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The Role of River Vigilance Committees to Address New Socio-Climatic Conditions in Chile: Insights from Ostrom's Design Principles for Common-Pool Resource Institutions

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Abstract: Chile is currently facing a mega-drought, which is expected to lead to a significant increase in the water stress level. Social conflicts related to water use are linked to the effects of climate change and a governance system marked by the privatization of the natural resources of public interest. This study aims to analyze whether the current Chilean water governance scheme can adapt to the effects of climate change through a critical observation of the role of the River Vigilance Committees (RVCs; private user organizations exercising the public function of water management), from the perspective of Ostrom's design principles for long-enduring Common-pool Resource (CPR) institutions. We analyze legal approaches, management mechanisms, and decision-making processes under the socio-climatic conditions that the country is currently facing. The results indicate that, with a few exceptions, the Chilean governance system does not allow RVCs to effectively incorporate the design principles—and, therefore, to achieve adaptation—due to dispersed functions, the exclusion of water users, and a lack of planning at different levels. We propose that water governance should consider the creation of River Basin Boards with broader planning powers, as well as the incorporation of different relevant stakeholders.

Keywords: adaptive governance; climate change; Elinor Ostrom; river vigilance committees; water governance

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1. Introduction

Water is regarded as a scarce resource, and it is becoming scarcer. Global freshwater use accounts for 3895.5 billion cubic meters per year [1], and approximately 2 billion people live in water-scarce countries [2]. Among the uses of freshwater, agriculture currently accounts for 69% of total water withdrawals [3], having been reported as 82% in the case of Chile (for agricultural and livestock activities) [4].

Chile has based its economic growth on the exploitation of natural resources, meaning that water is a fundamental element for the agricultural sector. Unfortunately, Chile has been experiencing a water crisis, influenced in part by a mega-drought that has extended over the past 14 years due to (among other factors) climate change [5]. Water scarcity poses problems not only for social and economic development, but also for environmental conservation [6].

The decrease in rainfall has intensified throughout the country over the past three decades, and significant deficits have been observed at almost all precipitation gauging stations [7]. Moreover, the World Resources Institute [8] indicated that Chile could face significantly increased water stress levels by 2040, classifying this risk as "extremely high".

Disputes over the use of water have significantly marked the history of social conflicts in Chile over the last three decades. The National Institute of Human Rights has indicated that 44% of the socio-environmental conflicts in the country are directly related to water [9], initially linked to droughts and the depletion of aquifers [10], but are now also related to inadequate water management and governance [11]. Considering a scenario of uncertainty regarding the effects of climate change, the World Bank [12,13] issued a series of recommendations to Chile concerning these matters; however, they still need to be implemented. Furthermore, water governance in the country has received multiple criticisms related to social inequality and the negative impacts on aquatic ecosystems [14–17].

The current Water Code (enacted in 1981) is Chile's most important legal body regulating water management, introducing water as a private good through Water Use Rights (WUR). The development of this model has occurred through three key principles: (i) the use of water markets for the management of water demand and supply; (ii) the right to exploit water as a private good protected by the State; and (iii) the delegation of water allocation management to private users [18–20].

The latter is regarded as a 'self-management' approach [21], meaning that private WUR holders become the most relevant actors involved in water use, management, and control within a specific territorial extent. They are generally grouped into Water Users Organizations (WUOs), described as private institutions exercising public functions in accordance with the Water Code. We distinguish two types of WUOs, based on the purpose of their administration: (i) WUOs extracting water from private artificial irrigation channels; and (ii) WUOs extracting water directly from rivers (natural flows). Within this second group, the River Vigilance Committees (RVCs) gather special attention, given that they are conceived as private institutions managing a public good (river basins or river sections). In this sense, managing water as a national asset for public use implies an important responsibility for RVCs, not only for having a coordinating role but also for taking care for the adequate allocation and conservation of water resources [22].

The political regime implemented during the military dictatorship in Chile set the context for the privatization of natural resources (and services of public interest) in the 1970s, 1980s, and 1990s [23], a process theoretically supported by the statements of Hardin's Tragedy of the Commons [24]. Years later, one of its most powerful critiques was proposed by Ostrom [25]—in her work titled Governing the Commons—where, in opposition to the dualistic classification of public and private goods, she invites us to take a third approach: the collective governance of common-pool resources [26].

Ostrom's theoretical approach has significantly guided Common-Pool Resource (CPR) institutions, and her eight design principles have been prominent across different disciplines [27]. Moreover, considering the climate change scenario, experienced not only in Chile but also worldwide, some studies have proposed Ostrom's principles as an alternative to achieve an adaptive water governance system that is sustainable, resilient to change and uncertainty, and which can address existing and upcoming conflicts involving water [28,29]. For instance, Heikkila et al. [30] analyzed fourteen interstate river basin compacts (agreements among states for managing interstate rivers) varying in terms of supply and demand settings. They analyzed the types of linkages established by each compact through a documentary analysis of their constitution agreements, official meeting minutes, and annual reports, which were coded according to Ostrom´s design principles. They concluded that there exists a direct correlation between the quality of the linkages and the socio-climatic conditions and management issues the states faced when signing those agreements, noting that the linkages which had been signed in times of scarcity and conflict had a broader diversity of principles involved. In addition, Quinn et al. [31] performed a qualitative assessment (through semi-structured interviews) of the extent to which each

design principle seemed to function in the administration of forest, pasture, and water resources in twelve villages in semi-arid Tanzania. They concluded that boundary-related issues and conflict-negotiation mechanisms were key in semi-arid zones, and that the need to adapt to address ecological uncertainty implied that numerous management organizations would be viewed as lacking or non-existent when evaluated through the lens of the design principle methodology, suggesting that the design principles should not be used as an imposed blueprint for water resource management systems; rather, they offer a framework for analysis. In this sense, Huntjens et al. [28] studied the applicability of eight refined and extended institutional design propositions based on Ostrom's principles, performing a documentary analysis of water management policies in the Netherlands, South Africa (river basins), and Western Australia (groundwater systems), and proposed a "management of learning" approach to deal with complexity and uncertainty, according to context-specific socio-climatic conditions.

Taking this into consideration, we agree that Ostrom's design principles comprise adaptive management processes, regarding adaptive governance as a social dimension in a sustainable ecosystem management (including freshwater systems) [32]. Therefore, we consider it important to analyze the applicability of Ostrom's design principles for CPR institutions within the context of the Chilean water governance system under the current socio-climatic conditions that the country is currently facing, within a scenario of increasing conflicts over access to water and uncertainty about the effects of climate change.

In Chile, Ostrom's Theory of the Commons has been applied within the legal framework, both in studies on the economic development model [33] and the communal property regime [34]. In addition, it has inspired a review of natural common property management structures [35], and their design principles for CPR institutions were partially used in the analysis of the Chilean legal groundwater regulation [17] and water management schemes [36]. In turn, the distinction among different methods for configuring property has been quoted by Vergara [37], justifying water markets (supply and demand relationships for the allocation of water resources) and creating distance from the conception of water as a public good of state concern.

