* newspaper (04.11.2009)

5.1.1 Water Codes Not the Origin of Water as Private Property

The first formal water code was enacted in 1969. It established a distribution of hydrological resources, but linked to land ownership. One of the distinguishing elements of that code as opposed to the current one is that at that time, *"for every kind of activity they had to present a productive project to be evaluated and then a water concession was given for a specific period of time, which normally lasted 20 years, after which it was re-evaluated and another permission was given"* (local agronomist independent expert).

The 1981 Code implemented two radical changes: land was distinguished from water and a water rights market was introduced (civil servant CNR user organization head). Farmers remember that previously, water was bought and sold, but it was always related to land (large-scale farmer 2). This changed from 1981:

> *"…in 1981, when the military regime ruled the whole country, a new law was passed where it was established that water was given to private parties through an exploitation right which took the form of private property, even registering this property in the Property Register"* (regional civil servant DGA)

From the results of this research, one may highlight the need to question the widely accepted thesis that the 1981 Code was responsible for the commodification of water (chapter 4). The interviews carried out confirm that there is widespread memory of pre-existing private access to hydrological resources. In Chile, some kind of water trading and some understanding of water as a private resource have in fact been present since the 19th century.

The Code reasserts what many farmers had already been doing in practice: "*The 1981 Code confirmed what we wanted to hear. It said: now you are the owner of the exploiting right that you*

have used for your whole life under the category of concession. And it was well received, we were happy. It is fantastic because now I can mortgage, I can sell and do a lot of things. Moreover, it is separated from the land to deepen the model" (local university expert).

Although there was a favorable reception from local farmers, there is widespread questioning of the model that the legislation constructed. The experts identified serious faults in the model, but an element highlighted by several parties is that through the 1981 Code, water rights received an economic value; hence, it would permit water scarcity issues to be addressed more effectively, even though the value was only economic: *"The positive aspect of the Code is that it was done for society to allocate a value to the water rights, but the problem is that this value would be only economic"* (local university expert).

However, the words of the different interviewees, experts, professors, users and members of civil society describe the need for better regulation of the trading and movement of water rights. In this context, user organizations from the Limarí basin have developed their own regulations to establish the limits and conditions of the transfers, which govern a large amount of the trading.

Furthermore, in this context, there is an argument between user organizations and the General Water Office (*Dirección General de Aguas*, or DGA) at a local level, due to the fact that the management authorizes transfers which the organization sees as harmful for other users: *"the DGA has authorized changes in the source of supply, which means that people who have water rights in the last part of the river or halfway have moved their rights to the Paloma reservoir. We have warned them about that, we have opposed it and we have suggested the corrections to the DGA but they have never considered our opinion"* (administrator, Limarí Monitoring Board).

5.1.2 Reforms to the Water Code

Among the responses of the parties related to governmental organizations and research centers, the effectiveness of the last and only Water Code reform is questioned. In general terms, it is possible to identify that in spite of agreement regarding the changes made, this reform is not considered sufficient to deal with the water scarcity problem in the North.

Out-of-use fee

The establishment of an out-of-use water rights fee was an innovation incorporated in 2005 with the purpose of reducing the concentration of control and stimulating the market (see chapter 4). Notwithstanding this, the interviewees pose many questions.

The reform promoted the intensive use of aquifers, because when groundwater levels are low, there are water wells which no longer work as they are not deep enough. The owner of such a water well has to pay a fee or leave the water extraction machinery installed. This is because it is sufficient to have installed the machinery to avoid paying the fee; for instance, to leave water pumps on water wells (DGA civil servant Ovalle). This encourages people to sell their water wells to other users who can build deeper water wells and continue with the use of the resource: *"…but how can they push me to use the water if my water well is dry… It is dry. How would I leave the water pump there so anyone could steal it or could steal the transformer and everything? Because now it is dry if the aquifer is deep down there. Then they say we have to pay and if I do not pay it is going to be sold at auction, someone else comes along, a mining company for example, and builds a deeper water well and takes more water"* (regional civil servant DGA).

In general terms, it is stated that the reform carried out so far strengthens the model, orienting it more towards to the market, because it tries to ensure that resources are available for use (local university expert). In addition, the cost is lower in comparison to the loss, which may militate in favor of divesting oneself of the rights. This is why in some cases it is more convenient to pay the fee. Another alternative is to sell the rights and in this way invigorate the market, but these rights are never returned to the State.

> *"I believe that the out-of-use fee, more than encouraging people to give up their rights, promoted investments. It invigorates … but in the same way, if you have a right and you have the construction, you do not pay the fee. Then maybe you do not use the water. But it does not incentivize the non-use of water. Not at all, it means the cost of the fee is lower than the cost of water, hence I prefer to pay the fee instead of returning or selling the water right"* (DGA user organization national division)

There are also elements that go against sustainability or ecological flow. For example: "*Pucon's municipality registered many water rights and I understand that they now pay around 200 million Chilean pesos for not using them. We have 1400 and as the law says that 1500 down, you do not pay, we are just out of it"* (CS South).

An element continuously questioned is the effectiveness of the out-of-use fee, mainly because it would not be appropriate for contexts involving scarcity, but rather where there is abundance and to avoid speculation (CNR Santiago). Otherwise, this reform establishes that when a fee is not paid the

water rights are auctioned. This last aspect is described as a wasted opportunity, because it would have been better to provide for the return of the water rights to the State in this situation:

> *"Another anomaly from the legislators is the out-of-use fee. Whoever does not use the water has to pay a fee, and you can see that in this area, it is stupid, I mean the person who does not use the water, you tell me, do I have to make him use it, when it is supposed to be the other way around…? Hey, leave it there; I should be paying the one who is not using the water. And if the guy does not pay the fee, the State auctions the water rights to the higher bidder. Just picture that, when they should have said it stays with the State…"* (regional civil servant DGA)

Ecological Flow

The implementation of an ecological flow was one of the best-evaluated aspects of the reform. However, a critical view refers to the fact that it is only applied to the rivers with available rights (which can be saved for an ecological flow). On the contrary, rivers in high-demand areas are already exhausted, there are no available water rights and therefore it is no longer possible to establish an ecological flow. This is paradoxical in that the areas that cannot have ecological flows are those that urgently need to establish a lower water level, as many of their rivers have completely dried up because of the intensive use of the resource.

The alternative is that the State would buy the water rights to establish those flows. Nonetheless, the costs are so high that this has been declared unfeasible. State organizations argue that they do not have enough resources to take ownership of the private rights because the price is so high: *"Of course, the State could expropriate, but the private parties can ask for the price they want, then where does the money come from to pay for those rights?"* (DOH Serena).

Ecological flow is considered a good choice but useless for the North, where there is no flow to take care of: *"No, there is no ecological flow, in other words that came out after all rights had been allocated. But in the South, yes, there are some rivers that still have rights to be given, so there it is possible, but there is an abundance of water there, here there is water scarcity"* (Cazalac expert).

Moreover, for some extreme drought situations, some associations explain that they change the flow of the river and conduct it from one channel to the next, with the aim of reducing water leakage: *"The thing that we do here is that when there is no water coming, for example 300 liters come instead of 2000, we know that the water will not be enough to reach the last part, because it is going to be absorbed and will not be enough, then the first canal is taken and the whole flow is led to it, and*

after that it is conducted to another one and so on and so forth; we do not conduct the water to the river, but only from one canal to the next." (leader Mostazal Monitoring Board).

In that case, in the center and to the north of the country, ecological flows would only have an effect for temporary or for non-consumptive water rights: *"Here, the ecological flow only had an effect for the ones who asked for non-consumptive rights, for example, if they ask for run-of-river plants, because at the beginning we had to leave water only for the canals and it could dry up until the rights were restored, yet today this is not the case, water must be left for the canals and also for the ecological flow. Besides for the temporaries, insofar as at the bottom of the river there is a spectacular estuary, then if the temporary rights could be applied without the need to leave an ecological flow, they could dry up the estuary, that is why they were asked for 1 lt/s"* (civil servant DGA Ovalle).

Change in use

One of the most controversial elements of the Code refers to the lack of restrictions on modifying the use of water rights. Water right owners can use this resource for their convenience, even modifying the initial use without any restriction. Despite this significant anomaly, the reform that was introduced only managed to establish one restriction, regarding the need to report the intended use at the time of requesting a right. However, this use can then be modified without any limitation.

The most common change of use in the North is from agriculture to mining. This is due to the "lt/s" being more profitable when used in a mining context:

> *"An exploitation water right for mining, I mean if the mining industry, it would be 100 times more expensive so… the farmer does not have the chance to buy an exploitation water right with that competition"* (DGA user organization national division)

> *"A water right for the mining industry is completely different to a water right for agriculture. First, the mining company asks for the right in a basin and takes the water away and uses it all. But in agriculture, the water is used in the same basin and all the poor irrigation, everything comes back to the basin, and moreover the watering does not last the 12 months of the year, it is not permanent and continuous, you water by season, twice a week, so the groundwater recovers. However, in the mining industry the water is taken continuously and permanently, every day of the year suck and suck, just like every water company. The use is*

completely different, but legally there are no differences, because when you ask for the water right, everyone asks for it to be permanent and continuous so they can sell it later" (DOH Serena)

Aware of the significant implications of a change in the use of water rights in a basin, farmers often directly oppose this kind of project, even though there is no legal basis to restrict it.

IMAGE 2: "MINING PROJECT INFURIATES FARMERS IN PAN DE AZUCAR"


Proyecto de minera irrita a agricultores en Pan de Azucar

Source: *El Ovallino* newspaper (09.10.2007)

Social and environmental costs are not taken into account when evaluating the efficiency of water use. This is looked upon as one of the worst problems of deregulation. In spite of the reform, the Code continues to encourage the use of water where it is more profitable. Across a broad range of the Chilean territory this means the mining industry: *"Currently the Water Code encourages giving the water right to the one that is more profitable. In that case, clearly in the North the most profitable industry is the mining industry. In other words, this cost is not assumed, it is not part of… the Water Code is strongly biased, it does not seek anything else, it does not point to an overall issue. The only thing it encourages is an intensive use of the resource"* (DGA user organization national division).

IMAGE 3: "LOCAL LEADERS WILL FIGHT FOR CHANGES TO THE WATER CODE"


SEGÚN INFORME DE EMPRESA SANITARIA

Si minera inicia proyecto, 30 mil personas quedarían sin agua

Source: *El Ovallino* newspaper. (03.04.2009)

Expectations of the reform and the role of legislators

A detailed analysis of the different interested viewpoints reveals frequently expressed doubts regarding the abilities of the policymakers to carry out the required reforms. The parliamentary

debate concerning the 2005 reform lasted more than a decade and the results have left a significant number of parties unsatisfied.

A common concern regarding the policymakers' work is the accusation that the legislators have investments that are directly affected by hydrological resources, for which reason the speed with which the amendments were introduced was affected. Another complaint is centralization of political decisions, resulting in a significant under-appreciation of the interests of other territories.

Among the key demands expressed for the reform is the need to modify the nature of water as a private property given in perpetuity: *"A constitutional reform was needed with relation to the nature of national property of public use and what is implied by it in terms of the concession of water rights that naturally, I mean from my point of view naturally, should not be given in perpetuity but should naturally be subject to inspection by proper authorities according to the limitations of availability of the resource characteristic of different ecosystems"* (*Concertación* civil servant, high government office).

During the last presidential term of the *Concertación* party (2006-2010), there was a debate concerning the necessity of reforming this aspect, including some sectors that demanded water nationalization. Nonetheless, this stance has not given rise to significant consequences, although in the agricultural context: "*A rumor started about agricultural reform to the water and about water rights being revoked and, of course, there are farmers that have a lot of political influence and there was huge pressure to stop the project"* (user organization head, civil servant CNR).

Overall, one may surmise that in the context of the legal framework, the different interviewees observe inflexibility and difficulties in modifying the structures.

5.2 Flexibility: Economic Regulations

Economic regulations define the conditions for trading water as private property. As mentioned, the Code does not establish sufficient regulations for the market, which has represented an important weakness. To address this problem, the user organizations themselves have seen the need to introduce internal regulations and rules to define transactions.

The economic rules involved in the management of hydrological resources refer mainly to the regulations that allow a water market to be founded. To a large extent, this is underpinned by legal regulations that establish the chance to sell and purchase both water rights and water volumes.

The importance of this opportunity is clearly reflected in the words associated with hydrological resources. The content analysis applied to every interview on this research shows that the words SELL and BUY (or PURCHASE) appear around 500 times with relation to water, while STOCK (or SHARES) has 212 references and MONEY 223.

It is common to see references in the interviewees' discourse to self-regulation within the water market, whereby State organizations would not have any influence. In general, it is assumed that private parties are autonomous when deciding how to use their own hydrological resources; hence, they do not have any limitations in carrying out their economic trading with their stock and water volumes. This self-regulation and the inability of the State's civil servants to interfere is reflected in the recognition of the head of the General Water Office that he obtains information about the cost of water through the virtual water market (DGA Ovalle).

An important change has been recognized following the introduction of the new Water Code. However, a market had existed since the beginning of the use of water channels, and it was only after the 1980 Code that it became possible to sell water separately from land, which has brought great flexibility to the market. However, the concentration of property has been rising in parallel.

> *Of course, there is a group in the middle, but 90% of our users are small and they have 30% of the water, that is the reality so the opposite situation could happen too.* (administrator, Limarí Monitoring Board)

The great difference and advantage of the market rules, from the point of view of some farmers, is that since the new Code it has become feasible to buy and sell water separately from the land, bringing great flexibility to the market. In addition, the status that the Code has given to water rights as private property has provided investors with security in relation to the use of the resources.

Moreover, due to the status that the Code has given to water rights as private and transferable property, there is an increased chance of investment because such investment involves less risk. In this context, and by virtue of the formalized water rights given and supported by the State, the market has been invigorated, leaving a great amount of transferable water rights available (Ovalle stockbroker).

5.2.1 Water Rights Market

This kind of market exists around the whole country, as previously explained (chapter 4). It is the oldest market, as a result of the selling of water rights since the 19th century ("water gifts" – *merced*

is an old-fashioned word for gift or favor). Nonetheless, after the division between land and water as a result of the 1981 Code, this market was invigorated around the whole country, and especially in the basins with scarce resources.

In the Limarí basin, the current cost of water stock can reach 8 million pesos. However, there is a certain range of prices, depending on the transfer limitations that exist and the legal conditions to which the rights are subject (whether they are "perfected rights[7]"). The cost of these rights always varies, due to there being no entity to set the price of the stocks; these are instead set by the market.

> *"The market sets the price. The prices are related to how much they are sold. Look, normally a good price, cheap is around 3 million for a stock, but by the example of the Cogotí reservoir where there is no water and each stock gives you 1500 mt3, the share cost is 6 to 7 millon pesos"* (illegal water stockbroker)

> *"The water exploiting rights are also distinguished if they are or are not "perfected". When they are not perfected they are cheaper. A "perfected" water right costs 1.5 to 2 million pesos more than the water right that is "not perfected". By virtue of that you are obviously avoiding the 6-7 month formality, which can sometimes last 1 year"* (water trading lawyer)

Although the water rights can be sold without being perfected, so they can be traded on the market, they must be registered in the Property Register. When this has been done, water rights can be treated as any other property or may even be used to guarantee a loan from a banking institution.

> *"In some basins which suffer from scarcity conditions, demand grows for rights that are generated by this market, which is primarily the sale and purchase of shares, water volumes, and mortgage rights. Many users levy the rights to a bank, and they mortgage them, they are property"* (CNR civil servant, user organization manager)

The Limarí basin was declared empty more than 30 years ago and from that time it has not been possible to register new water rights. The amount of water rights and the proportion of water volumes have been settled; therefore, water can now only be accessed when buying rights on the market.

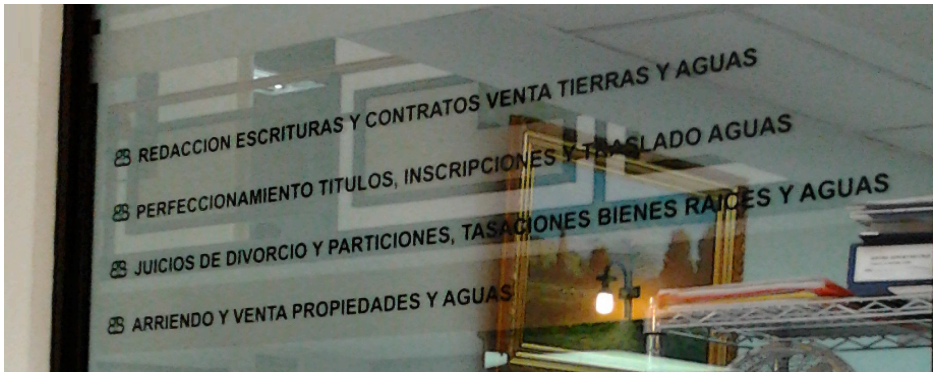
[7] The "perfection" formality takes into account the incorporation of legal characteristics from water legislation. When a water right is "perfected" it is possible to carry out the different formalities with the DGA (transfers, change of supply source) and also it is possible to apply for water benefits.

> *"As the basin is empty and the rights settled, the common sense is that all water rights are set and for that reason the only way to obtain them within the current legal framework, it is only through the market, by virtue of not having any other legal route to them"* (local university expert)

Due to these requirements, lawyers' intervention is fundamental for the operation of the market. There are now law firms that only work in water trading and legalization of water rights.

> *"The water exploitation right, as it is, is a property that has a registration which has a series of steps and contracts during the different stages of transfer, and all that needs, let us say, study, at least from the legal point of view"* (water trading lawyer)

IMAGE 4: LAW FIRM SPECIALIZING IN WATER TRADING



Photograph taken in Ovalle, March 2013

Finally, it is important to emphasize the common dissatisfaction shown by the interviewees concerning the high cost of water rights. Farmers identify that the price of stocks has significantly risen during recent years, making it ever harder for small and medium-sized producers to maintain their agriculture business. Owing to this, many countrymen state that they have had to sell their shares in order to be able to cope with financial difficulties. It is not normally possible for them to subsequently recover their stocks and reestablish their wealth.

5.2.2 Spot Market

This kind of market refers to the sale and purchase of water volumes. In contrast to the water rights market, the spot market only works in some basins of the country where there are enough facilities to store water and make water transfers, and where there are user organizations that support and administrate this kind of trading.

The most important spot market in the country is located in the Limarí basin. Due to the facilities of the Paloma System, the professional nature of the user organizations and precise resource management in the reservoirs, many water volume transactions are possible in the Limarí basin. Moreover, its reservoirs function as a kind of water bank.

Even though this market has grown, the information provided by the interviewees shows that not everybody can be involved in water volume trading. In addition to the difficulties presented by the high unit costs of water during droughts, there are cultural elements and issues relating to access to information that make it difficult for traditional small-scale farmers to take part.

> *"Small farmers have very limited participation in the market, in many cases these people cannot be involved because they are at the highest part of the basin and do not have any access to the facilities to channel the water. Thus, it is not related to the fact that they do not want to participate, but instead they cannot; that they do not participate culturally is one thing, but they also cannot transfer their rights easily. Moreover, there are restrictions from the point of view of information and communication, these people are not connected; they know what the organization officer says, but they do not have the chance to enter the online market"* (local university expert)

At the same time, agriculture companies below the level of the reservoir (this is a limited watering area) have a significant trading level, because in many cases it is more profitable to buy water volumes, particularly during drought time.

In the case of farmers who own water rights on the reservoir, an equivalent strategy to the sale and purchase of water volumes is water renting. This is a very old practice, dating from the beginning of intensive production within the basin water, when water renting started among neighbors.

> *"In the areas where there are no reservoir regulations, what they trade is not the water volume, it is a flow that changes with the passing of time, so they can rent the water exploitation right for a whole season, but they can start with 1 lt/s and later 0.3 lt/s by stock, so it has other restrictions; the difference between the legalized and the non-legalized area is very important"* (local university expert)

After the enactment of the Water Code, this old practice has continued but is now within a legal framework. These kinds of transactions are fundamental in contexts where there is no chance to join the water volume market.

5.2.3 Water Trading

According to our interviewees, in order to keep trading costs at a low price and to have the chance to develop a water market it is necessary to have sufficient facilities to perform water channeling. This allows hydrological resources to be conducted to areas with higher profit per cubic centimeter of water.

The biggest traders of water in the area are the large agriculture companies. Apart from having more supplies, which allows such companies to buy water though it is expensive, they have huge volumes of permanent crops, which must be maintained during times of drought in order to avoid a large loss on investments and at the same time fulfill existing export commitments.

> *"The ones who used to buy, as usual, were the companies that were there; just think that they have contracts with shipping companies and people who must honor contracts, then they cannot say 'you know I am going to have less production, now I will stop watering 50 hectares', that is impossible: they must buy water, they have to provide, as I was saying, for the deficit by buying more just in case, and that happens mainly because they paid those high costs when they bought, for the small ones there was not any chance"* (electronic market administrator)

On the other side, the vegetable farmers (who work with temporary cultivated fields, mainly growing vegetables) are normally the ones who sell water. This is because it is more profitable to sell the water of the season than to seed during a time of drought.

> *"The vegetable farmers say: in other words I cannot buy water at a cost of 140 pesos if what I am planting is not profitable… that is why I do not plant, and instead sell the water"* (electronic market administrator)

5.3 Flexibility: Major Regulators and Small Regulators

To continue with the theoretical approach developed in chapter 3, we acknowledge organizations that are part of the regulation and administration of access to hydrological resources as important aspects in ensuring the flexibility of the system. When these organizations work at a general level, we call them major regulators.

5.3.1 Involvement of the State

The primary regulators are involved with the current institutional framework and legislation established to govern water access. In addition to legislation (summarized in the section concerning legal regulation), the institutions responsible for water administration are the main regulators (chapter 4 presents an institutional description of these State organizations).

According to the evaluations of the different stakeholders, the ability of State organizations to govern access to hydrological resources is widely questioned. On the whole, most critics point to weak assistance from State organizations in the regulation of access to water. Additionally, farmers adopting a pro-market position claim that the market is not properly regulated; they identify market deregulation on behalf of the State as an important problem, as it leaves the decisions affecting the market in the hands of private parties.

> *"particular situations happen because of the lack of rules in the market, when in practice the State should be the market regulator and would be able to ensure the more efficient use of water, depute and transfer everything to private parties, and finally private parties distort market management due to very specific situations"* (company administrator 3)

One of the problems identified by civil servants from State organizations relates to their own inability to intervene in the market, to reject changes in the use of the resources and to restrict the number of seeded hectares according to the shares owned.

> *"There is not any chance to limit the changes in use of water rights. Nor can we restrict the cultivation field size area. This is a very problematic situation, because we cannot restrict farmers, in other words, if a farmer has 20 stocks and imagine those 20 stocks are enough to water 20 hectares, this farmer could absolutely have these 20 stocks and plant 40 hectares" (*DGA civil servant, Ovalle*)*

Civil servants from State organizations accept that their role should be providing the conditions for the market to operate as well as possible and to be extended to other basins. The Limarí basin provides an example in this respect. Among the conditions necessary to enhance the operation of the market are the regulation of water rights (rights legalization restructuring, registration in the Property Register, etc.) and the improvement of access to information. An example of this is the electronic market, since this initiative is supported by the CNR with the aim of publishing the information and then showing the prices in the market.

At the same time, the State takes part in water management at an economic level in two ways: benefits and large investments in reservoirs. The benefits vary according to the size of the farmer's

business, but the ones who receive the most are larger farmers and agriculture companies. This is due to the fact that in order to have access to benefits, it is necessary to have the capital to co-finance the investments.

