
Article:
Lopez Porras, G orcid.org/0000-0003-2023-1239, Stringer, LC orcid.org/0000-0003-0017-1654 and Quinn, CH orcid.org/0000-0002-2085-0446 (2018) Unravelling Stakeholder Perceptions to Enable Adaptive Water Governance in Dryland Systems. Water Resources Management, 32 (10). pp. 3285-3301. ISSN 0920-4741

https://doi.org/10.1007/s11269-018-1991-8

UNRAVELLING STAKEHOLDER PERCEPTIONS TO ENABLE ADAPTIVE WATER GOVERNANCE IN DRYLAND SYSTEMS

Gabriel Lopez Porras[1*] , Lindsay C. Stringer[1], Claire H. Quinn[1]

Abstract

Adaptive water governance seeks to increase a social-ecological system's adaptive capacity in the face of uncertainty and change. This is especially important in non-linear dryland systems that are already exposed to water scarcity and increasing degradation. Conservation of water ecosystem services is key for increasing adaptive capacity in drylands, however, how stakeholders perceive water ecosystem services greatly affects how they are managed, as well as the potential for adaptive water governance. This paper focuses on identifying the system's potential for enabling adaptive water governance by analysing different stakeholder perceptions on water ecosystem services. It takes the Rio del Carmen watershed as a case study, offering important insights for an increasing number of water-scarce regions. Semi-structured interviews were conducted with key stakeholders in the watershed in order to unravel their perceptions and understand the governance context. We found disparities in how stakeholders perceive water ecosystem services have led to water overexploitation and several conflicts over water access. Our results indicate that stakeholder perceptions have a major influence on the system's adaptability, as they shape the acquisition of water ecosystem services. Divergent stakeholder perceptions act as an important barrier to collaboration. Generating and sharing knowledge could facilitate the development of a common vision, allowing all actors to co-

* ✉ Gabriel Lopez Porras
eegilp@leeds.ac.uk

[1] Sustainability Research Institute, School of Earth and Environment, University of Leeds, Woodhouse Lane, Leeds LS2 9JT, UK.

create information about water ecosystem services and the system state, engaging them in a participatory process, suitable for their context, and that will better support adaptive water governance.

Keywords Social-ecological resilience · Water scarcity · Agricultural systems · Knowledge sharing · Conflicts · Mexico

1 Introduction

Adaptive water governance (AWG) integrates collaboration and learning processes to increase system adaptive capacity in the face of uncertainty and changing social-ecological conditions (DeCaro et al. 2017). AWG suits contexts such as drylands, which are naturally exposed to droughts, land degradation, and desertification. Implementing AWG in drylands is challenging given complexities inherent to these social-ecological systems (SES), requiring deep understanding of the governance context (Chaffin et al. 2016; Gunderson et al. 2016). Societal perceptions of what is important reflects how governance and institutions influence and shape SES (Díaz et al. 2015). Governance models must consider society's priorities and risks in order to achieve development, human well-being, and secure the ecosystem services on which livelihoods rely (Mortimore et al. 2009). This is vital in a dryland context, because people have different perceptions of "water scarcity", shaped by their political, cultural and economic biases (Forouzani et al. 2013). An important step towards AWG is unpacking the formal and informal rules that underlie system interactions, establishing boundaries and identifying linkages and feedbacks between stakeholders (Stringer et al. 2017). Social constraints that underpin linkages, are called institutions (North 1990). Institutions establish how governance systems operate, influencing the values stakeholders give to water ecosystem services (WES), and how

individuals use natural resources. By understanding these institutions and governance systems they can be intentionally directed to halt WES losses (Díaz et al. 2015).

Increasing conflicts over water access and overexploitation of scarce water resources are indicators of management failures and an undesirable state of water governance (Chaffin et al. 2014). For instance, access to water rights in the Rio del Carmen watershed, located in the most arid part of the Chihuahuan desert in Mexico, have been closed since 1957 (Diario Oficial de la Federacion 1957) in an attempt to avoid overexploitation or damage to the watershed. Water use rights have been issued using technical studies that guarantee water volumes for existing rights and the ecological balance of the watershed (Diario Oficial de la Federacion 2015). Nonetheless, overexploitation has increased since 2000. Water depletion, along with recent droughts and other environmental changes, have encouraged water conflicts, demonstrating inefficient water management (Quintana 2013) underpinned by governance failures. To transform this into an opportunity for AWG, an analysis is needed of system rules, linkages, and feedbacks shaping the SES (Chaffin et al. 2016).

