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Magical Realism for Water Governance Under Power Asymmetries in the Aracataca River Basin, Colombia

RESEARCH ARTICLE

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ABSTRACT

The Ciénaga Grande de Santa Marta is a wetland complex characterized by its high productivity and different systems of biodiversity use associated with water. The Ciénaga receives fresh water from rivers descending from the Sierra Nevada de Santa Marta. Changes in the water dynamics of these rivers since the early twentieth century have been causing serious social and ecological changes in the region. The Aracataca river is one of these rivers that showed a drastic change in its water availability. In this research we study the relation between cooperation and hydrological dynamics that shapes the water governance system in this basin. The study combines quantitative data obtained from the hydrological description and qualitative information derived from interviews and a role-playing game workshop, which was analyzed from a social-ecological perspective. The analysis shows that the historical management of water, characterized by conflicts between individual and collective interests, power asymmetries, and the heterogeneity between actors, has established a problematic scenario. Our analysis at river basin scale showed difficulties in water governance regardless of water annual variability, thus requiring structural changes that allow the development of coordinated processes toward collective action. This research identifies elements that can enrich the management discourses of the Aracataca river basin and the Ciénaga as a whole, highlighting the importance of understanding environmental issues as problems of common pool resources.

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INTRODUCTION

Wetland ecosystems play an essential role in maintaining ecological processes which yield benefits for different human groups that include the regulation of the chemical properties of water, the buffering of atmospheric phenomena (Mitsch & Gosselink, 2000), and the production of hydrobiological resources (Vilardy-Quiroga et al., 2011). The dynamics of global change and human pressure on the natural resources provided by wetlands have accelerated the degradation of these ecosystems, affecting their natural dynamics of variability and the provision of ecosystem services (Koch et al., 2009).

These transformation processes are particularly relevant in a country such as Colombia, where wetland ecosystems represent an extensive portion of the continental territory (Vilardy-Quiroga & Cortés-Duque, 2014). The Ciénaga Grande de Santa Marta (CGSM) is the largest coastal wetland in the country, consisting of a complex of estuarine lagoons that is part of the deltaic plain of the Magdalena River in the Colombian Caribbean. This wetland system receives fresh water from the Magdalena River, the main river in the country, and rivers descending from the Sierra Nevada de Santa Marta (SNSM). It is characterized by its high biodiversity and various livelihoods closely linked to water, especially associated with fishing (Carvajalino-Fernández et al., 2017).

The CGSM main transformations began to occur at the beginning of the 20th century (Vilardy-Quiroga, 2009). These have consisted of hypersalinization of soils, mangroves dieback, modifications in the structure of fish communities, water pollution, and changes in sediment circulation (Botero & Mancera-Pineda, 1996). The degraded environmental conditions of the CGSM are a consequence of economic development policies with poor understanding of the system, demographic changes, and political instability associated with the armed conflict (Torres et al., 2016; Vilardy-Quiroga et al., 2011).

One of the CGSM's tributary rivers is the Aracataca River. Agricultural production is the main driver of change in the river basin, especially palm oil. Land occupation has followed a dual scheme of peasant and enclave economies, with intensive use of water for irrigation (Cabeza, 2014). The historical context of water management has led to inequalities in water distribution, conflicts over its use, and the reduction of the flow at the mouth of the river which has affected the fishing population in the lower basin.

The purpose of the paper is to study the relation between cooperation and hydrological dynamics that shapes the water governance system in the Aracataca river basin. We follow a mixed-methods approach to integrate hydrological and institutional variables with the purpose to study the key challenges around water governance in the Aracataca River basin following a social-ecological systems' (SES) perspective (McGinnis & Ostrom, 2014). Water management in the basin is described as a Common Pool Resource (CPR) problem (Ostrom, 1990) while the river basin constitutes the spatial and institutional domain of the study. We describe its hydrological characteristics using supply and demand parameters in dry, wet, and normal years and analyze the institutional arrangements and their relationship with water dynamics. We also study the relationships between the hierarchies of the governance systems to understand power relations and identify decision-making mechanisms with different levels of formality (Stoker, 1998).

It is worth noting here that in vertical water systems such as river basins and irrigation systems, tailenders hardly receive water in the necessary quantities, or they do it at a very high cost (Shivakoti & Ostrom, 2003). Spatial asymmetries among those who are near or distant from the resource (Ostrom & Gardner, 1993) are largely due to the conditions of subtraction of water as a CPR, as the use given by one person affects the possibility of other people to use the resource (Tang, 1992). This occurs in the Aracataca River basin, where the problem of collective action in the irrigation system of palm oil producers (headenders), among others, limits the access to water of the fishing community (tailenders). Thus, we focus the analysis on the lower basin because the collective action problems become most evident there given the conditions of vulnerability and reduced capacity of fishermen to transform the system.

STUDY AREA

The Aracataca River basin, with an area of 166.258 ha (Figure 1), is part of the alluvial plain formed by rivers that descend from the western slope of the Sierra Nevada de Santa Marta (SNSM) and flow into the CGSM (Bernal, 1996), in the Department of Magdalena.[1] The influence of the trade winds of the Northern Hemisphere creates arid and semiarid conditions, which are strongly affected by the El Niño Southern Oscillation (Vilardy-Quiroga & González-Novoa, 2011). The rainfall seasonality in the lagoon delta complex is characterized by a rainy season that extends from April to November, with one peak in May or June, a local minimum in July and the most intense peak in October, and by a dry season that runs from December to March. The spatially well-differentiated rainfall regime in the lagoon delta complex determines a water deficit gradient that grows from -211.6 mm yr-1 in the southern to -1146.8 mm yr-1 in northern areas (Blanco et al., 2006).

The Aracataca river is one of the freshwater inlets (17.4 m^3s-1) that influence the seasonal variation in the water level and contribute to oxygenation, circulation of