Although Ostrom's precepts have already been used in the general analysis of water management in Chile, we find it interesting to evaluate whether the country´s unique water management model can promote adaptation to climate change, regarding the RVCs as an object of analysis. Given the significant influence that the self-management approach of the RVCs has in the water sector, it is important to analyze their role in addressing social and environmental conflicts within the current Chilean water governance framework. Therefore, this study aims to understand the performance of RVCs in adapting to the current climate change scenario, taking Ostrom's eight design principles as a baseline for analysis. For this, we examine RVCs as long-enduring Common-Pool Resource organizations, focusing on their integration mechanisms, decision-making processes, and socio-environmental responsibilities.

2. The Socio-Climatic Scenario: The Current State of Water Resources and Water Management in Chile

2.1. Hydrological and Climatic Conditions

The Chilean continental territory spans from 18° S to 55° S (4300 km) and is surrounded by the Pacific Ocean and the Andes mountains, encompassing a large latitudinal and longitudinal diversity of geographical, hydrogeological, and climate settings.

The climatic characteristics are highly variable across the country. In the northern part (18–33° S), arid and semi-arid conditions are observed, varying to a Mediterranean climate in central Chile (33–42° S) and temperate-wet climates in the southern area (42–55° S). Rainfall displays great intra-seasonal, inter-annual, and decadal variability, controlled by both frontal systems hitting the coast and large-scale climate processes such as the El Niño Southern Oscillation [38]. The average annual rainfall varies from 0 mm/y in the northernmost part of the country to 200–1000 mm/y in central Chile, while in the area extending from 35° S to the south, precipitation increases to over 1000 mm per year [39].

Regarding the seasonal variability in central Chile, the winter months (May to August) concentrate 85% of the total annual rainfall while, during the summer months (December to March), the average annual rainfall is less than 5%.

Regarding surface water, the average runoff values in the northern region have been observed in the range of 1 to 20 m^3/s, those in the central zone vary from 100 to 4000 m^3/s, and those in southern Chile may reach over 10,000 m^3/s [40]. Groundwater in the north is made up of fossil waters, as rainfall is extremely low, while central Chile has alluvial aquifers of very high transmissivity, so water users are prone to use groundwater both as a backup and a primary choice for use. Snowpacks and glaciers are critical components of the water supply in Chile, and snowmelt is the main streamflow source during the dry season [41].

Just as rainfall and runoff rates vary across the country, the same can be observed for water availability, which is territorially unequal. From central Chile to the north, the average water availability per inhabitant is less than 800 m^3/year while, in the south, this average exceeds 10,000 m^3/year [42]. Likewise, nearly 60% of the population is concentrated in a territory that is considered arid, where more than 70% of the national GDP is produced [43]. Traditionally, Chile has concentrated its irrigated agricultural production in the central zone for internal consumption and exportation based on fruit trees and cereal crops. Irrigation is key for producing high-quality crops and orchards, as rainfall is less than 15% of average annual values in the middle of the agricultural season [40].

However, climate change has posed an increasing risk to water supply. Chile is currently experiencing a situation of water scarcity, as reflected by a decrease in rainfall that has been intensifying [7]. If these conditions continue, the agricultural sector will be significantly affected. Due to climate change effects such as global warming, the main export-earning crops are expected to move south (resulting in land-use changes), and agricultural employment may decrease over the next few decades [44].

2.2. Chilean Water Management and Governance

In Chile, it is difficult to specify the functions related to entities managing water due to institutional dispersion in the matter. According to an assessment carried out by the World Bank in 2013, more than 40 public and private organizations are involved in water management in the country, revealing a system that presents overlaps and a lack of clarity in the performed functions [13].

In its original version presented in 1981, the Chilean Water Code allowed water regulation as a private good through WURs, expressed in units of volume per unit of time (i.e., cubic meters per hour; liters per second). WURs were given in perpetuity and free of charge. They are conceived as private property and, therefore, could be sold or mortgaged. Furthermore, a WUR was not subject to a specific use, and the holder could change its use without justification. The State grants a WUR to anyone who requests it, if it is available, and the Water Code allows for the use of water markets for re-allocation. In this sense, in the case of irrigated agriculture, for instance, WUR owners can use a transaction system to re-allocate the resource to those users who need more water to satisfy their production.

This situation was recently changed by a legal reform in 2022 (Law 21.435), in which important environmental and human rights aspects were incorporated into the regulations of the Chilean Water Code. Although the structure of the water market is maintained in the regulation, obligations to report the use of water to individuals are incorporated, the period for the constitution of WURs is limited, and a hierarchy of uses has been incorporated for the first time, prioritizing human consumption and ecosystem preservation [45,46].

Regarding management aspects, the Water Code allowed for the establishment of a dual institutional system: a centralized administration exercised by the state administrative institutions, within which the General Water Directorate (DGA, in its Spanish acronym) plays a very important role, and a decentralized administration, corresponding to the WUR holders organized in different sections of the same river basin—the River Vigilance Committees (RVCs).

At present, the bodies that manage water at the basin level are the RVCs. Currently, there are 57 RVCs legally constituted throughout the country [47]. Despite recognizing and promoting the importance of self-management, the RVCs do not ensure that all those affected by water management can participate in decision-making or resolve conflicts, as the RVCs are composed exclusively of WURs holders. The RVCs are mainly located in sectors related to agricultural activities in water-scarce areas, where the current Chilean water management system has been regarded as ineffective and insufficient to deal with the water crisis [14,15].

3. Materials and Methods

This study used a qualitative strategy, which allowed us to collect data to obtain more robust evidence to achieve our research aim [48], based on three steps: (i) descriptive legal analysis, (ii) documentary analysis, and (iii) semi-structured interviews.

The descriptive legal analysis involved a review of the legal norms applicable to water governance in Chile, as they are applied at the national level, regardless of geography- or climate-specific characteristics. The descriptive legal analysis was useful to determine the nature of the legal bodies involved in water management, the type of institutions involved, and the modifications that this normative scheme has undergone over the past few decades. The main legal bodies reviewed were the Political Constitution of Chile of 1980, the Water Code of 1981, and Law 21.435, which modified the Water Code [49]. This method allowed us to analyze the relationship among the normative configuration of the Chilean legal scheme and the practical consequences observed when exercising the functions of RVCs in Chile.

The second step involved analyzing the theoretical approaches of Ostrom's eight principles for long-enduring CPR institutions applicable to the RVCs, regarding the eco-social reality in which the RVCs carry out their functions (Table 1). For this, we performed a documentary analysis, which included government reports and the scientific literature on the functioning of river management in Chile and its socio-climatic conditions. The public sources of these reports were the Chilean General Water Directorate (DGA), the National Irrigation Commission (CNR), the National Institute of Human Rights (INDH), the Chilean Ministry of Environment and the Chilean Ministry of Agriculture. The main sources among the private organizations were the Chilean Institute of Engineers and Fundación Chile.

