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CORRUPTION AND CONFLICTS AS BARRIERS TO ADAPTIVE GOVERNANCE: WATER GOVERNANCE IN DRYLAND SYSTEMS IN THE RIO DEL CARMEN WATERSHED

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ABSTRACT

Water governance in the Rio del Carmen watershed has failed to achieve sustainable water use, generating social conflicts, water overexploitation, and grassland loss. This leaves it unable to adapt and learn, to reconcile different stakeholder perspectives and to adequately respond to uncertainty. Adaptive water governance regulates water access through flexible, inclusive and innovative institutions, increasing system adaptive capacity in the face of uncertainty. This is necessary for water-scarce systems since they suffer context-specific exposure to land degradation and climate change. This research focuses on how water governance regulates water access in the Rio del Carmen watershed, Mexico, identifying key legal and institutional features that could increase adaptation and secure water resources in the long-term. 27 semi-structured interviews were conducted with key stakeholders in the watershed, in order to understand the water governance structure and its system dynamics.

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It was found that water mismanagement, overexploitation, and conflicts over access to water are due to the lack of application and neglect of formal rules. Results indicate that breaches of the legal framework are commonplace, permitted by corruption of both former and current government officials. Many farmers have institutionalized this corruption in order to access water; increasing social conflicts and hindering any type of planning or water management, which, in turn, continues to affect the ecological conditions of the watershed. By understanding the governance system, its structure and the interactions that weaken and bypass formal institutions to the detriment of water resources, stakeholder engagement has emerged as an entry point for enabling collaboration and acceptance of formal institutions. This process has the potential to create a formal network, as a Watershed Committee, that could be honoured in practice through the efficacy of this engagement.

Keywords Social-ecological resilience · Water scarcity · Agricultural systems · Stakeholder engagement · Mexico

1. Introduction

Drylands are expanding as a result of environmental change and mismanagement (Huang et al. 2017). Resulting droughts, desertification and degradation accentuate the emergence of often violent conflicts in these regions (IPBES 2018). Adaptive capacity in dryland systems is the ability to develop innovative solutions to face unpredictable changes or disturbances in a water-scarce context (Reed and Stringer 2015; Folke 2016). Adaptive water governance

(AWG) seeks to foster this adaptive capacity through knowledge generation, flexibility, cross-scale collaboration and subsidiarity, as basic principles that can increase system resilience (Hill Clarvis et al. 2014). A central challenge in increasing drylands' resilience is the conservation of societal benefits obtained from freshwater sources, also known as water ecosystem services (WES), as they are the basis for maintaining multiple ecosystem functions and sustaining and improving human well-being (Davies et al. 2016; Pravalie 2016). WES conservation needs proactive management of natural processes, if they are to sustain dryland livelihoods (WWAP 2018). However, in dryland systems like the Rio del Carmen watershed in Mexico, where agriculture is the predominant livelihood activity, the mismanagement of WES has resulted in social conflicts and ecological degradation (Lopez Porras et al. 2018), which generate a loss of resilience and increase vulnerability (Reed and Stringer 2015).

Analyses of water governance systems have revealed many failures in the conservation of WES, particularly because governance regimes often do not exhibit a good fit with the societal and environmental context in which they are applied (Smidt et al. 2016; Pahl-Wostl 2017). Centralised and top-down governance lack stakeholder collaboration and learning processes, and for these reasons, these approaches have been losing legitimacy (Akhmouch and Clavreul 2016). They are also viewed as unfit to respond to non-linear dynamics (Armitage et al. 2009), such as the continuous and unpredictable variations in climate, water quality or vegetation cover (Capon et al. 2015). Systems like the Rio del Carmen watershed, where informal institutions have considerably greater influence than formal institutions (Lopez Porras et al. 2018), have weak governance structures that fail to conserve WES. They cannot be restructured and improved by simple governance reforms unless the required conditions for their operability are considered and analysed (Pahl-Wostl and Knieper 2014), and stakeholder involvement is enacted (Akhmouch and Clavreul 2016).

In order to improve human well-being and increase system resilience in drylands, access to WES needs to be regulated within an inclusive and integrated water governance regime (Aylward et al. 2005). This requires a feasible legal and institutional structure with the underlying elements of learning, connectivity, collaboration, flexibility, and subsidiarity (Figure 1), where WES access can be adjusted according to the system needs in the face of uncertainty (Hill Clarvis et al. 2014; DeCaro et al. 2017). Sarker (2013) highlights how collaboration and users' autonomy to manage their resources, supported by the financial, technological and legal resources that the state can grant, increases efficiency in water governance. AWG offers one route towards these features (Cosens et al. 2018). However, as found in Australia's Murray Darling Basin, where the excessive use of water resources for agriculture led to environmental degradation and water quality problems, water reforms and their implementation is highly challenging in dryland systems that have institutional problems and conflicted interests (Alexandra 2018). More information is needed regarding the potential for restructuring dryland water governance and the implications for AWG (DeCaro et al. 2017).

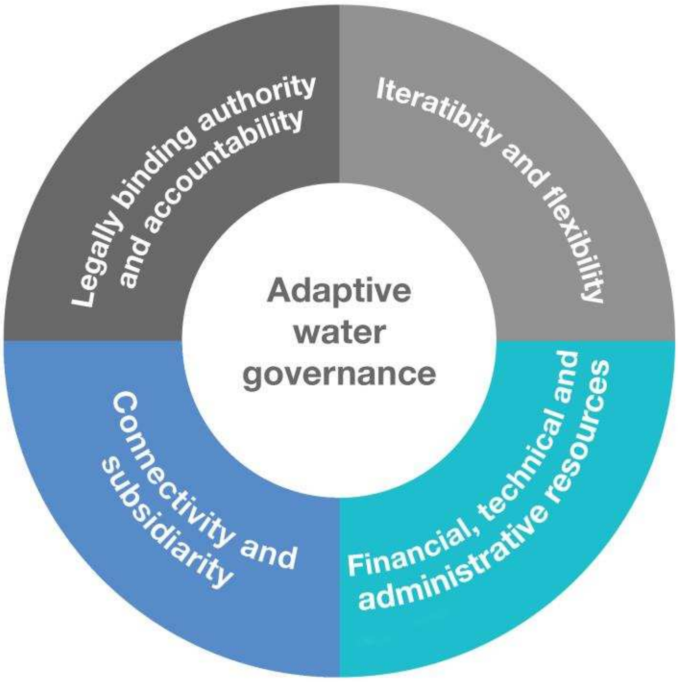

Figure 1 *Adaptive water governance conceptual framework*

This paper critically assesses and describes how water governance regulates access to WES, with the aim of identifying key legal and institutional features that could support adaptation and secure WES, using the Rio del Carmen watershed as a case study. To do this, we ask: 1) What is the legal and institutional structure of water governance in the watershed? 2) How has water governance affected water availability and WES in the watershed and for whom? and 3) What kind of conflicts and trade-offs are taking place in the watershed and how are these shaped by institutional aspects? By answering these questions, we describe 1) the main societal and institutional aspects of the system, 2) the social-ecological interplay in relation to water governance and the benefits that stakeholders obtain from WES, and 3) stakeholder interactions and their side effects. Capability for achieving adaptation can be found in system properties, like the legal, social or political potentials, though there are also barriers that hinder AWG (Cosens et al. 2018). Ways in which system adaptive capacity can be enhanced can be revealed through a social-ecological system (SES) assessment. We highlight the main issues that undermine adaptive capacity of water governance in dryland systems, and identify entry points within the social and legal structure that could help to restructure the system's governance in order to "reduce or even break resilience of the current system to enable shifts away from the current pathway(s) into new ones" (Folke, 2016, p. 4).