But the most important investments in terms of hydrological issues are connected to investment in reservoirs. There have been large investments in this area, but all during the first part of the 20th century. According to the point of view of many of the interviewees, reservoir investment has not been sufficient in recent years.

In this respect, one may compare two contradictory points of view which come from the State and are related to reservoir investment:

> *"Chile is an undeveloped country from the hydrological point of view, that is why in other words, the investments during the last 50 years have been quite basic"* (right-wing civil servant, high government office)

> *"How you can justify the separation between water and all that stuff, they justified it saying that it was the only way for the country to grow and then big investors could come. But the most incredible thing is that the largest investment, in the reservoirs for instance, it is made by the State. Later, the users did not pay a single penny. Deep down the State gives away water and facilities to them. What is more, now private parties are the owners of the reservoirs, imagine that they spent so many years when private parties did not pay for maintenance, it was better for the State to give the reservoirs to them, so they at least can maintain them. Even though, after that, when there is a problem, they ask to the State for solutions"* (DOH Serena)

As it is possible to observe in these speeches, the right-wing civil servant considers that there is not enough investment. Meanwhile, the left-wing civil servant (the latter) argues that the State has invested heavily in facilities and that both these facilities and water rights have been given to farmers for free.

An important State enterprise to enhance market conditions has been the State-supported (CNR) creation of the electronic market. Nonetheless, the main market-related legal regulations concern user organizations, which are the ones who set the boundaries on water movements.

Among the main roles of the State is the audit of private parties in order to prevent water theft and misappropriation related to its management.

IMAGE 5: DGA INTERVENES IN HUATULAME RIVER DUE TO IRREGULARITIES IN WATER EXTRACTION

Source: *El Ovallino* newspaper (15,07,2007)

The interviewees' comments show that the roles of the main State organizations relating to access to hydrological resources are as follows:

- DGA: water rights regulation and audit of use
- CNR: benefit to encourage efficient watering
- DOH: building and maintenance of reservoirs

However, it is also noted that since there are faults within these organizations, it is frequently necessary to seek the resolution of water-related conflicts in the courts. Hence, a litigation culture has developed around water right-related conflicts, with litigation becoming a commonly used tool, mainly employed by user organizations and farmers with greater financial resources.

IMAGE 6: COURT RULES IN FAVOR OF WATER RIGHT HOLDERS FROM RECOLETA RESERVOIR

Source: *El Ovallino* newspaper (12.11.2008)

One of the important findings of this research was the identification of the market as the main regulator of water access. Entrepreneurs, lawyers and stockbrokers all agree that the market is highly deregulated.

> *"The Oversight Board is a water administration organization, but neither has power over them nor can decide over them, because the ones who can really decide are the owners and the DGA does not meddle. It is a profoundly deregulated market"* (lawyer for entrepreneurs)

Thus, the interviewees emphasize the lack of major regulators as the main problem in the management of hydrological resources. In this sense, the absence of legal regulations for the basin, together with the limited involvement of the State, represents one of the main difficulties in achieving sustainable management of hydrological resources.

5.3.2 User Organizations

In the Chilean model, user organizations have the important function of hydrological resource administration. This is established in the Water Code and it has been promoted by State organizations during recent decades. In fact, the interviews conducted with State civil servants show, the considerable efforts from *Concertación* governments to strengthen user organizations. The aim has been to try to encourage community administration of the resources, although in legal terms water rights are individual.

From this point of view, user organizations have performed an important role in hydrological resource administration and in establishing rules for market management. However, both entrepreneurs and large-scale farmers have heavily criticized the conditions and regulations that these organizations impose on the market as a whole and on water transfers in particular. According to these groups, the regulations betray a lack of knowledge from leaders and administrators and would only hinder the free market (company administrator 3).

In this regard, one of the most critical aspects has been that the DGA frequently authorizes permanent transfers that are later questioned by the user organizations, which deny them because they consider the rest of the user organizations would be harmed.

> *"I am the first to check those transfers and the last word is given by the DGA, if they say that it is transferred, it is transferred and I have to accept it; but I am the first who can oppose along with the Board lawyer, because it harms others and we are here to safeguard everybody's interests, everybody"* (user organization administrator, Hurtado river)

Concurrently, experts consider that the role of the OU has been very important, precisely because they are the ones who set the boundaries for water transfers and establish few rules for its development.

> *"The organizations started to regulate this movement, because they realized that when a right was transferred from a particular channel, the channel would continue having the same area and it was not flexible, it did not grow smaller, then the costs rose and the losses from leakage were maintained or increased; so they perceived that it could be just like that, but there must be a way to govern the transfers, by pointing out that these could be moved in some directions and in some others could not. By this time, certain rules started to develop and there was some narrowing of the free-market and multidirectional model"* (local university expert)

The user organizations themselves established that purchasers of water volumes must be the owners of water rights in the basin. This was implemented with the aim of reducing opportunities for water stockholders, who are the stockbrokers involved in the sale and purchase of water, taking advantage of privileged information and engaging in speculation based on prices.

Meanwhile, the involvement of user organization administrators and leaders in water transactions was also subject to regulation, on account of the obvious conflict of interest among leaders, administrators and entrepreneurs. Some people who used to work in user organizations and who had access to privileged information would do business with entrepreneurs. To address this issue, it has been established that temporary transfer requests may only be made by the owners of water rights, or by administrators of agriculture companies that have obtained the corresponding consent.

But these regulations only relate to annual amounts or to the water volume market (spot market), it being considered that in legal terms it is not feasible to establish conditions for the sale and purchase of water rights.

> *"The transfers of title deeds are defined according to the DGA rules and the Water Code. Because it is a title, it is yours. On the amounts there are interventions, there they can establish the rules, but not on the property. It belongs to you and you do not need to ask for permission either for selling or for purchase or anything else"* (Ovalle stockbroker)

User organizations have also set rules defining fines amounting to percentages of water volumes for the transfer of amounts. These percentages correspond to the estimated loss occurring during transfer. However, they are widely questioned by users.

> *"I would like to know what the purpose of this is. There you have one of the big businesses of this administration. I transfer water, they make me pay it at a high cost and I do not know where that water is going to. That is their decision, but they do not explain why. So the organization can say we were transferred 100,000 mt3 and we received only 66,000 from that guy, nothing more, and the rest can be distributed. Because it is not only me, there are many who are punished too, so there is a considerable volume"* (mid-size business farmer 2)

Within this context, there are State civil servants, farmers, and leaders who highlight the regulation introduced by the user organization, by reason of which the market operates with a degree of order. The civil servant responsible for the Ovalle DGA, for instance, states clearly that if the user organization had not established regulations, the market would not be feasible.

> *"In order to have a water market there is some kind of separate regulation, additional rules have to be established apart from the rest of the country. If you*

> *pay attention, you will see that the user organizations themselves introduce these regulations because they have to preserve order, if there were not these additional rules that each organization possess and we only had the Water Code, it would be impossible, unfeasible to establish this market"* (DGA civil servant Ovalle)

Conversely, an evaluation of responses from experts and civil servants from State organizations clearly shows that the existence and proper functioning of the user organization is viewed as a key component for the reasonable administration of hydrological resources. In fact, the mere existence of the user organization is associated with a better administration of the resource, as the basins with more water-related difficulties are those without an operating user organization.

> *"If you go to the more struggling basins, this will always be associated with the fact of not having organizations and having high demand. The organizations in some way put pressure on public associations that are responsible for the issue. That is how we get an opposing party. And the Oversight Board participation in some basins has been essential to maintain administration of the resource"* (CNR civil servant, user organization head)

Ultimately, it is important to highlight that it is the user organizations that control the reservoirs. Though built with State money, reservoirs are subsequently given over to users so they can manage their own hydrological resources.

IMAGE 7: LA PALOMA ADMINISTRATION GIVEN OVER TO WATER RIGHT HOLDERS

Source: *El Ovallino* newspaper (13.09.2008)

5.3.3 Entrepreneurs

Water transaction entrepreneurs have played an important role for many decades in the Limarí basin. Information regarding available water rights and water volumes is crucial for buyers and sellers to be able to trade with each other.

Whereas such entrepreneurs represent an old tradition in the area of this basin, the legitimacy of this practice is also questioned. There are several criticisms of these entrepreneurs, who in this area are called stockbrokers (*corredores*), but the less formal ones tend to be singled out. Yet this kind of service is not considered illegal: *"The stockbrokers are not banned, it is not illegal, I am not sure if it is 100% legal either, but this is how it works"* (CNR civil servant Santiago).

In the main square of Ovalle, the capital city of the province, it is possible to find these traditional stockbrokers who are looking for water rights purchasers and sellers. They place themselves on a bench or in a nearby cafe. The farmers know where the stockbrokers are and that they can gain access to the water (volumes or rights) that they need through the stockbrokers.

IMAGE 8: STOCKBROKERS ON OVALLE SQUARE

Photograph taken in Ovalle, March 2013

During recent years and by virtue of an enterprise from experts and the CNR, an electronic market has been established in Ovalle. The purpose of this project was to establish a legalized system, permitting transparency in terms of market information and thereby lowering trading costs. It is an initiative aimed at improving access to information on market prices. This enterprise has indeed made prices transparent, with the prices of water volume trade posted weekly online.

IMAGE 9: ELECTRONIC MARKET INTENDED TO MODERNIZE WATER TRADING


Buscan modernizar transacciones
del agua con mercado electrónico

Source: *El Ovallino* newspaper (15.07.2009)

Many farmers use the electronic market as a source of information in spite of not using it for the trades themselves. The prices that are published work as a general reference point for water purchasers and sellers. The response to the electronic market has hence been very positive, particularly from the companies that are the main users of the electronic market and that value the security offered by this legalized institution in comparison to traditional water stockbrokers.

> *"Conversely, in this way it is safer. Look, I have an amount of water, they offer me a price, as I have researched I say this is the cost, after that they tell me if there is anybody interested at this price or if there are any sales I can apply, then tell me if there is anyone interested in my water and if they accept the price that I offered or if they thought it was expensive, I say to them how much I can discount, but then I do not worry and I know this way it is safe, I will not have problems at the time of being paid or if they give a credit check, whatever"* (small farmer 1)

During its early years the service was offered for free on the grounds that it was financed by the CNR, but the same CNR later requested that charges be introduced. Since 2013, the electronic market has operated with its own rates and the organization is self-financed as a result.

> *"The National Water Commission told us we have to charge and we do not have big problems with doing so, people are prepared to pay for the service"* (electronic market administrator)

In general, farmers seem to be satisfied with the operation of the market and that is why they pay for the service. The main users are large agriculture companies, as the extent of their trading means it is essential for them to reduce transaction risks.

> *"We have been very successful and well-received by companies. At the beginning there were so few and now there are a lot of companies that clearly prefer us. They are the ones who purchase the most"* (electronic market administrator)

5.4 Flexibility: Cultural Evaluations

With regard to the elements that define the flexibility of the system, there are varying appraisals concerning hydrological resources, property rules and forms of administration. With the aim of observing these appraisals, we have divided them into the three groups that were most prevalent in the interviewees' responses: the water business, related legislation and the status of water as private property.

To compare the different perspectives, we divide informants into: (a) interviewees that are part of State organizations; (b) farmers, user organization leaders and entrepreneurs; and (c) experts and members of civil society.

5.4.1 The Water Business

The interviewees' descriptions demonstrate that water value is directly related to its estimated economic use. The following diagram shows a comparison of the views of the different parties regarding water as an economic resource and its relation to business.

TABLE 5: WATER EVALUATIONS

Topics	State organizations	Users, leaders and entrepreneurs	Civil society and experts
Water scarcity and price	*"Yes, here the water price has risen, indeed… as this place it is, the growth of the interest for certain farming, the water price will continue rising" (DGA Ovalle)*	*"As the place has grown a lot, yes, the growth during the last 30 years in the area has been great…I believe around 3 times what I used to plant. Then the water has become now… in fact it is more expensive than the land" (mid-size farmer)*	*"When there is little water, we have to distribute it in an efficient way, the best way of doing so is through an established system of prices and a market" (pro-market expert)*
Water rights as stocks	*"There is full awareness about the intrinsic value of water, the economic value that the water has" (DGA local civil servant)*	*"Water is a great business, it allows you to sell quickly and at a good price, rent or even mortgage the water" (water trading lawyer)*	*"Water can even be confiscated. Farmers mortgage water rights to ask for loans. Water shares are money. It is taxable at a capital level. It is property as any other. It has no restriction. It is capital. (civil society Ovalle)*
Actions as resources	*"Here you can store water, the reservoirs work as a water bank. Farmers store water volumes as if in a checking account, in fact they can store it from one year to the next" (DOH La Serena)*	*"The water business is very good. Even for us, if you are a lawyer you do not charge in money, you charge in water stocks. I have water shares without land" (water trading lawyer Ovalle)*	*"If a person has a piece of land and has 6 or 8 water shares, and receives an offer from 8 to 10 million pesos for one water stock, sell, leave his/her land to dry, sell the water and it is over. Then, it is true than in many valleys like this the same thing is happening, they are dying because there are no people to work, to make the valley sustainable"(civil society Ovalle)*
Water trading	*"You were going to ask the Board president: "Hey, do you sell water in here? No, we do not sell here, people keep their water". But you go and check the Property Registry book and there are lots of sales from the same people to the big companies that are now located there. So, if after that you go to the same water communities, they say: "no, we do not sell here", or it is still seen as something wrong: "someone who sells water, so wrong". (DGA national division user organization)*	*"So this lady has around 200 water stocks and she does not seed anything and the land is rented to other users and the water does not pass. Then, every year she sells the amount of these 200 water shares, she sells the whole amount, she rents the water… she is profiting without any movement. She does not have a single plant and uses the water for her own benefit" (mid-size farmer)*	*"People do not like to say they sell water. If you ask a farmer directly if he has sold water, he would say he has not. There is an idea of water as a universal right and that is not tradable. There is resistance, but of course, they do it anyway, because they can earn a lot. It is negatively seen, that is why they do not like to say that they are sellers" (pro-market expert)*
Importance of water	*"In terms of the landscape, if you look, it is clearly stated where to water and where not, because vegetation changes, the soil looks different, it is evident where they are watering and where they are*	*"Look, do you see those trees that look dry on the hill? Those are like that because they have suffered damage from frosting during recent years and also because of the*	*"Water is important for the whole society, because the economic activity that creates the most working opportunities is farming. That can be felt, years of drought and sales go down, everything goes*

	not and that is part of the landscape, it has been integrated here forever. It is part of their culture. Channels are the limits, watering areas, seeded areas, farming, reservoirs, rivers. It is lived, it is seen, it is felt, you can feel it in your pocket, it is completely essential" (DGA Ovalle)	*lack of water. Trees dry out" (mid-size farmer)*	*down, the market weakens, services too, many things happen, when there is a bad time for farming it goes to the heart of Limarí; if agriculture suffers, Limarí suffers" (local university expert)*
Quality of water	*"In the old times, farmers fertilized with products that filtered in too fast and the plants could not absorb it, then the rest polluted groundwater. Now they use less polluting products" (INDAP Ovalle)*	*"Pollution issues are the urban centers close to the channels. People are dirty, they come and throw waste in the canal, because the water takes it and it is not seen. There was also more complete research recently about water quality in the basin and the truth is that the results were not that awful" (Camarico administrator)*	*"With the passing of time water has been contaminated. If you see the dam after rain… It is just that one of the things that has been done is to abuse fertilizers, pesticides, and stuff like that. Vine farmers above all. Now less damaging products are in use, but anyway they still pollute the rivers" (CAZALAC expert)*

In spite of the possible contrasts among the different kinds of parties, it is clear that there is an agreement on the economic value of water. The high cost of water in the area, either as stock or as water volume, is directly related to its scarcity. Due to the absence of State regulation on the economic value of water, prices change only because of market conditions and the strength of supply and demand. As a result, the systematic rise of water cost is associated with the rise of cultivation in the area and the consistent increase in cultivated areas.

Amongst the interviewees' assessments, it is interesting to highlight that water is associated with economic concepts such as stocks or shares (regarding water rights) and checking accounts (referring to the opportunity to retain water volumes in the reservoirs). In the same way, the opportunity to use water rights as backup for credit requests (the chance to mortgage) is crucial in understanding the economic value of this resource.

At this time it is understandable that general access to water and ownership of hydrological resources is related to economic wealth. As the image below implies,, water is associated with other resources like oil.

IMAGE 10: "THEN THE SITUATION WOULD BE IMPROVED, THAT AFTER LOOKING FOR WATER FOR SO LONG WE FIND OIL"

Source: *El Ovallino* newspaper (02.07.2008)

Without denying the importance of the economic value of water, there is also an important symbolic element, which is the relationship between water and life (and, hence, productivity). This is understandable because the main economic activity in the area is agriculture and as a result of the semi-arid nature of the geographical terrain, watering makes it possible to develop different kinds of crops.

IMAGE 11: THE IMPACT OF WATERING ON THE LANDSCAPE

Photograph taken in Caren, March 2012

The photograph clearly demonstrates the difference between the soil that can be watered and that which cannot. The green color throws the distinction into sharp relief. The boundary between green and gray or brown is the borderline separating the areas with and without water. Where there is water, there is life.

One of the aspects closely related to water value in a scarcity context is agriculture as a source of employment. In the north of Chile, whereas agriculture is not the primary source of income (in many places mining is the most important), it is the activity with most labour mobility and creates more work.

Another interesting aspect is the relation between water and business. The most traditional farmers do not like to admit they sell water, because it is not socially acceptable to earn money trading water. Despite this resistance, farmers do sell both water volumes and water rights on a regular basis, on the grounds that the money they can earn by selling is significant.

Finally, as regards water quality, although a water pollution problem is identified, it is not seen as an important matter for the basin.

5.4.2 Legislation

Analysis of the parties' discourse regarding current legislation and its suitability as a regulatory mechanism for water administration reveals a generally negative view but with different levels of emphasis. To depict these differences, we group parties into State organization members, users and user organizations, and civil society and experts.

TABLE 6: LEGAL REGULATION EVALUATION

Topics	State organization	Users, leaders and entrepreneurs	Civil society and experts
Water property	*"First of all, here water does not belong to the State, water belongs to private parties, because private parties can ask for a right and the State gives it in perpetuity and inheritably, I mean, even when they die the right stays in private hands" (DOH Serena)*	*"There is not any kind of restriction on stock trading, there cannot be, at this moment and according to this law, each owner can do whatever he/she wants with his/her water. It can be sold, it can be rented, the Board cannot say a word, nor the State" (mid-size farmer 2)*	*"First of all, here water does not belong to the State, water belongs to private parties, because any private party can ask for a right and the State gives it in perpetuity and inheritably. I mean, even when they die the right stays in private hands" (civil society Ovalle)*
Water/land division	*"Second of all, and this is really serious, here the water code from 1981 divided the water from the land and that cannot be because that causes the environmental problems" (DOH Serena)*	*"It has slightly facilitated businessmen buying water at other places and where there are microclimates, if not, it would not be possible to bring water from other places to more productive areas,*	*"This code, from my point of view, incorporates something that makes the water issue vulnerable, which is the division of water and land. This gives rise to many abuses" (national expert)*

		making water lost at some places when it is needed; here, I think this also has helped" (small farmer 1)	
Main access	*"It is unlike other countries where the basin organizations are public, collegiate, and decisions are taken according to the common property and so certain areas receive priority. For instance, drinkable water is saved. Here it is not, here rights can be transferred where there is the biggest investment" (CNR civil servant, user organization head)*	*"It is not possible to apply the same Water Code for everybody, the same for people from the south of Chile and people from Arica" (mid-size farmer 3)*	*"There is no priority, as water has an owner the State cannot say: this is priority for drinkable water, so you have to stop producing" (Cazalac expert)*
Ability to cope with scarcity; lack of powers	*"We have applied several decrees of scarcity… we are living an exception that is becoming a rule. So there you wonder: Does the Water Code give an answer? I think it does not" (DGA national division user organization)*	*"If the government produced draft legislation to be passed and asked everyone who owns a water well or that is building one, because of course they do not have water and do not have any other form to water their crops, you have a deadline, extract water from March to July, an amount of liters per extraction, that could be a solution" (mid-size farmer 2)*	*"We have to modify article 19(24) of the Constitution relating to the delegation of authority to concede water rights, in other words the transfer of the property, and where there are political influences that are creating discomfort for citizens because of the water scarcity" (civil society Santiago)*

It is important to highlight that large-scale farmers and agriculture company administrators see weaknesses in the Water Code but at the same time emphasize important advantages to this legislation, apart from the opportunities it produces for agricultural exploitation. Among these advantages are the chance to invigorate the market, which will make a bigger number of rights available, the opportunity to transfer water from a more profitable source, and the security given to this form of property.

Also worth noting is the difference in the views of political leaders, depending on the wing they represent (political representatives from the current right-wing government and from the former government, which was left wing, were interviewed).

The right-wing political stance highlights the chances given by national regulation to grow private investment, allowing the State to be free from constant spending on the issue. The view of the left-wing leader, meanwhile, highlights the deficiencies of the Code and the narrow scope for State organizations to act in order to confront problems relating to hydrological resources:

Right-wing representative: *"in Chile when you bring the project to an investor you say; look, I have water, I have energy, I have land. Then, you give them a concession and you give it all and they pay on their own, and that is how you increase your income, if the State stays out of the issue"* (right-wing civil servant, high political office).

Left-wing representative: *"when there is a regulatory framework and market conditions, civil servants are required to respect that framework and consequently the framework for action is quite limited"* (Concertación civil servant, high political office).

The participants compared above both held high political office relating to hydrological resource management during the period in which their party was in government. It is clearly important to recognize the different values that inform the beliefs of each political party.

To conclude, another criticism of the legislation points to the lack of influence from authorities in addressing the abuse of hydrological resources and the spread and intensity of exploitation. Legislation does not confer any power on the State to establish limits for users: *"well I think this is natural selection, the only thing that will force farmers to stop seeding is a drought. I believe, I mean it is painful for people, it is complicated for me, because of my responsibilities, but there is no way to set a limit to the number of hectares they plant. The only way is natural selection, in other words the one who has to live is going to live, and the one who was buying water just because is going to understand that what he can really plant is less than he thought, a half or a quarter"* (DGA civil servant Ovalle).

5.4.3 Common or Private Property

The final central elements in water value concern property and the kind of property that is associated with water. Based on the economic and legal rules connected to water access, the ownership of water incorporates the management and distribution of and access to hydrological resources.

Although hydrological resources are recognized in the Water Code as national property, most interviewees agree that water is private property. Those maintaining that water is national property admit that this would only be on paper because through water rights, which govern access to hydrological resources, it is possible to presume water is a private property.