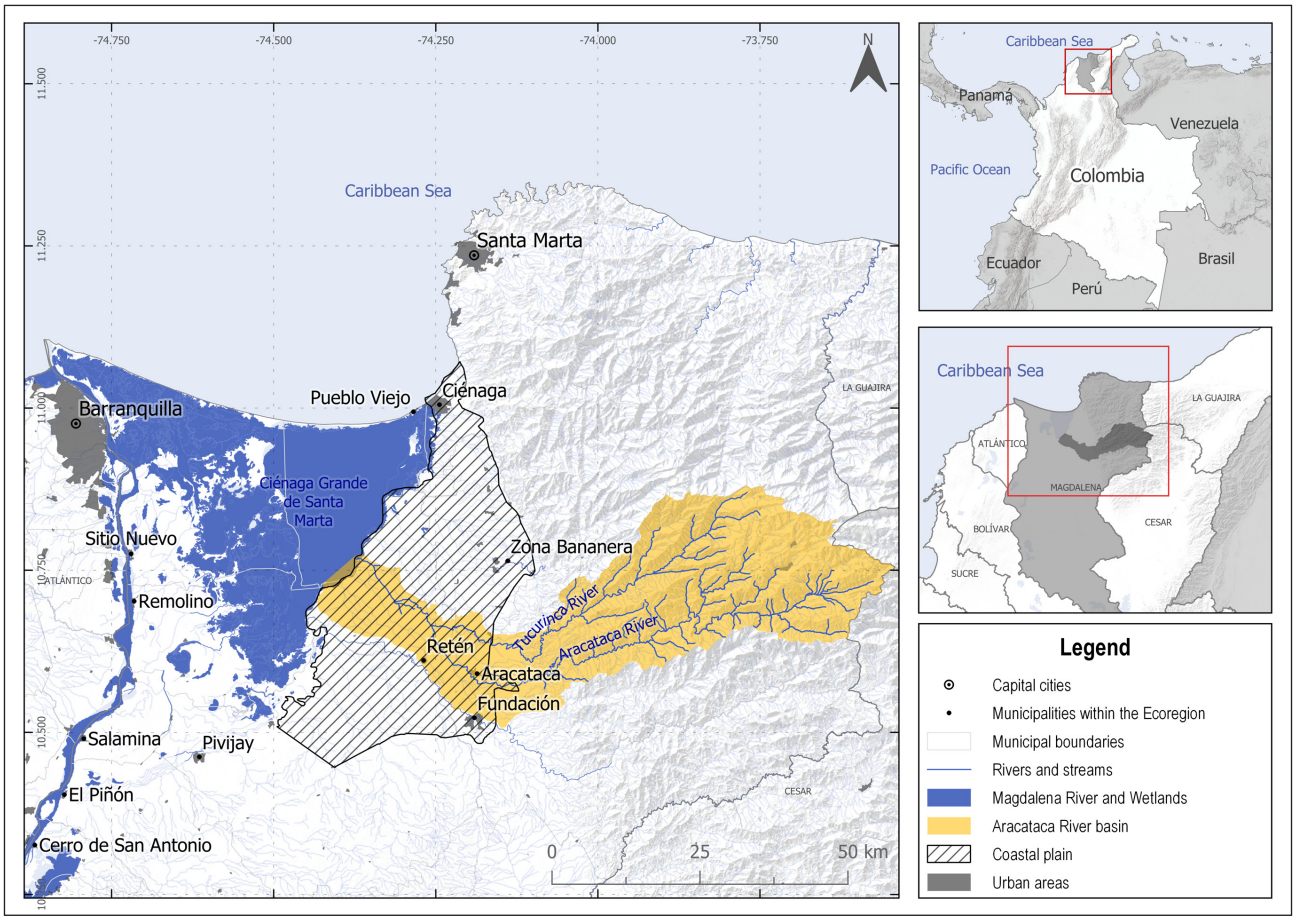

Figure 1 Aracataca River Basin. The lower basin corresponds to the coastal plain (0–100 m.a.s.l.).

sediments, temperature variation and salinity levels of the southeastern part of the estuarine complex. These characteristics have significant effects on the composition and distribution of biological communities (Bernal & Betancur, 1996; Invemar, 2018). The flow of the river varies based on this seasonality (Hoyos et al., 2019).

The occupation history of the region and the development models implemented have ignored this ecological complexity and the hydrological connection between the Aracataca river, the CGSM, and the sea, as well as its relationship with livelihoods and socioeconomic dynamics (Vilardy-Quiroga, 2009). This has caused changes in the hydrology of the river and therefore in the ecology of the CGSM (Botero & Mancera-Pineda, 1996; Botero & Salzwedel, 1999; Röderstein et al., 2014). This has been particularly evident in the lower basin, where agricultural practices have defined the strategies for water harvesting causing the most critical appropriation and provision problems as CPR and on the ecology of the CGSM.

Since the 18th century, the alluvial plain of the Aracataca River has had a strong agricultural tradition (Herrera & Romero, 1979). The introduction of commercial banana cultivation in 1887 (LeGrand, 1983) was motivated by the Colombian government's interest in positioning itself in the international market (Cabeza, 2014; Herrera & Romero, 1979). The government developed irrigation systems with canals, dams, and reservoirs (Cabeza, 2014), leading to conflicts due to the unequal distribution of the resource, initially among farmers, settlers, and banana companies (LeGrand, 1983) and, more recently, among palm oil producers, banana producers and small-scale artisanal fishermen (Salzwedel et al., 2016).

Actors within the Aracataca River who make decisions regarding water are diverse. In the upper part of the basin, Arhuaco indigenous communities predominate with a population of 22,134 people (DANE, 2005). In the middle part of the basin, coffee producers are the main economic actors, and in the lower basin, palm oil producers are organized in an association of irrigation district users, with 380 associates in 2019. Although banana producers are also in the basin, they occupy a very small portion in the watershed area and in the irrigation district users. At this point is located the municipal seat of Aracataca, with 30.149 people (DANE, 2005). At the mouth of the river on CGSM land is the Trojas de Cataca, a floating community of artisanal fishermen of 154 people (Aguilera, 2011), which

represent 20% of the original population that decided to return after a massacre executed by paramilitary groups in 2000 (CNMH, 2014). The situation of this community is critical, as 98% of the population consumes water with no treatment. Several cases of acute respiratory infections and acute diarrheal diseases have been reported, caused by the consumption of non-potable water, poor sewerage, and aqueduct service, as well as water pollution through agrochemical waste from palm crops (CNMH, 2014).

Oil palm plantations in the region appeared around 1950, inheriting historical dynamics and conflicts over water (Rangel et al., 2009). Oil palm (*Elaeis guineensis*) has been successful in the area due to the high solar radiation and nutrient conditions of the soil. However, this crop requires high levels of rainfall. A secure irrigation is therefore essential for its productivity (Cabeza, 2014). The irrigation demand from this crop in the Colombian Caribbean is high compared to the national demand. This is due to the low water supply in the dry months (Mejía, 2000) and the poor efficiency of gravity or flood irrigation systems (Álvarez et al., 2007). The regional environmental authority formally regulates the use of water in the Aracataca basin by allocating water permits. Nevertheless, compliance with water regulation is low and illegal use of water is common. On the other hand, the office of National Natural Parks of Colombia is responsible for ecosystem conservation in the lower basin.