2. Study area and methodology

2.1 The Rio del Carmen watershed

The Rio del Carmen watershed (Figure 2) is located in the driest area of the Chihuahuan desert, in Chihuahua, Mexico (Quintana 2013). Its vegetation, average rainfall, and climate conditions (Figure 3) are representative of many dryland systems (Safriel et al. 2005). It is composed of 3 main aquifers: Santa Clara (upstream), Flores-Magon – Villa Ahumada and Laguna de Patos (both downstream). More than 90% of water from these aquifers is used for agricultural purposes (CONAGUA 2015a), producing mainly chilli, pecans, cotton, alfalfa, sorghum, and maize (Lopez Porras et al. 2018). However, the three aquifers are considered to be overexploited (DOF 2018). The most important river is the River Carmen, whose waters are retained in the Las Lajas dam with a capacity of 91.01 million m^3 (INEGI 2003).

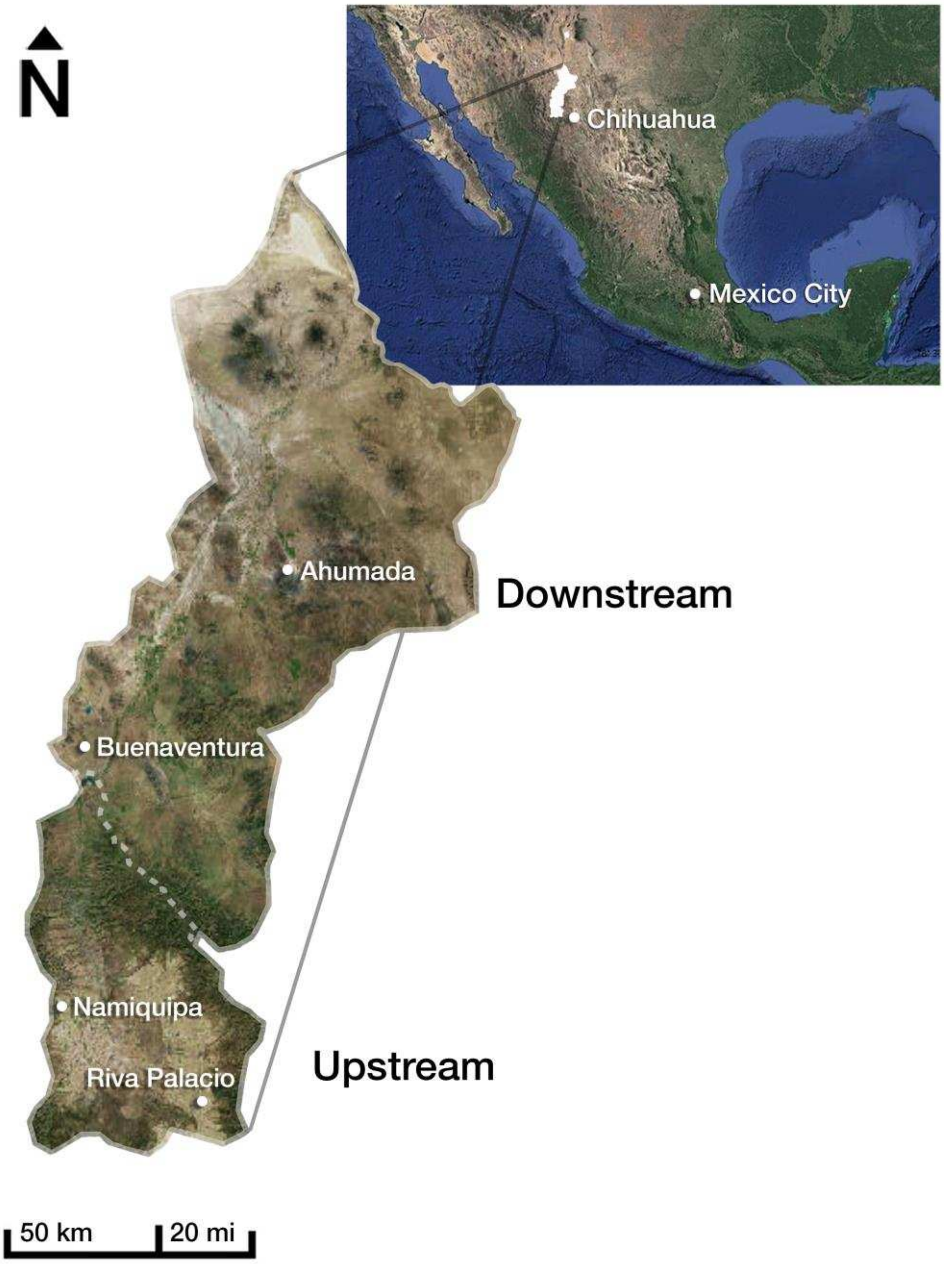

Figure 2 *Location and upstream and downstream divisions in the Rio del Carmen watershed. Images obtained from INEGI, (2016).*

Cultural diversity in the Rio del Carmen watershed is marked by the coexistence of two different agricultural communities: The Mennonite community settled upstream and Mexican farmers settled downstream (Lopez Porras et al. 2018). Each group has its own unique agricultural production model: Mennonite farming techniques are more intensive and technology based, while Mexican farmers use more traditional techniques that rely on significant labour inputs (Manzanares Rivera 2016). In the 1950s, downstream areas saw substantial agricultural growth, so a presidential decree was issued in 1957 ordering the creation of the Irrigation District El Carmen 089 along with the necessary hydraulic infrastructure (Las Lajas dam), in order to support and control agriculture in the area, and avoid water overexploitation (DOF 1957). Many of the Mexican farmers downstream are organized through this Irrigation District. The same presidential decree also established an undefined period of restricted-access for new water exploitations in the whole Rio del Carmen watershed, to avoid lowering the watershed´s water cycle and affect the water availability needed for the Irrigation District agriculture (DOF 1957). This means that new applications for water rights in the watershed will only be issued if studies determine that there is water available (LAN 2016).

Given the increasing depletion of ground water, numerous conflicts over water access have arisen between the groups (Quintana 2013), a situation that has been reported by the international press (Burnett 2015). To date, this situation has not been resolved, in part due to the cultural differences and differing perceptions over WES between Mennonites and Mexican farmers (Lopez Porras et al. 2018). As a result, the Rio del Carmen watershed social-ecological context presents some interesting challenges from the point of view of water governance in dryland systems.