This paper identifies a system's potential for enabling AWG, by analysing different stakeholder perceptions about WES, using the Rio del Carmen watershed as a case study. Targeting this aim, we ask: 1) Who are the key stakeholders in the Rio del Carmen watershed? 2) Which communities and economic activities have access to water and why? and 3) How do different stakeholders in Rio del Carmen perceive WES? Unravelling how stakeholders perceive WES, how they are organized, and the institutional constraints that underlie social-ecological interactions, will help identify how AWG might emerge in water-scarce contexts (Young 2010), which are increasing globally (Huang et al. 2015).

2 Research Design and Methodology

Governing water in dryland systems to balance multiple water demands across different stakeholder groups faces many challenges (Cosens 2015). The Rio del Carmen watershed offers a useful example. This watershed is largely supported by 3 aquifers: Santa Clara, Flores Magon Villa Ahumada and Laguna de Patos. Literature suggests the first two aquifers are overexploited, while Laguna de Patos has a concession volume similar to the annual recharge volume (Diario Oficial de la Federacion 2015). The watershed has a dam (Las Lajas), located on the Santa Clara River, with a total capacity of 91.01 million m^3y^{-1} (INEGI 2003). The watershed's main environmental problems are land use change (loss of grasslands due to conversion to agriculture), desiccation and groundwater overexploitation (CONABIO 2014). The social context is complex: different conflicts over water access have arisen, and authorities have been unsuccessful in solving the social and ecological crisis (Quintana 2013; Athie 2016).

Exploration of the social context regarding water access and the perceptions of WES that shape water governance helps to identify barriers to AWG and incompatibilities in future collaboration and learning processes (Gunderson et al. 2016; Medema et al. 2017). We started with stakeholder analysis (Reed et al. 2009) to understand the formal and informal interactions among stakeholders, the diverse perceptions in the watershed, and how water shapes the social context, using a qualitative approach.

Stakeholder analysis followed an iterative research process where 13 semi-structured interviews were conducted during June 2017 across different stakeholder categories: 6 government agencies, 1 university, 1 NGO, 1 industry group and 4 agricultural communities. Categories were designed based on information from Quintana (2013) and Manzanares Rivera (2016), and prior experience of the first author in the watershed. Interview participants nominated others using snowball sampling, identifying more interviewees from different stakeholder categories (Bhattacherjee 2012). Interviews had multiple starting points so all stakeholder categories were properly represented, assuring all views were captured.

An interview protocol was developed covering water access, governance and WES. The interviewer nevertheless followed up on other important issues raised during interviews (DiCicco-Bloom and Crabtree 2006). Interviews were recorded in Spanish, transcribed into English and anonymised.

The dataset was analysed and deductively coded (Bernard 2011). This involved classification and coding under headings of: conflicts and trade-offs in water use, water access, water governance and perception of WES in the watershed, in line with the research questions.

Secondary data on the watershed's average annual water availability, natural recharge, and social conflicts were collected using datos.gob.mx/ and www.infomex.org.mx. These data were analysed qualitatively using the same themes as for the interviews. Findings were triangulated (Kohlbacher 2006). Contradictions between sources were noted and resolved according to the contingent factors or personal experiences that shaped the differences (Bhattacherjee 2012).

3 Results

3.1 Identification of key stakeholders in the Rio del Carmen watershed

Three stakeholder groups emerged as most important regarding water governance in the Rio del Carmen watershed: the National Water Commission (CONAGUA), the Mennonite community and Mexican farmers.

CONAGUA is the Mexican government agency in charge of national water management, through application of the National Water Law (Athie 2016). When we refer to CONAGUA we refer to its Chihuahua Local Directorate, which is directly linked to water governance in the watershed. In Mexico, water access is a human right guaranteed in its Political Constitution, and its conservation, as well as conservation of vital ecosystems linked to water resources, are

considered public utilities[1]. The literature identifies that CONAGUA has several institutional deficiencies, limited economic and human resources, and an inadequate legal framework that has not allowed proper water management (Athie 2016). Officials within CONAGUA noted this too:

> There is no control over the watershed, the legal framework is not respected by Mennonites or by the water users from the lower part of the watershed, and the water use rights are not respected (CONAGUA official B).

> CONAGUA needs more human and economic resources, we need comprehensive water reform, with specialized courts, as they are largely unaware of the topic (CONAGUA official D).