TABLE 7: COMMON OR PRIVATE PROPERTY

Topics	State organizations	Users, leaders and entrepreneurs	Civil society and experts
Water owners	*"In other words the law says that water is yours, you register your property in the Property Register, and it is your water so is like having a house. From the legal point of view, it is theirs and that is how they get it" (DGA civil servant Santiago)*	*"How do they suppose they will tell me what to do, it is my land, it is my water... I can do whatever I want" (large-scale farmer)*	*"That is right, they know it is their land. Although the first instruction is that water constitutes governmental property and what you have is an exploitation right, people see themselves as owners and that is it, it is their water. They do not distinguish between*

			an exploitation right and water itself" (civil society Ovalle)
Water bank	*"The Oversight Board has everything under control, it is like a bank that takes away your money so you do not lose it and gives it back to you according to the rules" (DGA Ovalle)*	*"Another innovation is that now we have begun to send the account statements by electronic mail, because there are lots of people who already use it, and many who operate in Santiago, but above all we send them to the companies" (Camarico administrator)*	*"Something else, I do not know if you knew that in here you can keep water as if in a checking account. Moreover, you can keep it from one year to the next, you can even sell this saved amount of water" (CAZALAC expert)*
National property	*"In the Water Code the resource is assumed as a national property of public use, but at the same time it is alienable. It is some kind of concession, but is really difficult to bring an end to this concession. At this point, the State would have to expropriate the resource and that is justified only under certain conditions and up to this time it has not happened" (CNR civil servant, user organization head)*	*"Nowadays water does not belong to the State, there are other owners and in this area where water is scarce, its rights are in the hands of people with the money to buy the stocks, it is that simple" (small farmer 1)*	*"A national property of public use, which is extra-trade, unsuitable as property and untradeable; it takes its value indirectly through the rights upon it. The right is not applied if society does not agree, in other words because of transitivity there is an estimated value for the scarce resource and that appears to me as an interesting view of the model and institutionality we have nowadays" (local university expert)*
Origins of water property	*"Before '81 there were rights, but these were not separated from land. Water rights have always belonged to private parties, but before the State used to be more influential and had more powers. On the contrary, now it does not, the State can pass a water scarcity decree or declare an agriculture emergency, but the damage to the party that loses its rights must be paid for by the State, they have to compensate them" (DOH Serena)*	*"Formerly that was the idea, that one hectare of land was a water stock that was the unit of measurement, because it was divided according to hectares. Besides, water used to be called 'watering hectares'" (Ovalle stockbroker)*	*"At least big farmers always say 'I have this flow, I had the channel and my grandfather also had it, this water has always been mine'. Later, when expropriations started during the Agricultural Reform, they also said 'this farm had this amount of water' and nobody changed it, nowadays it is divided into many plots and the right given is proportional to it"(Cazalac expert)*
Self-regulation by private parties	*"But this is what we have to do, we do not have any other option, seeing that the governance system promotes private resource exploitation, it is not on the track of common property, but rather on the track of private property. So, there are instruments to promote private exploitation. Though we know that this is going to bring us problems in the future, we cannot do anything else" (CNR civil servant, user organization head)*	*"When there is already an Oversight Board, it is already regulated and they are almost autonomous on the decisions, even the DGA has nothing to do to interfere" (leader, Limarí Monitoring Board)*	*"It is an absent State, not only from the assessment point of view, not only assessing the use of the resource, that is the point, because it is a national property of public service and we gave the State the legal authority to be responsible of it, so it is their work and that has weaknesses along the whole territory" (local university expert)*
The private culture	*"In this country the issue on private property is so entrenched, your property, your land, your house, your water... that you do not see what is collective, the most important*	*"How do they suppose they will tell me what to do, it is my land, it is my water... I can do whatever I want. I mean this water is mine. The idea mentioned in the Code*	*"It is so entrenched that in those areas there are many people who still think that having a water right is connected to the plot, so it is part of the land, it is part of my activity, I have it integrated into*

	thing is yours. For that reason, anything the State can do is only suggestive, nothing more" (DGA national division user organization)	*about water being national property is like showing respect for the country… In other words, if I want to use it I do it and it is only mine" (large-scale farmer)*	*my routine. In my opinion the ownership of water has been established in the area" (local university expert)*

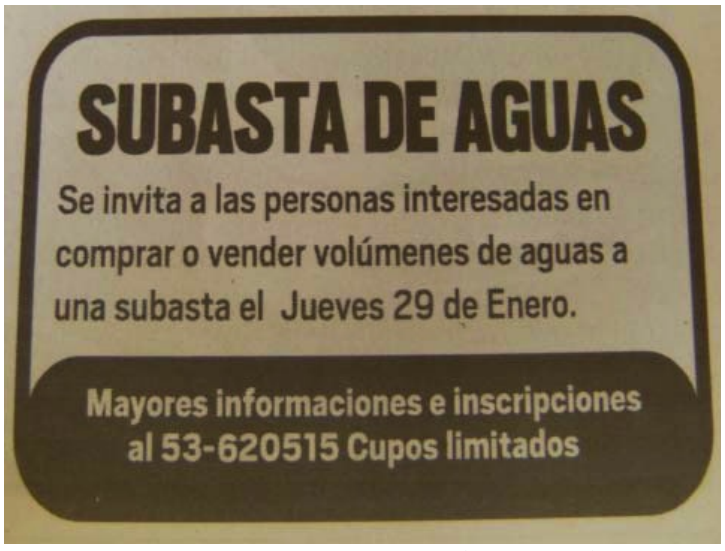
Although there are differences among parties about water property and who it belongs to, there is general agreement around the idea of national property of public use as mentioned on the Water Code, but in practice there is also a common impression that water is private property. This idea originated prior to 1981, although after the Water Code the opportunities to trade water were multiplied.

> *"…everybody knows that water belongs to them, some by use and others because they have water stocks. A continuity that started 4 to 5 generations before assuming water belonged to them, and now they have legalized it and say 'I have 32 water stocks' that in the past may have been 28 or so. And the old man knows the water belongs to him, indeed it does belong to him, although what belongs to him is a water exploitation right and not the water, but people do not see that"* (user from above reservoir)

Even those who do not know that water is separated from land still see water as private property. It is possible to identify ideas of water property from the most traditional to others, likewise coming from companies and large-scale farmers, who hold their own water savings, in the same way someone holds financial savings in a bank.

Within this context, there are daily water trades in the basin through organized water rights auctions.

IMAGE 12: WATER AUCTION. PEOPLE INTERESTED IN PURCHASING AND SELLING WATER VOLUMES ARE INVITED TO COME TO AUCTION ON THURSDAY 29TH JANUARY



Source: *El Ovallino* newspaper (27.01.2009)

The different and varying perspectives outlined above demonstrate the idea of water as private property that has been established among farmers. Regardless of their particular emphasis, farmers of all sizes share the idea. Likewise, civil servants from State organizations involved in water management also see it as private property, dismissing the declaration of water as national property in the Water Code: "*The State has nothing to do, because it is real estate, something you own, it belongs to you. It is a lie to say that it is property of public use, a lie, a lie"* (DOH Serena).

This has happened because the Code creates an ambiguous situation, where water is national property of public use but there are also individual private rights. Water is supposed to be a national property of public use, but at the same time it can be traded. However, this problem is not the exclusive responsibility of the Code, because on its own it would not make a great difference to the idea of water as private property, which was already culturally established.

> *"Water, in truth, in practice is still a national property of public use, it was given to people as an exploitation right so they could use water according to their own needs and for that purpose they had to fill in a request form, the state evaluated if the water was available and if it was, then it was given to the person and then the private property was given, taking the right with an actual registration in the Property Registrar"* (regional DGA, civil servant)

One cross-cutting evaluation is that the constant absence of the State lessens its control over hydrological resources in the country. The causes include the lack of State powers and the restrictive interpretation of the Water Code. State civil servants maintain they only have tools to promote the private exploitation of the resource.

> *"When the State gave water use to normal people, it gave them everything, even the control over how it was going to be was lost, the State lost powers on the administration of the hydrological resource; essentially the state tried to get rid of everything to invigorate the market, it tried to be very small and give away most resources to private parties. So we cannot say or do anything, only in a catastrophe if there is no water, I believe then we would have the ability to administrate what is left, if there is anything left"* (regional DGA, civil servant)

5.5 Collaboration: Horizontal

As set out in chapter 3, the ability to connect the different elements of a system is an essential quality to develop resilience. When we consider social systems, this connectivity is directly related to associativity and to the different appraisals with regard to it.

There are different dimensions where distinguishing associativity in relation to the access to and use of hydrological resources. Traditional associativity, user organizations and support networks figure among the key types of associativity.

5.5.1 Traditional Associativity

It is possible to identify a tradition of collaborative action from the interviewees' discourse. In the past, these traditions were very important for farming activities and for the administration of water channels. Yet most of these activities have disappeared, and only a few of these traditional associativity actions continue to be practiced.

One of the activities identified as community work is channel cleaning, which is organized a couple of times during the year by association members with the aim of cleaning water channels to allow their proper operation.

> *"For channel cleaning each one cleans its own front, that is, for every channel, each farmer cleans his/her own front, because channels have common places. That is why it is called a community, these are cleaned with everybody's help"* (leader, Mostazal Monitoring Board)

Another traditional activity maintained in some places is the *Mingaco*. This word describes the practice when farmers harvest with the help of neighbors, family members and friends, giving each other support through the supply of a workforce. However, this activity is almost extinct.

> *"When the task is set, a group of people assume it and then they take turns among neighbors. It was very common before to see this community work, it was a celebration, there was a feast later which attracted people to the thresh"* (mid-size farmer)

> *"Here we called it Mingaco, someone had lots of peaches and to peel them they said 'let's have a Mingaco', they prepared a feast and a celebration but they peeled the peaches during the threshing season. At the end they would eat and after that they would go somewhere else and thresh. But now those things are not done anymore"* (community leader)

This kind of associativity is ever less commonplace. All interviewees agreed on the fact that these activities are disappearing. Moreover, civil servants from the government, experts and members of civil society offer a cross-cutting analysis, explaining that there are serious difficulties for farmers to work together. This would only work for small groups with similar characteristics and a clear purpose.

> *"There are a few exceptions, groups of 5 to 8 people who have done something… but these are very specific cases. They are selected and they trust each other.*

> *There has to be something underneath that allows them to work. If you think about this for mass use, it does not work"* (civil society Ovalle)

> *"No, everyone has to do things for themselves ('cada uno mata su chancho' is a Chilean idiomatic expression meaning each person is responsible for his/her own actions, responsibilities or duties). There have been some experiences but almost all of them have failed, I have not heard of any successful one. Look, they used to keep everything in a storehouse, later they used to sell produce as a community looking for a good price, but very often it happened that a customer came and talked with one of them aside saying 'but I can buy from you at this amount of money'… Then the old man, instead of selling as part of a community, would sell it on the side, in that way he earned a little bit more but did harm to the rest"* (INDAP civil servant Ovalle)

5.5.2 User Organizations

Hydrological resource administration is delegated to private parties, who must meet the requirements established in the Water Code. For this reason, hydrological resource administration needs to be collaborative.

> *"As water in Chile is conceived as national property but managed by private parties, the only way of seeing water as common property is through the administration carried out by user organizations"* (DGA national division user organization)

As set out in chapter 4, there are three kinds of user organizations: Oversight Boards, Channel Management Associations and Water Communities. Oversight Boards are the most important organizations in the basins, as they manage water use on rivers or parts of the river, obliging Channel Management Associations to organize themselves. The latter are smaller organizations that are responsible for water administration on channels. Nowadays, in the Limarí basin there are large Channel Management Associations with responsibility for administering reservoir water. The Water Code establishes the rules to create and operate as part of a user organization.

Due to the networked system of dams and channels in the Limarí basin, the Paloma System has been established (see chapter 4 for detail). This system operates as a confederation of organizations for controlling allocations by Oversight Boards and large Channel Management Associations in Limarí. This umbrella organization has no legal support. The Water Code does not provide for the option to authorize an organization to create an integrated water administration system in a basin. Owing to this, it was necessary to create a figure to achieve such a system, as it went beyond the provisions of the Water Code.

The Paloma System is made up of nine other user organizations, including an Oversight Board.

> *"The Paloma System is something very different to what we have seen before at a national level. In fact the system is not acknowledged under the Water Code. In the Paloma System you can take water from the Paloma reservoir, from Huatulame river or from the Recoleta supplier. Because you use all this as if it were a huge water bag and you see availability across the whole Paloma System, and from then on you can exercise your rights"* (DGA national division user organization)

In addition, user organizations from the Limarí basin are highly professional in comparison to organizations from other parts of the country. Most of them have hired professionals, mainly administrators and security guards (who are responsible for opening and closing the floodgates on water channels). This professionalism is based on their long tradition. The Limarí basin has had user organizations since 1893, when the first Oversight Board was created. This history has given rise to a significant difference between the abilities of this and other user organizations from across the country. The management of information within these organizations is directly related to this aspect. The more professional they are, the more chance they have of managing the information relating to their own hydrological resources.

A comparison with organizations in other basins reveals that the latter have a lower level of formality and professionalization. This is one reason why the water market operates in a better manner in the Limarí basin than elsewhere; in order to have an operating market it is needed organizations to manage the resources.

> *"There are more traditional areas, regions VI or VII for instance, where there are people using the same old methods. They have land and wait for water to come as they did 40 years ago. How they manage the organization is still the same too. Managers on these organizations are perpetual; indeed they inherit positions and see themselves as social associations. And the assemblies have really low participation"* (CNR civil servant, user organization head)

It is fundamental for the growth of large farming companies to have user organizations that operate properly. In order to maintain an efficient watering system, good management of channels and dams is essential. Farmers and managers from agriculture companies link an efficient watering system (a technological one) with the opportunity to carry out transfers and not waste hydrological resources in areas where they are not needed. The impact from the regulation applied by different user organizations is key in this respect.

Finally, the user organization is the partnership strategy most appreciated by different stakeholders when talking about its operation. However, user organizations work in the same way as private

corporations because they act on behalf of farmers according to the amount of water stocks each person has.

Assembly and Elections

To understand the limitations faced by user organizations as expressions of associativity, two main elements must be distinguished: assembly operation and the relationship between votes and water stocks.

Election of representatives is one of the most critical aspects when dealing with user organization rules. Leaders are chosen within a democratic process, but the votes are related to the amount of water stocks each farmer has. The election of executive committees for user organizations is defined by the votes corresponding to each water share. Thus, the amount of shares a user owns will determine the influence the vote has in relation to the whole number of users. In this respect, a common complaint is that managers represent the interests of large-scale farmers and do not care for everybody. Small and mid-size farmers feel under-represented.

> *"Normally these are organizations with five managers, if I have the vote to choose three, I will have all the control, these three will define the president and that is it. That harms organizations, because in many cases there is no alternation of representatives and many are not called to be presidents"* (DGA civil servant, Ovalle)

> *"The Water Code is not democratic in this sense because the more you own the more influence you have. This constitutes a problem within small organizations, in those that are poor because the ones who have more can do whatever they want"* (DGA civil servant, Ovalle)

Within some organizations this regulation has been disapplied and the traditional one farmer, one vote system has been introduced, in spite of knowing this is an illegal procedure and that it makes collective decisions weaker, because a decision can be questioned at any point by any member of the organization.

> *"Normally large-scale farmers are the ones who take part in these organizations and additionally user organizations share this characteristic of private corporations, the decision making is linked to the biggest number of stocks, and for that reason they are normally managed by the majority stockholders. It operates just as any private rights corporation. It is clear, more stocks, more votes. Now there are some organizations where decisions are taken in the one person one vote system, but only at a local level"* (CNR civil servant, user organization head)

According to the assessments of State civil servants and experts, this difficulty for small farmers in organization decision-making harms user participation in organization assemblies.

> *"Small farmers almost do not participate because they have very little influence. They only have to wait for the water to be delivered to them; meanwhile, the others decide"* (INDAP civil servant, Ovalle)

> *"When you are a small farmer they normally do not fulfill their promises, they never fulfill the programs they give"* (small farmer 4)

There is a significant difference in the level of experience of leaders from the traditional small farmers' area who propose themselves as representatives. Managers from agriculture companies are better prepared to confront technical decisions.

> *"Those things happen because our leaders are not prepared and when there is a meeting they do not talk about the important reasons for it, or they ask for a written answer for instance, then they allow one thing after another to happen, many times due to the lack of knowledge. But it is a serious problem because others have taken advantage and left less water available for us. Look, they said that temporary stocks would become permanent, and that is feasible because they have the election, the means and persuasion to change the whole assembly's mind, while the rest observe the making of deals and how they are losing at the same time in astonishment"* (cooperative leader)

> *"This is the danger with what we are exposed to nowadays, we are suffering from it. Because there are companies with a great amount of shares which can really influence the managers' election of user organizations, making it harder for us to be heard"* (manager, Limarí Monitoring Board)

It is interesting to observe that certain current leaders share this critical assessment of the influence that farmers with more shares can exert, because they see that their own work is harmed by the power of large agriculture companies.

> *"People are unsupportive, most of them are not supportive, for instance if I have a channel 8km long and water reaches to the 4th because from then on it leaks, I do not care for the ones who are further along; the ones who are nearer do not care either, they do not help with money to fix it if there is no benefit for them, the problem belongs to the ones who use it further along"* (user organization manager, Hurtado river)

Assemblies, which represent the chance for stock owners to ask leaders for reports on how their interests are looked after, suffer from low attendance. This is explained by the low expectations of small farmers of their ability to influence user organization decisions.

> *"During the assemblies, situations are reported more than discussed. People attend because they want to know how much water they are going to get or*

> *because we are going to give them free hot-dogs or because they can make conversation with some people, it is some sort of social meeting for the ones who have not seen each other for a while"* (Cogotí manager)

The same leaders acknowledge the informative aim of assemblies because decisions are made by the administration. It is also highlighted how many restrictions there are for valid votes (people do not attend, have few stocks or are in debt and their votes are not valid), so it is normal for people in the administration to have a majority.

> *"To make a decision there must be a 51% agreement, the majority, but according to the amount of shares each person owns. You can have stocks and be a debtor, if you paid until the 30th April of the previous season and the assembly is held in June, you can take part in it. If you are from a company you have the authority to represent it, another chance is to go to listen, if you have not paid you can talk, give your opinion, give suggestions, you have the right to speak but not to vote. For example, during the last assembly, there were 5500 channel stocks and only 3200 attended the meeting and from that number 2800 are valid votes, one person there could own 1000 stocks, then this person has almost made the decision"* (Camarico manager)

Although organizations represent some sort of associativity, they have serious difficulties and face much criticism for not acting in the interests of the whole community. Nonetheless, organizations are useful to manage community stocks quickly, because decision-making is done as a whole and they can enable changes that can only be easily carried out at a community level (such as waterproofing water channels or seeding clouds to stimulate rainfall).

> *"Organizations are useful for community actions, for instance cloud seeding, because asking stockholders for 100 pesos each would be war; but here we reach an agreement, as we did in Cogotí, when we talked about it during the assembly, everybody supported the idea. Moreover we agreed on a budget so there was nothing to argue about, we divided it up as a social fee"* (Cogotí manager)

> *"It seems this associativity is the only one authorized by law as compulsory. It may appear strange but the constitution says nobody can force you to be part of any organization, not even the neighborhood council. But you have to be a member of these organizations and oversight boards, you cannot say you do not want to because it is the only way to receive your water"* (Camarico manager)

5.5.3 Support Networks

Farmer support networks represent another dimension where there is a chance to observe associative relations. The leading one is the support of relatives and the second one involves neighbor support. While users explain that they support neighbors and relatives by lending

machinery or doing work, they say that sharing water volumes is far more complicated. Due to scarcity, they only lend water to each other subject to a commitment to return it as soon as possible.

> *"There are things we can do to help each other. But not with water, that we cannot, water is complicated. It can be machinery, a farmer tractor or lending workers, those kinds of things. But not water, because you plant according to the amount of water you have, you cannot plant more as it is very difficult. At least I do not do this, if it is only one person I can lend water but I am going to need it back on a specific date and the person has to cope with it on his/her own; I am taking a risk of not having it back. But I think that part is hard, people do not help each other with water"* (mid-size farmer 3)

Water lending is more common among relatives. Due to the spot market, they can do this even if they are located deep within the basin. In this sense, the Paloma System is a useful tool for supporting relatives.

> *"Now I am watering a little more because my cousin lent me some water. I ran out of water in February. He has some more and I borrowed it. But I do not have any idea of how this works. It is good for me because I can water"* (small farmer 3)

> *"This year my brother helped me too with a little water. I was running out of it and he lent me some from the other river, but that is because we are family and we work together too"* (mid-size farmer 2)

A common way of giving support is to share the harvest for consumption among relatives and neighbors:

> *"For instance I have avocados for breakfast, and jam that I consume and share with other people like friends, neighbors, so you offer this and later others share with you"* (small farmer 2)

> *"As we know the issue is easier. For example a friend of mine has tomatoes, another has onions, and I plant potatoes… so we keep each other informed. Hey, come to get a bagful of potatoes… and that is how we share. Not always, but whenever we can"* (small farmer 3)

One user strategy is to rent water in groups (or share a water provision or the water right) during a season. Traditionally this occurred among neighbors. A water right was transferred and the person using it in practice was responsible for paying the organization fees.

> *"Sometimes we rent by turns, we lend the turn. One farmer can say to another, 'Hey, today I am not using my turn, I am going to let it flow, you can use it'"* (pro-market expert)

This was later legalized through the spot market and this is how people sell water volumes in the most anonymous fashion (through the electronic market). Even companies engage in this practice of renting water when they cannot otherwise gain access to the Paloma System.

> *"Before the water right was rented, today the cubic meters are sold, which is the same, there has always been a way"* (small farmer 1)

5.5.4 The Trust Issue

A cross-cutting element in all forms of associativity and collaboration is the trust that exists among people and towards organizations linked to water administration.

The interviews carried out clearly show that serious mistrust exists, mainly from small owners towards those with a larger amount of water stocks, and more so during periods of water scarcity. This is related to the great influence exerted by large-scale farmers on user organization decision-making. In addition, such farmers or companies who have many water stocks are accused of selling water yet continuing to use it as if they had not done so (with a large volume, this is harder to control).

Another source of mistrust is illegal water extraction. Among farmers, the risk of suffering water theft creates significant mistrust.

> *"For instance, in the North some mining company that needs water goes to these huge users and buys their water which does not represent a problem for them because they have more water, more rights and everything. If they take one cubic meter nobody notices, nobody complains. They keep using the same amount of water but on paper they sold the water to the mining company. Later, when they need more water the thing these large-scale farmers do is to buy it from small farmers, but at a very low cost… I do not know, 100 thousand pesos. Meanwhile they pass their water rights to the mining company at 10 million pesos. As they are part of the administration they control the information and profit from it"* (DGA national division user organization)

Leaders are accused of taking advantage of privileged information about the water market for their own benefit. The consequence of this is a lack of interest in making the market transparent.

> *"The idea is that the same organizations are the real estate agents' office for water rights, but they do not do it because it is not convenient as the administration has the largest amount of water rights and they do not want this to change, and want to continue being the only ones making profit"* (DGA national division user organization)

IMAGE 13: INVESTIGATION INTO LOST CUBIC METERS OF WATER IN COGOTÍ

Source: *El Ovallino* newspaper (09.10.2008)

Another aspect of this mistrust relates to the large planting areas that it is clearly impossible to maintain during times of water scarcity.

> *"You can find planting over a larger area than it is possible to water with that proportion of the resource, for me it is suspicious to see they plant more trees, more vines each day. Because there is no water; I do not know where they get it"* (trading lawyer Ovalle)

State civil servants have a very critical stance with respect to the user organization leaders. It is claimed that a significant percentage of administration members take advantage of their status in order to take more water than they are supposed to have: "*I would say that 70% of presidents from Oversight Boards take more water than they should"* (DGA national division user organization).

Water rights titles are a problem too, making the amount of water stocks held by some user organizations increase because their administration has permitted it to occur.

> *"In this organization there were 12,000 water stocks and now there are around 13,000 and nobody knows how. They said that the organization leaders take advantage of this kind of situation. Look, there are several studies with pieces of advice on how to administrate water efficiently, but through the passing of time it has become clear to me that they do not want to, they have many interests involved"* (trading lawyer Ovalle)

IMAGE 14: AUTHORITIES CALL TO REPORT IRREGULAR WATER PROFITS

Source: *El Ovallino* newspaper (14.03.2008)

Water theft is the main cause of the mistrust that pervades the system. There is mistrust among neighbors or towards organizations. Indeed, during times of extreme scarcity people accuse each other of stealing water through illegal wells.