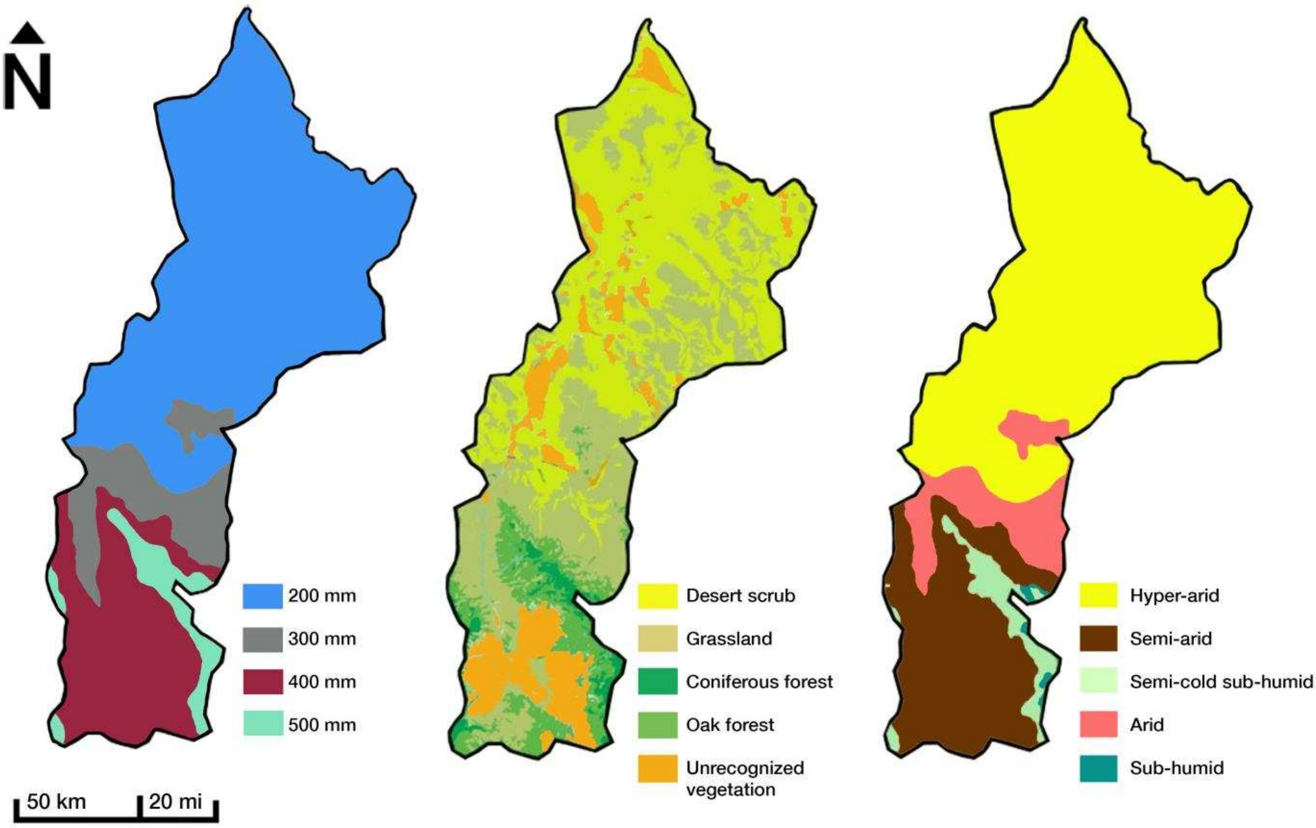

Figure 3 *Precipitation, vegetation cover and climate conditions in the Rio del Carmen watershed. Maps modified from information obtained from* INEGI (2016)*.*

2.2 Research design and methods

In order to assess the governance system, which integrates the political, legal, economic and social features of governance (Pahl-Wostl 2017), we first used stakeholder analysis to identify the key types of stakeholder that play a dominant role in the water governance of the Rio del Carmen watershed (see Reed et al. 2009; Lopez Porras et al. 2018). The stakeholder categories, based on the literature and verified in the field, consisted of farmers, government officials, consultants/industry, NGOs and academics.

2.2.1 Sampling

A combination of snowball (Reed et al. 2009) and purposeful sampling (Patton 1999) approaches was then used, asking interviewees to identify and nominate other stakeholders that would provide significant information regarding water governance in the Rio del Carmen watershed. The snowball sample had multiple starting points, beginning with an interview in each stakeholder category in order to avoid a biased sample (Sulaiman-Hill and Thompson 2011; Seale 2012). In qualitative research, sample size and participant selection do not require representativeness or statistical significance to legitimize the findings (Luna-Reyes and Andersen 2003; Reed et al. 2009). Instead, to obtain in-depth qualitative data, the purposeful sample allowed us to better understand the governance system in the Rio del Carmen watershed, by obtaining in-depth insights from relevant stakeholders rather than generating generalized data from a population subset (Patton 1999). The stakeholder nominations resulted in a sample of 27 interviews with representatives of the main sectors related to water access and agriculture in the watershed (Table 1), consisting of 14 farmers, 7 government officials, 4 consultants, 1 NGO and 1 academic.

Table 1 Description of the organisations and sector representation from each stakeholder category.

Stakeholder Category	Farmers	Government officials	Consultants	NGO	Academic
Sector representatives	Mennonite community	National Water Commission	Agricultural management	World Wide Fund for Nature	Faculty of Zootechnics and Ecology of the Autonomous University of Chihuahua
	Mexican farmers	Secretariat of Environment and Natural Resources	Legal advice		

		Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food	Agricultural products and trade		
		State Coordination of Civil Protection			

2.2.2 Data collection

Data was collected with the ethical approval AREA 16-148 granted by the Research Ethics Committee at the University of Leeds. To obtain the qualitative data needed to understand the governance system from all stakeholder perspectives, the semi-structured interview method was selected, given its suitability for producing this in-depth information (Reed et al. 2009), by uncovering “the complexity of real-world systems through detailed stories and descriptions” (Luna-Reyes and Andersen, 2003, p. 286). Based on the results obtained from Lopez Porras et al. (2018) and the first author’s prior experience in the region, an interview protocol was designed (Appendix). Semi-structured interviews were then conducted in Spanish by the lead author from February to April 2018, in the municipalities of Ahumada, Buenaventura, Chihuahua, Namiquipa and Riva Palacio, in the state of Chihuahua, Mexico, since the identified stakeholders were located in these municipalities. Given the conflict context in the watershed, neutrality and non-bias were necessary to conduct the interviews and have access to all stakeholders (Luna-Reyes and Andersen 2003). This non-biased question wording and approach can be found as an Appendix (Bhattacherjee 2012).

2.2.3 Analysis

Interviews were recorded in Spanish. In May 2018 they were transcribed, at which point they were translated into English and anonymised. Prior to the interview, a consent form was signed by each stakeholder indicating that they understood the nature of the research, what the data would be used for, and how anonymity would be maintained.

Transcripts were analysed using NVivo 11 for Windows using the content analysis method (Bernard 2011) based on a deductive coding technique (Luna-Reyes and Andersen 2003), where coding categories where determined on the basis of the adaptive governance literature (Cosens et al. 2018). The resulting codes were: agriculture, economic and social drivers, environmental change, institutional and structural features, water management, WES access, trade-offs, conflicts, entry points for adaptation, and legal compliance. During the process, indicative stakeholder quotes were structured in a matrix of codes (Figure 4) in order to test the accuracy of the coding process. Secondary data on aspects including water availability, legal provisions such as the restricted-access decree, and pecan production in the watershed, were obtained from the Federal Government of Mexico's websites: https://www.gob.mx/conagua; www.dof.gob.mx; http://www.diputados.gob.mx/LeyesBiblio/; http://gaia.inegi.org.mx/; and https://datos.gob.mx/. Secondary data was analysed using the same coding criteria as the interviews in order to facilitate data validation (Patton 1999). The data obtained from the semi-structured interviews and the secondary data were compared, and triangulated with other sources related to water governance in the Rio del Carmen watershed, such as Athie, (2016); Burnett, (2015); Manzanares Rivera, (2016); and Quintana, (2013). By doing this, we avoided the weakness associated with the use of a single data collection method (Patton 1999). This also helped to validate and verify the results, by corroborating the consistencies of the data and identifying where the differences were (Chi 1997). The explanation of the governance system started from the integration of the coding matrix using the system narrative method (Luna-Reyes and Andersen 2003). This qualitative method “allows for causal analysis and exploration of the interplay of complex system components” (Rissman and Gillon, 2017, p. 90). For contradictions during the cross-data validity checks, a complementary approach was used since differences did not necessarily refute each other, so they were analysed in context and were included to demonstrate the perception of each interviewee (May 2010).