These issues, along with water scarcity, have contributed towards conflicts over water access, where CONAGUA needs to get involved. Given its inability to monitor compliance with the law, punish those who do not comply, and to control corruption (Murillo-Licea and Soares-Moraes 2013; Athie 2016), CONAGUA sometimes participates as an arbiter and sometimes as part of the problem. According to the Transparency Unit of the Federal Judicature Council of the Federal Judicial Branch, in Chihuahua state alone, 559 lawsuits were filed against CONAGUA in a period of 23 months, for not solving citizens' requests (CJF 2016). A CONAGUA official said that:

> Many times we have reached favourable agreements, but on other occasions, we have received legal demands which are out of the conciliation process. In these cases, the courts are the ones who must decide who is right, and according to the ruling, CONAGUA must abide by what is dictated (CONAGUA official C).

[1] The character that acquires a public good when it is fundamental for the Government to satisfy collective social and economic needs.

This situation has increased distrust in CONAGUA, causing displeasure for several farmers. Some of them blame CONAGUA for the crisis that the watershed is experiencing (Quintana 2013). Both Mennonite and Mexican farmers stated that CONAGUA "is closed to the complaints and needs of farmers" (Mennonite A), and "[does] not have the technical or human capacity to attend to the situation in the watershed" (Mexican farmer A).

Another important group in Rio del Carmen's water governance is the Mennonite community. Mennonites are located principally in the upper part of the watershed, in the Santa Clara aquifer. Around 1930, Mennonite colonies arrived in Chihuahua, initially establishing in the Laguna de Bustillos watershed. Population growth caused them to expand, including the Rio del Carmen watershed (personal communication, CONAGUA official B). The Mennonite community is very traditional, religious, peaceful and hardworking (Quintana 2013). Nevertheless, they have been involved in several conflicts with Mexican farmers over water access. Mexican farmers accuse Mennonites of construction of illegal dams and wells (Athie 2016).

As a consequence, combined with CONAGUA's inactivity in addressing the problem, in 2012 a significant conflict arose when Mexican farmers started to destroy dams supplying the Mennonites. Despite there being "about 10 conflicts, more or less" (Mennonite A) between Mennonites and Mexican farmers, the conflict in 2012 "was the only serious conflict" (Mennonite B), which resonated in national and international media (Quintana 2013; Burnett 2015). Additionally, Mennonites in the watershed have been involved in several legal challenges. According to one CONAGUA official:

> There are many legal complaints against the upper part of the watershed [where the Mennonites are located] because of change of land use from grassland to irrigation,

> also SEMARNAT[2] has lodged several complaints against those persons because they do not have the authorizations for changing land use. Unfortunately, those are processes where farmers have found weaknesses in the law and they can obtain some protection from the courts (CONAGUA official B).

As they have expanded, the Mennonite community has become more heterogeneous, with both traditional and modern Mennonites. Traditional Mennonites are said to be "more conscious about the situation and the consequences of overexploitation, however, Mennonites in the Rio del Carmen watershed are not the most conscious, they are the most materialistic" (State Government official B). A private farmer said this new generation of Mennonites "over-exploits the aquifers and has monopolized most of the volume of water of Chihuahua" (Mexican farmer B).

Mennonites in the Rio del Carmen watershed do not consider there to be water scarcity, stating that: "Underground water does not affect nature, it comes from deep" (Mennonite B), "The water levels have not dropped a lot in that area, the wells have not gone down" (Mennonite A). Consequently, modern Mennonites do not consider their agricultural activities are damaging the watershed or those who live in it; on the contrary, they see their activities having a positive effect. One Mennonite said:

> All people have benefited from this, for example, if a neighbour needs workers, he employs 20 to 25 persons at the time of sowing, it benefits the population, several families, not just himself as the owner of the farm, but all the people who are searching for jobs (Mennonite B).

Modern Mennonites are recognised by the economic prosperity they have achieved as a result of their agricultural activities (Manzanares Rivera 2016), which are designed on "building a

[2] SEMARNAT the acronym in Spanish for the Ministry of the Environment and Natural Resources.

family heritage" (Mennonite B). Some of their only complaints are that some Mexican farmers do not want to let them access water: "they do not let us work, do more things, they do not let us improve" (Mennonite A). Nevertheless, given their peaceful culture, they believe they have not increased social tension, for instance when "once they [Mexican farmers] broke a dam..., we could not do anything" (Mennonite A). Despite this, an interviewee stated that "now we have more communication with them [Mexican farmers] because they understand that it is family heritage, we are working to live, to progress, nothing else" (Mennonite B).