> *"Everyone is doing it and they all have wells and take a lot of water, but I think that in some way they take advantage because there are people who really have*

> *problems, maybe they need more than I and by law they have to take their water and I will be stealing from them. Well it is true, if everyone steals I steal too, but I am not going to abuse the system, it is only because I need it or I could lose my annual crop"* (small farmer 4)

Security guards are also subject to suspicion. Some large-scale farmers even hire people to monitor the guards when they are delivering the corresponding water because the farmers assume that the security guards take bribes from other parties and do not deliver the appropriate amount of water.

Conditions of extreme scarcity have meant that conflicts among irrigators have worsened and reports and incidents of water theft have increased. This is also an issue due to the low tolerance of illegal water extraction in situations where water is scarce.

An additional mistrust focus lies in fines for evaporation, which is a decision taken in each organization to counteract the effects of transfers. This can be related to a lack of knowledge, though there is also mistrust centering on the idea that these cutbacks are being used for other ends.

> *"And what happens to this 34%? I would like to know what it is for. Here we have an example of the big profit this administration is making. I transfer water, they ask me for a fortune and I do not know where this water is going. They ask for it but do not explain why"* (mid-size farmer)

However, it is also highlighted that the Limarí case sees organizations taking care of their prestige in order to secure respect: "*People here avoid this, there are many people who are more Catholic than the Pope but the habit is to protect the organization. There are things that still work under gentleman's agreements and others have failed, anything can happen. Normally there is still respect"* (civil servant DGA Ovalle).

5.5.5. The Cooperative Failure

There are many stories about cooperatives in the basin that failed soon after being founded. Users, State civil servants and experts all agree that this kind of initiative does not work.

Many causes are linked to this failure:

- The lack of preparation and resources for people to make the cooperative operate properly (community member 2)

- How people address the failure to sell their products on their own (community member 2)

- After one gives up, the rest also leave (company manager 4)

- Leaders take advantage of others by keeping the money for themselves (small farmer 2)

- There is a cultural mistrust issue: "Chilean people are like this" (small farmer 2)

- The dictatorship ended some successful cooperatives (mid-size farmer 2)

The few successful cooperative experiences (Pisco Capel, Pisco Control) are falling away. Small farmers are a minority and there are people trying to buy all that they have left (mid-size farmer 2).

INDAP declares that at a certain point it tried to encourage *Profos*, a cooperative system that ultimately failed. Many were ended by the managers that had established them because of insufficient control.

> *"At some point INDAP interfered, trying to form the* Profos, *which were some sort of associativity; as cooperatives they assigned professional managers to run the administration because farmers did not know how to, but soon managers sold everything and took the money, they cheated on the old men… so these* Profos *were a disaster"* (civil servant INDAP Ovalle)

The cooperatives that are left do not operate regarding water issues, but only for purchasing or selling farm products: "*Each person does whatever he/she wants with his/her water. It would be better to do it as a group. I believe that in our cooperative we should manage everything but having a strong ruling system, so the one who does not comply with our rules has to leave the cooperative with a fine" (*cooperative leader).

5.6 Collaboration: Vertical

Vertical connectivity is another important characteristic in a resilient system. This happens between higher and lower nodes, not only at the level of similar or close ones (as in horizontal collaboration). The central point of the issue is the relationship between the State and farmers, and the relationship between experts, the State and farmers from the area.

5.6.1 The Relationship between the State and Farmers

The relationship between the State and farmers is mainly reflected in the benefits awarded for watering and dam construction. User organizations play a particularly important role because they distribute the benefits. Thus, the main State organizations with responsibility for hydrological resources (CNR and DGA) have special people and units responsible for maintaining relations with user organizations. The kind of support initiatives applied will depend on the orientation of the government. They may include encouragement and legalization of structures, training and

legalization of water rights, and formalization of user organizations. There are significant differences between governments. Before, much effort was invested in training and empowerment, while with the right-wing government the emphasis has been placed upon legalization with the aim of developing conditions for an operating market.

> *"Now we work with organizations that look for a strengthening of their basis, before the work was concentrated on improving the skills of administration members, users, giving a lot of training. Currently the work is focused on strengthening legal conditions inside the organization, legalizing"* (civil servant CNR user organization head)

> *"Today is different, there are no ideas to create leadership or strengthen participation, now it is important to know the Water Code, its rules, to know about their rights and how they can participate. Before, we used to work giving leadership training, conflict resolution techniques, etc. It was an organizational view. Nowadays it is more important that the organization is legal"* (civil servant DGA, user organization head)

Within the same units which operate with user organizations, their processes are recognized as cumbersome. Although the objective is to encourage the creation of organizations, the slow and complex procedures make legalization difficult: "*for instance, as a service we want to encourage the foundation of user organizations, but our procedures are cumbersome, so we need to change that*" (DGA national division user organization).

At a national level, differences between State and user organizations are serious either. In Limarí, one of the important elements is that the regional management has many years of experience and organizations have been well established for decades. Their collaborative relationship in this context is long-standing and is better than in the rest of the country.

The user organization complains of the slow process, particularly during times of scarcity. This is due to the process of raising capital during emergencies remains slow and badly timed because it tends to arrive when there is no water available.

> *"Unfortunately, the geomembrane arrived late, it should have been here before the money was authorized in June and the first truck arrived on 5th December. The Regional Government provided the capital for the geomembrane, but the problem was how late it arrived to us"* (manager, Limarí Monitoring Board)

Reservoir construction represents a large investment contribution from the State to private parties. After the reservoirs have been built and become operational, they are transferred to private parties for administration. Due to a lack of clarity in the procedures introduced by legislation, there are

significant difficulties. There is also a huge gap in the temporary rights that may be created when reservoirs are built.

Post-transfer reservoir management is completely independent. Private parties decide how to divide up the water, though at some level government organizations (mainly DOH and DGA) give technical support, while not making decisions.

Cloud seeding represented a strategy developed during a time of emergency where State and organizations tried to collaborate. This strategy was heavily criticized because of its lack of effectiveness, in addition to the imposition of a procedure, requests for financial resources and the refusal of permission to control the work performance.

> *"Now for instance they tried artificial rain, we were a little worried because they were sending this artificial rain project; they say, "Limarí has to give this amount of money and Elqui this…" The State is supposed to give 50% and the rest comes from us. I believe that there is a view that the State is too inflexible; there is almost no dialogue on this issue"* (manager, Limarí Monitoring Board)

The most common criticism of State organizations is how governmental policies change with a new government. Sometimes half-completed training is simply discontinued, or established agreements vanish with the administration introduced by the new authorities (manager, Limarí Monitoring Board).

> *"An important change with the new government regarding our relationship is that today it is not easy to speak either to the ministers about important issues or to the national managers, and we see how regional managers from organizations are not empowered, I mean today they do not dare do anything. So there is a noticeable change. For example, we in this room, when the Water Code was under review, Humberto Pena was the national manager and he agreed and disagreed with us on many things, but several things we discussed at this table were added to the amendments to the Code, he took a day to come here to talk to us. The current authorities have never scheduled a meeting, is almost impossible to talk to them"* (manager, Limarí Monitoring Board)

A common argument is that the State should support users and provide the resources which will be returned through taxes: *"If farmers stop producing, how much money will the State lose only through IVA* (valued added tax)*? As soon as the Government provide the required resources for large-scale and small farmers, they ensure their own income through taxes"* (manager, Limarí Monitoring Board).

The number of hurdles to overcome to obtain benefits makes it harder for small farmers, which is not the same for larger private parties. This represents a further criticism.

> *"In this matter I have a strong criticism to make of the government authorities because we have fought a lot to have some help with technical watering support, and they have given none because the INDAP for instance does not work. The one that operates really well is the CNR, which operates through public tenders, within which the winner is the person who gives the most; for a company that is going to spend 500 million, receiving 250 is very good business, but for a group of people who have around 0.2 to 0.3 hectares and more, to invest the 50%, I mean the 250 million, is impossible. So we cannot do it either through the INDAP or through the CNR"* (cooperative leader)

INDAP should take care of the most vulnerable parties. However, there is a large group that does not qualify to receive the INDAP support and does not have the resources to apply to the CNR.

State civil servants also confirm that they suffer from a lot of pressure from large-scale farmers because the latter complain in Santiago and are given what they want.

> *"They do not want to invest their money so they ask for it from the State. The State has no obligation to do so but some civil servants feel intimidated when a large-scale farmer comes, because the ones with power come to them and say they are going to complain in Santiago or make an accusation to a minister because they are giving trouble… and that is how they act, here there are really powerful farmers, more than in any other place here in Limarí"* (DOH Serena)

The difference in State contributions has been important since the change in government, due to the right-wing administration asking that everyone apply for the public tender. Later the largest user organization, which has the most financial resources, has more chance of receiving the new benefits.

> *"Before, the money was distributed taking into account the size of the farmer's company and within this contest divided by hand, or according to niches that had priority issues, for instance: I have a program in Choapa, I have something in Elqui, back then they used to do micro-contests to a regional level, they even offer to a community level so this allowed the service to guide the investments giving support to the smallest farmers. This was heavily criticized by the change of administration with the idea of creating greater rivalry within the system; more openness for them was to make the contests public and create no more individual niches but contests with Macrozone"* (civil servant CNR user organization head)

There are State contributions that are classified as inefficient and that only fulfill an image function (Cazalac expert). Some of these initiatives are only focused on achieving a larger number of votes when they appear to be doing something. Cloud seeding is the most heavily criticized policy in this respect.

> *"If there is scarcity and the "Niña" is going on, to begin with there are no clouds. The cloud seeding is done when there are clouds, when it is about to rain then it could work. "It rained", they say, it rained because it was going to rain, not*

> *because of the cloud seeding. Well, anyway it rained, it worked and everybody was happy; the thing I have read about people who do this say the amount of rain does not reach 15%, it would never end the drought… Instead of raining 50ml it would rain 55ml. There is not much difference"* (Cazalac expert)

5.6.2 Relationship among Experts, State and User Organizations

A fundamental bond to strengthen the resilience of a social system is that which expert communities establish with the rest of the associations, whether these are user or State organizations.

Amongst the main difficulties identified is the lack of systematized research. Users highlight that there is no clear way for them to access the content of scientific reports. Nor are State organizations well informed in this regard.

> *"I believe that it needs to be systematized a bit more so each required area and the government are well informed, and also for the investors and producers being aware of the risks they could face"* (company manager 3)

One of the topics in which the presence of experts can be identified is in the research conducted on climate change. In general, users do not speak about this topic. However, they easily identify centers which are devoted to the study of climate change in their region, and obtain information from such centers, on the basis of which they demand specific projects such as the building of new reservoirs.

> *"We have learnt so much about climate change from the information they gave us on the stages of the study. It seems that it did not have those good results. It has helped us to understand what could possibly happen in a better way"* (manager, Limarí Monitoring Board)

User organizations and experts work collaboratively in this respect. The users provide the experts with information relating to the market and conditions of the basin, to be used for academic purposes. In return, users receive information from the experts' reports.

> *"We receive their support, we reached an agreement to collaborate on the market issue and we receive their information in return, but for academic purposes only"* (electronic market manager)

Centers like CEAZA and CAZALAC are the most active ones, giving seminars and lectures to farmers (DOH Serena). Some time ago, INIA was also a prominent center (civil servant DGA Ovalle).

An example of this vertical collaboration is the creation of the electronic market. This initiative was produced by a network made up of CNR, PUC (*Pontificia Universidad Catolica*), CORFO and the users. Investments from CORFO (at the outset) and CNR (when the previous investment proved insufficient) were necessary in order to make the virtual market operative. This money allowed experts from the

Global Change Center (from PUC) to work with user organizations from the basin, the objective being to clarify market information (prices mainly) and thereby offer a tool to reduce asymmetry in available market information.

5.7 Socio-Ecological Memory: Knowledge

Knowledge of the ecological environment in general and the availability of water resources in particular are fundamental in understanding the relationship between the community and its natural environment. This knowledge is developed both nationally and locally, arising both through traditional and scientific knowledge.

From the interviews, it is possible to identify a general issue regarding a lack of information about the water cycle, the capacity of aquifers, snow density and even the amount of water stored in reservoirs. Moreover, there are difficulties in understanding the given water rights, since many of them are registered in books in different locations of the country, without a unified system that systematizes the information about these rights.

Furthermore, information on the 1200 meter-point is almost non-existent because the tools to make appropriate measurements are not available. This is mainly due to the lack of investment in this kind of instrument.

In parallel, one of the weaknesses identified concerning knowledge of the water cycle and associated climate projections refers to the fact that Chile has only worked with a single meteorological and hydrologic model, which naturally increases uncertainty.

Regarding access to water resources, a major challenge concerns obtaining adequate knowledge regarding the exploitation of aquifers. This is due to the invisibility of the water source and the ignorance surrounding aquifers; it prevents users thinking about groundwater as a common source. In this context, the ignorance of state organizations in relation to aquifer conditions is notable. For example, the director of the DGA says he does not know the extent to which the basin is overexploited.

Part of this lack of knowledge relates to the lack of regulations on the use of water resources. After the construction of reservoirs and the establishment of the 1981 Water Code, the extent and intensity of crops in the area increased dramatically, and they have since required higher water availability and flexibility for use in addition to systematically increased acres with permanent crops, placing stress on the water cycle.

5.7.1 Local Traditional Knowledge

There are also important differences in farmers' knowledge with respect to agricultural exploitation. The oldest ones are reluctant to use machines and increase the extent of their crops, leaving them unable to increase their wealth but helping to maintain more sustainable farming compared to intensive farming and industrial agriculture.

However, this kind of knowledge is ever less commonly used. This is mainly due to the change in the characteristics of farmers and a sustained increase in the large agricultural companies from outside the basin. At the same time, the traditional farmers who continue using local knowledge have had to face constant changes in climate over the past few years, not knowing when and how much to plant, with traditional knowledge proving of little use when unexpected seasonal changes occur.

Based on this, many small traditional farmers say they suffer major losses, mainly because they make decisions to grow plantations that require a lot of water resources. This happens even when user organizations announce the availability of water for the season. Apparently, practices such as trust in God and belief that it will rain enough have ended up damaging farmers on multiple occasions.

There is a clear and important difference among types of farmers involving management of the availability of water. The most prominent have support from professionals who handle the necessary information to make appropriate use of the resources, while the smaller ones do not have the information or the ability to process it, and during drought years they may make incorrect decisions.

However and at the same time, it is observed that there are external companies who do not know the water needs of the plantations in the region, so they tend to buy fewer shares of water than are necessary for the crops. In this sense, it remains a disadvantage to be without local knowledge.

5.7.2 Scientific Knowledge

From the analysis of the interviews, the way in which knowledge is transferred from experts to users and State organizations is a serious concern. Interviewees indicate the need for greater cooperation among universities, the State and the private sector.

Communication difficulties between the scientific sector and the State mainly relate to the lack of access to information and the lack of interest of State-dependent agencies.

The receipt of scientific studies by the State has serious difficulties. As much as they may be positively received, many such studies end up stored in official desks without being broadly applied.

This is due to the State's lack of resources, personnel and skills to make use of the knowledge obtained.

State organizations face a serious lack of knowledge. For example, the General Water Office (DGA) does not have accurate information about water rights given nationwide and currently in use. To address this problem, they are currently working on a national register of water resources. In general, there is serious concern over the DGA's information management, as they are legally responsible for managing the information on water rights and yet other State organizations identify them as entirely deficient.

In addition to this problem in the DGA, a deficit is identified in the information that the State and experts give to the private sector, leaving plenty of room for interpretation, which can lead to serious consequences for the sustainability of watersheds.

On the other hand, user organizations do receive some information from experts on the availability of water and snow in the basins. However, they identify the need to improve the delivery of information and its systematization. This is because farmers still do not have sufficient data to make informed decisions and assess the risks associated with inadequate management of water resources.

A major problem is, for example, that the Paloma System is found to actually have less water than the amount stated in the official records. This is a severe problem when all the water has been consumed; it is known that people will demand more but that water does not exist. This shows a deficit in knowledge and management of the operational model of the system. To address this problem, divers have been hired to measure water levels and use this information to correct the previous erroneous data, but only when the water was running out.

In general, State civil servants, farmers and their user organizations express the need for further information on the conditions of the aquifers, the amount of water in reservoirs, the water quality in rivers and the forecasts made.

5.8 Socio-Ecological Memory: Learning

Based on the interviews, it is possible to identify different dimensions related to learning in socio-ecological memory. There are elements that can be associated with learning from the system, but more importantly, there are critical elements that demonstrate the absence of this learning.

5.8.1 No-learning: More Intensive and Extensive Farming

Users themselves identify a weak general learning ability as a weakness. One of the most critical concerns is that the measures implemented to tackle drought stop when the drought ends. This is not appropriate considering that droughts are cyclical in the region.

> *"Besides you know what will happen, if the drought is over and this year is good, the reservoirs are supposed to be filled and they will immediately forget about this issue. Nobody is going to talk about cloud seeding, the law will continue to operate but with the assigned resources and we will be relaxed for three more years, then when the drought comes again, it will last seven more years, there we will start again. During the first half of the drought, it will really worry us and when we solve the problems this alarm will be ended and this is a never-ending story. Now if all you are doing everything and the drought stops, we should continue to do so for the next term so it would not merely be useful to face what is happening now"* (Hurtado river user organization head)

This is connected to water scarcity. Nevertheless, there is another directly related factor that has not been fully addressed: there are no limits on farming exploitation. The farmers themselves recognize the need to set limits and regulations for farming exploitation, since they identify excessive demand on water resources.

> *"We are a little irresponsible on the amount of planting and we have no limits, and as there are people with so much capital that have no limit to spend it, then they buy 500 acres, they live buying and continue to buy water but basically if the water is a resource that has a limit then it is impossible to give them all the water they need"* (mid-size farmer)

The evaluation made by farmers, user organizations and experts is that the current drought is not greater than that which began in 1996. However, the planted area is much greater, so the effects are very different.

> *"It happens that the plantation area has greatly increased. So there is a higher demand. According to statistics, the drought is not worse than 1996, it is about the same, but the planted area has increased by 40% therefore water demand is greater. The resource usage is more intensive"* (Hurtado river user organization head)

With the same amount of water rights, a much wider area with permanent crops has been irrigated, which requires a continuous use of water.

The local authority (DGA) recognizes this problem, but assumes that the State has no chance to enact new regulations. The only option, then, is "natural selection": those who have sufficient water rights will survive.

> *"As time passes, the demand for water goes up, because the water stocks are the same, but the use of water is higher. Think of the fact that in the year 1997 we had the Cogotí reservoir almost dry, Paloma from 750 million of mt3, had only 48 million less than now and Recoleta was 9 million of the 100 of capacity. So with that high demand the system was almost broken and today Cogotí is 40 million, Recoleta also other 40 and Paloma is about 130, we are practically in the same conditions as in 1997 because the irrigated area has grown. And the problem... well I think this is natural selection, the only thing that will not allow farmers to continue planting is a drought. I think it is painful for people, it is difficult for me, for the office I hold, but there is no way to limit the number of hectares planted"* (civil servant DGA Ovalle)

A key aspect of this issue is the replacement of temporary crops with permanent crops: "*Until 1980 or so, it was a period in which the deficiencies were not noticed because the agricultural sector had not yet developed as far as it has now. We were also flexible, if you planted wheat and had less water, and then you planted less. Today with permanent crops ... I remember in 1997 we had 15,000 hectares of plantations and today we have about 40,000, later every time a drought comes the situation becomes more complicated*" (manager, Limarí Monitoring Board)

An assessment by Paloma System administrators themselves suggests that the basin has reached a limit of efficiency in the use of resource, taking into account the intensity and length of crops. This limit has increased the risks, since changes in the water supply directly affect agricultural production. Although it may seem obvious, for years there has been no learning on the subject.

5.8.2 Learning: Transfers and Losses

Nonetheless, not everything is negative. One aspect that is positively evaluated and evidently constitutes a lesson learnt from the system concerns the regulations conducted by user organizations with regard to water transfers.

For many years, these regulations did not exist and it was believed that if anyone had a water right in the basin, this could be transferable from one place to another within the basin. However, due to multiple movements, user organizations began to resent these changes, because if an amount of water rights vanished, the same costs would be spread among fewer users, whereas if new rights were added, sometimes user organizations had problems with the ability to conduct them.

> *"It was previously thought and thus divulged that if you purchased a right from an organization, you could take it and transfer it to another organization and use it to water in a different place, almost like a magical movement and as if water balances could change places, well that happened for a while and there was a high transfer of water rights. But then it started happening that organizations*

> *began to regulate these changes, because they realized that when a right disappeared in a given channel, the channel was still the same section and was not elastic, it did not shrink. Then they realized they could not come and just make it transfer, but they had to have some way to regulate transfers, only permitting transfers in certain directions"* (local university expert)

Although there are some differences, in general all user organizations have established procedures for water transferring, by setting limits, penalties and costs for different kinds of transfer.

One aspect that was restricted is that in some cases transferring is limited to seasons, cannot be permanent, and must be made on a yearly basis. This allows for authorization only if there is enough water during the season and the use of other water users is not affected. A threshold is also set, as this allows a minimum volume to be established for transferring in the reservoir.

> *"So what we want by applying the temporary transfer is that the user continues participating in the costs of the original channel and must apply for an annual transfer, established for the season. That provides the chance to prevent the user from causing harm to others. Another determination made is that the allocations that are transferred have a maximum volume in the reservoir, in order to fit water availability, and the number of shares that are moving every season must be assessed"* (manager, Limarí Monitoring Board)

Another interesting innovation in this respect is that some user organizations have established rules allowing the distribution of losses so this does not only affect the last users in the water channel. This certainly is a decision for the good of the collective that is taken through learning.

> *"We will implement a new system to manage the losses. Before a community had a loss, and so another had another, but now we will make a unified system where losses are going to be calculated to be covered by everyone together, sharing payment for losses"* (administrator Camarico)

5.9 Self-organization

Finally, self-organization is an important element observed in a resilient system. To some extent, it includes the previously mentioned features because only a flexible and connected system that is capable of learning is able to modify itself. In addition, however, some extra elements of self-organization are set out below.

5.9.1 Innovation Capacity

Most of the innovation skills in the socio-ecological system arise out of the market. Innovations take effect rapidly within this framework. User organizations also promote innovation. The State organizations undoubtedly show the least innovative skills.

Government civil servants see their own innovation skills as fairly limited. They are constantly working to address emergencies, being unable to address longer-term issues: *"I believe that we only see times of emergency, so we have to save the situation because we have to pay attention to what is happening today "*(DGA national division user organization).

The same users and leaders affirm that the ability to create change only appears in times of emergency and does not remain when the emergency has been overcome. In fact, one of the criticisms that leaders make is that State authorities expect the system to collapse, not doing enough to prevent this outcome. In this context, users also consider that government actions to address drought are merely short-term reactions that can only mitigate effects.

> *"There are no problem-solving skills for the long term in the authorities. Imagine what could be done if it were so, we would improve irrigation, ponds for people, channel lining, change hoses, but if there is no water, how could you do this improvement work?"* (electronic market administrator)

Likewise, major faults are revealed in coping with drought conditions when prior investment had been necessary but was not undertaken: *"what happens is that besides looking for aquifers, other than taking water from the river, it is necessary to make great efforts and investment to install water pipes, from anywhere, but that investment should have been made yesterday, not tomorrow"* (manager Paloma System).

Senior management figures in State organizations maintain that a 50-year overview is not easy to establish, as the political pressure to be effective before elections is very high. At the same time, farmers have a short-term view: they are all concerned with saving this year's harvest, to cover for emergencies.