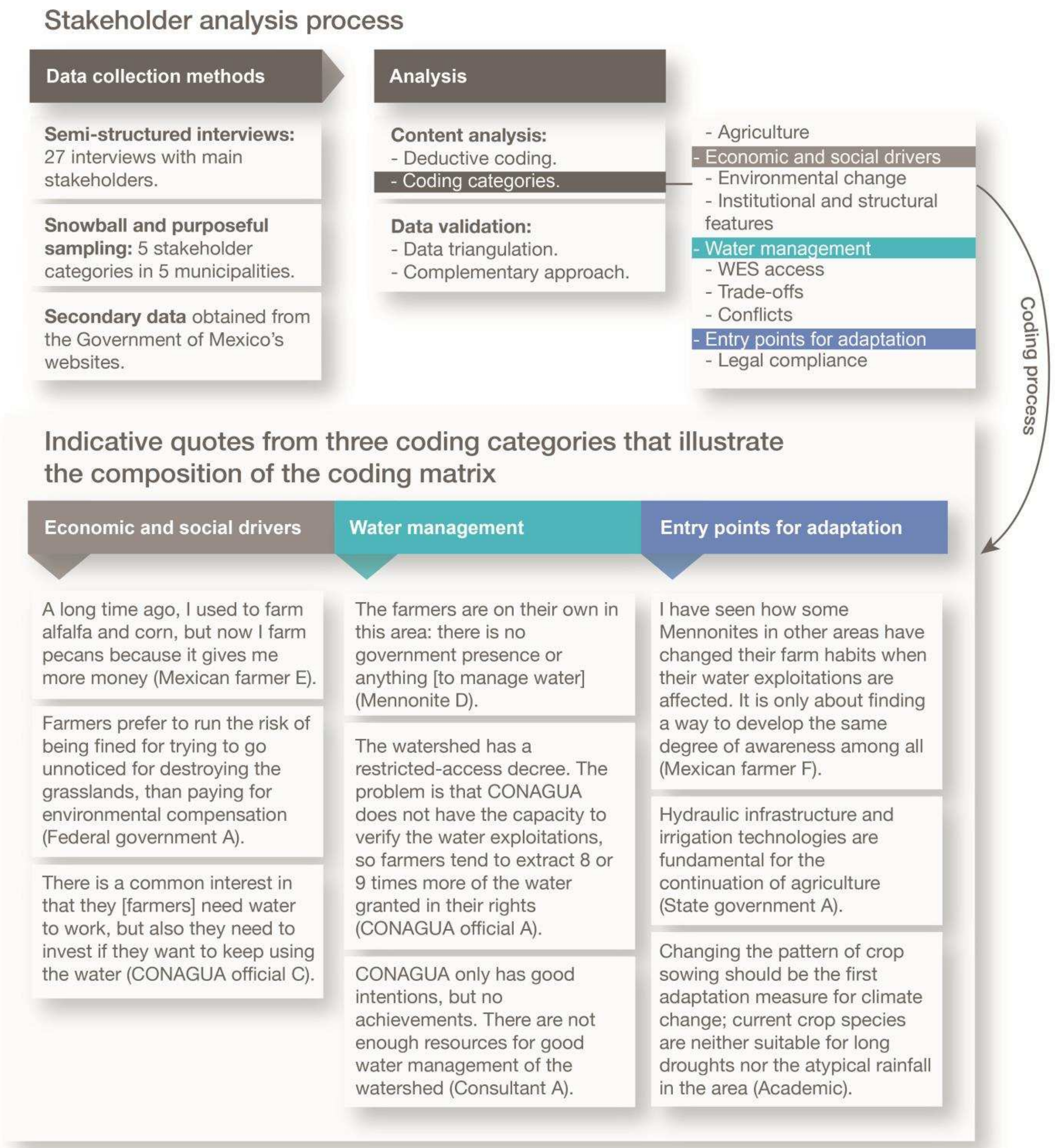

Figure 4 *Stakeholder analysis process and coding process with three indicative quotes from three coding categories that illustrate the composition of the coding matrix.*

3. Results

3.1 What are the legal, economic, political and social features of the water governance system in the watershed?

3.1.1 Legal and institutional structure

Article 27 of the Political Constitution of Mexico establishes that the State is the original owner of water resources located within national territory, and the use or exploitation of water can only be made through concessions granted by the federal government. In this sense, the National Water Law establishes a water-rights system to grant concessions for water exploitation, and designates the National Water Commission (CONAGUA) as the government agency responsible for the national water management. CONAGUA's framework of action is regulated by 3 legal instruments: the National Water Law published in the Federal Official Gazette on 1st December 1992, the Regulation of the National Water Law published in the same Gazette on 12nd January 1994, and the Interior Regulation of the National Water Commission published in the Gazette on 30th November 2006. Accordingly, CONAGUA's structure encompasses 3 governance levels: National, Regional Hydrological-Administrative, and State level. The administrative units that relate to Rio del Carmen watershed governance are the River Basin Councils, the Chihuahua Local Directorate, and the Irrigation District El Carmen 089.

River Basin Councils are mixed and collegiate organizations that hold supportive, consultative and advisory roles between CONAGUA, other government agencies, and society, being the space for public participation in water decision-making (CONAGUA 2016). The Rio del Carmen watershed is located within the Rio Bravo River Basin Council, which covers 358,870 km^2 distributed across five States, and has thirteen different types of climate according to the Köppen climatic classification (CONAGUA 2013). The Rio Bravo River Basin Council is located in the state of Nuevo Leon, more than 800 kilometres from the Chihuahua Local Directorate (Google 2018). "*It is a regional participation space formed by civil society and the government. It has representatives from all sectors of the state of Chihuahua, such as agriculture, livestock, and industry, even has a representative of the Governor of Chihuahua*" (CONAGUA official C). However, when asked if they had participated in council processes, or if the farmers from the Rio del Carmen watershed had representation on that council, CONAGUA officials said no, they had not been invited. Both Mexican farmers and Mennonites did not know what the Rio Bravo River Basin Council was, expressing it with statements such as "*I do not know it, rather we are organized through an irrigation district, that's where we participate*" (Mexican farmer D), or "*I have never participated or been invited to any CONAGUA meeting*" (Mennonite B). None of the farmers nor CONAGUA officials interviewed had been invited to or had participated in a council process.

At State level is the Chihuahua Local Directorate. The Directorates are the local organisations representative of CONAGUA´s water management throughout the Mexican states, applying for its policies, strategies, programs, and actions (CONAGUA official C, interview transcript). Regarding water management in the watershed, "*CONAGUA has been trying to address the farmers' claims and has been monitoring the piezometric level of the watershed*" (CONAGUA official B). Nonetheless, interviewees noted that the Local Directorate lacks human and economic resources in its management. For example, "*The technical data for water resources is not obtained according to the procedures that the law dictates. There are only 5 or 6 inspectors in Chihuahua State and they never go to the Rio del*

Carmen watershed to verify and measure water access” (Consultant D). The National Water Law establishes that restricted access areas like the Rio del Carmen watershed should have a comprehensive watershed management program and participatory processes for designing and implementing Mexican Official Standards that regulate water access. Also, this law envisages the creation of organizations such as Watershed Committees or Technical Committees of Underground Water, among other formal institutions, for enabling participative water management according to the specific water-system needs. The Local Directorate is the starting point for these processes. However, “*the Local Directorate has not designed any watershed management programme; its bad reputation has caused it to lose acceptance in the watershed and therefore it has had less presence in the area*” (CONAGUA official A). Likewise, “*there are always isolated requests to increase the watershed's regulation: these are people* [farmers] *worried about their work, but nothing has been done*” (CONAGUA official C).

The only CONAGUA organizational unit where there is farmer participation is the Irrigation District El Carmen 089, “*which is formed by several civil associations that are called irrigation modules, and a water district chief designated by CONAGUA*” (Mexican farmer D). According to the National Water Law, irrigation districts must have the hydraulic infrastructure, surface water, and groundwater necessary for their activities. Therefore, the Irrigation District El Carmen 089 “*is supplied from the Las Lajas dam and the Flores-Magon – Villa Ahumada aquifer, through common water rights granted to the district during its creation*” (CONAGUA official A). However, participation and the decisions taken in the Irrigation District El Carmen 089 only cover the area under its management, so in this institutional structure, there is no space for collaboration at watershed scale. This means that despite the water cycle occurring at the watershed scale, the current water governance system does not have any collaboration or decision-making process that can increase SES adaptation at this scale.