The third stakeholder group identified are Mexican farmers, made up of ejidatarios[3] and private farmers. Many of these farmers are organized into an Irrigation District called El Carmen 089, created in 1957when closed access was established to secure water exploitation (Diario Oficial de la Federacion 1957). Additionally, a section of the District has exclusive water rights to 51,030 million m^3y^{-1} from the Las Lajas dam by presidential decree from 1976 (Diario Oficial de la Federacion 1976). The Irrigation District and most Mexican farmers are located in the Flores Magon-Villa Ahumada aquifer, downstream of the Santa Clara aquifer and the Mennonites.

Around 2010, when Mexican farmers began to notice reduced water availability, and detected upstream exploitation, they self-organized, giving rise to a social movement 'Defenders of the water of the Chihuahuan desert'. They called upon the authorities to remove illegal exploitation, enforce the law on illegal conversion of grasslands to farmlands, eliminate economic support to those who exploit water illegally, and not to provide them with electricity (Quintana 2013).

When the authorities failed to solve the problem, they began occupying government offices and blocking roads and railroad tracks. At one point in this contestation, they were able to

[3] Ejido members; ejidos are agricultural communities that manage their land collectively.

coordinate actions with CONGAGUA to demolish dams and close wells. However, conflicts are not over. Within this group, a grassroots (militant activist) organization called El Barzon has been most concerned about and committed to the conflicts over water access. Its leadership has been key in the organization of Mexican farmers dissatisfied with the environmental state of the watershed and water management (Quintana 2013). El Barzon has been fighting illegal water use in the Santa Clara aquifer, a situation that a Mexican farmer described in an interview:

> There are 3 main conflicts: The use of surface water that is a tributary of the Carmen River that is illegally retained by the Mennonites. Another problem are illegal wells, more than 300 wells have been detected and do not have authorization from CONAGUA. Also, there is overexploitation of the aquifer that Mennonites do; they use more water than they are allowed to. This aquifer [Santa Clara] has a concessioned volume of water of 3000 ha of irrigation, approximately, however, there are 60,000 ha irrigated (Mexican farmer B).

However, Mennonites say that when they began to sow, before all these conflicts over water access in the watershed, CONAGUA never asked them to obtain any authorization for water exploitation: "at that time we did not need any permits or water rights to use the water, we could extract it without anyone telling us anything" (Mennonite A). This is unlikely because the State holds the original overarching property right to water resources. Water cannot be used without government authorization. Even in areas where water extraction is not limited, CONAGUA must be notified of planned exploitation. In this case, formal norms and rules were not respected by the modern Mennonite's agricultural practices. This is due to: lack of awareness on the part of Mennonites, and CONAGUA's lack of presence in water management and law enforcement.

Following this, Mennonites in the watershed began to look for ways to acquire water rights, so they started buying the few remaining water rights in the Santa Clara aquifer, and divided them to legalise their water exploitation. A CONAGUA official reported:

> Those were water rights that allowed use of 300 thousand m^3y^{-1} of water per year, each one, and they were bought and divided into several water rights for wells of 20,000 or 30,000 m^3y^{-1}, however, we know that they are extracting around 800,000 m^3y^{-1} of water in each well (CONAGUA official C).

Athie (2016) says that extracting a higher volume of water than that allowed by water rights is not unique to Mennonites. Mexican farmers have also done this, having seen there are no consequences for breaking the law. Consequently, there have been several attempts to solve the conflicts in Chihuahua; from coordinated inter-institutional actions designed to identify and stop illegal water exploitation, to mediation processes. A state government official said:

> I was asked in 2012 to organize a mediation meeting between El Barzon and the Mennonite community. We had two meetings. The problem was that only the most conscious members of the Mennonite community [those not engaged in agriculture] went to the meeting, not members that are using the water illegally. So, the meetings did not have effective results (State government official B).

Another interviewee added:

> We sat down twice with the Mennonite Central Committee, which has contact with the leaders of the Mennonite colonies. However, we could not advance because the traditional Mennonite community is overtaken by modern Mennonites (Mexican farmer B).