> *"We are looking at such a short-term view because we all want to save this year's production. Many people who grow vines have already harvested, they are calm. Grape growers still face a little more suffering, but we must persevere, we have to pray because we harvest in August, September, so we still have several months. We want to harvest this season but if we do not we have to prune, then there is no longer anything to do because we will not win"* (mid-size farmer)

However, user organizations have shown the ability to innovate when managing emergencies. In 2013, they dug wells in the reservoir, in order to pump and deliver water into the channels (Paloma System manager). An important part of the innovations relate to improving water conduction, in order to reduce losses on the small amount of water they have (electronic market administrator). In

fact, user organizations also conduct innovations with a long-term view, mainly in the form of regulations and limitations on transferring (as previously discussed).

The most important innovation to address the problems of water has been the "water tables". These initiatives were commenced during the *Concertación* governments and were intended to improve coordination among the different stakeholders of a watershed and promote dialogue, with the aim of developing integrated watershed management. However, these tables failed for several reasons, mainly because of the absence of supporting legislation and paralysis resulting from the change of government.

There is a major ongoing project concerning the possibility of transferring water from southern Chile to regions with more difficulties in accessing water. The market itself has been the main driver for this project and it is seen as the great innovation for the coming years, since it would allow water to be moved from Region VIII to Region III.

Finally, expectations of profound changes including changes in the Code are considered possible only if a significant citizen movement were to occur, which would be the result of a water crisis affecting a large part of the population. There are no other ideas considered useful in moving towards a significant change in the water management system.

5.9.2 Self-transformation Ability

From our discourse analysis, we can identify that the ability of self-transformation is quite limited. As seen in the previous section, so far only user organizations have attempted to develop market regulations, with the State showing itself to be incapable of doing so. However, it is interesting to note that, in general, there are significant expectations of greater market regulation from the State; even private parties themselves require more regulation.

One of the major difficulties in stimulating long-term transformation relates to decisions that are made only in relation to short-term consequences. This is especially difficult for politicians as the immediate consequences of decisions may have significant repercussions in subsequent elections.

> *"Many think about the vote for the following month and that vote is the whole problem; they lose ground on everything that is structural. We have a beautiful plan for a reservoir with an estimated amount of time and defined deadlines, resources as a priority, but if someone else comes along and says "it is not a priority I prefer to spend all that money on buying grass for the animals because we will have more votes", there is not much we can do"* (senior right-wing government politician)

State organizations identify the market as a major impediment to implementing changes. This is because the State does not have enough resources to purchase the water rights that would be necessary to boost actions for safeguarding sustainable basins.

> *"We are tied beyond bureaucracy, the market issue is sharp, complicated, sometimes you have projects but do not have rights, and you simply do not have any right, for example, go and buy rights at Puclaro, La Paloma, they are no longer sold. One can do many things but after that it results from not having rights, it is a super sensitive issue, the market works but of course it is not as open as going there and buying"* (CNR civil servant Santiago)

The Need to Regulate Crop Spread

The main request is the need for regulation of crops or seeding. Free competition will not maintain ecological homeostasis in the basin, a diagnosis shared even by large agricultural companies. Users expect regulation from the State or from user organizations to establish limits on the spread of plantations.

> *"It was never thought to generate some kind of guidance towards investment, stating a limit of cultivated areas, making a distinction between permanent crops and annual crops. It does not exist because I think that maybe the State says 'this is not my problem' and then those who have to worry about it are the private parties, but when a problem occurs it also affects the State because the labor force needed, used and affected, become a burden to the State, probably because of the taxes forgone, and on the other hand the State often has to ask the banks themselves to freeze charges and so a series of events begins that, like it or not, affects the whole nation and therefore also the State"* (company manager 3)

In this context, the State ought to say that the basin is sufficient for a specified amount of people and should be devoted to a specified type of exploitation (mining, agriculture, etc.). But State organizations stress that they do not have any powers to set limits on agricultural exploitation and that this should be done by the user organizations that have the power to apply regulations.

> *"But the issue of the best way to manage reservoir resources, there is nothing, there is no planning, there may even be an increase in producing fields, but the drought has lasted a while. This is not new and people are still planting without being aware of this being a cyclical matter, that we may have a good year or one that almost permanently limits the ability to act. Monitoring Boards have the autonomy to allocate their irrigation seasons and is very little that the DGA can do there. So they are the ones who have all the power to decide on how the resource is consumed and how it is not" (*CNR commissioned officer user organization)

The Chances of Legislative Change

Another key element in the analysis of the timelines of self-transformation refers to the possibility of the system improving legal regulations, specifically the Water Code. In this context, the difficulties and limitations revealed by the process of reforming the Water Code in 2005 have shown the poor management of politicians and legislators on this topic, in addition to a general lack of interest throughout the whole country.

After 12 years of parliamentary discussion, only minor modifications were adopted, which even then did not substantially change the model in practice. In addition, important mistakes were made, such as forcing people to use water or sell to others if they did not use it. There was no vision of sustainability in the 2005 reform, the most important consideration being to improve the market.

> *"In 2005 they had the big opportunity to amend the Water Code. The subject of fees came up and whoever does not use the water has to pay the fee, and you see that in this area, that is stupid, it means that whoever does not use the water is obliged to use it when it should be the other way round... Hey, leave it thereI should be paying whoever does not use the water, and after they say "well…if you do not pay the fee". What is the State doing? Auction to the highest bidder, when it should have said it goes to the State"* (DGA Serena)

However, ecological flows were an important innovation. But as they do not take retroactive effect, it is necessary to look at ways to establish ecological flows in those rivers that are already exhausted: "*what exists is the ecological flow as law, it's not true and you have to leave it, but that came out after all the rights had already been granted. In the South it is easier because there are rivers where there are water rights that have not yet been given. It is possible there, but because there is water abundance and there is no scarcity"* (CAZALAC expert).

In this context, demands are connected mainly to the recovery of water ownership by the State and the public status of water. The interviews identify a possible alternative: to re-declare water as national property of public use, establishing priorities for water use, safeguarding the constitutional right to human consumption and protecting minimum flows to maintain the sustainability of basins.

> *"Most of the proposals relate to article 19(24) of the Constitution, oriented at repealing and reforming the legal system and water property, recovering the public domain, and declaring it as a national asset for public use, establishing priorities for human use, and establishing a flow to ensure availability to protect the basin. These three issues are key. All these are expressed in a specific Draft Law. The problem is how long it will take to be processed, if it is processed"* (civil society Santiago)

In general, respondents talk of the need for change in the policy to deliver rights in order to ensure integrated basin management.

> *"If we want one thing at the basin level, we need to establish different management. An integrated management is impossible today with the institutions we have. If I own I can use all the water, that is what happened recently in the Aconcagua for example, where there was a verbal agreement, apparently someone did not respect it and left no water for the rest... but he had every right to do it from that point of view, of course"* (civil society Santiago)

In this context, there are representatives identified with name and surname who have agricultural interests or defend the interests of others. Some even shamelessly steal water, abusing their parliamentary position. The problem is that people continue choosing them as politicians. They also have a lot of influence and therefore are not easily monitored or fined.

> *"Congressman XX, a* Democrata Cristiano*, this gentleman has spent years in the sector, years as a deputy. It was very easy to see that he was stealing water because his water rights were two liters per second, he had three wells and yet had two hills planted. So, either he was God or he was stealing. He had no way to justify the amount of crops. He is a deputy for the area, it was the same people who elected him and his son is the Mayor of Cabildo. Then you say how? How can people choose him if it is so obvious that he steals water? But people do choose him"* (DGA national division user organization)

Another source of problems was the "*Ley del Mono*" established in the context of this reform. Certain parliamentarians misused information and took advantage of their circumstances to make many wells and regularize groundwater rights. The difficulties generated by such regularizations continue to this day in some pending cases.

> *"Regulation was attempted with a modification made in 2005, which was that a grace period was given to legalize water wells through what was called "the transitional quarter". This was called the "*Ley del Mono del Agua*", which allowed farmers to regularize wells of 2 liters per second to the north and 4 liters to the south of Santiago"* (CNR commissioned officer user organization)

One of the political parties identified as having ulterior interests involved in water rights is the *Democrata Cristiano* party. Many of its members have direct or indirect interests in the area and hence retain the model and oppose the development of greater control. Both members of civil society and civil servants from State organizations themselves, who have faced pressures from these politicians, identify this as problematic.

According to a former minister, the main difficulty in making amendments to the legislation was the lack of quorum. For instance, a major constitutional reform to the Water Code has been with Congress since 2009.

> *"In our country and the poor formation of the Chilean Parliament, for these kind of reforms a certain quorum and majorities are required and at least at the time, I'm speaking of the time when I was a Minister, we did not have the quorum needed to make those changes. However, there was an attempt in the government of President Bachelet, a constitutional amendment regarding water was entered in November or December of 2009. Of course, it is paralyzed in Congress, this being simply a matter of the views with respect to the resource and the profound nature of the debate"* (*Concertatión* officer, high political office)

One of the finest achievements of civil society in terms of promoting discussion about the reform of the code and water problems was the recent establishment of the Commission of Water Resource Certification and Drought (*Comisión de Recursos Hídricos de Certificación y Sequía*). This permitted the separation of the discussion of water from the Public Works Commission, where it had achieved no importance.

> *"We managed to establish a Commission of Water Resource Certification and Drought with the Parliament, which means that water issues are removed from the discussion of the Public Works Committee"* (civil society Santiago)

Procedural Modifications

Another element identified in the discourse analysis is linked to the need to modify the procedures relating to water resource management. It should be highlighted that the diagnosis primarily establishes the changes that are necessary but have not so far been implemented.

In this context, greater collaboration is required among different sectors of the State associated with the problem of water resources.

> *"Agriculture, Mining, Environment, Public Works and National Assets were all linked for water in State territories and I think that it was also the Ministry of Planning and Cooperation, memory may fail me at this moment, then the way to handle this is a way that has much to do with politics and I am talking about politics of management, that is to say, to identify meeting places where positions are discussed, ultimately that consensus is reached between the positions, I think more than a battle of strength this is a fight of convenience, you have to achieve the greatest benefits by sector at the time of managing. I do not believe in having a war of the titans within the State apparatus, that seems harmful and inefficient to me. Quite the opposite, I think chances have to be created under presidential*

> *instruction, so they have the power to confer the highest authority on Ministers to manage the nature of agreements"* (*Concertación* civil servant, high political office)

On the other hand, it is also necessary to strengthen accountability. Users, civil servants, and even the former minister agree on this point: *"Strengthening accountability is urgent and immediate, in that respect, because a very important part of water scarcity is associated with its indiscriminate and clandestine use. Then there is a first measure from what we can call the manual, absolutely from the manual, but then other instruments that are related, for example, to reviewing the flow for different projects to check if the environmental variables developed in a manner other than as expected, this is an available legal institutional mechanism"* (*Concertación* civil servant, high political office).

In general, the State should have more tools to act on issues of water management in the northern sector, where there is a permanent state of drought: *"What we should aim for is to assume that drought is a normal phenomenon in this sector and thus we need to have contingency plans, A, B and C. And how to manage a water culture in the region where water is valued differently and how I can empower the State to complain if necessary and to be able to act against these monsters, who run the region, manage water and do what they want"* (DOH La Serena).

The DGA is viewed as a weak unit. It is argued that the ideal answer would be to install a Ministry of Water: *"We have a weak General Management, we should aim now for a Ministry of Water, as in other places. It is a fallacy to speak of integrated watershed management, you cannot talk of an integrated watershed if you do not have a minimum level of water control"* (civil society Santiago).

The CNR view is that neither the State nor user organizations have tools to regulate access. Water is delivered and then traded to the highest bidder: *"Water resources are used ever more intensively; with more efficient use, the cultivated land expands and resource demand increases. The Ministry speaks of Chile as an agricultural provider and where they want most of the production to be exported, that means important requirements, then all signals go towards promoting a more intensive use of the resource and organizations do not get into these issues. But if we at governmental agencies do not have the ability to regulate these issues, user organizations have even less. There is no way to define to which area resources should be allocated either, here water rights were given away and now they operate to the highest bidder, we have no role"* (CNR commissioned officer user organization).

Another important limitation is that it is not possible to restrict the change of use: *"The truth is that it is not possible to restrict the change of use. And the situation is so critical that we cannot even limit*

the farmers, if a farmer has 20 water stocks and assuming that these 20 stocks will manage to irrigate 20 hectares, that farmer might well have those 20 stocks and plant 40 acres" (Ovalle DGA officer).

Adding Expert Knowledge

Finally, another major difficulty associated with limitations in self-transformation concerns the incorporation of expert knowledge (also referred to in the section on vertical collaboration).

Here, a key element is the need for information on the extent and intensity of sustainable crops in the basin. A further concern is the type of crop that can be planted by seeded area: *"Perhaps regulate some crops, because here with a free market economy, everyone plants whatever they want, wherever they want and it is really important to know about areas, studies, I do not know, there are things that you can no longer do. The number of hectares in certain areas and obviously continuing to improve regulation, there are many things to do, the Monitoring Board, I think they have to continue improving the regulation of and access to information"* (company manager 1).

From another point of view there is also the project of a systematic increase in seeded land. For example, the CNR plans and works to double the irrigated surface with planned new works: *"Those are long-term plans for the coming 20 years, we should double it, I mean nearly double the irrigated area that these new works incorporate"* (right-wing civil servant, high political office).

Because of this difficulty in the sharing of expert knowledge, the idea has developed that managing water resources must be well-proportioned and respectful of the economic value of water, but consideration of the environmental dimension has been postponed, with serious consequences.

> *"In Chile the economic dimension of the resource has been seen as essential, that is to say, while there has been support for economic activities and also the dimension of provision for the population, as well as support for the lives of human beings, the environmental dimension of the resource has been postponed or ignored and not properly managed, which has had consequences in the short-, medium- and long-term availability of the resource"* (*Concertación* civil servant, high political office).

6. Adaptability and Vulnerability in Limarí Basin

The adaptive ability of a socio-ecological system refers to the system's reaction to a specific threat. For the purposes of this study, climate change is considered as the threat, particularly its expression through prolonged droughts.

As we saw in chapter 2, how a system responds to a threat depends on the characteristics of the system in terms of its resilience. However, it is also possible to distinguish four key elements connected to a specific threat: threat identification, threat control, recovery from damage and chances of transformation to deal with new threats. Below we address each of these aspects in turn.

6.1 Threat Identification

The interviews recognize different dimensions in the identification of threat. The three most frequent are climate change, water scarcity and economic risks.

These three dimensions all refer to threats related with climate changes and how the region has been affected by an intense drought for more than seven years. Emphasis of the precise problem varies depending on the kind of interviewee.

There are also elements that crosscut these recognized threats: the lack of information on water availability (especially aquifers), absence of regulations for the intensity and spread of seeding, the introduction of mining companies and water quality decay.

6.1.1 Climate Change

Most interviewees describe a change in the characteristic weather, which represents the main source of threat. Experts, State civil servants and leaders of user organizations speak directly about climate change. However, only a few farmers refer to this global phenomenon, though many link changes in climate with the currents of *el Niño* and *la Niña*.

Among the main changes observed in prevailing weather conditions is the variation in snow density, which consequently produces less water in the area and means water evaporates faster. The zero degree isotherm has been shown to have moved from 1000 to about 1500 meters.

> *"Snow density is different, for a cubic millimeter you had so much snow before, now the same cubic millimeter of snow produces less water, the density is different. There is more space, more air, so when the sun rises the air evaporates and the other influence is the area. I mean, through global warming the isotherm*

> *has shifted, back then snow falling with a density of 0.8 was supposed to fall at 1000 meters, for example; now, as the isotherm has shifted, the amount supposed to fall at 1000 is now falling at 1500; and the amount supposed to fall at 1500 is now falling at 2000. So the density or the area and quality of the snow has changed"* (Camarico manager)

Although the explanations for this change in the snow are not attributed only to climate change but also to the phenomena of *el Niño* and *la Niña*, there is a certainty and consensus about the change in snow conditions during the last decade.

> *"Hopefully the isotherm will not continue rising because that is also making the issue more complicated. The forecast from now until 2100 is four or five degrees and obviously it will tend to rise and the natural reservoir we have in the mountains will no longer be the same. We are facing a scenario in which within 50 years it will not have the same volume, because the idea is, to face it, the area is going to be even more desertified than is today, so you obviously have to restrict, water is restricted and immediately crops will certainly be restricted"* (right-wing civil servant, high political office)

> *"I do not dare accept the causes that tend to be asserted because I do not know its origin, maybe it is a natural change but whatever it is, it is happening. The rain curves are especially low, the thaws were not as violent before but it is happening one month earlier than it used to. I even have a photographic record of this, I work from photos, I have been taking them from one point, since I am here putting them next to each other with the date. And thaws happen early, a photograph from September three years ago is not the same as September now with similar rainfalls. I have understood that the effects can be seen in the long-term, 50, 70 years later, let us say that is the catastrophic effect, not before but on a small scale it is because the snow is gone before"* (administrator, Hurtado river Monitoring Board)

Knowledge Production

There are also fears of serious deficiencies in the production of knowledge concerning climate change. This may be because there is an absence of interdisciplinary research and the social and human aspects are not taken into account in tenders and therefore are not seriously tackled by the experts.

> *"I think for example that everything related to drought and also to flooding, which are the two extremes, there is an important part of the social sciences that should be involved, but there is no interest in that. In the State there is no idea of this need"* (national climate change expert)

In addition, experts in general distinguish that this field of research is only beginning to be recognized, meaning knowledge remains highly rudimentary. One of the reasons for this uncertainty

is that measurement points are scarce and instruments are not up-to-date. Therefore, many of the projections are made using imprecise estimates.

> *"I would say that we boast that at a Latin American level we have a great network, the truth is it is not that bad, but it turns out that when the points were defined to establish monitoring stations, 30 or 40 years ago, those were the appropriate points, nowadays upstream of these points you have the situation that resources are being extracted to be used for some purpose"* (national climate change expert)

> *"So far I would say that there is nothing very concrete about it, we are just beginning. There are no further studies of these and in these cases we have been working based on secondary information, in other words nothing new, but based on what has already been done. So, many times you are making estimates to determine what the problem will be here in Santiago, but we have no calculations at the points where they will extract the resources; we have them at a specific point and we do the estimate to transfer the measurements. So it is not very accurate" (national climate change expert)*

It is also recognized that an important part of knowledge acquired is not taken into account by State organizations. Although government agencies request studies, a large proportion of the results have not been read, much less factored into decision-making. Experts point out that in spite of identifying interest among groups of professionals who work in public bodies on issues of climate change, their main interests and priorities are those of the organization, with initiatives subsequently lost in time and reliant only on personal interest.

> *"I have been interviewed by other people from Universidad de Concepción and they asked me 'What are you doing on climate change?' and I answered nothing, to be honest. But of course the question could also be, 'What are you doing to address water stress?' Sure, because the climate change issue somehow becomes secondary, regardless of whether the probability is high, and effectively certain regions will be affected, basically our main problem is the water stress situation"* (CNR officer Santiago)

The greatest source of knowledge identified is the National Climate Change Plan, though it is recognized by its own producer as very uncertain and limited. Though some of the civil servants interviewed highlight its quality and the need for projections regarding climate variability over the next century, the plan is not taken into account for producing adaptation policies.

> *"We hold to what we have, from predictions that researchers tell us 'here it will rain less and there is going to be less snow', that is what they tell us, so we will not have our first reservoir in the mountains and the snow, we should build more reservoirs in the Andean foothills to collect rain water, but there is nothing about that"* (manager, Limarí Monitoring Board)

Moreover, users also claim that the information in expert reports on climate variability is available for investors.

> *"In fact, I think systematizing is needed for each of the areas that are required, so the government is informed, another for investors to be informed and another so that those who actually produce are fully informed and know the risks they face"* (company manager 3)

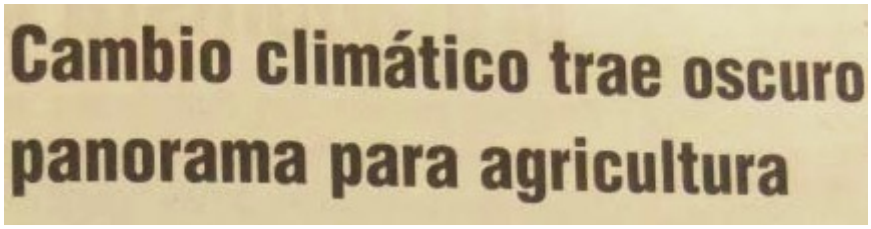
Regional research centers that have greater prominence and maintain an ongoing collaboration with civil servants from the area, farmers, and leaders of user organizations are the main sources of information.

> *"In this sector the role of the universities is very important. They are in research centers like CEAZA, CAZALAC and they have the topic very well integrated, they encourage activities such as seminars, talks for farmers so they can have a culture on these topics. They are very important in the region"* (civil servant Serena DOH)

Farmers identify crop problems that are associated with changes in climate, either as a global phenomenon or through ocean currents, which lead to problems in agricultural production.

> *"I have had problems that I never had before and I attribute them to climate change, for example I have my fruits; usually these are very standardized in terms of size and this year I have had lower quality"* (large-scale farmer 2)

IMAGE 15: CLIMATE CHANGE BRINGS BLEAK OUTLOOK FOR AGRICULTURE


Cambio climático trae oscuro panorama para agricultura

Source: *El Ovallino* newspaper (03.12.2007)

6.1.2 Water Scarcity

Since the construction of reservoirs, the system has only failed twice due to extreme drought, in 1996 and 2013. Nonetheless, after the failure of 1996 there was heavy rainfall, meaning the reservoirs recovered. 2013 was the first time that the shortfall was maintained for a long period. Region IV has now experienced seven years of drought, and the reservoirs will be dry by the next season. This will mainly affect the Limarí province where there is greater agricultural production.

> *"In Region IV, I think we have had about seven years of drought and believe me that within two more months the dams will be dry, at least in the Limarí province which is the strongest of all of northern Chile, as far as acreage is concerned. The early vegetables, the fruit which comes to us, the grapes and vegetables*

> *consumed in Chile are there; we will reach two months with reservoirs at zero, absolutely zero"* (right-wing civil servant, high political office)

The vast majority of interviewees identified the fact that it may not rain next winter as a major risk. Without rain the new season would be catastrophic, because there is simply no water in the reservoirs, with no reserves for the new season.

> *"Well, if it does not rain this year obviously it is going to be catastrophic, because the reservoirs will not be able to sustain agriculture as we know it so far, that requires a lot of water and there is no water"* (independent agronomy expert)

The prediction for the season divides into three scenarios: it rains enough for the season; it rains just a little so it is not possible to sustain the entire season; and it does not rain. In the last case, companies would stop producing. One possible consequence would be that a lot of entrepreneurs would leave the basin, with serious consequences for the province.

> *"If it does not rain next year, entrepreneurs are going to leave, I do not know where, but for people who work who make a living from that I do not know what is going to happen, there will be major complications, we prefer to think it will rain"* (small farmer 1)

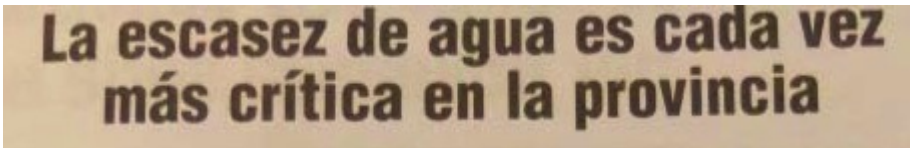
Agriculture

It is recognized that efficient irrigation has permitted the achievement of maximum efficiency in water use, but this has the consequence of a much higher risk. Due to the intensive use of the resource, the planted area affected by the drought is much larger. This issue is very important for large agricultural companies and mid-size and large-scale farmers with efficient irrigation systems: *"Today the issue is much more sensitive because the same pond waters three times the hectares"* (company manager 1).

A serious difficulty when establishing the idea of drought is that even if the year is “normal”, the system will remain under significant water stress, because there is not enough water for the reserves to recover. This is because the system works with a horizon of three years.