3.1.2 Societal complexity in the governance system

Governance problems in the Rio del Carmen watershed have their roots in the social complexity of the area following the establishment of early Mennonite settlements. The Mennonite community initially arrived in the Laguna de Bustillos watershed around 1930, but when the community started to grow "*a group of consultants in coordination with a credit union of Mennonite farmers, with great lines of credit with many banks, started to buy the upstream grasslands, dividing them into smaller plots, and selling them with irrigation systems*" (CONAGUA official A). In this process, "*CONAGUA officials at that time were advising this group of developers, selling them some water rights so that they could be divided into different plots, telling them that they could use more water than allowed and nothing would happen*" (Mexican farmer D). "*This offered an incentive to settle in the watershed, but CONAGUA lied, many of the rights were false*" (Mennonite A). And now, "*former CONAGUA officials are advising Mennonite farmers with all their acquired knowledge of how to break the law*" (Mexican farmer D), by "*lodging requests for defence in courts, and delaying the trials so that the Mennonites can continue extracting water without water rights*" (CONAGUA official A).

Around 2010 the Mexican farmers became involved in violent conflicts against the Mennonites, arguing that the upstream illegal water use was affecting their exploitations and increasing water depletion (CONAGUA official C, interview transcript). Afterward, due to CONAGUA's mismanagement and its inability to resolve the dispute, the Mexican farmers started to work in an inter-institutional way with several government officials to solve the illegality that was taking place in the watershed (Mexican farmer D, interview transcript). However, the situation is difficult because "*downstream farmers ask for the removal of all illegal exploitations, with zero openness and flexibility to negotiate, but unfortunately, nothing can be done until Mennonite litigations are solved by the courts*" (CONAGUA official A). By 2015 the violence had receded, because *"the rain has been filling Las Lajas dam and that has them* [Mexican farmers] *calm*" (Mennonite D). However, in late 2017 the Mexican farmers "*received proof of 395 apocryphal water rights that the former CONAGUA Chihuahua Director sold to his family and to upstream Mennonites*" (Mexican farmer D), which exacerbated tensions, generating new violent clashes, and highlighting the fragility of the social relations in the system (Consultant D, interview transcript).

3.2 How has water governance affected water availability and WES in the watershed and for whom?

3.2.1 Agriculture and WES access

Besides CONAGUA's mismanagement, there are three core issues that have been shaping agricultural practices in the watershed, and thus WES access: i) environmental change, ii) crop choices and iii) lack of irrigation technologies. "*In Chihuahua the rainfall is torrential, we have had 100 mm of rain in less than an hour which causes great soil loss and no infiltration for aquifer recharge. However, this helps to maintain the Lajas dam full to its* *maximum capacity*" (State government A). Irregular rainfall has caused some farmers to build retention ditches as an adaptive strategy, while others combine rain-fed irrigation with water wells. However, due to underground water depletion, it seems that "*hydraulic infrastructure and irrigation technologies are fundamental for agriculture continuity*" (State government A).

Farmers have selected "*highly water-demanding crops that have a close relationship with water overexploitation*" (CONAGUA official B). "*A big problem is that these crops fight against nature, they are not suitable for the watershed, and the reason is the short-term profitability of the crops*" (Consultant C). Pecan planting has been increasing downstream because its market price is very high, even though the crop needs a huge amount of water. In the agricultural cycle 2013-2014 the Irrigation District El Carmen 089 had 3,156 hectares of pecan (CONAGUA 2015b). According to Sifuentes et al., (2015), in Mexico around 14,000 million m^3 y^{-1} of water is used to irrigate one hectare of pecan trees, which is more than double the 7550 million m^3 y^{-1} of water per hectare that maize needs (Collet 2004). Hence, in that single year, the Irrigation District used approximately 44,184,000 million m^3 of water only for pecan production. Notwithstanding, the Irrigation District has the infrastructure and the water rights which should sustain that agricultural production, but depletion levels and the decrease in surface water are restricting water access. Furthermore, surface irrigation is commonly used downstream, which is unsuitable for the sustainability of agriculture in the watershed, as it represents a significant source of water loss and leads to soil erosion, as a CONAGUA official stated:

> "*Currently many downstream pecans are young, and even with a glass of water I can go and water them, but when they begin to produce, it will be impossible to water them with these depletion levels and irrigation methods*" (CONAGUA official A).

Upstream is a different situation, as the main crop is maize and Mennonite agriculture uses sprinkler irrigation (Mennonite A, interview transcript). However, optimization of agriculture through irrigation technologies has been an incentive to increase the agricultural frontier and irrigate more, since the Mennonite irrigation technologies are for large-scale agriculture, so they have been changing the upstream grasslands to croplands. "*They* [Mennonites] *do not sow in 5 or 10 hectares as Mexicans, they sow in 100 or 200 hectares*" (Mexican farmer G). Regarding the irrigation, "*They* [Mennonites] *say that if you water little the plant produces little, but if you water the plant a lot it produces a lot*" (Mexican farmer F). This increases the pressure on WES. Besides that, the lack of information regarding all the upstream crops that are being irrigated by the Mennonites without water rights, does not allow for any comprehensive agricultural planning (CONAGUA official A, interview transcript). As stated by almost all interviewees, regulation is necessary, where "*strategies for saving water and not oversupplying the market can be implemented*" (Mexican farmer D). Moreover, this regulation needs to establish what type of irrigation technology should be used for each type of crop, clearly define the agricultural frontier in order to protect the grasslands, and set crop restrictions (Consultant C, interview transcript).

3.2.2 Social and ecological impacts

Water availability is defined by the volume that can be extracted without affecting the water and ecosystem balance (CONAGUA 2015a), so from this perspective, ecological thresholds in water-based SES are crossed through water depletion. Underground water is getting towards that point as it is alarmingly overexploited (Figure 5). "*In the last 4 years the water levels in the aquifer have been decreasing. We have had to deepen the wells which is very expensive, but also we are already drawing very deep water*" (Mexican farmer G). The watershed has surface water availability (Figure 5), nonetheless, the construction of illegal dams upstream is causing serious alterations to the water balance. "*30 years ago, we had surface water flow of 100 million* m^3y^{-1}*, and in 2012 we discovered that the surface water flow had dropped to 66 million* m^3y^{-1}" (CONAGUA official A). Given illegal water access (Figure 5), there are no reliable data regarding water access and its availability. Again, this is an important barrier to any agricultural planning in the watershed.