Due to lack of resolution and coordination between Mexican farmers and modern Mennonites, along with CONAGUA's lack of interest in and ability to solve the problem, “many farmers

were discouraged and stopped participating, they are no longer trying to solve the problem in the watershed" (Mexican farmer A). For this reason, El Barzon raised their efforts above the Chihuahua Local Directorate of CONAGUA. An ejidatario said:

> We have received international protection: the Inter-American Commission on Human Rights issued precautionary measures to some members of El Barzón, and with this, we have managed to force the authorities to sit at an inter-institutional table to design an operation for the closure of illegal wells (Mexican farmer A).

3.2 Water access in the Rio del Carmen watershed

In Mexico, water is divided into consumptive uses: agricultural, public supply, self-supply for industry, and thermoelectric; and non-consumptive use for hydroelectric plants (Athie 2016). The main water use in the watershed is agricultural. In the Flores Magon-Villa Ahumada aquifer it represents 98.6% of water use, in the Santa Clara aquifer it represents 96%, and in the Laguna de Patos aquifer it represents 87.3% (CONAGUA 2015).

Cultural diversity has created different models of agricultural production, and the interests that underlie each one are antagonistic, adding complexity to the system (Manzanares Rivera 2016). For instance, modern Mennonites use an agricultural model that Manzanares Rivera (2016) called highly specialized emerging developments, which consists of the execution of very intensive farming practices implemented through technologies that optimize agricultural production. Modern Mennonites state their agriculture is sustainable and brings great benefits. When asked whether they considered their agricultural developments could continue over the next 20 years, they replied "Yes, I think there is enough water and there are not so many wells in the area" (Mennonite B), "I believe it is going to get better" (Mennonite A). This agricultural model has made Chihuahua one of the main agricultural producers and exporters in Mexico

(Manzanares Rivera 2016), producing 14 tonnes of maize $ha^{-1}y^{-1}$ (Quintana 2013). Implementation of high-efficiency irrigation practices and technologies to access groundwater resources is expensive, as a CONAGUA official said:

> A kilometre of electrical cabling costs 120,000 pesos approximately, drilling of wells costs 500,000 pesos approximately, plus water well equipment of 400,000 pesos, and the irrigation system that costs 45,000 pesos per hectare; this is a big investment (CONAGUA official B).

However, this agricultural model puts pressure on scarce water resources, (Quintana 2013), since it underlies *"a business vision with large*-scale agricultural production" (Mexican farmer A). Given these circumstances, and experiences of this agricultural model in other aquifers where Mennonites have settled, this intensive water use has several negative effects on WES, risking the continuity of agricultural activities and neglecting sustainability (Manzanares Rivera 2016).

There are also the Mexican farmers. According to Manzanares Rivera, (2016) ejidatarios do not use water resources intensively, and commonly their agricultural practices are oriented towards subsistence. However, Quintana (2013) noted, from 2001 to 2010 the Irrigation District El Carmen 089 increased its irrigation area by 262%, with the Mexican farmers in the Flores Magon-Villa Ahumada increasing their agricultural area by 29.1% per year. In principle, this should not have happened, as the Irrigation District has had the same water rights since its creation. An ejidatario said:

> We have a water use right granted based on the land that was given to the ejido founders. Those are plots of 30 ha for each ejidatario, which is entitled to make use of 270,000 m^3y^{-1} of groundwater per year; according to technical data and irrigation sheets, that volume of water should be sufficient. As for the surface water that

> corresponds to the Las Lajas dam, we are at the mercy of rainfall and the rain catchment in the dam, so from the 30 ha only 10 to 15 ha at most are sown, so we always have land without irrigation for lack of water at the dam (Mexican farmer A).

Finally, there are the private farmers who have a traditional production model. They conserve their grasslands for livestock or mix rainfed agriculture with water exploitation. However, some have been encouraged to investment in irrigation systems that allow more intensive use of water resources, since they have seen the large profits made by modern Mennonites (Quintana 2013). A state government official stated that:

> Although they [Mexican farmers] have the right to use water, that does not give them the right to abuse water resources. Farmers in the Rio del Carmen watershed are sowing a huge number of walnuts, which will cause a water collapse in the area; it is necessary to impose a plan that achieves the sustainability of the watershed, which Mennonites and Mexican farmers should abide (State government official B).