METHODS

We did a hydrological analysis of the Aracataca river basin and conducted fieldwork in Aracataca and Santa Marta during 2019. The purpose of the hydrological analysis was to describe the dynamics of the water in the basin while fieldwork consisted of semi-structured interviews and a role-playing game workshop (Steiner, 2020). The interviews were carried out to collect general information on water management in the region and issues within the watershed perceived by each type of actor. The role-playing game workshop allowed the analysis and synthesis of a socioecological problem while exploring the reactions of the participants to different configurations of the system. This mixed-methods approach had the purpose to articulate institutional and hydrological variables, in order to explore relationships between water catchment strategies and hydric dynamics of the basin. The information collected was integrated based on the SES analytical approach. Annex 1 presents the tools used to document the SES variables.

The basin was delimited as a hydrological domain and as the unit for the analysis of the institutional arrangements. Based on a literature review on the topics of power asymmetries and challenges faced by tailenders (Lam, 1998; Ostrom & Gardner, 1993; Shivakoti & Ostrom, 2003; Tang, 1992) and on prior knowledge about conflicts over water in this specific area, we decided to focus our analysis on the problem between palm oil producers and fishermen in the lower basin. Since the wellbeing of fishermen in the Trojas de Cataca community depends on upstream water management, our methodological tools focused on describing the dynamics of water use among palm oil producers.

HYDROLOGICAL ANALYSIS

For our hydrological analysis, we used the water scarcity index (1). This index represents the relationship between water use by different users and the surface water supply available for the same spatial and temporal resolutions (García et al., 2010). The index is reported as a percentage, indicating the relationship between total water demand and net water supply (Domínguez et al., 2010) and the degree of pressure on water supply and water supply vulnerability (IDEAM, 2015). Net water supply and total demand were calculated from the parameters of the following equation, where I_e is the scarcity index, D_t is the volume of total water demand, and O_n is the net water supply in the basin:

$$Ie = \frac{Dt}{On} * 100\% \quad (1)$$

Different classes of water resource pressure are distinguished: high, when the demand reaches 41% or more of the water provided by the supply source; medium, when the demand is between 21 and 40%; moderate, when the demand is between 11 and 20%, and low, when the demand is below 10% (Rivera et al., 2004).

We used a percentile-based approach to define dry and wet conditions from average monthly precipitation data of 39 pluviometric stations in the region of interest. The pluviometric data is available on the IDEAM's (Institute of Hydrology, Meteorology, and Environmental Studies) Hydrometeorological Monitoring Network website (IDEAM, 2019). This approach, as explained by Steinemann et al. (2015), allows statistically consistent scenario creation processes capable of representing a wide range of precipitation conditions. We fitted precipitation data to parametric statistical distribution models of Pearson family type and then used the percentile 10 and 90 to respectively define dry and wet conditions. To define normal conditions, using the same precipitation dataset, we calculate the mean value of the fitted statistical distribution. A more detailed description of the followed fitting method can be found in Domínguez et al. (2008).

The calculated average monthly precipitation in dry, normal, and wet conditions and average monthly

temperature data from 41 climatological stations of IDEAM's network were used as input variables to calculate the annual surface water supply, following the water balance equation (2), where Y is the runoff, X is the precipitation and ETa is the actual evapotranspiration. The actual evapotranspiration was calculated using the Thornthwaite-Mather's method (García & Montoya, 1972). For both the precipitation and temperature data, the process of data selection and completion followed the methods presented in CAR (2015).

$$Y = X - ETa \tag{2}$$

We estimated the water demand (Mm^3) by adding the urban and rural domestic demand (Ministerio de Ambiente Vivienda y Desarrollo Territorial, 2003; Ministerio de Vivienda Ciudad y Territorio, 2010), the livestock demands for pig, cattle, and poultry consumption (DANE, 2016; Resolución 00011912 de 2019), agricultural demand (Allen et al., 1998; IDEAM, 2015), and industrial demand (Atencia, 2014; DAABON, 2019; Resolución 2263 de 2011; Resolución 4147 de 2018).

The agricultural water demand was calculated using the cultivated area per crop in the water basin, a calculation that was made based on the reported areas per municipality by DANE (2016) and the relative area occupied by each municipality in the water basin. Permanent crops were assumed to have a constant crop coefficient (Kc) equal to its final growth stage, meanwhile transitory crops were assigned with a mean Kc to sum up the Kc differences in the crop stages. Field capacity was assumed as 50 mm because of the well-drained soils of the water basin (CORPAMAG, 2013). Industrial demand was represented by the water consumption of 6 oil mills present in the water basin. When the water demand of a specific oil mill was unknown, an average data completion was applied. Because of the data availability, we calculated water demand on an annual scale for 2019, the same year in which the institutional analysis was performed.

We used ArcGIS, ESRI (10.5) and Python (2.7 & 3.8) software (ESRI Inc., 2016; Python Software Foundation, 2020) to conduct our calculations and for spatial representation. Annex 2 shows the hydrological parameters used.

SEMI-STRUCTURED INTERVIEWS

We conducted 11 semi-structured interviews (Ander-Egg, 1995; Bonilla-Castro & Rodriguez, 1995) with managers of irrigation districts, leaders of the Arhuaco council, representatives of the oil palm guild, experts in palm certification, managers of coffee associations, municipal officials, palm oil producers, and representatives of the regional environmental authority. The purpose of the interviews was to capture different actors' understanding of water related issues in the basin. Therefore, we preferred to implement few in-depth interviews with key actors that would provide detailed information, rather than having a large sample with redundant information. Interviews also were used for the adaptation of the role-playing game (RPG) called *Upstream* (Steiner, 2020).

ROLE-PLAYING GAME WORKSHOP

The RPG was implemented to approach the CPR problem from a socio-ecological perspective as this methodology allows identifying aspects of the problem that are not evident during an interview. Specifically, the role-playing game had more importance in the description of the governance variables, interactions, and outcomes of the SES, than in the characterization of the other subsystems (Annexes 1 and 3). For this purpose, we adapted an already existing RPG to represent the Aracataca river basin and its dynamics. The original RPG called *Upstream* was designed to represent water management in the Cravo Sur River basin, located in the Colombian Llanos. We used information obtained from our hydrological analysis, a literature review, and the semi-structured interviews to adapt and calibrate the RPG to the Aracataca River basin (for details see Steiner, 2020).

The game modeled the action arena that involves the management of water for irrigation in the lower basin, proposing different configurations of water availability and possibilities for dialog, from which the responses of the actors were evaluated (Allington et al., 2018). Annex 3 illustrates the variables, and the observed elements present in the RPG.

The RPG consists of a game board, which represents the river basin (Figure 2). Blue fields in the middle of the board represent the Aracataca River and small water tokens simulate the flow of water. At the end of the river, a green vessel represents the CGSM. The game setup includes the CGSM ecosystem and its need for freshwater inflow to uphold its ecological functions. Players are located along the board. Their goal is to capture water tokens, which they need to make their oil palm and banana farms work. To represent the upstream-downstream subtraction problem, players located in the upper part of the gameboard were allowed to capture water before those located in the lower part. The number of available water tokens varies in each round, representing the seasonal variation in the water supply (i.e., rainy and dry tested interspersed). Water storage infrastructure is not available by default in the game so, if it was identified by the players as a factor that needed to be solved, it had to be designed by them as a water management strategy.