Finally, after the documentary analysis, we conducted five semi-structured interviews (year 2022) with one government employee, two academic experts on the management carried out by the RVCs, and two members of two RVCs that were considered pioneers in carrying out activities that go beyond what is merely established by the law, which therefore deserved to be particularly analyzed as, according to our knowledge, they could involve a greater diversity of principles than other RVCs at the national level. These RVCs covered the Biobío River Basin and the first section of the Cachapoal River and its tributaries. These five interviewees were asked questions about the functioning, organizational forms, and management schemes of these RVCs.

In this sense, documents and transcripts of interviews were critically analyzed in relation to their compliance to Ostrom's design principles for long-enduring CPR institutions in the following manner: (i) the legal and documentary analysis allowed us to identify the degree to which norms and the general management context governing the operation of RVCs in Chile complies with Ostrom´s principles, and (ii) the semi-structured interviews allowed us to identify which of Ostrom´s design principles were particularly followed by the two selected RVCs, in relation to the legal context in which they were embedded.

Table 1. Ostrom's design principles for long-enduring Common-Pool Resource (CPR) institutions [25].

Number	Principle	Content
1	Clearly defined boundaries	Individuals or households who have rights to withdraw resource units from the CPR must be clearly defined, as must the boundaries of the CPR itself
2	Congruence between appropriation and provision rules and local conditions	Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local conditions and to provision rules requiring labor, materials, and/or money
3	Collective Choice Arrangements	Most individuals affected by the operational rules can participate in modifying the operational rules.
4	Monitoring	Monitors, who actively audit CPR conditions and appropriator behavior, are accountable for the appropriators or are appropriators
5	Graduated sanctions	Appropriators who violate operational rules are likely to be assessed by graduated sanctions (depending on the seriousness and context of the offense) by other appropriators, by officials accountable to these appropriators, or by both
6	Conflict resolution mechanisms	Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials
7	Minimal recognition of rights to organize	The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.
8	For CPRs that are parts of larger systems: Nested enterprises	Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises

Study Areas

Figure 1 shows the jurisdiction of the RVC of the first section of the Cachapoal River and its tributaries and the RVC of the Biobío River Basin, which operate in the river basin of the same names, located in central and south-central Chile, respectively. The Cachapoal River sub-basin (34° S 70° W) runs for 170 km and is characterized by a temperate Mediterranean climate. Its population is 584,000 inhabitants, 30% of whom work in agricultural activities, and it originates from the Andes Mountains and ends in the Rapel Reservoir [50]. Three different RVCs operate on the territories of this sub-basin; namely, the first, second, and third sections, with the RVC of the first section of the Cachapoal River and its tributaries (from now on, the 'RVC of the first section of the Cachapoal River') being located at the headwaters of the river.

The Biobío River basin (36° S 73° W) originates from the Icalma and Galletué lakes in the Andes mountains and flows to enter the Pacific Ocean near Concepción city after following a course of 380 km. The basin has a population of about 1,206,070 inhabitants [51]. Its climate is a transition zone between a warm temperate Mediterranean climate and a humid temperate or rainy climate. Productive sectors in the basin are related to forestry, agriculture, industry (pulp and paper, metallurgic, chemical and oil refinery industries), and the hydroelectric sector, being the main source of energy supply in the country [52]. Land-uses in this region are mainly allocated to forest plantations, at 2.2 million hectares (about 60% of the total area) [53].

Figure 2 illustrates time-series for the first section of the Cachapoal River and the Biobío River basin, based on data obtained from Alvarez-Garreton et al. [54]. Available time-series are representative for each region, providing homogenized data on precipitation, temperatures, potential evapotranspiration, and streamflow at the basin scale.

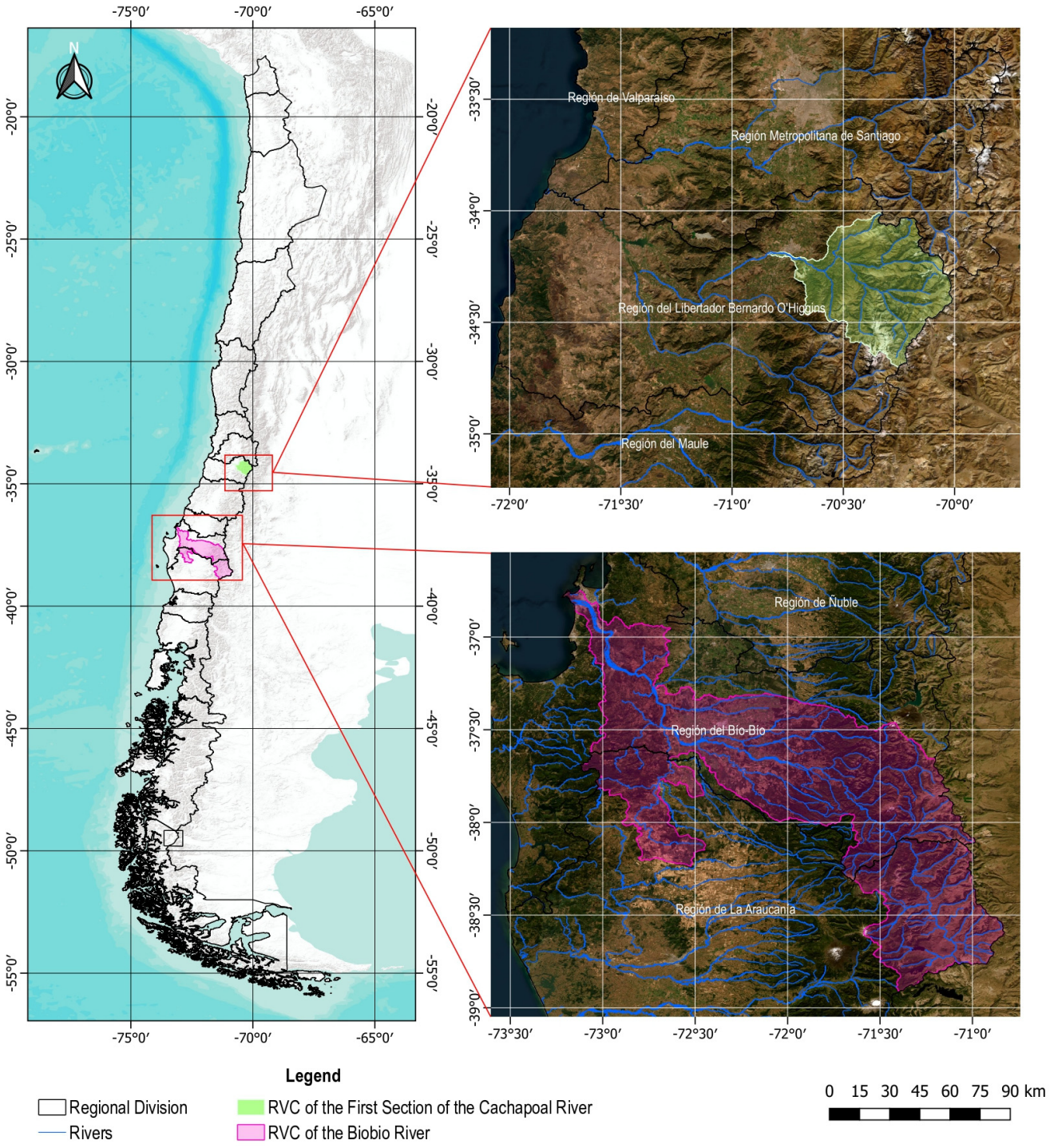

Figure 1. The jurisdiction of the RVCs of the first section of the Cachapoal River and The Biobío River Basin.