Some private farmers have modified their practices, expanding into more water-demanding crops, because of the profits they generate. The massive planting of these species is unsustainable, as a CONAGUA official said "Those crops are very likely to collapse, due the watershed typology where the average extraction per well is 30 litres per second, which is insufficient for plots of 50 ha" (CONAGUA official B); yet, the private farmers planting them see these crops as "patrimonial since they can last 100 years producing, so my children can inherit them, and so on" (Mexican farmer B).

Six main problems regarding water access have shaped water overexploitation in the watershed (the relationship of each stakeholder group with these problems is shown in Table 1):

1. Unsuitable cropping: the main crops are chilli, alfalfa, walnut, cotton, sorghum, and corn, but because of the high water quantities they require they are not suitable for the watershed (personal communication, CONAGUA official C).

2. Illegal removal of grasslands: illegal land use change, where grasslands have become cultivation plots, has placed significant pressure on water resources. According to the Ministry of the Environment and Natural Resources, there are no records of any authorization for land use change regarding the creation of irrigation plots in the Rio del Carmen watershed (SEMARNAT 2017); so land conversion after 2003[4] was carried out illegally.

3. Non-compliance with the law: according to a CONAGUA official "conflicts should be attacked through legality. Farmers already have an inclination to solve problems through the law" (CONAGUA official C). However, law enforcement has been difficult due to corruption within CONAGUA (Murillo-Licea and Soares-Moraes 2013; Athie 2016), and legal procedures are "only simulation acts without any consequences for those who break the law" (Mexican farmer A).

4. Poor water management: as a CONAGUA official stated:

> The problem is that we have many budget cuts, so the problem of Chihuahua, being a dryland state... With several issues due to drought, we need more personnel, we have very few inspectors, and they are not enough for the number of water exploitations or the number of ins*pection visits they should make… We cannot properly manage water* with the limited personnel we have (CONAGUA official D).

[4] This is the year in which the General Law of Sustainable Forest Development was issued, which establishes the requirements for changing the use of land.

5. Climate change: the watershed has suffered increased drought, "which means the watershed does not produce the minimum water amount established in law for its availability" (CONAGUA official C).

6. Perverse incentives for overexploitation: water for agricultural use has no taxation (Athie 2016), the cost of electric power for water exploitation is subsidised and farmers have access to grants. Water use and extraction is therefore very cheap, contributing to its overexploitation. These economic incentives mean that water cannot be adequately valued since they encourage excessive use, altering adversely the way WES are perceived (Quintana 2013; Athie 2016).

Table 1 Relationship between stakeholder groups and indentified problems in the Rio del Carmen watershed

	Stakeholder group		
Identified problem	CONAGUA	Mennonites	Mexican farmers
Unsuitable crop species	There is no crop regulation in the watershed legal framework.	*"I started with* alfalfa and cotton, *but now I sow corn"* (Mennonite B).	*"The crops that are* developed in the region are jalapeno chilli, red chilli, *alfalfa and walnut"* (Mexican farmer A).
Illegal removal of grasslands	SEMARNAT is in charge of grassland management.	This situation is taking place in the Santa Clara aquifer, as the Mennonites have access to loans and machinery to convert grasslands to farmland.	Increase of the agricultural frontier has been carried by both Mennonites and Mexican farmers (Athie 2016).
Poor water management	*"We still have not* managed to measure how much water is being extracted in the watershed*"* (CONAGUA official C).	Mennonites do not participate in any water management processes.	Mexican farmers have been trying to create and establish working groups for improving water management.
Non-compliance with the law	Water depletion shows CONAGUA's inefficiency in law enforcement. The closed access declaration has failed to guarantee water	*"Mennonites have* many legal advisers, they have filed requests for defence to stop administrative processes against	Some Mexican farmers have begun to break the law, as they have witnessed there are no consequences for doing so.

	exploitation to the Irrigation District, and water availability does not meet the minimum required by law.	*them"* (CONAGUA official B).	
Climate change	"Water rights were granted in a regular or average state of the watershed, under other environmental conditions, and given the decrease in runoff, conflicts have increased" (CONAGUA official C).	"In the last few years there has been no drought problem, it has rained for the farmers" (Mennonite A).	"We have been having problems with the crops, this year we did not have the frosts that the walnut needs, and we had atypical hailstorms that damaged our crops" (Mexican farmer A).
Perverse incentives for overexploitation	Electric subsidies and grants can be obtained only by water right holders.	They benefit from these economic incentives.	They benefit from these economic incentives.