The workshop was attended by nine participants, including palm oil producers, oil palm and banana technicians, one representative of a palm oil extractor and

representatives of an environmental NGO. All participants voluntarily agreed to be part of the activity. Eight of the participants adopted the role of producers, and one adopted the role of representative of the irrigation district who was responsible for distributing water among producers. Five rounds were played, in a span of three hours.

In our workshop, we presented three situations: 1) negotiation of water harvesting permits, 2) watershed management plan, and 3) intense drought. In the first situation, producers must negotiate their water harvesting permits with the irrigation district representative. The person with this role could determine the limits of the permits and conditions at his own discretion. Players were given five minutes to negotiate their permits. In the second situation, players had to discuss how to build and implement a watershed management plan. Five minutes were given for this too. And last, an intense drought was presented, where water tokens decreased. These three conditions represented changes in the rules of the game that forced players to design strategies to harvest water efficiently, to decide whether to leave available water to the tailenders, and to build agreements for water distribution. Table 1 shows the possibilities of action and decision by role under two seasons and three situations.

Figure 2 RPG workshop in Aracataca.

WATER AVAILABILITY SCENARIOS	SITUATIONS	ROLE	GOAL	DECISION OPTIONS
Rainy Dry	Negotiation of water permits	Producer	Catch water tokens to keep farms producing	How much water to take
				How much water to negotiate
	Watershed management plan			To leave water for tailenders or not
				To build and fulfill agreements or not
	Intense drought	Representative of water district	Distributing water among producers	Permit limits assigned per player
				Distribute water equitably or not

Table 1 Player roles, goals, and decision options along five rounds.

RESULTS

SUPPLY, DEMAND, AND SCARCITY INDEX: RESOURCE UNITS AND RESOURCE SYSTEM (RU, RS)

As seen in the map (Figure 3), the highest water supply values (more than 900 mm) are found above 100 m.a.s.l. in normal (A) and wet (B) scenarios, while the lowest water supply production is recorded below that altitude in both conditions, exactly where the oil palm landscape is located. This finding indicates that in the upper basin, precipitation is greater than the actual evapotranspiration, and there is always surface water in this part of the basin, while in the lower basin, the precipitation does not exceed the ETa at the annual scale, and thus, the supply is provided only by the water that runs off the SNSM. In wet conditions (B), water supply values are the highest, reaching more than 1800 mm in the upper basin and never acquiring a value of 0 mm in the lower basin. In dry conditions (C), however, water supply in the whole basin area is below 900 mm, mostly with a value of 0 mm. This indicates that in dry years, precipitation does not exceed actual evapotranspiration in any part of the basin, and the supply values do not exceed 400 mm in the upper basin.

As to water demand on an annual scale, the total demand is equivalent to 103.14 Mm^3. The scarcity index for the Aracataca River basin is moderate for normal years (11%), high for dry years (64%) and low in wet years (5%) (Domínguez et al., 2008; IDEAM, 2015) (Table 2).

CHARACTERIZATION OF THE SOCIOECOLOGICAL SYSTEM AND INSTITUTIONAL ARRANGEMENTS

We characterized the basin as a social-ecological system following Ostrom's SESs framework using the results from the semi-structured interviews. Then, for the governance subsystems and interactions, we focused on the lower basin, given its relevance in the appropriation-provision problem among palm oil producers and fishermen.

Social, economic, and political context (S)

Water management is framed within a historical and political context that defines the forms of water use. First, governments at the departmental and municipal levels have promoted the development of the agricultural and industrial sectors without implementing specific strategies that regulate agricultural expansion as a function of water supply. In addition, economic strategies do not align with

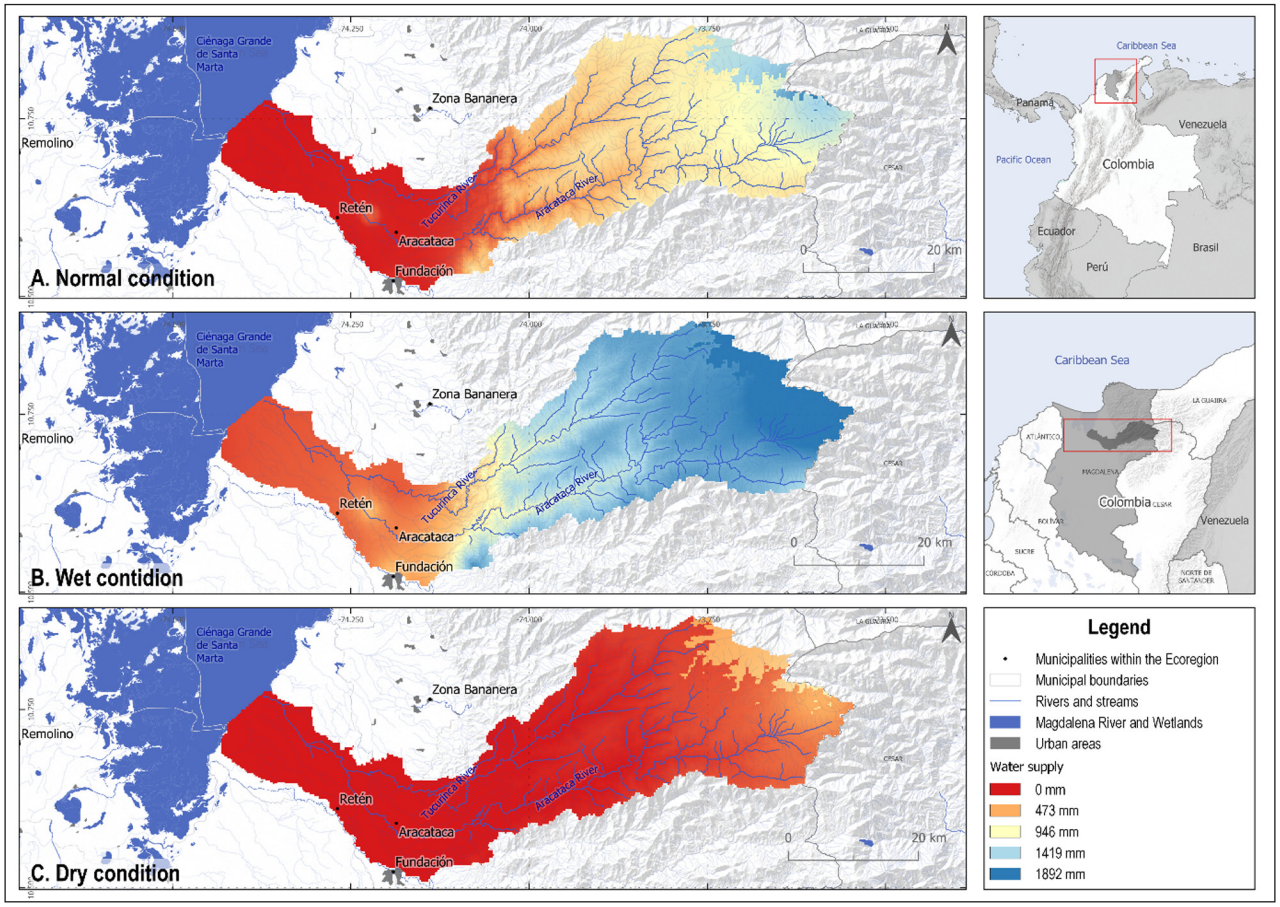

Figure 3 Spatially distributed annual water supply for normal **(A)**, wet **(B)** and dry **(C)** conditions.