The study areas have different hydrological situations, even though the same climate regime forces both. Figure 2 highlights water scarcity, climate change, and variability conditions, showing the records for two main hydroclimatic variables that affect the water balance: precipitation and streamflow at the outlet. On one hand, precipitation is the only water input to the systems, while streamflow mimics water availability. It is worth noting that topography, geomorphology, hydrogeological setting, size, land-use, and land-cover control rainfall–runoff processes. Overall, since 2010, there has been a decreasing trend in rainfall and streamflow for both sites, while granted water rights show negligible increases,

conforming to a scarcity scenario worsened by the current drought. The first section of the Cachapoal River encompasses 2400 km^2 with a maximum elevation of 5150 masl. The mean annual precipitation is 1328 mm with a strong seasonality that peaks in winter (May to September). Since 2008, the 48-month Standardized Precipitation Index has been in the drought band, from marginal values in 2010 to extreme drought in 2020, as precipitation has declined significantly. The seasonal, inter-annual, and decadal variability is related to a substantial decrease in stream flow (ca. 30 m^3/s per decade). Annual mean flows are less than 20 m^3/s, with peaks during winter from runoff and spring from snowmelt, while surface water rights account for ca. 5 m^3/s.

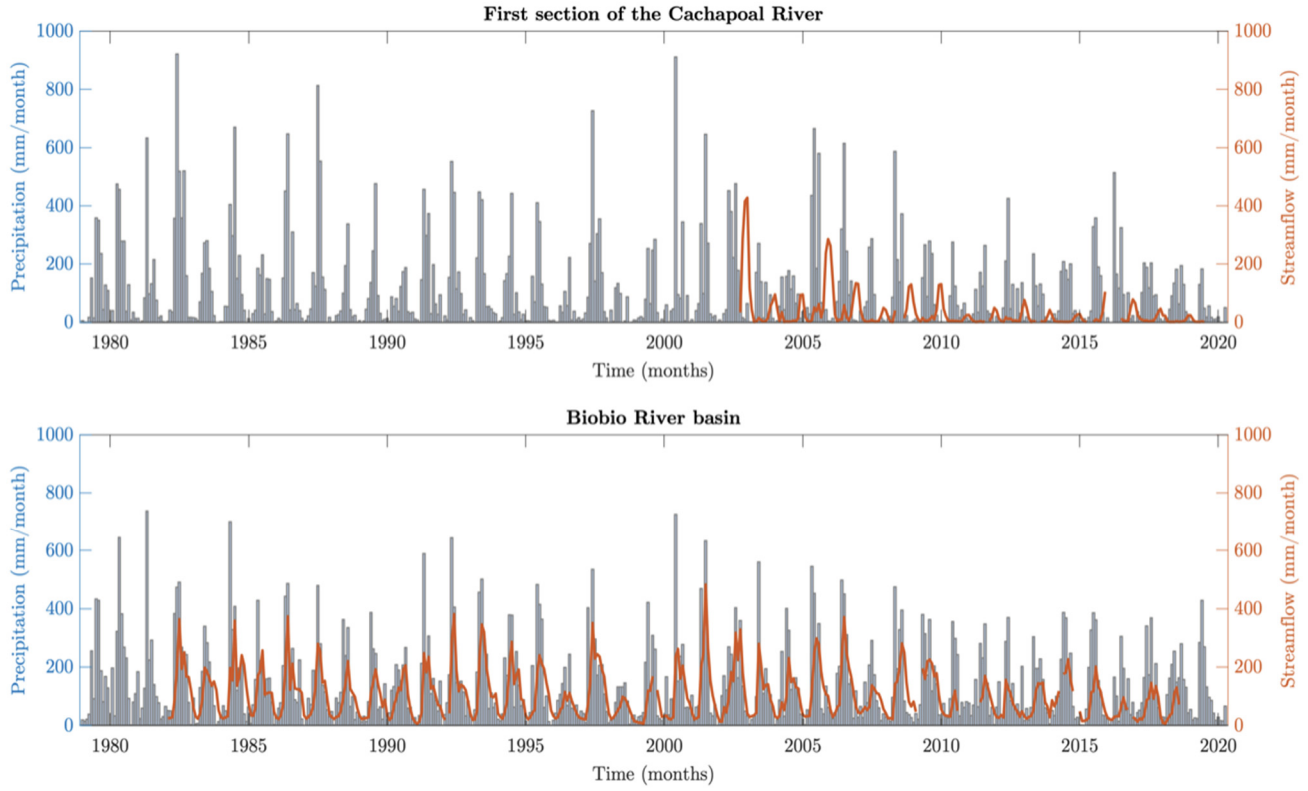

Figure 2. Time-series of precipitation and streamflow at the outlet for both study areas. Both variables are in mm for comparison. Data from Alvarez-Garreton et al. [54].

The Biobio River encompasses 24,270 km^2 with a maximum elevation of 3509 masl, which discharges into the Pacific Ocean after 380 km. The mean annual precipitation is 840 mm, with a strong seasonality that peaks in winter (May to September). As the drainage area is ten times that of the first section of the Cachapoal River, stream flows are less sensitive to rainfall. However, the annual precipitation in headwater watersheds is close to 3000 mm. Since 2008, the 48-month Standardized Precipitation Index has been in the drought band, from marginal values in 2010 to strong drought in 2020, as precipitation has declined significantly. The decrease in streamflow has been ca. 55 m^3/s per decade. Annual mean flows are less than 1000 m^3/s, with peaks during winter. Since 2010, the summer streamflow has been less than 200 m^3/s, while surface water rights account for ca. 149 m^3/s.

Both sites are under increasing pressure, facing decreasing precipitation, and rising seasonal and inter-annual variability. However, the Biobio River basin appears to be in a better position, as its size allows it to buffer upstream changes in rainfall and snowfall. For instance, water from the Andes re-circulates in the central valley through natural groundwater recharge, percolation from irrigation land, and discharge from industries. The Cachapoal River heavily depends on rainfall and snowmelt in a smaller area, with a much lower chance of water re-circulation within the system.

4. Results

4.1. Ostrom's Design Principles for Long-Enduring CPR Institutions Applied to RVCs

Ostrom provided several examples of long-lasting CPR institutions, arguing that institutions maintained over a prolonged period are signals of success [27]. She explored the favorable and unfavorable conditions for developing long-lasting CPR institutions, and identified the eight design principles which are essential for success [25]. Below, we critically apply Ostrom's design principles of CPR Institutions to the internal decision-making mechanisms of RVCs, including the processes of participation, collective action, and learning.