3.3 Stakeholders' perceptions of WES in the Rio del Carmen watershed

WES are the benefits that contribute to human well-being, obtained from freshwater ecosystems, like rivers, lakes, groundwater, and wetlands (Martin-Ortega et al. 2015). They are divided into: 1) supporting services like soil formation and nutrient cycling, 2) regulating services like water and climate regulation, 3) provisioning services such as water and food supply, and 4) cultural services like recreation, tourism and cultural identity (Safriel et al. 2005). Informal institutions such as stakeholders' perceptions and formal institutions like the water legal framework (Prell et al. 2010), shape the way these services are procured and thus the way water is accessed and managed (Díaz et al. 2015; Gunderson et al. 2016).

CONAGUA cannot go beyond what the legal framework establishes, so its institutional perception of WES is firmly limited to what is established in National Water Law. Accordingly, in this law, water has no environmental value, only a fiscal value, hence it has a coercive economic procedure – an administrative process through which the government requires

citizens to comply with their fiscal obligations – which separates it from environmental law (personal communication, Garcia de Icaza, 2017). Indeed, the only penalties that the National Water Law applies are pecuniary (Athie 2016), which do not guarantee or pursue the restoration of water or its related ecosystem services. Therefore, CONAGUA is restricted to the economic management of water resources.

In addition, within CONAGUA, perceptions of the watershed's environmental condition differ among officials. While one interviewee said that

> There is no ecological deterioration in the area. We have been monitoring groundwater quality, and no variation or deterioration in water quality caused by overexploitation has been detected. The same quality of water has been maintained for many years (CONAGUA official C);

another stated that:

> There have been a lot of changes since 1992, we have more drought occurrences in the watershed, which has meant that the watershed does not produce the water that the NOM-011[5] *establishes for the availability of water… downstream, now there is* the presence of iron and fluorine, and we have evidence that arsenic is increasing. At this rate, we will have to discard these sources of water supply (CONAGUA official B).

Water quality is paramount in dryland systems. Disparities within CONAGUA make it very difficult to conserve water regulating services that allow infiltration processes that both improve water quality and sustain its quantity. Nevertheless, some CONAGUA officials recognise the relationship between vegetation loss and provisioning and regulating services:

[5] Mexican official standard which states the determination method for water availability, which includes the natural discharge compromised to secure ecosystem functions.

> More grasslands are being removed and more shrubs, oaks, conifers are being felled, which influences the lack of water and fosters climate change. If there is no water production, then the aquifer is not recharged, nor is there any runoff for the Las Lajas dam (CONAGUA official B).

Furthermore, the differences in how modern Mennonites and Mexican farmers perceive WES (Figure 1) are reflected in the way they use water for agriculture. Modern Mennonites perceive WES as an inexhaustible source of inputs for agricultural production. This relates to their religious beliefs that water is limitless because God provides it (Burnett 2015). Also, their education plays an important role. Schooling is provided until secondary level in Low German, after which they work on the farms, so not all of them can read and write in Spanish (personal communication, Mennonite B). This limits their access to updated information related to watershed state: "They are a closed group, they provide their own schooling, they do not receive education on natural sciences or issues related to water and hydrologic cycles" (Mexican farmer A). These two reasons would explain why Mennonites in the watershed do not account for or recognise WES. Moreover, they also explain why it makes no sense to Mennonites that CONAGUA and Mexican farmers want to restrict their water access; hence attempts to solve the conflicts in the watershed through the conciliation process fail.

Although Mexican farmers' economic activities rely on water use, most of them recognize the value of WES in supporting their livelihoods, including the relationship between grasslands and water resources. As an ejidatario said "there are fewer plants in the soil, and with the torrential rains there is no infiltration, a lot of soil loss, and less water. With good grassland management water would be allowed to permeate and recharge the aquifers, but they are running out" (Mexican farmer A). Even so, Mennonites perceive those agricultural practices as inefficient, as an interviewee said "They [ejidatarios] don't want us to irrigate our lands, they *don't* want us to use water, they want all the water for themselves but in the end, they do

not even use it" (Mennonite A). Mexican farmers recognise the finite nature of WES, and their importance in provisioning and regulating water, as well as supporting soil formation. Despite this, some private farmers are starting to prioritize economic benefits by using crops that are unsuitable for the current context of the Rio del Carmen watershed, which increases the pressure on water resources and generates another area of conflict (Figure 1).