Average supply (Mm³)	Normal	992.18
	Dry	161.38
	Wet	2047.66
Demand (Mm³)	Domestic	2.26
	Industrial	0.46
	Livestock	0.58
	Agricultural	99.84
	TOTAL	103.14
Scarcity index	Normal	11%
	Dry	64%
	Wet	5%

Table 2 Summary of the hydrological analysis.

planning instruments and protection figures that regulate the use of land, water, and biodiversity, such as the declaration of the CGSM as an Exclusive Reserve Zone for the artisanal extraction of fishery resources, or the watershed management plan (Decreto 1640 de 2012; Decreto 2811 de 1974). Additionally, the historical armed conflict in the region has been related to the establishment of illicit crops and drug trafficking routes in the SNSM foothills and the incursion of paramilitarism in the CGSM, which has led to distrust among actors and erosion of the social capital.

Ensuring spaces for dialog and participation in decision-making regarding water management are important challenges in the basin. Different local initiatives have emerged since the 1980s to establish communication bridges based on the management of natural resources, for example, ProSierra, Fondo del Agua or ProCiénaga. However, the lack of continuity and guarantees of participating in those spaces prevent the consolidation of collective processes that consolidate a joint strategy for water governance.

Related ecosystems (ECO)

The interviewees identified a clear relationship between water extraction of the Aracataca River and the dynamics of the CGSM. This relationship is revealed in the reduction in freshwater volume that reaches the wetland complex, mainly attributed to the infrastructure of the irrigation district. The lack of fresh water affects fish populations and the resource availability for floating communities.

> *"Water does not reach the Ciénaga, and for that reason, you can no longer see the fish migration. Only on weekends does the floodgate [of the irrigation district] open, and that is when a little water is released"*. Palm plantation technician in Aracataca, September 18, 2019.

> *"The water problem has meant food security problems for the floating population as, due to lack of fresh water, fish have left, and people have to go further to fish"*. Municipal representative, August 28, 2019.

Thus, the extraction of water by the oil palm guild reduces water availability for the population of Trojas de Cataca, carrying with it changes in fishing resources.

Actors (A)

Actors involved in the Aracataca River basin are very diverse. Water access differences arise from infrastructures for water access, location and/or asymmetries in decision-making power. First, while palm oil producers have a consolidated irrigation infrastructure, fishermen do not have an aqueduct or sewage system. On the other hand, those actors located upper in the system access water first and in greater quantities than do those located in the lower part of the basin, which have the most negative impacts on fishermen, the tailenders in this water vertical system.

Nevertheless, the most critical difference between actors is the asymmetry in decision-making power with large palm oil producers having much more power than small producers and fishermen of Trojas de Cataca. In the case of small palm oil producers, for instance, this is mainly because the board of directors of the water user association usually make decisions that benefit large producers. Here it is worth noting that the members of this board are appointed based on the favors related to the distribution of water and not on voting, thereby reducing the participation of some producers. Similarly, fishermen are disadvantaged compared to palm oil producers in the collective processes of construction and transformation of institutional arrangements because as there are not effective spaces for dialog and negotiation.

Governance system (GS)

The regional environmental authority grants catchment permits to users' associations, such as irrigation districts (Ley 41 de 1993). These permits determine the volume of water granted and a fee that must be paid for water used. The districts must distribute the granted amount of water to the affiliated producers. The amount of water each producer receives depends on the cultivated area. In the lower basin, for oil palm crops, the irrigation district is managed by a water user association. Irrigation districts are public entities administered under a private system of user associations (Decreto 1881 de 1994), in this case, palm oil producers. Distribution is conducted in shifts, where producers who have paid their fees are prioritized (Resolución 498 de 1997).

Water is managed under a primarily public scheme, which eventually acquires private characteristics for both individuals and groups. That is, water is a CPR with conditions of high rivalry and low exclusion, whose formal access is not open but regulated by the state as a public entity that temporarily grants private use rights to individuals or user associations. Any water uses in excess or not granted by the environmental authority is considered illicit.

However, this regulation for the appropriation of water designed at the constitutional level is misaligned with what occurs at the collective and operational levels where informal and illegal institutional arrangements dominate water access. Such arrangements are characterized by extraction of greater water volumes than needed for cultivated areas, no-payment of tariffs, construction of infrastructure independent of the irrigation district and lack of monitoring and sanction. Furthermore, money transactions and favors in exchange for water outside the concessions granted are common.

Thus, formal and informal governance systems overlap as illegal practices have been normalized. On one hand, formal institutions specify strategies for the appropriation and provision of water, such as rules that sanction individualistic behavior (Ley 1333 de 2009), that explicitly regulate the time frame for collection (Decreto 1541 de 1978) as well as the amount of water allowed (Acuerdo 193 de 2009; Ley 41 de 1993; Resolución 498 de 1997). On the other hand, in the field illegal practices have consolidated as the institutional arrangements for water management. This has resulted in the inequitable distribution of water, conflicts between small and large producers, erosion of trust and a shortage of water in Trojas de Cataca due to reduced flow at the mouth of the Aracataca river.

One emerging response to this problem has been a pro-collective rights movement (span. acción popular) in the community of Trojas de Cataca. In Colombia, a popular movement is a legal mechanism that is exercised to prevent damage or stop violations of collective rights. These rights include the enjoyment of a healthy environment, ecological balance, the management and rational use of natural resources, the protection of areas of ecological importance, and access to a service infrastructure that guarantees public health (Ley 472 de 1998). The main purpose of the popular movement of Trojas de Cataca is to update the regulation of water use to guarantee a healthy environment for the floating population and to recover freshwater input to the CGSM. It is an initiative that appeals to the collective level but has effects at both the operational and constitutional levels because it involves actors and proposes actions at all three levels.