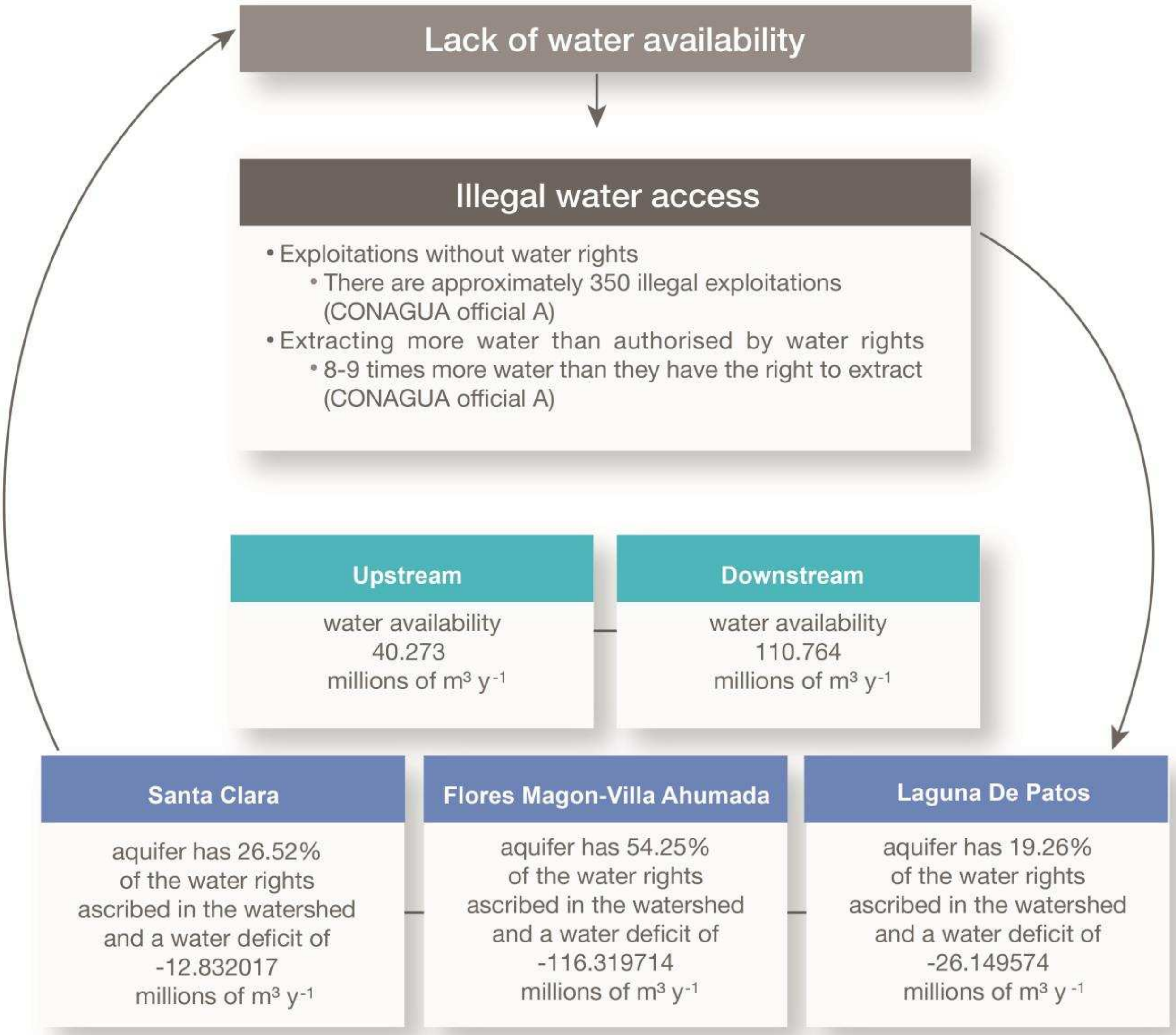

Figure 5 *Socio-ecological water interactions in the Rio del Carmen watershed. Data obtained from DOF, (2016), DOF, (2018) and CONAGUA official A.*

WES, such as provisioning water for irrigation, regulating and supporting services linked to water infiltration, as well as soil and vegetation conservation, are in decline. "*Upstream, there are approximately 50,000 ha that have been transformed to agricultural use in the last 15 years, without any authorization*" (CONAGUA official A). The ecological disturbances that this generates are largely affecting downstream farmers, particularly because "*the water that fills the Las Lajas dam, from where the Mexican farmers are supplied, is produced upstream where the Mennonites live*" (CONAGUA official A). This is why Mexican farmers are the more interested group when it comes to addressing water overexploitation, addressing grassland loss, and arranging inter-institutional working groups. They have submitted proposals, for example, to "*create a trust fund for climate change adaptation through the conservation of grasslands and WES, by taxing 1% of agricultural production*" (Mexican farmer D); however, to date, they have not achieved any outcome.

Crop choice also causes impacts on WES availability. For instance, the ecological conditions of the watershed cannot support large pecan plantations. "*If someone sows pecans, it should be mandatory to use a drip irrigation system*" (Consultant C), as all pecan investments that farmers have made in the watershed can be lost if current agricultural practices continue to increase the depletion levels, "*It is possible that in the future I will have to cut all my pecan trees, because many pecans are being planted and there will be no water to irrigate them*" (Mexican farmer A). On the whole, it can be observed that water governance in the Rio del Carmen watershed does not regulate water access in relation to availability as established by CONAGUA; on the contrary, water is accessed according to the number and types of crops that farmers wish to harvest, with individual decisions being made without any planning at watershed scale (Consultant A, interview transcript).

3.3 What kind of conflicts and trade-offs are taking place in the watershed and how are these shaped by institutional aspects?

3.3.1 Corruption and conflicts as barriers

Several statements assert that corruption within CONAGUA is the culprit of illegal water access:

> "*CONAGUA has created a black market for water rights, and the worst thing is that despite being the only way to get them, many are false and they ask for money so they can continue exploiting water illegally*" (Mexican farmer A).

> *"When we go for help, they* [CONAGUA] *tell us that our water right is false, they charge us money to regularize our exploitations and then it turns out that what they sold us is also false, and still, they extort us by asking for money so as not to remove our exploitations"* (Mennonite A).

However, CONAGUA officials said that they have been trying to solve the problem of illegal exploitation:

> "*Between the years 2013-2014 CONAGUA, the federal police, and other agencies tried to destroy the illegal dams that are located upstream, but we could not continue since the Mennonites started to lodge requests for defence in the courts*" (CONAGUA official A).

Some Mennonites recognise this situation stating that, "s*ome water exploitations are illegal because CONAGUA has been selling fake property rights*" (Mennonite A), and that is the reason why Mennonites started to lodge requests for defence in the courts. Nonetheless, some Mexican farmers see this situation as untenable, stating that, "*they* [Mennonites] *do not mind getting into corruption and paying for false water rights whenever necessary; they* *do not care if that is affecting us and our families*" (Mexican farmer E). The concern is that the exploitation of false water rights are taking place outside CONAGUA's control and jurisdiction, because when "*the judges grant the requests of the defence, CONAGUA cannot interfere, until years after when the litigations are finished and the watershed depleted*" (Mexican farmer D).

Many farmers referred to this corruption, which has conceded the illegal water access, as the source of social conflicts. "*The grounds of the dispute are that the authorities do not enforce the rule of law, CONAGUA does not make farmers respect the law, so Mexican farmers do it their way*" (Mexican farmer C). Furthermore, "*with the recent conflicts caused by corruption of the former director of CONAGUA, the government does not want to get involved, it is very dangerous*" (Mexican farmer G). Although these conflicts have resulted in the destruction of some dams that Mennonites used for irrigation (Mennonite D, interview transcript), "*the peaceful way of being of the Mennonites has not fed the animosity*" (CONAGUA official A), rather, it is fuelled by their illegal water access. From CONAGUA's viewpoint, "*conflicts between farmers are an economic issue: everybody's interest is to have enough water to irrigate, but due to the water shortage in the watershed, we cannot generate an agreement with which all the parties agree*" (CONAGUA official C). Nevertheless, according to other stakeholders, the problem is more complex than only conflicting interests between the farmers, it is also because, "*a system based on corruption has been established over water access in which some CONAGUA officials and many farmers are working, and they will not easily allow this to change because that is what generates them money*" (Consultant D).

3.3.2 Side effects of social conflicts

"*The conflicts in the watershed have caused a distancing between CONAGUA and the farmers*" (CONAGUA official A). CONAGUA's attention to the watershed needs has been almost nil, "*they never give an answer, you cannot communicate with them*" (Mexican farmer C), "*when we ask CONAGUA for help they never come, they do not do anything*" (Mennonite C). WES loss and fragmentation of the social fabric are not the only outcomes that corruption has produced: "*The lack of both agricultural planning and water management, make the farmers compete locally, instead of collaborating to be productively competitive at greater scales*" (Consultant A). In other areas of the State of Chihuahua there have been "*several commercial alliances between Mexicans farmers and Mennonites, however, the social context in the Rio del Carmen watershed makes collaboration almost impossible*" (Mexican farmer F).

In this regard, a Mexican farmer said that one strategy to mitigate corruption is "*through collaboration with the farmers to verify that all the water exploitations comply with the law*" (Mexican farmer E). This coincides with a CONAGUA official's statement:

> *Farmers must contribute with human resources in order to verify and regularize the rule of law in the watershed. For instance, there is another area in Mexico where a Committee composed of water right holders is the one that authorizes and verifies the exploitations, and the government participates only to support and strengthen that organization* (CONAGUA official A).

Despite these attempts and proposals from some Mexican farmers to improve the management of the Rio del Carmen watershed, coordination with CONAGUA has not been achieved. "*The problem is that the stakeholders with more influence* [CONAGUA officials] *and more economic resources* [Mennonite farmers] *are benefited by the status quo*" (Consultant D). This power asymmetry strengthens unsuitable institutional conditions and incentivises corruption, given the niche of impunity that is created, as a Mexican farmer stated:

> *The fear of being sanctioned or imprisoned is the main reason for legal compliance because freedom is a priority for every human being. The high level of corruption in the watershed derives from this lack of fear, since corruption has no consequences either for the farmers or CONAGUA officials* (Mexican farmer D).