4.1.1. Clearly Defined Boundaries

Defining the boundaries of a CPR and specifying who is authorized to use it is the first step in organizing a collective action. It is essential to determine the scale of the processes and to recognize the actors involved in terms of defining who is responsible for the management, construction of the rules of use, and the development of the mechanisms to exclude others in order to prevent over-exploitation. Additionally, it is important to determine the carrying capacity of the system to sustain the extraction by the individuals of the collective and to understand the regenerative capacity of the natural system [25].

The current Chilean water management model has been criticized for a lack of updated information (which is also deeply centralized) regarding the current availability of water, the effects of climate change on surface water and groundwater, and the hydrogeological behavior of the aquifers [11], which is the responsibility of government organizations. For this reason, collecting adequate data about the CPR's boundaries, the carrying capacity of the system, and the number of actors involved is usually performed by the RVCs, which generally use their resources to obtain such data. However, economic and professional resources differ among the RVCs in the country, and some cannot afford data-monitoring systems.

Another issue regarding CPR boundaries is related to determining an adequate spatial unit for water management. Globally, the river basin is generally considered the most accepted territorial unit for water resource management [55–57]; however, although the Water Code specifies that RVCs have jurisdiction on a river basin, in practice, these institutions have been historically organized on river sections (articles 263 and 264 of the Water Code).

In this sense, multiple RVCs can co-exist in a single river basin, as is the case for the RVC of the first section of the Cachapoal River (located at the headwaters of the Cachapoal River) with respect to the RVCs of the second and third sections (located downstream, in the same river). The fact that the same river stream is shared by three institutions that have independent forms of self-management inevitably causes some conflict and communication problems among them, which have arisen due to the mega-drought conditions that the country is currently experiencing.

The latter does not seem to be a problem for the Biobío basin, as it is the only basin that has a RVC with a jurisdiction extending from the source of the river to its river's mouth. This implies an advantage when it comes to resolving conflicts and managing the river basin according to its complete hydrological condition.

4.1.2. Congruence between Appropriation and Provision Rules and Local Conditions

The rules for using, managing, and protecting water must be clearly defined. Community decision-making requires adopting a collective agreement that considers the perspective of local cultural and social values, thus considering the collective capacities and ecological characteristics of the CPR. In this sense, the rules of use must be defined in accordance with the environmental, social, and economic conditions within the boundaries of the CPR [25].

This principle is linked to the first one, in terms of the coherence among the norms and local conditions that respond to the need to react to the specific management challenges of the CPR. In the case of water management, this specificity connects to a 'territorialization' of WURs (i.e., a process that is a consequence of geographical and climatic diversity).

This process forces—especially in conditions of scarcity—the performance of different practices to precisely address the resolution of problems regarding governance and resource allocation [58].

General legal and management factors in the Chilean case, however, encounter two obstacles: on one hand, national standards that homogenize the management of radically different water realities are used [17], while on the other hand, the artificial sectioning of river basins (two or more RVCs can manage different river sections) has been carried out, thus reducing the capacity for internal coordination. In addition, territorial planning instruments are currently only obliged to include urban areas (communal, inter-communal, and metropolitan), and not rural areas, which can encompass important zones of the river basin that are not adequately regulated.

In this regard, RVCs have shown an unequal performance when facing the various issues that may occur in their areas of action, involving the contamination of irrigation channels, coordination between different uses, and the need to increase efficiency when facing conditions of scarcity [59]. Some of these organizations, such as the RVC of the first section of the Cachapoal River, have been able to address such issues, assuming roles that go beyond the conventional duty of water distribution. This RVC participates in the river quality monitoring program organized by state and private agencies, actively engaging with scientists and other RVCs. As an example, one of its members stated the following:

> *"I insist that cooperation agreements work as long as people want them to work. Therefore, people are more important than documents. We have been involved in different water boards, such as environmental certification boards for agricultural schools, and we are free to do so. Others have told us not to get involved in things that are not written (Water Code). But not here. Here, in everything related to the water problem, we say: let's do it!"* Member of the RVC of the first section of the Cachapoal River

In addition, the RVC of the Biobío River Basin aims to incorporate an Integrated River Basin Management, considering the protection of water quality, ecosystems, and groundwater availability [60]. As one of its members declared,

> *"I arranged a second meeting, a few months later, in the same place with the same actors [. . .]. I asked them to make other decisions, for example, the characteristics that our RVC was going to have. I suggested that the characteristics of this RVC should not be the standard characteristics of all the RVCs, but rather that we should aspire to something more, that we should aspire to a basin organization that would really allow us to carry out integrated management. And I believe that this got a lot of people excited. I asked the universities to explain to us what the training process was like [. . .] which were the limitations and problems for this [. . .]. One of the characteristics we defined was that we were going to cover the entire basin [. . .] from the source of the river in the lagoons to its estuary"* Member of the RVC of the Biobío River Basin

4.1.3. Collective Choice Arrangements

This principle enables CPR institutions to adapt their rules to local circumstances, as individuals interacting directly with each other and the physical environment can modify these rules over time to better adapt them to changing environmental conditions. The rules of use may be flexible under critical disturbances; however, with the return of standard conditions, the community should review the rules and their compliance [25].

When reviewing the basic conditions that allow agents to jointly manage an economic good, Ostrom has pointed out that most individuals affected by the operating rules should participate in their modification. This possibility is manifested not only in the foundation of these rules, but also in their permanent revision and adaptation following the social-environmental changes observed at the local level. Water regulation requires feedback, as the current environmental crisis scenarios force the need for a dynamic perspective [61].

Taking these factors into consideration, the Chilean management model presents some particularities in relation to what it considers to be the "most affected individuals".

According to Ostrom, this concept clarifies that those affected by a certain condition (i.e., water scarcity) suffer—in one way or another—the consequences of changes in the allocation or administration of the CPR [25]. According to the Chilean legislation, RVCs can only be composed by WUR holders and, in practice, most of the country's RVCs are composed of agricultural irrigators [62]. However, there are other water uses that could be affected by the changing socio-climatic conditions of the river basin, such as cultural and recreational activities that do not operate under the WUR system. In this regard, there are individuals who use water for several different purposes and do not have the opportunity to participate in the RVC's decision-making processes.

Although the RVCs were traditionally mostly composed of farmers who used water for irrigation and industrial purposes, since the beginning of the 2000s, several RVCs have changed their statutes to incorporate sanitary and hydroelectric companies. The RVC of the first section of the Cachapoal River initiated this process, including actors such as mining, sanitation, and hydroelectric power generation companies. Some RVCs have considered incorporating different users since the beginning of their foundation process, as is the case of the RVC of the Biobío River Basin. Moreover, it is important to highlight that some agricultural irrigators have recently incorporated hydroelectric generation systems within their irrigation channels.