This movement, initiated in 2018, requests public and private entities at the local, regional, and national levels to take certain actions aimed at stopping the threats to the riverbed and guaranteeing the collective rights of the population of Trojas de Cataca. The popular movement is considered an expression of constructing and modifying institutional arrangements, aimed at creating spaces for dialog, transforming conflicts, encouraging participation of different actors in decision-making, and developing monitoring and sanctioning strategies.

> "*If it weren't for this type of measure, nothing would happen. None of the measures of the regional environmental authority work. What works is now the follow-up that will be done for the popular movement from the national oversight entities. There has never been a judicial action of this type, and we may end up serving as a reference for the other watersheds that also deliver water to Ciénaga and find themselves in similar situations. There has never been, at least in the Department of Magdalena, a measure of protection of collective rights with respect to ecosystems in the framework of a popular movement*". Municipal representative, August 28, 2019.

However, it does not address the structural problem of the contradictory formal and informal governance systems. Since this movement is so new and due to the robustness of the dynamics of distrust and illegality, expectations about tangible outcomes of the popular movement and the potential of transforming the situation of action in the basin are unknown.

Interactions (I)

Interactions are manifested as emerging conflicts between users. In addition to the conflict among palm users and fishers (described above), there are also conflicts among palm producers associated with the distribution of water between large (more than 100 hectares) and small (less than 20 hectares) producers, which are more pronounced during the dry seasons of the year, when there is less rainfall, and dependence on irrigation becomes critical. Although, based on the water user association of the irrigation district, the criterion for water distribution is providing service to those who pay for it, small producers still feel that water is reserved for large producers, regardless of who pays or does not.

> "*In this part of the basin, we always have water, but you know how it works; the big fish eats the small fish, and the big producers always have water [...]. Large producers always have priority; they never run out of water*". Small palm producer, September 17, 2019.

Outcomes (O)

The most critical outcomes of the system are inequitable distribution of water, illegality, lack of cooperation, and reduced flow at the mouth of the river, with effects on the water and ecological dynamics of the CGSM. These results are mediated by the absence of spaces of dialog between actors, deficiencies in monitoring and sanctions, the exclusion of certain actors in the modification of institutional arrangements during the processes of decision-making, and contradictory overlapping governance systems.

These limitations reduce the possibility that the different actors share their knowledge about the resource system, the problems perceived in the basin, the points of view about existing conflicts. This hinders the learning process and the needed collective action to modify the structures of the governance system that have resulted in undesirable outcomes (Figure 4).

RESULTS OF THE ROLE-PLAYING GAME WORKSHOP

The outcomes of the RPG workshop showed specific responses of the actors in the lower basin to the changing water availability (Annex 4).

In rounds 3 and 4, institutional arrangements for water appropriation emerged regarding water distribution among participants, first dictated by the representative of the irrigation district and then by consensus. In round 4, a norm to guarantee water for the CGSM also emerged. Nevertheless, these three norms did not work as intended because illegal water harvesting still occurred and was not sanctioned, while those in the lower basin stated that they ran out of water during the drought rounds.

It is interesting to note that even when players saw that emerging institutional arrangements did not work, no new agreements or sanction strategies were discussed. This could have been related to the fact that only some players participated in the dialogue spaces and proposed strategies, while others remained passive and condescending with those who showed leadership. It is also interesting that this resembles the real-basin situation where breaking the formal rules is common and no new collective agreements were created to regulate water access.

> *"Being many people and all agree for the common good, that does not happen in real life. It does not work because there is no consciousness of water, we believe that it is an eternal resource and that we will always have it. There is also no honesty. There is also no interest in collectivity"*. Palm plantation technician in Aracataca, September 17, 2019.

Regarding monitoring and sanction, although players were aware of the actions of others and were able to identify who breached the agreements in rounds 3 and 4, the participants never designed a sanction that would promote compliance with the norms. During deliberation and decision-making moments, players socialized their individual results from each round. Public accusations were also made about the breach of agreements and demands were made for their compliance, again, without

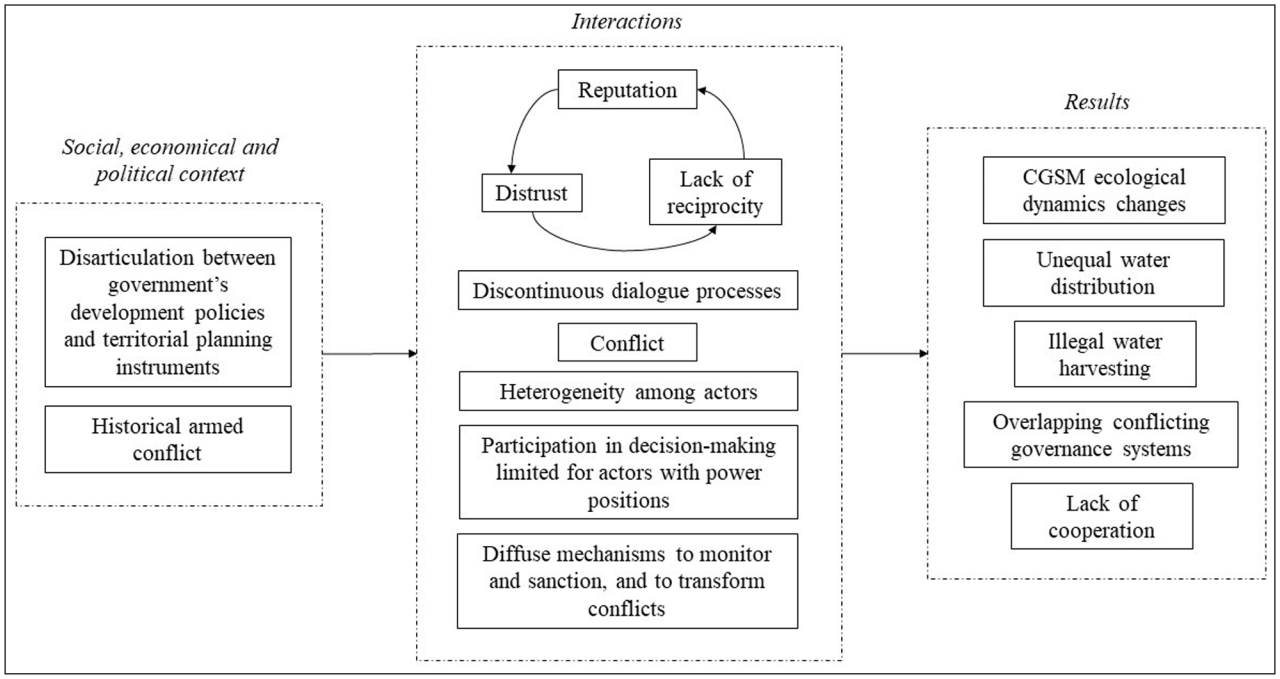

Figure 4 Interactions and outcomes of the SES.

establishing sanctions. Agreements were established to solve water allocation and to guarantee the provision of the resource in the dry rounds, but they did not reach any collective strategy to guide water management in the basin. Concrete conflicts did not emerge, other than the claim of downstream players about the scarcity of water at their water uptake point.