> *"It is drying up, I could say anything about the rainfall, and this year was a normal year with a lack of snow. But it rained, is almost difficult to say drought, even the new boss, the new Executive Secretary of the General Commission of Irrigation, he accepted it and said there was no drought, of course, if the rainfall supports the opposite idea. Where was the drought? Our system is for three years, this year our system stores 1 million cubic meters. You have to store water for three years and three years were already fulfilled and this year people already said that the dam would remain at 25 million, we will maintain 20. That is very little, at 25 million the level will stay under the valve and will not reach it to come out"* (manager, Hurtado river Monitoring Board)

IMAGE 16: INCREASINGLY CRITICAL WATER SCARCITY IN THE PROVINCE



Source: *El Ovallino* newspaper (10.01.2008)

Water Companies

The cubic meter is becoming more expensive and water companies are forced to buy water to meet demand. This can have serious consequences for public consumption.

> *"The cubic meter is about 120 and the water company charges 400 pesos, well they also charge for conduction and treatment... so go figure. For this reason, this situation can become really complicated. Because they have to buy the water they are missing, anyway they are controlled by volume and then they say ok, let them take their right of 100,000 m3, but then they took 150,000 and extra volumes they have to pay as a rent"* (civil servant DGA Ovalle)

There is preferential treatment for water companies in the sense that they do not take turns and receive a continuous supply of water.

> *"The water company provides preferential treatment in the sense that they give water continuously, they do not take turns or anything. But they do engage in apportionment, which means they will share the 66% also with them. And if it is not enough, you have to go like the rest to the water market and buy"* (civil society Ovalle)

It is important to emphasize that part of the problem is that water companies are private and are legally guaranteed profitability, so if the price of water is very high, they also raise the cost of drinkable water. Then the Monitoring Board declares that although priority is given to the water companies, they must purchase water rights or water volumes like the rest of the users, as they are a private corporation.

> *"What they have done in other basins is also to rent or purchase water rights. Sure, so this year we will have around 20 million if they use 9 million, I think there are also restrictive measures and restrictive situations inside houses, you will have to use less water, but what they have been required to do, and I remember that in previous droughts in Santiago, water companies had to rent rights because they claimed they did not have enough and they were told "well, this thing is based on rights, so like any private party as this water company is a business, then rent your rights""* (leaders, Limarí river Monitoring Board)

Moreover, currently declining volumes are already affecting the dilution of waste by water companies, which directly affects water quality. This problem will undoubtedly worsen if it does not rain during the next season.

> *"There are farmers who are affected, especially first channels that are close to the unloading zone because as the water slips it gets diluted, but first channels are affected, because they get water of very poor quality. We have repeatedly made complaints to the Superintendence of Sanitation Services because the truth is that the water is insufferable in appearance and odor. Then there is a serious problem"* (leaders, Limarí river Monitoring Board)

The fall in water quality becomes patently obvious when the river is approaching the mouth. This is because the dilution rate is lower and sewage, fertilizer remains and salts from soil erosion are added to the water.

> *"In the Limarí river the change in water quality is evident, when you go down to the end of the river, the salinity increases by the presence of watersheds and in dry years it also becomes more acute, because the rate of dilution flow is lower. Then the issue on wastewater appears, the issue on water quality, which is also affected by products used for agriculture"* (leaders, Limarí river Monitoring Board)

IMAGE 17: PEOPLE COMPLAIN AT SOTAQUI BECAUSE WATER GOES BROWN

En Sotaquí reclaman porque el agua les sale color café

esde hace tres emanas que el vital emento se ve raro, que preocupa a los ecinos de esa locali- ad. Pero la empresa segura que todo stá en regla.

Francisco Zúñiga Michea, de Sotaqui, hace tres semanas ue lo está pasando mal or culpa del agua potable

El poblador de Sotaqui tomó esta muestra de agua y que no puede consumir por su coloración.

Source: *El Ovallino* newspaper (27.09.2007)

For water companies to have priority an Emergency Decree must be passed, by way of which the Monitoring Board should give priority to safeguarding human consumption. In the case of people who do not have access to a drinkable water network and where the wells of the rural drinkable water system have gone dry, water is brought with cistern trucks.

> *"There the highest priority is drinkable water which is guaranteed throughout this year in large cities, and for areas that are obviously far from big cities and do not*

have wells the network is brought closer through trucks with drinkable water, that happens today, but the big cities are supplied" (right-wing civil servant, high political office)

IMAGE 18: LOS CANELOS LOCAL COMPLAINS OF SPENDING MORE THAN A MONTH WITHOUT DRINKABLE WATER

Source: *El Ovallino* newspaper (30.10.2009)

6.2 Control Capability

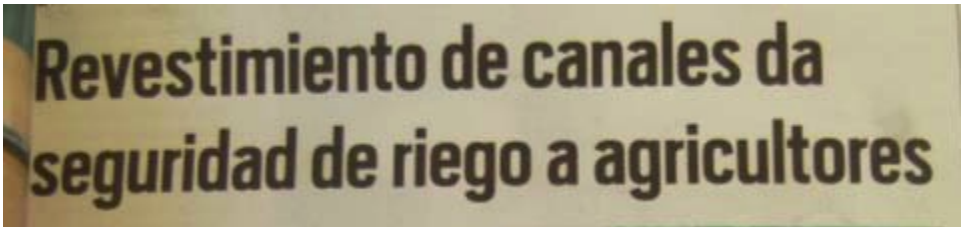
When the adaptive ability of a system is evaluated and threats are identified, it is necessary to observe the chances of controlling them. In the context of the socio-ecological system being analyzed, the main control strategies are efficient irrigation, the water market and State benefits. Of course, these control strategies are applied with obvious differences depending on the type of farmer and the farmers' own abilities to control the threat.

Below we describe different parties' evaluations of the various control strategies. The parties considered in this study also commented on the strategies implemented to address situations of scarcity.

6.2.1 Efficient Watering

Channels and reservoirs are essential to increase irrigation efficiency. These contribute to cutting the amount of fresh water that is "lost" into the sea, storing and distributing when plantations require water. These elements together provide what farmers call "security of irrigation".

IMAGE 19: CANAL LINING GIVES FARMERS SECURITY OF IRRIGATION



Source: *El Ovallino* newspaper (04.02.2009)

To achieve this security of irrigation, maintenance of reservoirs and canals in addition to distribution of stored water are fundamental tasks. In this context, user organizations play a very important role, since they are responsible for the management of irrigation facilities and water distribution according to user rights.

For the Limarí basin, the Paloma System bears responsibility for coordinating the distribution of water from reservoirs and channels, deciding how much water will be distributed each season and coordinating other user organizations in this respect. This system would work very well in normal drought times, but when scarcity is extreme or has already been widespread for years, as in the case of the latest drought, clear problems emerge in controlling the threat.

For example, last year it was decided to use all the water, although this did not meet the recommendations of the Office of Hydraulic Works, which indicated that water should be saved for the next season.

> *"The model proposed by the Office of Hydraulic Works suggests maintaining water availability in the reservoir at about 30%. But farmers said 'what we get today with watering 30%, next year another 30%...' because with 30% many crops die. Then they said, 'Let us water more calmly and next year we will see...'; they are depleting their resources, they preferred to exhaust the grant and they distributed practically all the water in the reservoirs. So, if this year is bad again... there will be no water to deal with it"* (civil servant DGA Ovalle)

Indeed, the following year after the interview was also a dry year and the reservoirs completely exhausted their water reserves.

6.2.2 Market to Control Scarcity

The interviewee responses indicate that the water market is the most important tool to deal with drought. Above all, the spot market or the opportunity to purchase water volumes represent the main strategy for mid-size and large-scale farmers, because when they do not have enough water to water their crops they go to the market and buy the missing volume.

During dry years small farmers sell their water allocations, while mid-size and large-scale farmers buy them. This is because large-scale farmers and agribusiness, apart from having the resources to buy water at market price, usually have permanent crops, which prevents them from suspending irrigation in a bad season, because trees die and their large investments disappear as a result. However, most of the small farmers have temporary crops, which are seeded each season. Thanks to this, they can decide not to plant during a dry season and instead may sell their water allocations. Thus, small farmers achieve a steady income, which in many cases is better at a financial level than the intended planting of a temporary crop.

There is also the chance to purchase water rights. This strategy is mainly adopted by mid-size and large-scale traditional farmers in the basin, who often purchase more water rights than they expect to require for their plantations, because having this surplus allows them to cope more effectively during drought years. Having more water rights than necessary in a normal year allows farmers to have more water availability in drought years.

The price of water in years of scarcity increases significantly. This is because there is no regulation to set the price of water (the water market is autonomous). Clearly, this has the consequence that only farmers with greater financial resources can afford to buy water rights or allocations of water during dry seasons.

> *"Yes but these are expensive, the price is about 100 pesos for the cubic meter, so you cannot afford it. Just imagine that for the chili I spent 9,000 cubic meters, and at 100 pesos each we are talking about 900,000 pesos... you cannot. The company needs 3,000, another 1,000 to pay for water, another 500 over here... so you cannot, it does not work for me. Then I have to lower my expenses, I cannot spend so much... and one of the major expenses is water"* (small farmer 3)

Until a few years ago, a common strategy to monitor the effects of drought was for organizations to overdraw on their water reserves, with the commitment to return the water requested during the next period. This worked in the manner of a credit line in a bank account. However, due to complications brought about by this system, this option was suspended. In addition, during extra dry periods like the current one, it is no longer possible to overdraw because the reservoirs have been emptied.

> *"Before it was normal that organizations used an overdraft, this was handled as a checking account, then they asked for loans and those were deducted in the next season. I mean if I requested 5% more, I had to deduct it from the volume of the following season. But this is not done any more, it was very complicated. What can be done is that a water organization buys from another organization, and they also lend or sell among themselves because they are interconnected.*

> *Irrigators can also purchase from each other, an organization that is complicated can buy certain volumes of water from another organization. I mean if the overdraft was cut off, then the only solution is peer lending"* (civil servant DGA Ovalle)

6.2.3 Role of the Government in Controlling the Threat

There are significant demands on the State during times of water shortage, with strong criticism when it does not meet expectations in terms of mitigation measures. Strategies that are implemented with State support to deal with emergencies include cloud seeding and emergency benefits.

Cloud Seeding

Of the strategies promoted by the State to deal with drought, cloud seeding is the most heavily criticized due to its high cost and the lack of evidence in support of its effectiveness.

> *"Well now they said 'we have to seed clouds'... but these are only lies, I am old here and I know it does not work. If there is drought and* la Niña *is happening, to start there are no clouds. So, seeding occurs when there are clouds, and when it is about to rain and as it is raining or not raining and it can work, 'it rained' they say, but it rained because it had to rain, not because they seeded. People who are dedicated to this also say that in this sector the increase in rainfall would never be more than 15%. There is not much difference"* (mid-size farmer 3)

Consequently, this strategy is mainly seen as politically motivated. The aim is to show that something is being done, even though in practice it has no significant impact on drought. But many farmers do welcome this gesture of trying to do something to deal with the drought.

> *"Well, cloud seeding is greatly appreciated, because it is better than doing nothing. At least one sees the Government's concern behind it, saying 'hey, look, we do not have our arms crossed looking mournful, at least we are doing something"* (company manager 4)

Emergency Funds

Among the resources released by the State in situations of drought are emergency funds, which are used for example to cover channels so as to avoid losing water through seepage. Such benefits are welcomed when appropriate. However, there are important questions in this area as well, because during the last drought the resources came when there was no more water in the reservoir, so there was no reason to cover the channels. To address the last emergency, the State gave five billion pesos, one billion to buy geo-membranes and four billion to be claimed through benefit applications. Yet

civil servants acknowledge that very little could be achieved, as due to bureaucratic difficulties, the resources did not reach the farmers in need.

> *"The regional government created a fund to alleviate the issue of this year's complex situation, which would become concrete through passing a development law to be administered by the CNR, providing four billion for two specific things: installing geo-membranes with a refueling system of channels, but cheaper to prevent infiltration; but there were problems in the transfer of funds and the money arrived late"* (CNR commissioned officer user organization)

Moreover, State organizations recognize that due to the scale of the drought, despite the resources invested to control its effects, they have not accomplished a great deal simply because there is no water.

> *"But in this emergency the truth is that there is little we could do, we have limited room for maneuver, I think the conditions do not exist for being able to bring more water than what we have, it is a huge drought and emergency actions have been numerous, but they will not mitigate all the terrible drought that there is"* (right-wing civil servant, high political office)

In addition to these emergency measures, the State supports small farmers with benefits and debt restructuring, or with food for animals.

> *"Well, little ones cannot buy water at the market, big ones can. The State supports small ones with benefits, bonuses, support, waivers, because all the small ones cannot pay their loans, the State must even give them nourishment, food for the animals"* (civil servant Serena DOH)

IMAGE 20: FIRST DROUGHT EMERGENCY BONUSES DELIVERED IN LIMARÍ


En Limarí entregan primeros bonos de emergencia por la sequía

Cuarenta fueron los beneficiados de la provincia más diez campesinos de Combarbalá.

Source: *El Ovallino* newspaper (01.03.2008)

IMAGE 21: NATIONAL COMMISSION OF IRRIGATION HANDED $548 MILLION TO IRRIGATOR ORGANIZATIONS


Comisión Nacional de Riego entregó $548 millones a organizaciones de regantes

Source: *El Ovallino* newspaper (15.10.2008)

Priority Access and Scarcity Decrees

It is very difficult for the State to establish priority uses, because as it is not the owner of the water rights, it must consider the interests of private parties. Despite this, in emergency contexts the organizations responsible for delivering drinkable water are given preferential treatment. For example, water companies are permitted to draw water continuously and are not subject to the shift system like other users. However, water companies are only given what they are entitled to have and if they run out of the water corresponding to them, they are forced to buy water to meet the needs of the population (DGA officer Ovalle).

IMAGE 22: EMERGENCY COMMITTEE IN LIMARI PRIORITIZES DRINKING WATER


Comité de emergencia en Limarí prioriza agua para la bebida

Source: *El Ovallino* newspaper (14.02.2008)

Legal remedies exist to expropriate rights and focus priority on human consumption. Nonetheless, to date these resources have not been used because it would be too expensive for the State (it would have to pay for the expropriated water rights at market price). As such, then, these powers have not yet been used.

> *"It is in the law but has never been used because, let us say 'we are going to leave all these avocado crops dry to give water to the lady', then who pays? We have not reached that yet"* (civil servant DGA Serena)

One of the strategies that the State has to address situations of water scarcity is through scarcity decrees. Under these decrees the State has some additional powers to authorize water extraction in order to deal with emergency situations. Interestingly, in some critical areas consecutive scarcity decrees have been established. Thus, the decrees that should be an exception become the norm and this context of normalized exception is constantly responding to the immediate emergency, meaning there is no chance to ensure the sustainability of the basin from a long-term perspective.

> *"These scarcity decrees are exceptions that can be established according to the Water Code. However, we have several scarcity decrees... we are experiencing an exception that is already becoming a general statement. So then you ask yourself: is the Water Code responding? I do not think so. Because, for example, what a scarcity decree allows is to extract water without a right to use it, to survive and to save your crops too. Then a new version is issued to function. It is supposed to be an exception, but now we already have three shortage decrees in Ligua-Petorca, for example. So we are living in a permanent state of exception"* (civil servant DGA OU)

The great difficulty presented by these states of emergency is that after 1981, even though powers were allocated to the State in these contexts, if any private water rights are violated in order to address the emergency, the State must pay. This is a severe limitation on taking action in emergency contexts.

> *"Before 1981 the State had more strength. Facing a drought for example, the State could define priority. There was an emergency and the State said, ok, first priority, drinkable water, second for animals and third for other uses. The State passed an emergency decree and managed water, however not now, the State can still pass a decree on water shortage or agricultural emergency, but the one who loses his right, the State has to pay for the damage, they have to repay them"* (civil servant Serena DOH)

6.2.4 Differences among Farmers to Confront the Drought

Strategies to control the threat of drought vary widely depending on the resources that farmers have. As mentioned above, the market is one of the main resources in coping with drought; however, market participation is absolutely conditioned by the resources available for farmers. What small farmers do is establish temporary crops, as a result of which they can and do sell their water volume (in some cases also the water right). Mid-size farmers attempt to buy water volume to cover or save what they can, favoring the planted areas that generate higher profits. Finally, big business and agricultural companies often meet their water needs by purchasing water volumes or new water rights.

> *"Then you start to see two phenomena: 1. Producers with no permanent crops who are willing not to plant that season sell water, usually at real prices, which suits them better than planting and means a secure income with no risk associated with drought, and sell that water to those that are more exposed to the effects of drought, basically producers of permanent crops. In this way, thanks to the market, in a drought situation you allow water to be redistributed, and the little water left gets to where it is most needed"* (pro-market expert)

Another strategy of large-scale farmers is a financial evaluation based on the amount of available water, prices and potential losses, thereby deciding which sectors are more profitable for planting and leading to a decision as to which sectors to water or leave dry.

> *"We just water less. I mean, we get water to whatever we can water, later we have to leave a part without watering. Last serious drought I was a kid, but this year I remembered it because you see dry trees. People decide where to irrigate, the rest is left dry"* (small farmer 2)

Those with fewer difficulties would be the traditional large-scale farmers, who by access to resources and knowledge of the area have more rights than planted hectares. A practice common to this

category of farmer is to buy three shares per hectare, as a protection strategy against drought.

Another strategy that is implemented, depending on the resources available, is to build emergency wells. Those who have sufficient resources (it is an expensive measure) build wells to extract the water that corresponds to them at surface level, from groundwater.

> *"Each private party has a pool of strategies, if you ask a private party how he manages when things are bad he will give you a list of things he will do, and believe me he is going to do them, and has them in order, and if you start to find out why he put them in that order, there is a fairly clear rationale. Among those things are: I reduce, I shrink, I used to grow ten, now seven, and the other three I am going to grow half, I will water it a couple of times in the season and I am going to shrink it and if it is more serious I leave those three and if it is even larger I leave the annual crops or the short-cycle ones and I stay only with permanent crops and if is even larger than that, I buy water on the spot market but well, if not, I make a well or I exploit the well that I already have from the previous drought"* (local university expert)

A strategy that is used by farmers with permanent crops is to cut the trees to the trunk, because as it requires less water, the tree has a higher chance of being saved.

> *"For those who are in crisis, what these people do is to cut the tree at the trunk so that the tree will not die because it stops the evapotranspiration, since the transpiration occurs through the leaves... then having no leaves, you just put a droplet of water and that holds the roots down, so the tree will not die"* (mid-size farmer 3)

Usually, we can say that the problem is always for the smallest farmers, since those with more resources can buy water, while smaller farmers can only reduce surface or introduce shorter crop cycles. They have neither the opportunity to buy water nor the chance to make investments in more efficient irrigation systems or to build wells. In addition, in some cases and despite forecasts of shortages, small traditional farmers continue planting intensive watering crops. Sometimes they do not make rational decisions, but it is merely a question of habit.

Finally, a fundamental difference was observed between the regulated and unregulated areas: in reservoirs it is not possible to trade water volumes but rather water stock or water flow (renting or buying). This means that in the case of the regulated area, irrigation security is much higher because it is possible to store large amounts of water and trade water volumes (local university expert). Paradoxically, some farmers who have water rights above and below the reservoir identify the supply below the reservoir as more problematic, since they run out of stored water, but above the flow continues, though it may be limited, and it is shared.

6.2.5 Prolonged Drought

From the perspective of user organizations, a common strategy is to deliver water through shift systems to avoid losses from leakage to the greatest extent possible. When this happens, each farmer must water whenever possible, but according to the watering schedule (manager, Hurtado river Monitoring Board). But in some extreme cases, another strategy to cope with drought is cutting rivers and then passing the flow from one channel to the next, in order to stop losing water through leaking and evaporation. In these cases, it is clear that the sustainability of the basin is not considered, as rivers dry up.

> *"In extreme cases, for example if it does not rain again this year, goodbye ecological flow. Nobody here is going to respect the ecological flow, here you need to water the trees, so everything will be consumed. Here what you do is whenever there is more water, for example, instead of 2,000, there are only 300 liters, we know that the water is not enough to get to the end, because it will be absorbed and will not be enough for anybody, then that is what is done, the first channel is taken and all the water is pulled, then passed to the other and so on, then we do not make it go through the river, but only from channel to channel. But that is only in situations of extreme drought"* (leader, Mostazal Monitoring Board)

All these strategies are for normal dry years. In critical periods, this is not possible, as there is no water to distribute, sell or pump. In the context of a critical period, strategies are limited to reducing planted land, closing the fields and working temporarily in another sector, migrating to the city in search of employment, surviving with State benefits, and receiving water in trucks.

In Limarí basin during the 2013 and 2014 seasons, the situation was so critical that the reservoirs dried up and the Paloma System failed, which meant they began to distribute river water as if there was no reservoir.

> *"When the reservoir fails, everything that enters corresponds to Limarí river, so I have to charge it to them. Who are the creators of water exploitation rights in the condition without reservoir, then the model establishes that the condition goes back to without reservoir"* (administrator, Paloma System)

In this extreme situation, farmers are seriously affected and it is also not feasible to ensure drinkable water, as this comes from the reservoir.

6.2.6 Cooperation as Control Strategy

Conflicts between farmers are more evident when there is a drought. Water theft is complicated and accusations between neighbors or between irrigators from the same communities become critical. Similarly, user organizations are more frequently questioned. Civil servants will only interfere when

there is no other option, since water problems are conceived as problems between private parties.

> *"We act when the situation is already out of control, before, the truth is that they have to solve the issue among themselves. It is like being in the jungle where the big eats the small, in fact it is, in theory, whoever has a lawyer and has financial resources to handle a conflict and therefore has more chance"* (civil servant DGA Serena)

Despite this, some basic cooperation agreements have been established in private when facing a great crisis, to confront the imminent shortage in terms of human consumption. These are called water tables (*mesas de agua*), which have worked under certain circumstances but so far have not been institutionalized and only work in response to the emergency and in specific contexts.

It is also possible to see some support networks operating in contexts of extreme scarcity. However, it must be highlight that these are scarce and limited to family networks.

> *"So imagine, I have to rent more land in order to water, I rent 16 in order to water 10. And now I am watering a little more because my cousin lent me a bit of water. Otherwise, I would have finished my water in February"* (small farmer 3)

6.3 Recovery Potential

The third step in the adaptation process is linked to the system's recovery from the threat. In this study, the different parties' discourse leads one to the conclusion that there is a chance of recovery, especially when comparing to past droughts and the diagnosis of the current situation.

6.3.1 The Market as an Alternative to Recovery

After several years of drought, farmers may face serious financial problems depending on the investments involved in damaged crops. Specifically at risk here are farmers with permanent plantations, who may suffer severe damage related to the death of trees. This mainly affects mid-size farmers, who generally incur debt in order to seed and cannot meet their financial commitments if their crops fail.

Small farmers who manage to react in times of crisis may decide to sell their water for the season, so they avoid losing crops and can overcome the dry season. This creates a much better position from which to recover.

> *"Then the spot market offers a unique opportunity for these farmers to reduce their exposure to risk. Either I failed in the season or I planted something and I see that the situation is very bad due to the drought, my plants are going to die, then I decide to stop my crop and sell the water, so then I could protect myself against the risk and keep my water rights. That is what many small farmers do, since the*

> *existence of this market has enabled them to face the risk in this way. However, large-scale farmers, besides buying water, also have crop insurance; they can take out loans and there are plenty of ways to face the negative effects of a drought"* (pro-market expert)

More traditional sectors, which do not participate in this market, can only try to save their animals and crops, but this is impossible in large droughts and very significant losses occur as a consequence.