4.1.4. Monitoring

CPR institutions have monitoring mechanisms relevant to the conservation of natural resources. In this sense, safeguarding natural resources through adequate management entails a greater community commitment to observing and recording processes, events and, in some cases, physical and environmental variables. This community-based monitoring system does not necessarily have to be valued by external agencies. The collective institution carries out the mechanisms to supervise the proper use of the resource. When the state or an external agent must sanction or validate a community monitoring mechanism, it is an indicator of the weakness and fragility of the community [25].

The factors subject to monitoring by the management institution vary. In the specific case of water management, this includes—among other aspects—the evaluation of compliance and decisions on extraction quotas, the proper use of extraction systems, the maintenance of minimum flows, and the environmental quality of the waters subject to administration.

In the Chilean management system, the Water Code provides the RVCs with the structure for their administrative bodies for exercising control and monitoring functions. In this matter, the Board of Directors of the RVC is empowered to ensure that water is collected by adequate structures (Water Code, article 274.1). In addition, this body may appoint a water distributor who reports to the RVC, in order to ensure that water is not subtracted or used by those without WURs (Water Code, article 278.2).

Monitoring water extraction is also carried out by public agencies, particularly by the DGA. Since the legal reforms implemented in 2018 and 2022, the State has expanded the DGA's attributions, incorporating the monitoring of the quality and quantity of the water in attention to its conservation and protection.

In the case of the first section of the Cachapoal River and the Biobío River Basin, both RVCs benefit from water quality monitoring programs at the river basin level, which are carried out thanks to the coordination of government agencies and private companies. The former RVC participates in the Cachapoal River Board of Directors which, together with other environmental committees, has collaborated with other RVCs, government agencies, and private companies to obtain water quality monitoring data in the sub-basins that composed the Rapel River basin for approximately 12 years. Although it does not participate directly, the RVC of the Biobío River Basin makes its decisions based on a program called the Biobío River quality monitoring program. The PMBB (in its Spanish acronym) was created in 1994, and has been monitoring the water quality of the Biobío river basin in a joint effort between the University of Concepción and private companies.

4.1.5. Graduated Sanctions

In solid CPR institutions, supervision and penalization are not carried out by external authorities but rather by the participants. The CPR appropriators create an internal compliance system to discourage those who are tempted to break the rules. Supervision costs are low in many long-term CPR institutions due to the rules in use, as there are usually both economic and moral sanctions. In collective action institutions, being repeatedly recognized as an infringer puts not only an individual at risk, but also the reputation of the collective unit (e.g., family) to which they belong [25].

Within the Chilean management context, it is important to highlight that RVCs follow the precepts of the Water Code with respect to the application of sanctions to its members. In this case, the supervisory duty carried out by the DGA as a governmental body is imperative. The DGA's resolution Number 185 established the Control and Enforcement Department, the main objective of which is to provide guidance, direct norms, and contribute to the "water watching and supervision" function exercised by the DGA in accordance with article 299 letters c and d [63].

Control and enforcement are administrative procedures defined in the Water Code, encompassing sanctions (if applicable), mainly of an economic nature (such as fines), and the ordering of certain administrative actions (i.e., shutting down illegal water extraction infrastructure). In the case of an infringement of the Water Code regulations, fines may be applied for tax benefits, which are graduated on a scale from the first to the fifth degree, depending on the nature of the infringement (articles 173 and 173ter of the Water Code). For the determination of the amount of the fine, the Water Code states that certain circumstances must be taken into consideration, such as the affected flow rate, surface waters or groundwater, whether the rights of third parties are affected, the number of harmed users, the degree to which the aquifer is affected, and the zone in which the infringement takes place, among others. For instance, obtaining a double registration of a WUR in the Public Water Registry, either intentionally for personal benefit or to the detriment of third parties, is one of the most serious punishable behaviors.

In addition to the rules that the RVCs must comply with according to the Water Code, some RVCs have additional graduated sanctions, such as the RVC of the first section of the Cachapoal River, which are related to moral sanctions. As one of its members detailed, it is possible to observe that this RCV has a monitoring system that involves sanctions if rules are not followed:

> *"One of our functions is to monitor extractions. We check the extractions all day and every day. We have a person who is assigned to do that. We have an operator who goes around and checks and telemetry systems that report. And now we are developing a software with a 'traffic lights' system that indicates that when is red, you are behaving badly or, if is green, you are doing well. It is that simple, with colors, because nobody has time to read a lot of numbers. But if you look at the website and somebody is green, and you are red, and everybody knows you are red, you are going to worry. Regardless of whether you are red or orange. Period. Nobody wants to be orange or red".* Member of the RVC of the First Section of the Cachapoal River

4.1.6. Conflict Resolution Mechanisms

In theory, in models of rule-governed behavior, rules are enforced by external agents and are usually indisputable. However, this is not often observed in practice, as rules can be interpreted differently by diverse appropriators. If individuals must follow specific rules for a long period of time, when infractions occur, there must be a mechanism through which the problem can be discussed and resolved [25].

In the case of RVCs, Rojas [22] has distinguished three ways of resolving conflicts arising from the use and management of water: (i) conflicts related to the exercise of WURs (in situations of faults or abuses committed in water allocation, or in their economic management) can be solved by the RVC's Board of Directors as an arbitrator (without the formalities of a court), and subsequently claimed in the courts of justice; (ii) requesting

external arbitration for the resolution of conflicts regarding the exercise of WURs through an administrative procedure initiated by the DGA; and (iii) directly resolving conflicts regarding the exercise and loss of WURs and all other water-related issues (article 181 to 185 of the Water Code) through a claim for protection that has a single objective—the immediate re-establishment of water use—ending with the interferences that disturb the exercise of the WUR [64]. Regarding the internal conflict resolution mechanism of the Board of Directors, fines and sanctions such as cutting off the water supply can be applied.

Other types of conflicts related to water use in river basins can be solved through administrative and legal means external to the RVCs (as they are not part of their legal attributions). A frequently used legal means to resolve conflicts is the "protection action" to safeguard certain fundamental rights contemplated by the Political Constitution (1980); for instance, to resolve conflicts involving the exercise of the human right to water [65]. However, this kind of action has not yet generated significant modifications to the water management system.

In the case of the RVC of the first section of the Cachapoal River and the RVC of the Biobío River basin, both entities do not have registered internal conflicts. This is particularity due, in our opinion, to the fact that the former has an advantage as it receives water in the highest section of the river, where there is generally greater control of the river flow distribution, while the latter has hydrological conditions that still allow it to have adequate availability for its members, who formed this RVC under a preventive principle in the face of negative projections of water availability in the future.

4.1.7. Minimal Recognition of Rights to Organize

Appropriators often design their own rules without developing formal governmental supervision systems. If external government agents control the development and compliance of the internal community's rules, this compliance system will not be sustained over time.

In this case, the RVC is considered to have a high level of autonomy in decision-making within the limits of its jurisdiction. Although the RCVs must be governed minimally by what is specified in the Water Code, the State does not intervene in internal water allocation systems or the mechanisms for re-allocating WURs (water markets usually govern the latter).