DISCUSSION

SCARCITY INDEX AND INSTITUTIONAL ARRANGEMENTS

Results found for the three scenarios suggest that, regardless of the variation in water supply, the main outcomes remain: inequality in water distribution, decrease in flow in Trojas de Cataca and conflicts among users. This suggests that the water issues in the basin are more complex than the numerical relationship between demand and supply. Thus, the governance system acquires relevance because the decisions made by water users and other actors are fundamental (Linton & Budds, 2014). The dynamics of the appropriation and provision of water are critical in the socioecological configurations of the system associated with the distribution of water, and in particular, its flow in the lower basin and the surroundings of the CGSM.

To ensure the necessary flow to maintain the ecological functions of the CGSM and access to water in Trojas de Cataca, it is key to solve the collective action problem and power asymmetries in the lower basin. In addressing this problem, the emphasis lies on institutional arrangements at the operational and collective choice levels among palm oil producers. From this starting point, problems of governance systems can be addressed at higher scales, such as cross-scale cooperation for the implementation of the watershed management plan.

Addressing the problem of collective action involves the design of congruent appropriation and provision rules, as well as its coherence with local conditions of the CPR, such as spatial and temporal heterogeneity of water supply, and with the heterogeneity of livelihood strategies among users (Cox et al., 2010). Also, it implies the renewal of a governance configuration that prevents the participation of less powerful actors (e.g., small palm oil producers and fishermen) in modifying operational and collective institutional arrangements (Ostrom, 1990). Material and bargaining power asymmetries must be addressed towards a multilateral decision-making model (Cascão, 2009). A renovation of the monitoring system is also relevant since the regional environmental authority has demonstrated not to be entirely efficient. Strengthening positive feedback between trust, reciprocity, and reputation among actors, is also essential to achieve and maintain collective action (Ostrom, 1998).

The level of water scarcity perceived by water users is largely associated with conflicts and a lack of coordination (Meinzen-Dick, 2007; Schlüter & Pahl-Wostl, 2007). Whether the abundance of resources (Gurung et al., 2006), moderate levels of scarcity (Torres et al., 2016), or high scarcity of resources leads to cooperation has been discussed (Bardhan, 2000; Ostrom, 2000). For the Aracataca River basin, despite the three annual water supply scenarios, the inequitable distribution of water remains, and the asymmetries of power related to decision-making are constant, so collective action has not been the main outcome.

HETEROGENEITY AND POWER ASYMMETRIES

Heterogeneity in CPR systems may take different forms and either facilitate or hinder cooperation (Baland & Platteau, 1996; Naidu, 2005; Usón et al., 2017), creating challenges for water governance. Although there is no consensus on whether how some dimensions of inequality promote collective action toward the conservation of CPRs (Baland & Platteau, 1999), in the Aracataca River heterogeneity is hindering cooperation.

Although diversity manifests itself in many ways and some specific configurations in certain contexts can shape conditions for collective action (Poteete et al., 2009), it raises the cost of negotiation in the construction of institutional arrangements and in defining desired collective outcomes (Bardhan & Dayton-Johnson, 2001). Groups with different socioeconomic and cultural attributes tend to lack trust and lack shared interpretations of reality, which contributes to processes of agreement mediated by conflict and a lack of collective action (Araral, 2009; Dayton-Johnson, 2000; Fujiie et al., 2005; Varughese & Ostrom, 2001). Also, those who have more interest in transforming the CPR problem, may have fewer opportunities to influence decision-making processes, given less infrastructure access and lower negotiation power, as in the case of fishers in Trojas de Cataca.

Differences between decision makers affect the joint understanding of a situation with respect to collective management and participation in solutions to the problems posed for CPRs, affecting which institutional arrangements the users choose, how they are maintained and whether users decide to follow the agreements or not (Bardhan & Dayton-Johnson, 2001). At the individual level, uncertainty about the preferences of others and the degree of dependence between actors can affect the incentives to contribute, and at the collective level, it can affect communication, monitoring and the reinforcement of institutional arrangements (Schlager & Blomquist, 1996). In contrast, common characteristics suggest common interests, which can increase the predictability of the interactions and actions of others, increasing trust among actors (Poteete & Ostrom, 2004).

In the context of the Aracataca River, we identified different dimensions of heterogeneity. One of them involves the verticality implied by water flow, where the differences in where the actors are located, i.e. the upper or lower basin, defines their role in the appropriation and provision of water. These differences have effects on the incentives perceived by each actor, reciprocity, trust, reputation, and collective action (Ostrom & Gardner, 1993). Verticality in water flow supposes an asymmetric relationship between actors in terms of access to water in time and quantity (Cárdenas et al., 2015). The physical and social distance between actors limits communication and any interactions that might lead to building trust and transforming conflicts (Swallow et al., 2006), representing an important challenge in governance in the basin. Specifically, in the Aracataca River's lower basin, palm oil producers can access water first and can develop water maintenance and distribution systems, such as irrigation districts managed by water user associations. Fishermen in Trojas de Cataca access the water later and receive the externalities caused upstream, affecting their well-being (Cárdenas et al., 2015).

Although spatial and technological differences asymmetries can encourage non cooperative behaviors and weaken norms, rules, and strategies for collective action (Bardhan & Dayton-Johnson, 2001), not all dimensions of diversity have deleterious effects on cooperation. It is important to ask which dimensions of diversity should be transformed and which should be sought, conserved, or reinforced to enrich the governance of water as a CPR. These attributes and desirable functions should be identified by the stakeholders themselves (Lebel et al., 2006).

Although the differences pose challenges for self-organized water management, innovation in institutional arrangements can contribute to navigating local conditions of heterogeneity (Varughese & Ostrom, 2001). Attributes of the group of actors may be less important in the success of collective water management, while the ability to adapt and learn, to redesign institutional arrangements, to establish dialog and negotiation processes, and to ensure autonomy in the redistribution of costs and benefits become more relevant. Even heterogeneous social groups may be able to devise institutional arrangements that allow them to identify shared issues for collective action (Poteete & Ostrom, 2004; Varughese & Ostrom, 2001).