Some farmers stated that "*the solution is to restructure CONAGUA*" (Mennonite A). Another proposed solution consisted of "*finding a way to develop the same degree of awareness among all groups* [farmers and CONAGUA] (Mexican farmer F). Nonetheless:

> "The common long-term objective must be water conservation for future generations, so each one must contribute to achieving a responsible water access" (CONAGUA official B).

4. Discussion

4.1 Conceptual framework and current water governance in the Rio del Carmen watershed

Knowing the complexities regarding the legal, economic, political and social features of the water governance system, the conflicts that are taking place, and the impacts over WES as highlighted in this study, is requisite for identifying entry points that could be used to restructure the governance regime, such that it better supports AWG in dryland systems.

According to the legal and institutional design principles of adaptive governance (DeCaro et al. 2017), and the adaptive governance principles for incorporating uncertainty into legislation and policy design (Hill Clarvis et al. 2014), AWG in the Rio del Carmen needs to:

- Be iterative and flexible in order to adjust water governance in the face of uncertainty. These uncertainties include precipitation variability and unanticipated changes in land coverage (Sietz et al. 2017).
- Give legally binding authority and accountability to stakeholders, to allow locally appropriate decision-making and encourage collaboration.
- Have financial, technical and administrative powers to self-govern WES in the watershed.
- Embrace connectivity and subsidiarity, so that different centres of activity can concur at the watershed scale, with local standards and policies.

In light of this, it is clear that the administrative river basin scale established by the National Water Law does not fit with the required elements for AWG, or with the social and ecological needs in the watershed. River Basin Councils are failed water organizations without representativeness (OECD 2013). The distance to and the lack of participation of the Rio del Carmen stakeholders in the Rio Bravo River Basin Council, is a barrier to the connectivity and subsidiarity that AWG requires. Governance problems are often different between local watershed scale and the wider river basin system (Cosens et al. 2014). This has been found to be the case elsewhere, such as in the Murray Darling Basin in Australia, where the large-basin scale and institutional complexity create bureaucratic obstacles that have undermined water governance and the implementation of water reforms (Alexandra

2018). Indeed, bureaucracy and institutional inefficiency is a problem that increases CONAGUA's corruption (Athie 2016). In this regard, despite the attempt to decentralize water governance through the creation of these councils, CONAGUA is still a centralised and top-down agency with no political stability, and no control over corruption (Murillo-Licea and Soares-Moraes 2013). Decentralization as an attempt to increase the effectiveness of water governance does not solve corruption, and any governance reform in this sense can be prejudicial to the SES (Pahl-Wostl and Knieper 2014).

Inefficient water governance regimes derive from inefficient formal institutions (Pahl-Wostl and Knieper 2014); and corruption is both a driver and an outcome of this situation, leading to negligent, colluded, and incapable water management (Quintana 2013). The main stakeholders, as water rights holders, do not have the legal authority to formally address corruption in water management nor deal with environmental dilemmas, nonetheless, they are those that are affected the most. In this sense, water governance has been reduced to farmers' will to comply with formal rules without an authority that safeguards the law, and since many lack this will, evidenced by illegal water use, it allows disaffection and disagreements between stakeholders to grow. Dryland adaptive capacity shrinks with social conflicts and WES loss (Mortimore et al. 2009; Middleton et al. 2011), but also lack of coordination is related to low system adaptive capacity (Pahl-Wostl and Knieper 2014). Conflicts over water access and water depletion are not only undermining the watershed adaptive capacity, but also creating unmanaged agricultural development.

4.2 Agriculture in a dryland context

Crop expansion and unsuitable agriculture are direct drivers of land degradation and water depletion (Marston et al. 2015; IPBES 2018). Improving dryland agriculture is of paramount importance, since desertification, an extreme form of drylands degradation (Reed and Stringer 2015), already affects around 70% of the world's agricultural drylands (Winslow et al. 2004). In this regard, desertification is a potential problem in the Rio del Carmen watershed, since the Chihuahuan Desert has been suffering from grassland loss and soil degradation (PMARP 2012; Caracciolo et al. 2016). However, the crops that are being sown in the watershed are unsuitable given its precipitation and climate conditions (Figure 3), and water overexploitation (Quintana 2013). As in the Limarí Basin in Chile, the absence of agricultural planning in dryland watersheds increases water scarcity and thus conflicts over water access, creating the self-produced problem of agricultural drought (Urquiza and Billi 2018). In the Rio del Carmen watershed depletion levels are increasing and water flow decreasing. Surface irrigation is not suitable in a water-scarce context (Becerra et al. 2006), and there are better technologies than sprinkler irrigation for maize, like subsurface drip irrigation (Olague et al. 2006). Accordingly, proactive WES-based governance is key to avoid watershed degradation, and to address the global challenges of climate change adaptation and contemporary water management problems (WWAP 2018). A governance system that adjusts agricultural production and crop selection according to the dryland context is needed in order to avoid desertification and support the restoration of degraded soil (IPBES 2018). This has been done elsewhere in Mexico, such as in the Nazas watershed in the north. This demonstrates that it is possible to establish water assets for agricultural planning in drylands, as long as there is an organized network at the necessary scale, with reliable data on water access, crop species, and land that is being sown (Sanchez Cohen et al. 2018). However, the Rio del Carmen does not yet have these aspects in place. Current governance problems will not change if current conflicts and corruption continue to permeate the social setting, because collaboration will be not achieved.

4.3 Entry points and barriers for AWG

An entry point for enabling collaboration, and thus addressing corruption, conflicts, and WES loss, is the inception of a process by which the stakeholders in the watershed get engaged and involved in the decision-making and management of water resources (Akhmouch and Clavreul 2016). This stakeholder engagement increases social awareness and acceptability of trade-offs when moving towards adaptation, while reducing conflicts over water access (Akhmouch and Clavreul 2016). Decisions taken within a network that engages a broad range of stakeholders from CONAGUA, the Mennonite community, and the Mexican farmers in the water management, will be more likely to be honoured in practice (Akhmouch and Clavreul 2016). This collaboration and acceptance will also open the door to formally establishing AWG in the Rio del Carmen watershed. Evidence from elsewhere with similarly conflicting stakeholders, such as the Southern Ocean case study, where the formalization of an informal collaborative network enabled the emergence of adaptive governance that addressed the fisheries crisis (Österblom and Folke 2013), indicates this is a potentially feasible proposition. Nonetheless, governance reforms should be based on research that considers societal and institutional features as system drivers, providing suggestions of what needs to be done differently, and with the inclusion of local knowledge (Wiek and Larson 2012; Anthonj et al. 2019). Based on our results, we have identified the creation of the Rio del Carmen Watershed Committee as an entry point that will formally restructure system governance towards AWG. Characteristics of this are as follows:

- Watershed Committees are a collegiate organization with government and private participation that will allow the collaboration between farmers, CONAGUA, and other authorities from the agricultural sector that can support sustainable agricultural development in line with the watershed conditions. This integrates the connectivity principle of adaptive governance.

- The committee is an ideal space for developing a suitable watershed management program, along with the Mexican Official Standard that the National Water Law requires for restricted-access area management. This embodies the subsidiarity principle.

- The committees must have rules of integration, organization, and operation, allowing a continuous verification and restructuring of their strategies according to the results. This incorporates the iterativity and flexibility principles.

- The committees should establish the attributions and responsibilities that their members have within their hydrological-specific areas, for the execution of their management programs. This includes mechanisms to strengthen verification, legal compliance, and establish conflict resolution processes, giving stakeholders the formal authority and responsibility that AWG requires.