Under this level of autonomy, the RVCs can elaborate their statutes, conflict resolution mechanisms (through private arbitration), sanctions, and the composition of their management bodies, all within the legal framework. Within the Chilean water governance system, this situation—far from generating a consensus on the exercise of these functions as an adequate exercise of autonomy—has been criticized due to the differences between the public administrative role (i.e., performed by the DGA) and the role carried out by the RVCs, the former presenting severe defects in terms of its supervisory capacity, support in conflict resolution, and maintenance of an adequate information system [36]. However, regarding the organizations, some interviewees recognized that maintaining a good relationship with government agencies and other RCVs is beneficial for water management.

4.1.8. Nested Enterprises

Complex and enduring CPR institutions are organized in various layers at the local, regional, and national levels. In this sense, the management of the CPR must be performed within a network of coordination, congruence, and effective communication between these levels [25].

The RVCs in Chile do not comply (or, at least, not fully) with this principle, considering the lack of mechanisms for linking local to larger-scale management plans. The only connection/correlation that could occur at different levels can be observed in the case of the RVCs regarding the other WUOs that compose them (Irrigation Channels Associations, Water Communities, and Drainage Communities). However, as they are goods (resources) of a different nature (a common good on one hand, and already-extracted private water on the other), it would not exactly imply a case of "nested enterprises".

In the case of a basin management organization being sub-divided to perform its functions under the supervision of a higher authority, or when sections of the same river coordinate their functions, shared management could occur at different levels, allowing the generation of management plans and general norms regarding the whole river basin in a binding manner. In Chile, the discussion about who could fulfil such a role has been settled either at the political or the legislative level, with relevant developments in the reform of the Water Code in the year 2022 and the Climate Change Law in 2022, both of which consider the future existence of strategic water resource plans at the basin level, elaborated within the framework of a national water resource policy.

Considering the principle of nested enterprises, two cases were observed in which the RVC of the first section of the Cachapoal River has associated with other public and private administrative entities: the Board of Directors of the Cachapoal River and the Colchagua´s Clean Water Board, both of which are coordinated by the regional ministerial secretary of the Environment (in a representation of the Ministry of the Environment at the regional level). These boards, which have operated since 2001, manage issues related to financing and monitoring the Cachapoal River's water quality, and are collaborative bodies in developing environmental education initiatives.

Before its formation, the RVC of the Biobío Basin attempted to conform a River Basin Council, aiming to link with other institutions at other levels. According to one of its members:

> *"(Given the uncertainty caused by Climate Change and other threats, such as the future Hydric Highway project) I organized a meeting in a very nice restaurant by the Biobio River, and I invited as many people as I could have access to, in order to discuss this issue. On that occasion, I took the precaution of also inviting users from the hydroelectric world, the industrial world and, of course, all the WUOs. I invited representatives of civil society, such as some people who also represented other uses, such as tourism, fishing [. . .]. I also included the academia [. . .] and I also included people from the government. I did a presentation about how I think resources should me managed [. . .] and, finally, I asked them a question: if after having learned about this, they thought it was necessary to organize a RVC. This was done in a very well-documented way, notes were taken, very orderly. And the response was unanimous [...] all those who attended were motivated and said: yes, let's organize it".* Member of the RVC of the Biobio River Basin

5. Discussion

In Ostrom's Theory of the Commons, the regulation of natural resources and property avoids the strict and traditional conception of state–private separation and, instead, constitutes a fertile mix of private and public institutions, recognizing the importance of local actors in the conservation or degradation of the commons. According to Singleton [27], Ostrom´s Theory of the Commons is prevalent, in part, as it becomes an alternative to the pessimistic approaches of a homo economicus that cannot cooperate effectively around natural resources. She responds to Hardin's Tragedy of the Commons, which points out that a group of individuals pursuing their interests in the administration of goods will tend to exploit the resource until its total depletion. In contrast to Hardin, Ostrom indicates that resources will not necessarily be depleted, as she analyzed certain cases in which resources were managed sustainably, rationally, and better than in a system based on individual private property [25].

This review of Ostrom's management principles in relation to the structure and functioning of RVCs provided some elements for discussion: the geographical framework of action, the concept of 'user', and issues regarding collective choice arrangements.

5.1. The Geographical Framework: Moving from Sectioning to an Integrated Management of the Commons

Regarding spatial (geographical) scale, some critiques have arisen around Ostrom's design principles. Singleton [27] has argued that, besides individual self-interest as a barrier

to successful CPR institutions, socio-economic forces outside the CPR institution could be important with respect to its likely success. However, the same author stated that this is partly valid because some design principles are aware that local institutions do not exist in isolation. In addition, Araral [66] has stated that Ostrom's critique of Hardin is useful in the case of small-scale, locally governed commons, while Hardin´s theory seems to remain valid for large-scale and global commons. This occurs as trust and reciprocity—two core factors to achieve cooperation in the commons [67]—can be observed due to face-to-face communication [66]. Thus, even though they are largely accepted, Ostrom's principles are continuously challenged under new theoretical developments and new observational information. In fact, trust and reciprocity were mentioned by interviewees when asked about the relationship that the RVC of the first section of the Cachapoal River had with other RVCs and public entities. The exchange of knowledge regarding how to respond to new environmental conditions has involved a learning process to move towards adaptation.

An important element of discussion is the definition of a range of actions for the management body, which must be determined in the geographical dimension. In the case of the RVCs, although initially determined by the river basin (defined in Article 3 of the Water Code), the law admits the possibility of sectioning a single river basin. This fragmentation generally exacerbates conflicts between upstream and downstream boards. To the best to our knowledge, the RVC of the Biobío River Basin is the only RVC in Chile whose jurisdiction covers the river from its source to its mouth. This has brought advantages in terms of resolving possible conflicts and is a positive step toward Integrated River Basin Management, which has been promoted to adapt to the effects of climate change [68].

Another issue that impacts the separation of the ranges of action corresponds to the separation that Chilean legislation makes for water management regarding the territory and its physical characteristics. Territorial planning instruments mainly concentrate on urban areas, not including the situation of watersheds that are not located in the urban context, with little possibility of regulating activities that cause direct and indirect effects on water availability and quality. In addition, the exclusion of WUR holders who extract water from the ground through wells [17] also affects the determination of the action ratio in geographical terms, due to a separation (in terms of management) between surface and underground water.

The proposal to strengthen the management of common goods in the case of water, by supporting the attributions and intervention of the RCVs or the creation of basin boards, should consider an extension of the territorial scope that effectively integrates the entire river basin, in both its urban and rural dimensions, and consider the capacity to influence and provide feedback to those institutions in charge of territorial planning. In addition, the legal territorial framework should allow enough flexibility to grant local management that adapts to the conditions of each river basin throughout the territory, according to different socio-climatic characteristics and the development of nested enterprises.