Another observed dimension of heterogeneity involves the asymmetries of power in decision-making regarding water management and participation in the construction and transformation of institutional arrangements. This asymmetry of power, particularly evident in the lower basin among the most disadvantaged, i.e., fishermen of Trojas de Cataca and the small palm oil producers, affects participants' incentives, actions and, therefore, the system outcomes (Schlager & Ostrom, 1992). Actors build power dynamics through actions at the operational level. Power involves the perceived legitimacy of formal institutional arrangements and the ability to define the rules in use (Clement, 2013). Thus, some actors have more power than others in decision-making about the distribution of benefits, either because of their economic advantages and physical infrastructure or because of their negotiation skills (Zeitoun & Jägerkog, 2011). Although power asymmetries do not necessarily determine the outcome of decision-making processes, the general benefits of an action situation will be available to agents with more power (Qin et al., 2019).

In the lower basin, the asymmetries of power consist of not only infrastructural disadvantages, i.e., in contrast to palm oil producers, the fishing community has no infrastructure to collect and distribute water, but also the loss of autonomy and marginalization of this community when influencing the decision-making agenda. Their limitations of individual and collective power translate into their inability to transform rigid institutional structures (Cascão, 2009).

Given the power asymmetries and the various dimensions of heterogeneity that we identified in the Aracataca River's lower basin, it is possible to affirm that, just as water problems are not merely technocratic and related to infrastructure, the social dimension of water management not only consists of access and distribution dilemmas. Water management directly involves political and power issues, which are manifested both formally and informally (Sultana, 2018; Zwarteveen & Boelens, 2014).

The discussion on institutional arrangements and water governance must explicitly address issues of equity, participation and justice for human well-being and the maintenance of ecological processes (Perreault, 2014). The analysis of the case study considering these elements is particularly relevant insofar as the need to transform the current structure of water governance has been identified (Neal et al., 2014).

Equity is related to how benefits and burdens associated with water use are distributed (Perreault, 2014), as well as rights to participate in decision making processes (Zwarteveen & Boelens, 2014). Participation is relevant since there are actors excluded from the possibility of getting involved in the development of autonomous water management mechanisms, i.e., their own infrastructure and their own rules in use. Fishermen and small producers are not participants in decision-making to distribute benefits. As long as all the actors can participate in the design of strategies for the distribution of water, fair situations will be created in the management of the resource (Neal et al., 2014).

Justice has to do with how disadvantaged actors experience and point out unfair situations regarding

water management (Boelens, 2009). This arises when a group feels that others are not contributing their share to the maintenance of water and the infrastructure for its allocation, or are taking more than their fair share from the CPR (Patrick, 2014). In the lower basin, given the power asymmetry, injustice is manifested in the absence of recognition of the right to access water for all actors, and of the claims and needs of the most disadvantaged. A fair system would consist of guaranteeing the means to address the social dilemma implied by the distribution of water and the right to make decisions, facing different scenarios of water availability in the basin, as we have shown. The perception of fairness is also a powerful predictor of trust (Neal et al., 2014), related to cooperation (Ostrom, 1998).

Thus, water governance must include equity, participation, and justice as institutional configurations to promote collective action. It is important that all actors across scales are included, so that those with less power are included in the processes of water allocation and decision-making to solve the social dilemma (Sultana, 2018).

CONSIDERATIONS REGARDING THE METHOD

Our mixed-method approach made it possible to characterize the Aracataca River as a SES based on interactions and outcomes, emphasizing the institutional arrangements within the lower basin. While the hydrological analysis allows us to explore the conditions of the water system, the interviews were useful to identify the actors and conflicts within the basin. The RPG, on the other hand, helped us to get information on the dynamics and patterns that emerge when different resource system and governance configurations are recombined (Bousquet et al., 2002). Because RPG offer new options for obtaining information through the observation of body language, attitudes, and direct actions of the players during a session (Barnaud et al., 2007), it was possible to identify institutional arrangements and interactions among users that would not have been made explicit through other methodologies (Voinov et al., 2018).

During the debriefing (Lederman, 1992) it was possible to identify specific issues within the basin that were most important to actors, for example, the need for technical information related to the supply of water, the illegality in water collection, the lack of a collective strategies, the inequality in water distribution, the ineffectiveness of monitoring and sanctioning processes, and the difficulty of reaching a consensus. Thus, the RPG workshop offered learning opportunities for both researchers and players (Camargo et al., 2007; Rodela et al., 2019).

The game evidence potentialities and challenges to address the problem of collective action among palm oil producers and its relationship with the well-being of fishermen in Trojas de Cataca. On the one hand, the methodology allows the experimentation of different institutional configurations, functioning as a platform for the design and testing of strategies, norms, and rules of provision and appropriation. However, the construction and maintenance of institutional arrangements implies long processes of consultation, building trust to attend the sessions, continuity of spaces for dialogue, the integration of different decision makers and, above all, being immersed in a long-term process at the basin scale that implies specific commitments of users, associations, and government entities. The scope of a RPG workshop is limited when addressing power asymmetries and the strengthening of trust, reciprocity, and reputation feedback. Therefore, it is only a tool that can accompany deeper strategies to manage changes in the political dimension of water management.

CONCLUSIONS

The three annual conditions demonstrated the variation of supply in the basin, with low, moderate, and high indices, in which supply is always exceeded by demand (the index is never equal to 0). Despite the variety of scenarios, collective action has not turned out to be the main outcome of the SES. This indicates that the configuration of the governance system outweighs the availability of the CPR in the construction of collective action. For future research, the calculation of the supply on a monthly scale, as well as the interactions between users, could provide greater resolution to the analysis.

The structure of the governance system in the Aracataca River basin is largely defined by conflict, illegality and the lack of effective monitoring and sanction mechanisms, conditioning an institutional configuration that contributes to the water problem in the study area. This assumes that individuals have little incentive to cooperate and perceive little legitimacy from control entities and formal institutional arrangements affecting disproportionally the fishermen, who are not just the actors in the tail of the system but also those with lower opportunities to modify its structural conditions.

The RPG workshop is a tool that can facilitate long-term process for the design institutional arrangements in the lower basin, but it requires being part of a process of structural change in power asymmetries.

NOTE

[1] According to the Political Constitution of Colombia of 1991, departments are geographical and political-administrative units with autonomy for economic and social development within its territory. They mediate between the Nation and the Municipalities.

ADDITIONAL FILES

The additional files for this article can be found as follows:

- **Annex 1.** Research methods and SES variables (adapted from Meinzen-Dick, 2007). DOI: https://doi.org/10.5334/ijc.1167.s1
- **Annex 2.** Parameters of the hydrological analysis. DOI: https://doi.org/10.5334/ijc.1167.s2
- **Annex 3.** Variables for the collection and analysis of information derived from the role-playing game (Source: adapted from Ostrom, Gardner, & Walker, 1994; Ostrom, 1990; Agrawal, 2002). DOI: https://doi.org/10.5334/ijc.1167.s3
- **Annex 4.** Outcomes of the RPG workshop. DOI: https://doi.org/10.5334/ijc.1167.s4

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COMPETING INTERESTS

The authors have no competing interests to declare.

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