> *"There are some, there are sectors that are very old in the basin, where it will not happen and it becomes: I will water precariously, I will make sure that my animals are well and I will be saved from drought as I have been saved for the last 50 years and they will do it that way, but those are the more traditional sectors, those who have not been touched by the magic wand of communications"* (local university expert)

An important difference between farmers is the production horizon. While those who have vegetable (or temporary) crops calculate their losses for the season, large plantations must consider their business on a five-to-ten-year scale. In this context, the damage to production and recovery times are also completely different.

At the same time and due to the market itself, one of the problems faced by State organizations in implementing recovery projects in the area is the high cost of water rights in dry seasons. Projects to address the prolonged drought become unfeasible, because the price that the State would have to pay to have rights cannot be met.

> *"We are tied up, beyond bureaucracy, the issue of the market itself is sharp, complicated, sometimes you have projects and have no water right, and you simply do not have any water right, for example, go and buy water rights at Puclaro, La Paloma, they are no longer sold. One can do many things and then you face having no rights, it is an extremely sensitive issue, the market operates but of course it is not as open as to go there and buy"* (CNR civil servant Santiago)

Due to the characteristics of the Water Code, although water is stated to be a national asset for public use, ending a grant of water rights means expropriation, an unthinkable option due to the costs it would imply for the State.

> *"Besides the Water Code has a trap, because it recognizes the resource as a national asset for public use, but at the same time is an alienable asset. It is like a kind of concession, but it is very hard to end this concession. Then the State would have to expropriate the resource and this is justified only under special conditions that so far have not occurred"* (CNR civil servant user organization head)

Thus, the State faces significant limitations in generating support strategies for the recovery of the area.

6.3.2 Intensive Farming and Depletion of the Basin

It is essential to highlight the difficulties that the basin faces in recovering from water scarcity with respect to agricultural over-exploitation. The spread of cultivated crops has tripled in recent decades, as has the intensity of the plantations. Before, there was a balance between permanent plantations (fruit trees) and temporary planting (vegetables). Today, the situation is very different because the proportion of land seeded with vegetables has decreased significantly.

> *"When the dams were installed people changed and switched to permanent crops, and therefore drought hits much harder than years ago"* (DGA civil servant Serena)

The problem relates specifically to the irrigation security delivered by the reservoirs, channels, and the chance to buy water, as farmers became reliant and accustomed to planting more than they could cover with the water shares in their possession. Thus, it is possible to say that the amount of shares remains the same, but the use of water is much more intensive and the watered area is far greater than before.

> *"People had their shares, with 20 shares they irrigated 20 hectares, later modern irrigation came and with 20 they irrigated 40 hectares and after they irrigated 60 buying water... you see? That means that over time the demand for water rises, because the shares are the same, but the use of water is much more intensive. The irrigated area has grown. But there is no way to limit the number of hectares planted"* (DGA civil servant Ovalle)

The main problem is that much dry land has been prepared for cultivation, working predominantly with permanent crops. Nowadays, investment losses are much higher and the stress on the basin is greater. In this context there is no opportunity for the State to regulate, there are no legal tools to limit the hectares cultivated or the kind of crop. This is also important because, the amount of water required varies depending on the kind of crop planted.

> *"You are in a cute hanging 'paltal' with avocados and have a drought and 50% of the avocados fall, have another drought and the remaining ones fall; the vine will hold more, the vine will hold. You water a little here, a little there and then you save the year, but not the avocados, that is the issue. I have had several avocado trees but I am giving it up"* (mid-size farmer 1)

IMAGE 23: PALTAL IN LIMARÍ BASIN

Photograph taken in Limarí basin, March 2013

6.3.3 Issues in Resource Administration

A critical element in recovery is the risk of the aquifer being damaged. This is because during drought, a common coping strategy is the construction of new wells and deepening of the existing ones. This can be performed by those with the necessary resources and in some cases makes it easier to cope with the crisis. The problem is that the aquifer is subjected to a demand surplus that makes it difficult for the recovery process, due to both over-exploitation and pollution of aquifers.

> *"Whoever has more money makes the deepest well and takes and takes, then those who built their wells first at an average depth are ending up with nothing, then they have to make another well. The problem is that you do not see the effects of an aquifer immediately, you see them later, in the river you see it from one irrigation season to another, but here you do not see, then suddenly you realize that there is no more water in the aquifer or the water has been contaminated with chlorides, with sulfides. Recovering from that would take centuries"* (DGA civil servant Serena)

Thus, one aspect that could significantly hinder the recovery of a basin after a drought is the depletion or contamination of aquifers through excessive use as a strategy to control the damage wrought by a drought.

Moreover, a critical element in recovery is that reservoirs also take several years to be refilled, meaning irrigation security is lost for several seasons. When the reservoir dries up, as happened during the last crisis, it is necessary to wait for several years of normal rainfall before returning to the reserve levels that gave security to the irrigation sector.

IMAGE 21: COGOTÍ RESERVOIR

Photograph taken in Limarí basin, January 2014

IMAGE 22: PALOMA RESERVOIR

Photograph taken in Limarí basin, March 2014

6.3.4 Aging and Migration as a Limitation on Recovery

Another element that reduces the chances of recovery is migration. Small farmers facing great droughts are forced to work in other sectors because they cannot plant on their land. In many cases they either move to the North to work in the mining industry or to the capital city of Chile, because there are supposedly more job opportunities. This profoundly limits the possibilities for recovery of

agriculture in the area.

> *"Many of the small farmers, the poorest, they are migrating. Because they cannot make it, then they have to go to work somewhere else"* (INDAP civil servant Ovalle)

At the same time, if businesses close because of the lack of water for their crops, a severe crisis occurs in the province, because farming is the main source of work. Water shortages and closure of plantations, in addition to the bankruptcy of agricultural companies, also push people to migrate to the North in search of more profitable work in mining.

> *"There are hundreds of thousands of seasonal workers who make their living there, with the employers, so if employers were not there, I do not know what Ovalle would be living off. There is much work, the harvest period, then pruning, later thinning, then tying everything up, what is meant by picking avocados, harvesting mandarins"* (small farmer 1)

> *"I spend a lot of time alone because kids go North to work because here there are no job sources, they leave"* (civil society 2)

The elderly are left alone on their land and new generations are going to look for work opportunities elsewhere. Subsequently, because of this migration, recession may occur at province level, which ends up being a further problem for the central government.

> *"It is a terrible unemployment problem that occurs, lost taxes because that production will not happen, the bank stops it because previously approved loans for crops are not available, then a mini-recession starts at a zonal level"* (manager, Hurtado river Monitoring Board)

This ultimately results in an increasingly aging population and the decline of small farmers and peasants, which further hinders the system's recovery from a severe drought.

6.4 Ability to Self-modify

Finally with respect to the ability of the system to adapt, it is necessary to consider the transformation of the system itself when facing a specific threat. The ability of the social system to make changes in terms of its relation to the environment when faced with similar threats in the future is essential to maintain the system adapted.

These possibilities of transformation are directly related to the ability of the system to innovate and self-organize (see previous chapter). In addition, we consider certain specific aspects that are directly related to drought.

To identify transformation opportunities, we considered evaluations from different observers concerning the following topics: evaluation of current strategies, adaptive expectations, expectations

for legislation, and integrated watershed management.

6.4.1 Assessment of Current Strategies

Stakeholders generally see strategies as reactive measures. All the strategies are concerned with addressing the emergency, with an inability to think about the long-term problem. Far from a transformation of the system, the strategies point to an even more intensive use of the resource.

> *"Today we need to update because we have droughts, because we have basins that can no longer be over-exploited, because we have to create a water highway and do cloud seeding, those are only reactive attitudes of a system in which we have not been able to think about the long term"* (national expert)

Similarly, organizations invest as much as possible in an efficient use of the resource, in order to extend land use with safer irrigation. This also involves intensive resource use without modifications to the model or strategies that incorporate the long-term sustainability of the watershed.

Paradoxically, the end of the drought is among the dangers associated with the lack of innovation in providing adaptation strategies. This is because the only way to achieve a level of awareness of the need to modify the model is through a sustained crisis over time.

> *"You know what will happen, if the drought is over and this year is good, imagine that the reservoirs are filled, they will forget the subject. No one is going to talk about the drought problem any more, the law will continue to operate but with resources allocated and we will be relaxed for three more years, then when drought returns that will last seven more years then it is going to start again, at first in the middle of drought, we will be alert and then as we solve the problems it is going to end and this is a never-ending story. Now if all you are doing everything and the drought stops, we should continue to do so for the next term so it would not merely be useful to face what is happening now"* (manager, Hurtado river Monitoring Board)

6.4.2 Adaptation Expectations

In the words of the great majority of those interviewed, there is concern only about the next season, about the urgency of the current irrigation plantations. Despite the issue of climate change appearing in some contexts, this is not reflected in the coping strategies employed. The horizon remains merely the following year.

> *"I think the only thing you can do now is pray for rain, because we have nothing left"* (small farmer 1)

Concurrently, the State shows no real interest in projections of vulnerability to climate change. There are only small groups or isolated professionals who show some interest in the results, but it is clear

that they have no resonance in the organization.

> *"There are groups in the Ministry for Public Works that are not formal, they invite you to deliver information from the results of your project, this is generally people who are working on climate change issues and water resources but it is informal, it is rather on its own initiative, it is not a requirement of the organization. But at least that could give rise to later having a group that is at least interested in the subject and can participate in something more formal in the Ministry"* (national climate change expert)

The DGA, which is the most important organization with relation to water issues, does not have a head of climate change. This makes it clear that there are no strategies from this organization (DGA officer Santiago). The CNR is somewhat similar. Although there is a person who has participated in a committee on climate change, it has not gone beyond assuming that the projections indicate future problems in access to water, but since the organization that implements different measures focused on efficiency in irrigation has no powers, then no relevant action is taken.

> *"Well, if everyone agrees that climate change affects water resources, if we are clear, then we should think of a more fundamental issue, but that is it, because truly, we do not do anything about it"* (CNR officer Santiago)

Moreover, in user organizations, although the problem is recognized, neither alternatives nor strategies are visualized to address climate change and drought in the longer term.

> *"I have been discussing the report I made to the Board, not in terms of climate change, but as statistics from the Board, I have detected the thaw comes a month before, that is how it was before, melting in September, now we are in August already, that happened and that is a fact, I am now at the stage that we have reported, we have talked but at this time we have no contingency plan in this regard"* (manager, Hurtado river Monitoring Board)

6.4.3 Ruling Expectations

A key element in the potential for transformation is the ability to modify the model. In order to do so, the law on administration of water resources must also be amended. In general, expectations are low in this regard. Different interviewees agree there is a lack of political concern about the water issue, the general lack of public awareness, and the lack of appropriate tools to generate amendments to the model.

For many of those interviewed it is essential to improve the institutional conditions of water management, for example by strengthening the oversight capacity of the State. This would be extremely important, since many of the scarcity problems relate to situations of over-exploitation.

Drought should be considered as a normal element of the sector, so as to achieve better contingency

plans. Here it would be essential for the State to have greater powers to control the different economic groups related to water resources.

> *"What one should aim at is to accept that drought is a normal phenomenon in this sector and thus have contingency plans, A, B and C. And how I handle a water culture in the region where water is valued differently and how I can give tools to the state for a better way to stay firm and you can act before these great entrepreneurs who run the region, manage water and do what they want"* (DOH officer Serena)

In general it is recognized that the Water Code is not adequate to face the situation and the institutional conditions to confront climate change have not been generated.

> *"So we have been living in a state of emergency for quite a while. And I do not imagine that this will happen or that it will be something specific, but rather climate change is a general issue. You will have moments of great drought and other water-intensive times. So, is the Water Code adequate to face this situation? No. Besides, there are no institutional tools to face it... I think we are not prepared. Not at all"* (officer DGA user organization)

However, far from having the intention to make changes to the legislation, representatives of the current government indicate that the model will achieve agriculture intensification through a more efficient use of water resources (right-wing civil servant, high political office). The stated path to achieve this aim is to develop more irrigation facilities, even considering building more reservoirs, channels, and even a water road. This latest initiative seeks to transfer water from the southern to the northern regions of the country.

> *"The water road is a long-term project, we want to get all the surplus that is in the South and bring it to the North which is where we have the problem"* (right-wing civil servant, high political office)

Expectations rest on a crisis of major proportions that results in social unrest forcing the model to be modified. This may occur when there is greater water scarcity in the central part of the country. In addition, new leaders who can trigger these processes of profound transformation are necessary.

> *"It seems to me that there must be constrained situations of access to the resource and there must be leaders that have the qualities to lead the process, but both conditions together: the need and the leaders, because the institutional and legal issues are too restricting to develop these community initiatives. Well, and third, but it should be first, there should be national mobilization on the water issue, where the State is pressured to re-legislate"* (civil society South)

6.4.4 Integrated Watershed Management

Finally, experts indicate that the only way to achieve adaptation to climate change is through altering

the policy for rights delivery and regulation through the market. It would not be possible to sustainably manage a basin with the current model.

> *"If what we want is a global thing in a particular basin, the way rights are being delivered today, where the one above may exercise all its rights carrying problems downstream, it does not work. So if you want something at the basin level, you need to create separate management, as integrated management is impossible with the institutionalism we have today"* (national climate change expert)

Geographically and administratively, Chile would be capable of installing an integrated watershed management system. But for this to be achieved, certain legal reforms are required to strengthen its operation and return to the State the legal tools to implement such a system.

> *"I believe that Chile has the potential to have an impeccable integrated watershed management to operate efficiently. However, there are certainly going to be some legal instruments that will have to adapt to a management structure based on the logic of integrated basin management; but I insist it has all the potential that the political and administrative division of the country offers us. We benefit from the fact that user organizations are sharply demarcated, consequently there are valid and recognized parties or interlocutors, which have legal significance and are easily identifiable. This is not unknown territory, there is a point that is key and that is a regular structure of the State which has jurisdiction over the resource. Therefore, the conditions are present, what is missing is to organize the public institution"* (*Concertación* civil servant, high political office)

In this context, the experience of the water tables is an important landmark. These are referred to as instances when efforts were made to implement a collective management of the basin. However, the descriptions of these instances indicate that the fundamental weakness of the experiences was that they were merely grounded in goodwill. There was no legal basis for collective decisions in these areas, and therefore, they were not valid and the great owners of water rights (agricultural and mining companies) did not accept the decisions that did not benefit them.

The experience of the water tables establishes the need for an amendment to the law to ensure that the decisions made are binding and that respect for agreements does not solely rely on people's will. According to the evaluations of our interviewees, there is no other option if we wish to move towards integrated watershed management.

7. Ability of Chilean Model to Deal with Situations of Water Stress

Water is one of the elements that are vital for humanity's survival. Although a large area of our planet is covered by water, the water resources available to humans are limited and of unequal geographic distribution. It is estimated that, at present, close to one-third of the world population lives under some form of water stress and that by 2025 this figure could grow to two-thirds of the world population (Mauser, 2010).

Chile is a good example of this situation. While in southern Chile there is abundant water resource availability, in the North we find very limited availability. Northern Chile is one of the driest regions in the world. It faces significant situations of water stress, accentuated by the intensive exploitation of its aquifers and surface waters through mining, farming, and industrial activities and urban sanitary services. In parallel, the projections for this zone in the light of climate change predict a possible intensification of water scarcity due to rising temperatures and forecasts of reduced rainfall. Multiple situations of vulnerability have thus been identified at rural and urban levels (ECLAC, 2009; CONAMA, 2008; AGRIMED, 2008; DGA, 2007).

Access to water resources in Chile is managed through a water market, wherein water resources are administered much like a commodity: subject to the forces of supply and demand and based on a free market regime that regulates the use and consumption of national resources. The legislation that established and legitimizes this market is the 1981 Water Code, which allows water rights to be traded independently of land ownership. Studies on this issue have identified various problems in this institutional framework, among them a significant concentration of water right ownership, a worsening of water stress, the absence of an integrated management of watersheds, and various limitations on government control of the resource (Chile Sustentable, 2010; Bauer, 2003; Donoso 2003; Hernández, 2006; Núñez & Soto, 2010; Gentes, 2007; CEPAL, 2003; SAMTAC-CEPAL, 2000; Banco Mundial, 2011). In spite of all these difficulties, the sole significant reform implemented in respect of the Water Code (in 2005) merely modified peripheral aspects of the institutional framework (such as the payment of license fees for non-use, ecological flows, and procedures for the creation of water communities, among others).

Considering the new scenario generated by climate change projections for the region, understanding the Chilean model and assessing its benefits acquires major significance. It is foreseen that the current water management difficulties may worsen as competition for water resources grows, and

ever more pressures are brought to bear on the current institutional framework (León, 2008; Hadjigeorgalis, 2004; Gentes, 2007). Faced by ever greater situations of water stress, both institutional governance and local resource management become vital for adequate water resource management and sustainability.

This research has aimed to observe the Chilean model for confronting situations of hydrological stress. This topic is key from the point of view of climate change, considering that the Chilean model represents a globally unique institutional response in the context of a country that struggles with an intensifying water scarcity issue in its northern and central regions.

With the aim of observing the conditions created by the Chilean model, we decided to research the situation in the Limarí river basin, in the north of the country, a place where the model has been operating uninterrupted for many years. We carried out numerous interviews in this basin, complemented with press and document analysis. This permitted the development of a general description of the socio-ecological system from a social perspective, assessing characteristics related to resilience in this kind of system and adding these analyses to an evaluation of specific reactions when faced with a water scarcity threat.

Below we present a summary of our main findings according to the research objectives and the different dimensions that arose from our theoretical approach.

7.1 Prominent Findings

- The perception of water as private property is previous to the 1981 Water Code. Since watering channel building began, farmers had established an indirect form of ownership of these constructions and hence proprietorship of water: “I have this flow, I built the channel or my grandfather built the channel and this water has always belonged to me”. From the 1930s onwards, when the basin was declared empty and the water rights were established, the water market began to take shape and the idea of water being a form of property became fixed, meaning that in order to have access to water it was necessary to buy water rights from others. Thus, the concept of water as private property was settled in the culture of the areas under study.
- The perception of water as private property cannot, then, be attributed to the Water Code. Even the current code is not completely internalized; many people, especially older generations, do not know they can sell water separately from the land, but they do know they can make money by virtue of water selling and that water is a private property that belongs to each person.

Nonetheless, the conditions that were established under the Water Code both invigorated the water market and decreased State powers to confront precarious situations.

- It is clear that the model deepens social inequalities. Farmers with enough resources receive several tools from the water market to confront water scarcity, while small farmers only can sell their water (although this does represent an alternative during periods of moderate water scarcity). At the same time, a sustained increase in the concentration of land and water property is clearly evident. Small farmers are decreasing and agricultural exploitation is ever more prevalent in the hands of large agricultural companies.
- The State does not have initiatives to address the challenges of climate change. Nor does it have them to confront extreme and sustained water scarcity. The assessment given by State civil servants revolves around difficulties they have in confronting scarcity issues, whether because of the lack of power conferred to them or the lack of available resources. Yet the same civil servants observe that their own policies only encourage the use of hydrological resources without providing any chance to appraise long-term sustainability.
- Currently, a huge number of small towns are being supplied by cistern trucks because they do not have sufficient drinkable water (groundwater, rivers, and other sources have run dry). This has affected the quality of life in many small towns and villages within the basin.
- The increasing migration is also related to water issues in the area. As many agricultural crops have been abandoned, people find themselves compelled to look for work in other sectors and areas. Furthermore, small farmers cannot continue living off their land and are pushed to change their occupation and move elsewhere.
- Mistrust is one of the most severe harmful elements for farmers and user organizations. It is evident that there are difficulties in creating associative initiatives. Experiences in the area have been full of failures (for example, cooperatives). Simultaneously, mistrust is widespread because of water theft, which is a common practice among both large-scale and small farmers during times of scarcity.
- A significant issue relating to the model is that it allows changes in use to more profitable practices through the market. Nowadays, the common changes in use are to transfer water rights to the mining industry or intensive agriculture. The problem is that this practice can have serious effects on the basin's sustainability, in addition to affecting individuals.
- To make changes in the model, a constitutional amendment implementing tools to manage hydrological resources at a basin level would be necessary. It could be possible to move towards

an integrated basin management system, at least in part, by making certain legislative changes. Among those elements that would benefit from this kind of integrated management are the political-administrative division and the long tradition of user organizations in the basins where water is currently scarce.

7.2 Resilience and Sustainability

The information gleaned from the discourse of different stakeholders reveals certain aspects that weaken the resilience of the system.

Flexibility: The market provides flexibility in the system. In addition to the legalization and respect of water rights, this has enabled water scarcity to be addressed on many occasions. However, over time this flexibility has lessened due to the lack of State regulation. The fact that farmers have no limit on the extension of their crops creates risk. The Paloma System and the water market allow farmers to seed much more than they could if they only made use of the rights they own. This implies serious consequences for sustainability: on one hand there is an intensive use of hydrological resources, while on the other, erosion comes about from seeding on steep slopes (which eliminates native vegetation).

The indiscriminate rise in permanent crops has led to over-exploitation of the basin and to a reduction of temporary crops, which has permitted the concentration of water use on permanent crops when necessary. If temporary crops continue disappearing in this manner, there will not be enough water to be transferred for permanent crops. One of the main problems for flexibility in the basin, then, is this significant fall in temporary crops. Likewise, innovation has permitted a more "efficient" but less sustainable use of the resource (in relation to production).

Connectivity: The professionalization of user organizations is the biggest strength in this area. These organizations bring users together and are favorable for making decisions as a group, in addition to being responsible for hydrological resource administration. Owing to the conditions for their confirmation, these are organizations requiring associativity for water management. Despite the significant opportunities for associativity, user organizations are deeply altered by the legal representation system they have, because those with more capital in the association have a greater opportunity to influence its decisions. The biggest difficulty in here is the repetition of inequality, which discourages small farmers from participating. Furthermore, mistrust and support network impairment can restrict connectivity within the system.

Memory: In this context, an obvious concern is how people are losing traditional knowledge concerning the relationship with the ecological surroundings. Nonetheless, one may observe a

difference between local farmers and the agricultural companies that come from other places to carry on business in the region. People from the area are more respectful of droughts and take more measures to prevent their negative effects whenever possible.

A further feature is that the State makes decisions about water management at a central administrative level, which makes it harder to take local socio-ecological memory into account in this process. Simultaneously, water seems to be less important for the State in general. For example, the State has no designated body to conduct or administrate water-related issues and conflicts. Responsibility and decisions are divided into different units and these are part of larger ministries where the hydrological issue is not so important (e.g.: DGA at Ministry for Public Works, CNR at Ministry for Agriculture, Ministry for the Environment).

Self-organization: Among the main difficulties recognized is the incompetence of the system in modifying hydrological resource administration rules. As these rules are defined by concentrating them in the State, though there is awareness of the difficult problems the model has in the area, local parties have no chance to control or make decisions about the rules. This is remarkable, taking into account that this is the basin where the model operates at its best and it is this experience that has given rise to the desire to emulate the model in similar basins.

With regard to the market framework, clearer innovations have been introduced, such as the establishment of an electronic market and the meaningful contribution of clearly stating prices and trading.

User organizations have also achieved the creation of new initiatives to encourage regulation, for instance restricting transferring. This kind of regulation has allowed problems between users to be avoided. Nevertheless, user organizations can only ensure that users make use of the amount of water to which their rights entitle them, but cannot interfere in the kind of use, the crop extension or the kind of crop planted.

7.3 The Adaptability Issue

Finally, through observation of the system when faced with a specific threat, one may judge the existing chances of adjustment. Below, we scrutinize the four elements set out in our theoretical chapter.