We argue that Ostrom's design principles are suitable for analyzing the community administration of river basins as common goods through a self-management approach. At the river basin scale, this mechanism adapts to territorial characteristics and the social traditions of those who benefit from CPR use. These principles applied to the RVCs emphasize integrating different types of stakeholders and their forms of participation, the relationship between these institutions and non-extractive uses, and their role in environmental conservation and the maintenance of water availability.

5.2. The RVCs and the Concept of 'User'

In Governing the Commons, Ostrom [25] refers to the concept of 'user for purposes of participation' which, in the Chilean case, applies to the RVCs as the entities in charge of managing WURs in rivers and/or river sections. According to Ostrom's perspective, this concept is geared towards considering users as individuals affected by the operating rules. In our opinion, in the case of water, this might not be so clear due to specific needs related

to advances in technology, population growth, and the effects of climate change, affecting its availability for ecosystem functions. In our understanding, this determines an unclear definition of the category of 'users'.

In the Chilean legislation, water management involves a restricted conception of users when establishing WUOs in the Water Code, particularly the RVCs. Such participation is restricted to WUR holders, represented by the Board of Directors. In this way, the user concept—which includes self-management organizations—is linked to the owner of the actual private right of exploitation. This situation, which is allowed by the Water Code, is detrimental with respect to the process of participation within the RVCs and, therefore, in conceiving an adaptive governance system.

The RVCs recognize the safeguarding of public interest [18], as their functions affect the conservation of a national good for public use, such as river basins. The conception of users, understood as only those with a direct economic interest in water extraction (consumptive or not), moves away from the configuration of a community regime such as the Theory of the Commons, as it does not incorporate all those affected by the decisions of the management body. Instead, it is concerned with generating mechanisms to protect the property rights of WUR holders. The Water Code does not distinguish geographical or cultural spaces in determining individuals or groups affected by decisions and rules. However, RVCs have made efforts to assume the functions that their context requires, even if they are not provided by law, as noted in Section 4.

The duality that RVCs face in terms of being a body constituted by private actors fulfilling the functions of a public body affects the incorporation of key users. The legislation does not distinguish the type of rights in question; therefore, the ancestral rights of native people and groundwater rights are not usually incorporated into RVCs. Indeed, groundwater users are allowed to conform to a different entity, different from surface water uses, even being part of the same basin. The problems caused by this lack of incorporation not only relate to an impairment of the right of some stakeholders to participate in the decision-making process within the RVC, but also to an impact on the public interest in trying—at least in part—to carry out a harmonious management of water allocation.

The described situation has been reversed in some cases by incorporating these types of users, but within the frameworks prescribed by the Water Code [69]. This is the case of the RVC of the first section of the Cachapoal River, into which legal entities such as ESSBIO (water sanitation company), the state company CODELCO (mining), and hydroelectric companies have been incorporated, which are WUR holders that have been excluded in the past. However, this is an exceptional situation in most RVCs, which has been driven by conflicts, some even reaching the Chilean courts. In this matter, the expansion of the concept of a Water User emerges as a necessary objective to be achieved to comply with real participation, which is a principle of adaptive governance of the commons.

It is essential to highlight that the modification of water governance in Chile does not necessarily imply a direct integration of other stakeholders into the RVCs. Rather, it is also important to re-think their role within a larger context, such as the already mentioned River Basin Councils.

5.3. Issues about Collective Choice Arrangements: The Water Shares

The existence of collective choice arrangements is one of the principles that Ostrom established in the configuration of permanent models for the management of a CPR. The possibility that the decisions are made by the majority of those affected corresponds to an important contribution of the author in the notion of democracy in the management of natural resources.

The application of the voting mechanism to RVC members based on shares, which are distributed according to the number of WURs held by each member (Water Code, article 268), is similar in this matter to the system of administration of a Joint-Stock Company [18]. Equating these shares to decision-making power is a sort of internal governance system, especially in the case of those profit-seeking legal entities, as could be the case of

business companies and corporations. The rationale is that the greater the investment (or economic interest involved), the greater the right to decide regarding the CPR. Although this could be understandable in a business company, we believe that, in managing the common interest, it does not adequately consider the special characteristics of water as a national good for public use.

The eventual inclusion of new stakeholders for whom the use of water goes beyond economic interest (subsistence farming communities, citizens and native peoples, among others) into management bodies necessarily implies re-consideration of the current decision-making mechanisms. In fact, the formal incorporation of other stakeholders in the use of water has been proposed for more than a decade. Documents such as the World Bank report [13] or the one prepared by the Chilean Institute of Engineers on Integrated Water Resources Management [70] have included several technical proposals to improve water management, incorporating the concept of integration into the Chilean water governance system. One proposal is to create new institutions (i.e., River Basin Boards) with the power to include different social and economic actors in the use of water resources, or the joint development of basin management plans that include RVCs and other WUOs. This could be a solution to the restricted power in decision-making that the current legislation provides for RVCs. However, the formal extension of the decision-making power of RVCs implies the inclusion of new actors besides WUR holders. Although this option regards the characteristics of a CPR institution (according to Ostrom's conception), it is currently doubtful whether RVCs will fulfill functions for which they are not mandated by law or for which they do not have financial aid. In this sense, transforming into an adaptive decision-making model requires major legal changes, including amendments to the current Chilean Constitution.

In this sense, the RVC of the first section of the Cachapoal River and the RVC of the Biobío River Basin go beyond some of the functions and boundaries stated by the Water Code. Although these RVCs participate in educational stances, collaborate with other entities, are worried about water quality issues, and are willing to consider the opinions of other relevant water users in the future, they do not fully comply with all eight of Ostrom's design principles for long-enduring CPR institutions.

6. Conclusions

From an analysis of the general characteristics of the water management and governance situation in Chile, it was determined that, although the RVCs recognize and promote the importance of self-management, they do not ensure that all those affected by water management can participate in decision-making or resolve conflicts, as they are composed exclusively of WUR holders. Contrasting with the obtained legal research results with Ostrom's design principles for long-enduring CPR institutions, there is an important exclusion of some critical water users (especially non-extractive users with no recognized or constituted water rights), an unequal decision-making process based on the number of water shares (in some cases linked to economic power), and a lack of integrated planning at different levels. Furthermore, as mentioned above, RVCs usually cover a specific section of a river basin, not the whole river basin. These characteristics, added to the current water crisis in Chile, seem worrisome when considering how to move towards an adaptive governance system.

The maintenance of the current water model in Chile contributes to the deepening of a governance and availability crisis, to social conflicts associated with water access and allocation, and to the imbalance in its different uses and functions to the detriment of those that are outside of the extractive economic categories.

The recent reform to the Chilean water legislation seems to be insufficient to correct these inequalities and inadequate in the face of the challenges posed by climate change and governance of the CPR. Chilean water governance should consider the existence of River Basin Boards with broader planning powers, incorporating water users in the various dimensions that such management affects.

A new form of governance that goes beyond these management mechanisms must take on these challenges to increase integration, enabling fair decision-making and coordination between different levels. To this end, the principles of the governance of the commons can provide not only a prism of analysis—as in this work—but also a basis for projection, adapted to the water and social realities in the Chilean case and worldwide.

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