- The National Water Law dictates that CONAGUA should provide the support, space, and mechanisms to promote and facilitate participation and collaboration in the public organizations that could help CONAGUA in water management, such as the Watershed Committees or the Technical Committees of Underground Water. This, in conjunction with other financing mechanisms, will give the necessary resources that AWG requires for its operation.

For such a committee to be formulated, stakeholder engagement is needed, with the acceptance of the of costs and benefits that this brings with it (Akhmouch and Clavreul

2016). The identified barriers for the stakeholder engagement include that those who are accessing water illegally do not have incentives to collaborate, since submitting voluntarily to this process will represent large losses in their agricultural investments, similar to a commons problem where individual benefits outweigh collective benefits (Hardin 1968). However, this risks the livelihoods of those who use water legally, so farmers with water rights need to take leadership and drive institutional change (Pahl-Wostl and Knieper 2014). The success of collaboration will depend on the acceptance of trade-offs that arise during the engagement. For farmers, this could consist of voluntarily restricting water access or stopping sowing certain crops; from CONAGUA this might mean giving farmers some licences or authorizations regarding water verification and management. But as demonstrated by the Southern Ocean case, an informal network that effectively engages the stakeholders in resource management, has the potential to evolve and be endowed with legal formality, in order to formally establish AWG (Garmestani and Benson 2013).

By assessing and describing the water governance system and how it influences the Rio del Carmen watershed, we have identified the main problems that undermine SES resilience. This is important for locating the potential to increase adaptive capacity in dryland systems. We have highlighted the main barriers to and needs for AWG. However, more research is needed in order to identify barriers and opportunities for enabling the necessary social engagement for AWG, along with improving understanding of the system conditions, institutional arrangements and the possible trade-offs needed to allow the emergence of AWG. This will be particularly challenging given the current conflicts.

5. Conclusion

Commonly, water governance does not fit with system requirements for WES conservation, which in turn decreases the system's adaptive capacity. This issue has to be addressed, especially in drylands as these areas are commonly exposed to land degradation and climate change. Governance problems grow when vulnerable dryland systems, with depleted underground water and large scale grassland loss, combine with water mismanagement, corruption, lack of coordination, legal breaches and unsustainable agricultural development. This was found in the case of the Rio del Carmen watershed, where these problems have generated ecological deterioration and significant social conflicts.

Addressing the issues that undermine the Rio del Carmen's adaptive capacity requires the establishment of an informal network with the engagement of a broader number stakeholders. This will guarantee the acceptance and distribution of the emerging trade-offs, in exchange for the continuity of agriculture in the watershed, and greater autonomy and participation in water management. Over the longer term it will be necessary that this stakeholder engagement embedded with local knowledge, be endowed with legal formality, in order to be effective, legitimate and sustainable, and create the required conditions for AWG, like establishing subsidiarity, flexibility, connectivity, and iterativity in the governance regime. Finally, a water governance assessment is required in order to understand the system needs and problems. Comprehending how the governance system shapes ecological and societal interactions enables identification of the barriers and opportunities to increase SES resilience.

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Conflict of Interest

None

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Appendix

Interview Protocol

1. Interviewee background

Are you a farmer, government official, agricultural representative or stakeholder related to the grasslands and the water governance of the Rio del Carmen watershed?

If yes, can you explain your activities?

2. What are the legal, cultural, political and social features of the water governance model in the watershed?

For the farmers

What species do you have been sowing in the last 20 years?

Why did you select those crops?

Do you think that there is a relation between the crop species and water overexploitation? If yes, do you think that a crop regulation is needed in the Rio del Carmen watershed?

How would you define the main features of the Mennonite and the Mexican agriculture, and what would be their main differences?

Is there another agricultural model that is taking place within the Rio del Carmen watershed?

What kind of permits did you need to start farming? (Please answer this from clearing the land to the sale of your products).

Have you received any government support? For example money, machinery, subventions or training.

Do you think grasslands regulation can support the water governance in the Rio del Carmen watershed? If yes, how?

Do you know what policies affect water governance in the Rio del Carmen watershed?

Do you know the spaces for participation regarding the water governance in the watershed? If yes, have you been invited to one?

Given the lack of CONAGUA´s law enforcement, what do you suggest it will be a good strategy to face the illegal exploitations?

For the other stakeholders

Do you think that there is a relation between the crop species and water overexploitation? If yes, do you think that a law to set the types of crops to be grown is needed?

Do you think that stricter regulations in the use of the grasslands can support the water governance in the Rio del Carmen watershed? If yes, how?

How would you define the main features of the Mennonite and the Mexican agriculture, and what would be their main differences?

Is there another agricultural model that is taking place within the Rio del Carmen watershed?

Do you know what the policy instruments are regarding the water governance in the Rio del Carmen watershed?

Do you know that the National Water Law establishes that closed access areas like the Rio del Carmen watershed should have a comprehensive watershed and aquifer management program, as well as participatory processes for designing and implementing a Mexican Official Standard that regulates the water access in the watershed?

If yes, do you know if CONAGUA has been taking steps to comply with these legal precepts?

Do you consider that some exploitations are breaching the National Water Law in the watershed? If yes, what do you suggest will be a good strategy through which to tackle the illegal exploitation?

3. How has water governance affected water availability and water ecosystem services in the watershed and for whom?

For the farmers

How and when did you get the land that you are irrigating and your water exploitation?

There is something that has impacted your land and your access to water since you got them?

What will be a good strategy to address the water deficit between the granted water and the annual recharge volume?

Do you think it will be possible to deny an extension of some property rights because of the overexploited status? If yes, what could be the criteria for giving or denying this extension?

Do you have noticed an increasing heat or drought during the last 20 years? If yes, what have you done in order to adapt your farming practices?

What would be a good strategy to recharge the aquifers of the Rio del Carmen watershed?

What agricultural technologies have you incorporated into your land to improve your water access and agricultural production during the last 20 years?

What would you do if the watershed were to be depleted this year?

How have farmers helped preserve the benefits they get from the watershed for their agriculture?

What have been the CONAGUA´s achievements in the Rio del Carmen management and the preservation of the benefits obtained for the agriculture?

For the other stakeholders

Regarding the data published by CONAGUA, the Rio del Carmen aquifers are overexploited. Do you think it will be possible to deny an extension of the property rights under the overexploited status? If yes, what could be the criteria for giving or denying this extension?

What could be another strategy to address the overexploitation?

What would be a good strategy to recharge the aquifers of the Rio del Carmen watershed?

In what way has the government has been supporting agriculture in the Rio del Carmen watershed?

What would need to be adapted to face climate change in the watershed?

What would happen if the watershed were to be depleted this year?

What positive results have been delivered in the application of water policies in the watershed?

What have the government been doing to preserve the benefits that the watershed is giving to the agriculture?

4. What kind of conflicts and trade-offs are taking place in the watershed and how are these shaped by institutional aspects?

For the farmers

What have CONAGUA been doing to address the conflicts in the Rio del Carmen watershed?

How are the conflicts over water access affecting you?

Do you know how it has affected other farmers too?

What are the main obstacles to collaboration in the watershed?

Can you tell me who, why and how would be affected if those obstacles are eliminated?

Do you think that Mennonites and Mexican farmers are willing to solve those conflicts?

If not, why not? If yes, why are they not solved?

What would you define as a “common ground” or “mutual interests” between the Mennonites and the Mexican farmers?

What would be your contribution as a first step to solve these difficulties?

For the other stakeholders

What has CONAGUA been doing to address the conflicts in the Rio del Carmen watershed?

How are the conflicts over water access affecting 1) the farmers, 2) CONAGUA´s management and 3) the watershed?

What are the main obstacles to collaboration in the watershed?

Can you tell me who, why and how would be affected if those obstacles are eliminated?

Do you think that Mennonites and Mexican farmers are willing to solve those conflicts?

If not, why not? If yes, why are they not solved?

What would you define as a “common ground” or “mutual interests” between the Mennonites and the Mexican farmers?

What would be your contribution as a first step to solve these difficulties?