Threat identification: the main threat identified is worsening scarcity related to desertification, soil degradation, water pollution, and financial problems relating to the harm suffered due to farming

exploitation. Concern regarding climate change is limited to experts and professionals from some user organizations.

Control capability: Face with an ongoing threat, the system loses control. Though there are some minor scarcities, the facilities and flexibility of the system allow such a threat to be addressed. Yet when it becomes widespread, as happened during the last drought crisis, the system does not have the tools to manage the threat. Over-exploitation and authorizing extensions of use is identified as the problem, with limits required on crop planting, but there is no strategy to prevent this activity.

Recovery potential: The ability to recover appears relatively restricted owing to the deep crisis and the resulting migration processes. All these seem to highlight that the basin will not be the same after the drought. There will be a larger concentration of property (small farmers sell, mid-size famers are bankrupt), a smaller number of the economically mobile population will remain, and there will be a rise in desertification and soil degradation. Owing to the empty pools, the system will take years to recover its storage level (if it does so at all).

A serious additional problem is that channel and reservoir overlaying conducted by the CNR for an efficient use of human resources has produced a systematic lowering of natural filtration and has caused harm to groundwater refill. This has severe consequences for sustainability of the water supply. The technological development of irrigation is specifically aimed at achieving a larger watering surface, without paying attention to the sustainability of the basin.

Within this context there are important anomalies in State responsibilities. For instance, the State needs to create proper conditions for the recovery of the system, providing guidelines for the appropriate kind of crop for the basin and specifying the amount of soil that should be used for planting. The lack of regulation means the basin has a lower ability to recover.

Transformation ability: Over-exploitation throughout the Limarí basin has clearly produced the current crisis there. A serious issue is that the system has not been able to stop over-exploitation and has no tools to do so. The government states that private parties are responsible for taking care of the sustainable management of the hydrological resource because they can and must do it. State civil servants accept that they cannot control private activity, though they are aware that over-exploitation could harm the aquifers and leave them useless for centuries. The chance of changing this situation is reduced by the previously identified weak ability for self-organization.

The opportunity for transformation is low mainly because of the need for profound legal reform of the exiting legislation. In spite of this, politicians appear to be indifferent or in some cases have water business-related financial interests, with the result that they do not wish to modify the trading rules.

In conclusion, unlike other authors I would say that the problem is not water privatization. Rather, the issue lies with the lack of power conferred on the State and the weak market regulation. Similarly, the State does not have the opportunity to ensure the sustainable management of the hydrological resources.

In addition to becoming aware that the effects of climate change that we are experiencing are the result of our emissions into the atmosphere, we are also witnessing how the indiscriminate growth of crops has sharpened these consequences. This is even starker in the context of a water stress situation such as the one that we have studied. The intensive use of resources has ultimately resulted in the collapse of the basin.

8. References

- Adger, Neil & Kelly, Mick (1999). Social vulnerability to Climate Change and the architecture of entitlements. Mitigation and Adaptation Strategies for Global Change 4, 253–266. Kluwer Academic Publishers. Printed in the Netherlands.
- AGRIMED (2008) Análisis de vulnerabilidad del sector silvoagropecuario, recursos hídricos y edáficos de Chile frente a escenarios de Cambio Climático. Centro AGRIMED, Universidad de Chile
- Alevy, Jonathan, Cristi, Oscar & Melo, Oscar (2011).PROYECTO: Mercado Electrónico del Agua en Chile. INFORME FINAL
- Alvarez, Pablo & Poncet, Y (2011) Evidencias de control sobre la constitución de derechos de aprovechamiento de aguas subterráneas en la cuenca del Río Limarí: caso Pozo Los Alerces, IV región, Chile. Borrador no publicado
- Álvarez, Pablo, Cortés, Mauricio & Pizarro, Iván (2011) Efecto de la construcción de embalses precordilleranos sobre el Sistema Paloma, Provincia del Limarí, Región de Coquimbo, Chile. Borrador no publicado
- Ashby, W.R. (1984) Sistemas y sus Medidas de Información. En: von Bertalanffy, et al. Tendencias en la Teoría General de los Sistemas. Alianza Editorial. Madrid. 3º Edición. 1984.
- Atay M., Jost J. (2003) On the emergence of complex systems on the basis of the coordination of complex behaviors of their elements.
- Attanasio, Orazio; Abigail Barr, Juan Camilo Cardenas, Garance Genicot and Costas Meghir. (2009) Risk Pooling, Risk Preferences, and Social Networks.
- Bauer, Carl (2003) Vendiendo agua, vendiendo reformas. Lecciones de la experiencia chilena. Revista Ambiente y Desarrollo. VOL. XIX / Nºs 3 y 4 / 2003
- Beck, Ulrich (1986) Risikogesellschaft. Auf dem Weg in eine andere Moderne. Suhrkamp, Frankfurt a.M.
- Beckers, T., Birkelbach, K., & Hagenah, J. (Eds.). (2010) Komparative empirische Sozialforschung. VS Verlag.
- Berger, P. L. and T. Luckmann (1966), Social Construction of Reality: A Treatise in the Sociology of Knowledge, Garden City, NY: Anchor Books.
- Berkes, F., Folke, C., & Colding, J. (2000). *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge University press.
- Bertalanffy Von, L (1976). Teoría General de los Sistemas. Editorial Fondo de Cultura Económica. México.

- Björn Nykvist (2012) Social learning in the Anthropocene. Governance of natural resources in human dominated systems. Doctoral thesis in Natural Resource Management. Department of Systems Ecology. Stockholm University
- Blaikie, P., T. Cannon, I. Davis & B. Wisner. (1994). At Risk: Natural hazards, People's vulnerability, and disasters. London, Routledge.
- Brandão, G.(2012). Acerca del concepto de sistema: desde la observación de la totalidad hasta la totalidad de la observación. *Revista MAD, 0*(26). Consultado el ago 1, 2013, de http://www.revistamad.uchile.cl/index.php/RMAD/article/viewArticle/18896/57575
- Cadenas, H. (2012). Paradojas de la diferenciación del derecho. Una perspectiva regional. En H. Cadenas, A. Mascareño, & A. Urquiza (Eds.), Niklas Luhmann y el legado universalista de su teoría. Aportes para el análisis de la complejidad social contemporánea (pp. 265-295). Santiago de Chile: RIL editores.
- Cardenas & Ostrom (2004) WHAT DO PEOPLE BRING INTO THE GAME: EXPERIMENTS IN THE FIELD ABOUT COOPERATION IN THE COMMONS
- Carpenter, S.R., B.H. Walker, J.M. Anderies, and N. Abel. (2001). From metaphor to measurement: resilience of what to what? Ecosystems 4:765-781.
- CEPAL (2009) La Economía del Cambio Climático en Chile. CEPAL, Naciones Unidas, Gobierno de Chile.
- CEPAL (2010) La economía del cambio climático en América Latina y el Caribe. Publicación de las Naciones Unidas.
- CEPAL/BID (2010) Cambio Climático una perspectiva regional. Cumbre de la Unidad de América Latina y el Caribe. Riviera Maya (México) 22 y 23 de febrero de 2010 CEPAL/BID
- Chan, Serena (2001). *Complex Adaptive Systems*. ESD.83 Research Seminar in Engineering Systems. October 31, 2001/November 6, 2001
- Chan, Kai; Anne D. Guerry, Patricia Balvanera, Sarah Klain, Terre Satterfield,Xavier Basurto, Ann Bostrom, Ratana Chuenpagdee, Rachelle Gould, Benjamin S. Halpern, NeilHannahs, Jordan Levine, Bryan Norton, Mary Ruckelshaus, Roly Russell, Jordan Tam and Ulalia Woodside (2012) Where are Cultural and Social in Ecosystem Services? A Framework for Constructive Engagement.. Source: BioScience, Vol. 62, No. 8 (August 2012), pp. 744-756. Published by: University of California Press on behalf of the American Institute of Biological SciencesStable URL: http://www.jstor.org/stable/10.1525/bio.2012.62.8.7
- Christmann, Gabriela; Ibert, Oliver; Kilper, Heiderose; Moss, Timothy (2012) Vulnerability and Resilience from a Socio-Spatial Perspective. Towards a Theoretical Framework. Working

Paper, Erkner, Leibniz Institute for Regional Development and Structural Planning, 2012 (www.irs-net.de/download/wp_vulnerability.pdf)

- Collier, J., & Hooker, C. A. (1999). *Complexly organised dynamical systems.* Open Systems and Information Dynamics, 241-302.
- CONAMA (2008) Plan de Acción Nacional de Cambio Climático 2008-2012. Comisión Nacional del Medio Ambiente (CONAMA), Gobierno de Chile.
- Cristi, Oscar; Vicuña, Sebastián; Gabriel, Luiz & Baltar, Alexandre (2001) Mercado de Agua para Irrigación: Una Aplicación al Sistema Paloma de la Cuenca del Limarí, Chile. Gobierno de Chile; Instituto Interamericano de Cooperación para la Agricultura. Agua, Vida y Desarrollo. Santiago de Chile, IICA, oct. 2001, p.1-12 Ilus
- Cumming, G. S. (2011). Spatial Resilience in Social-Ecological Systems. Cape Town: Springer.
- Cumming, G. S., and J. Collier (2005). Change and identity in complex systems. Ecology and Society 10(1): 29. [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art29/
- Cumming, G. S., Barnes, G., Perz, S., Schmink, M., Sieving, K. E., Southworth, J., Binford, M., Holt, R. D., Stickler, C., Van Holt, T. (2005). *An Exploratory Framework for the Empirical Measurement of Resilience.* Ecosystems, 975-987.
- Cumming, G.S. (2011). Spatial resilience: integrating landscape ecology, resilience, and sustainability. Landscape Ecology 26:899-909.
- Denzin, N. K., & Lincoln, Y. S. (2011) Handbook of qualitative research (4nd ed.). Thousand Oaks, CA: Sage Publications.
- DGA (2007) Estimaciones de demanda de Agua y proyecciones Futuras. Publicación Dirección General de Aguas, Gobierno de Chile.
- DGF (2006) Estudio de la variabilidad climática en Chile para el siglo XXI. Departamento de Geofísica, Facultad de Ciencias. Físicas y Matemáticas, Universidad de Chile.
- Díaz, Raúl (2008) El recurso hídrico: acceso, reglas y restricciones en zonas áridas, Cuenca del limarí, Chile. Seminario de Título para optar al Título de Ingeniero Agrónomo y al Grado Académico de Licenciado en Agronomía, Universidad de La Serena.
- Dietz, Thomas; Ostrom, Elinor & Stern, Paul C. (2003) The Struggle to Govern the Commons. Science 12 December 2003: 302 (5652), 1907-1912. [DOI:10.1126/science.1091015]
- Diment, Ping Yu, Karin Garrety (2001) Complex Adaptive Systems as a Model for Evaluating Organisational Change Caused by the Introduction of Health Information Systems
- Donoso, Guillermo (2003) Estudio de Caso del Código de Aguas en Chile de 1981. Asociación Mundial del Agua. SAMTAC Comité Técnico Asesor Sud América

- Douglas, M. & Wildavsky, A. (1982). Risk and Culture: An essay on the selection of technical and environmental dangers. Berkeley: University of California Press.
- Douglas, M. (1992): Risk and Blame, Essays in Cultural Theory. Londres: Routledge.
- Douglas, Mary (1978) Natural Symbols: Explorations in Cosmology. Harmondsworth: Penguin Education.
- Douglas, M. (1996) La aceptabilidad del riesgo según las ciencias sociales. PAIDOS Iberica.
- Eidelson, Roy (1997) Complex Adaptive Systems in the Behavioral and Social Sciences. Review of General Psychology 1997, Vol. l,No. 1,42-71
- Ellikson, Robert (1993) Property in Land. The Yale Journal
- EMG Consultores (2011) Estimación del Precio de Mercado y Precio Social de los Derechos de Aprovechamiento de Aguas. Informe final para Subsecretaría de Agricultura, Santiago.
- Engle, Nathan (2011) Adaptive capacity and its assessment. Global Environmental Change 21 (2011) 647–656
- Ferrando, Francisco (2002) Cuenca del Río Limarí, Chile Semiárido: Aspectos de la Oferta y Demanda de Agua. Revista de Geografía Norte Grande, 30: 23-44
- Flick, U. (2008) Triangulation. Eine Einführung (2nd ed.). VS Verlag für Sozialwissenschaften.
- Flyvbjerg, B. (2011) Case study. In N. K. Denzin & Y. S. Lincoln (Eds.), The Sage Handbook of Qualitative Research (4th ed., pp. 301-316). Thousand Oaks, CA: Sage.
- Folke, Carl (2006) Resilience: The emergence of a perspective for social–ecological systems analyses. Global Environmental Change 16 (2006) 253–267
- Folke, Carl; Hahn, Thomas; Olsson, Per & Norberg, Jon (2005) ADAPTIVE GOVERNANCE OF SOCIAL-ECOLOGICAL SYSTEMS. Annu. Rev. Environ. Resour. 2005. 30:441–73
- Fuster, Rodrigo (2006) Equidad en el acceso al agua en la agricultura. Evaluación del modelo chileno de gestión de las aguas: El caso de la cuenca del río Limarí. Universitat Autònoma de Barcelona / ICTA. Programa de Doctorado en Ciencias Ambientales
- Galaz, Victor (2004) Stealing from the Poor? Game Theory and the Politics of Water Markets in Chile. Environmental Politics. Vol.13, No.2, Summer 2004, pp.414 – 437
- Gallopın, Gilberto C. (2006) Linkages between vulnerability, resilience, and adaptive capacity. Global Environmental Change 16 (2006) 293–303
- García-Ferrando, M., Ibáñez, J. & Alvira, F. (2001) El análisis de la realidad social. Métodos y técnicas de investigación. 3ª ed. Madrid, Alianza, 2001.
- Geertz, C. (1994) Conocimiento local: ensayos sobre la interpretación de las culturas. Paidós Ibérica. 1994.

- Gentes, Ingo (2007) Las aguas transadas. Estado de arte de las propiedades hidráulicas y del impacto del mercado de derechos de agua en Chile. Santiago de Chile, octubre de 2007. Convenio de prestación de servicios entre la Sociedad de Desarrollo OXFAM LTDA. y el autor.
- Gotts, N. M. (2007). Resilience, panarchy, and world-systems analysis. Ecology and Society 12(1): 24.
- Gunderson L. H. & Holling C.S. (2002). *Panarchy: Understanding transformations in human and natural systems.* Washington, DC: Island Press.
- Gunderson, L.H. (2000). Ecological resilience: in theory and application. Annual Review of Ecology and Systematics 31:425-439.
- Hadjigeorgalis, Ereney (2004) Comerciando con incertidumbre: Los mercados de agua en la agricultura chilena. Cuadernos de Economía 2004
- Hann, Chris (2007) The State of the Art. A new double movement? Anthropological perspectives on property in the age of neoliberalism. Socio-Economic Review 5, 287–318
- Hardin, Garret (1968) The tragedy of the Commons. Science, New Series, Vol. 162, No. 3859. (Dec. 13, 1968), pp. 1243-1248
- Hartvigsen, Gregg. Ann Kinzig, and Garry Peterson (1998) Use and Analysis of Complex Adaptive Systems in Ecosystem Science: Overview of Special Section. Ecosystems (1998) 1: 427–430
- Haughton, G. (2002). Market Making: Internationalisation and Global Water Markets. Environment and Planning 34: 791-807.
- Holland, John H.; (2006). "Studying Complex Adaptive Systems." Journal of Systems Science and Complexity 19 (1): 1-8. <http://hdl.handle.net/2027.42/41486>
- Holling, C. S. (1973) "Resilience and stability of ecological systems". in: Annual Review of Ecology and Systematics. Vol 4 :1-23.
- Holling, C. S. (1986) Resilience of ecosystems; local surprise and global change. pp. 292-317 in Sustainable Development of the Biosphere, W. C. Clark and R. E. Munn, editors. Cambridge University Press, Cambridge.
- Holling, C. S. (2002). *Understanding the complexity of economic, ecological and social systems*. Ecosystems, 390-405.
- Hufschmidt, G. (2011) A comparative analysis of several vulnerability concepts. Nat Hazards Volume: 58, Issue: 2, Publisher: Springer Netherlands, Pp: 621-643
- IPCC (2007) Cambio climático 2007: Informe de síntesis. Contribución de los Grupos de trabajo I, II y III al Cuarto Informe de evaluación del Grupo Intergubernamental de Expertos

sobre el Cambio Climático. Equipo de redacción principal: Pachauri,R.K. y Reisinger, A. (directores de la publicación). IPCC, Ginebra, Suiza.

- Livenais, Patrick & Aranda, Ximena (2003). Dinámicas de los sistemas agrarios en Chile árido: La región de Coquimbo. Editores Cientificos. LOM
- Lovelock, James (1979) Gaia: A New Look at Life on Earth. Oxford University Press 1979.
- Luhmann, Niklas (1986) Ökologische Kommunikation. Frankfurt a.M.: Suhrkamp.
- Luhmann, Niklas (1991) Soziologie des Risikos. Frankfurt a.M.: Suhrkamp.
- Luhmann, Niklas, (1984). Soziale Systeme. Grundriß einer allgemeinen Theorie. Frankfurt a.M.: Suhrkamp.
- Luhmann, Niklas (1997) *Die Gesellschaft der Gesellschaft.* Frankfurt a.M.: Suhrkamp.
- Mack, N., Woodsong, C., MacQueen, K. M., Guest, G., & Namey, E. (2005) Qualitative Research Methods: A Data Collector´s Field Guide. Family Health International.
- Mamadouh, V. (1999): Grid-Group Cultural Theory: An introduction, in: GeoJournal, Vol. 47, pp. 395-409
- MATURANA Y VARELA (1984). El árbol del conocimiento. Editorial Universitaria. Santiago
- Maturana, H. (1990) Biología de la Cognición y Epistemiología. Ed. Universidad de la Frontera. Temuco, Chile. 1990.
- Mauser, Wolfram (2010) Wie lange reicht die Ressource Wasser? Vom Umgang mit dem blauen Gold. Forum für Verantwortung. Fischer Taschenbuch Verlag. Frankfurt am Main, Juli 2007.
- Ministerio del Medio Ambiente (2011) Segunda Comunicación Nacional de Chile ante la Convención Marco de las Naciones Unidas sobre cambio Climático. Gobierno de Chile
- Nassehi, Armin (2011). La teoría de la diferenciación funcional en el horizonte de sus críticas. Revista MAD, 0(24). http://www.revistamad.uchile.cl/index.php/RMAD/article/viewArticle/13529/13802
- Norberg J, Wilson J, Walker B, Ostrom E (2008) Diversity and resilience of social-ecological systems. In: Norberg J, Cumming GS (eds) Complexity theory for a sustainable future. Columbia University Press, New York, pp 46–79
- Norberg, J. &. Cumming, G. S. (2008). *Complexity theory for a sustainable future.* New York: Columbia University Press.

- North, Douglas C. (1990) Institutions, institutional change and economic performance En: James Alt , Douglas C. North. (1990) THE POLITICAL ECONOMY OF INSTITUTIONS AND DECISIONS
- Nykvist, Björn (2012). Social learning in the Anthropocene. Governance of natural resources in human dominated systemsDoctoral thesis in Natural Resource Management. Department of Systems Ecology. Stockholm University
- Olson, Mancur Jr., (1965, 2nd ed., 1971). The Logic of Collective Action: Public Goods and the Theory of Groups, Harvard University Press
- Olsson, P., C. Folke, and T. Hahn. (2004). Social–ecological transformation for ecosystem management: the development of adaptive co-management of a wetland landscape in southern Sweden. Ecology and Society 9(4):2. [online] URL: http://www.ecologyandsociety.org/vol9/iss4/art2.
- Ostrom, E. (2009). "A General Framework for Analyzing Sustainability of Social-Ecological Systems". Science 325 (5939): 419–422. doi:10.1126/science.1172133. PMID 19628857.
- Ostrom, Elinor (1990). Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press. ISBN 0-521-40599-8.
- Ostrom, Elionor (2000) Private and Common Property Rights. In Encyclopedia of Law and Economics, vol. II. Civil Law and Economics, ed. Boudewijn Bouckaert and Gerrit De Geest, 332–79. Cheltenham, England: Edward Elgar.
- Peña, Humberto; Luraschi, Marco & Valenzuela, Soledad (2004) Agua, desarrollo y políticas públicas: la experiencia de chile. REGA – Vol. 1, no. 2, p. 25-50, jul./dez. 2004
- Pezo, Luis (2010) Sociedad Civil y Desarrollo Rural: Trayectorias de Participación Social en la Comuna de Río Hurtado (1990 – 2008). Tesis para optar al grado de Magíster en Antropología y Desarrollo, Universidad de Chile.
- Poteete, Amy R. ; Marco A. Janssen and Elinor Ostrom (2010) Working Together: Collective Action, the Commons, and Multiple Methods in Practice. Princeton University, New Jersey
- Rappaport , Roy (1977) Naturaleza, cultura y antropología ecológica
- Rappaport, Roy (1996) Risk and the human environment
- RAPPAPORT, ROY A. (1977) La maladaptación en los sistemas sociales. Chicago (Illinois, Estados Unidos).
- Rodríguez, Dario & Arnold, Marcelo (1991) Sociedad y Teoría de Sistemas. Editorial Universitaria. Santiago. Chile.
- Rubin, H. & Rubin, I. (1995) Qualitative Interviewing: The Art of Hearing Data. Sage Publications.

- Saterfiel,Terre; Gregory, Robin; Klain, Sarah; Roberts, Mere & Chan, Kai (2013) Culture, intangibles and metrics in environmental management. Journal of Environmental Management 117 (2013) 103e114
- Schubert, Johannes & Gill, Bernhard (2010) Climate Change: The Co-Evolution of Coping Technologies and Cultural Biases – A Culturally Informed Varieties of Capitalism Approach, in: Soeffner, Hans-Georg (Hrsg.), 2013: Transnationale Vergesellschaftungen. Verhandlungen des 35. Kongresses der Deutschen Gesellschaft für Soziologie in Frankfurt am Main 2010.
- Schwarz, Michiel and Michael Thompson (1990) Divided We Stand Redefining Politics, Technology and Social Choice University of Pennsylvania Press.
- Smith, Thomas S. & Gregory Stevens (1994) Emergence, Self-Organization, and Social Interaction: Arousal Dependent Structure in Social Systems
- Tompkins, E. L. and W. N. Adger. (2004). Does adaptive management of natural resources enhance resilience to climate change? Ecology and Society 9(2): 10. [online] URL: http://www.ecologyandsociety.org/vol9/iss2/art10
- United Nations (1992). The Dublin Statement on Water and Sustainable Development. Adopted January 31, 1992 in Dublin, Ireland. International Conference on Water and the Environment
- von Benda-Beckmann, Franz, von Benda-Beckmann, Keebet & Wiber, Melanie (2006). Changing Properties of Property. Berghahn Books, New York.
- von Foerster, Heinz (2003) Understanding Understanding. Essays on Cybernetics and Cognition. Verlag, New York
- Walker, B., C. S. Holling, S. R. Carpenter, and A. Kinzig (2004). Resilience, adaptability and transformability in social–ecological systems. Ecology and Society 9(2): 5. [online] URL: http://www.ecologyandsociety.org/vol9/iss2/art5
- Watts, Michael & Bohle, Hans (1993). The space of vulnerability: the causal structure of hunger and famine. Prog Hum Geogr 17: 43
- Wiener, N. (1979) Cibernética y Sociedad. Editorial Sudamericana. Buenos Aires.
- Zegarra, Eduardo (2002) Water Market and Coordination failures: the case of the Limarí Valley in Chile. Dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy Agricultural and Applied Economics. University of Wisconsin-Madison