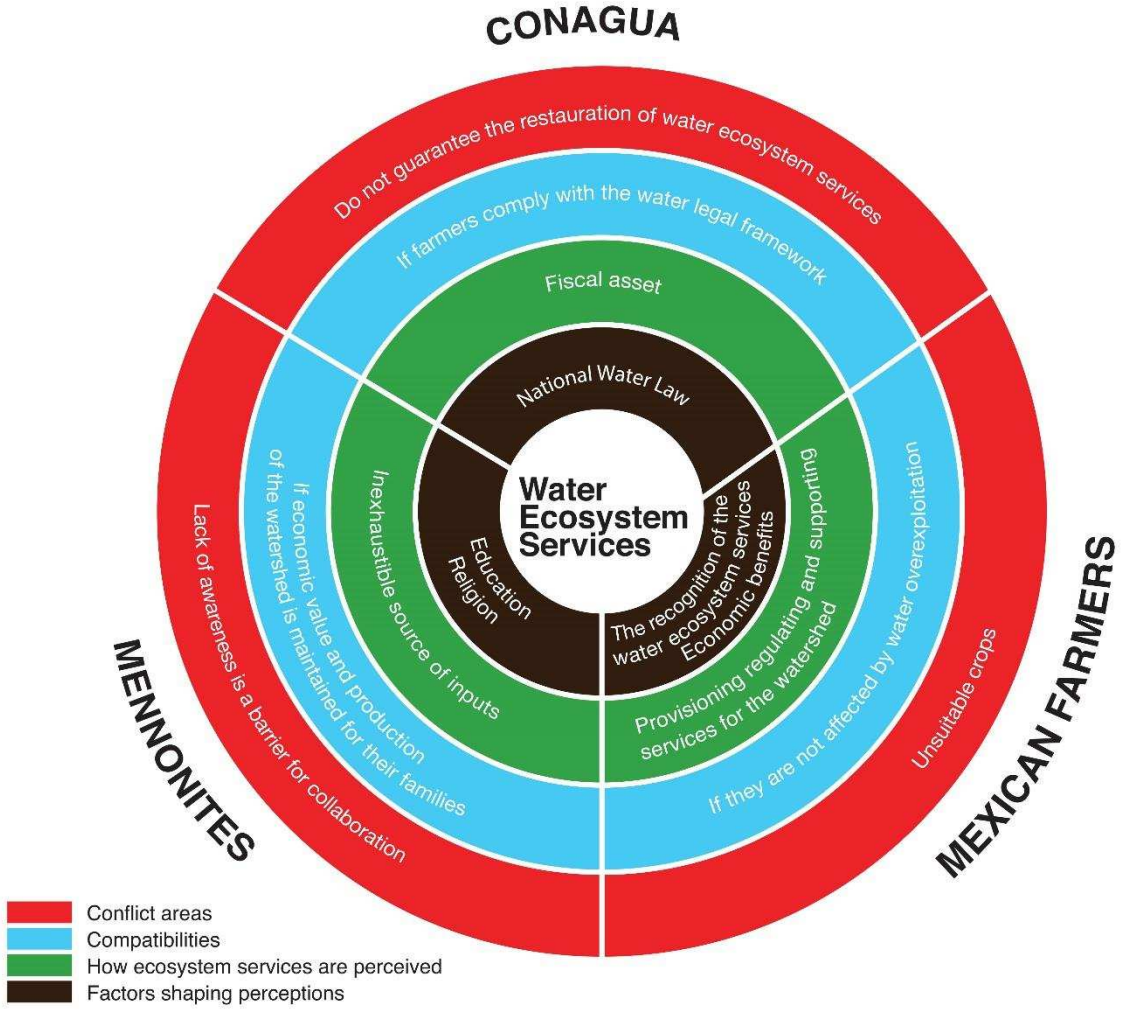

Figure 1 Stakeholder perceptions, compatibilities and conflict areas for restoration of water ecosystem services.

4 Discussion

This paper has identified the key stakeholders in the Rio del Carmen watershed; unravelled water access; highlighted the main drivers that have shaped it; and examined how WES are perceived by key stakeholders. It provides an important contribution to discussions regarding the required conditions for an adaptive model of governance to be successful, by understanding the governance context and the institutions that comprise it.

The main problem is that some farmers have suffered from overexploitation of water, causing conflicts over its access. The water access crisis is a consequence of unsuitable crop species, illegal removal of grasslands, non-compliance with the law, poor water management, climate change, and perverse incentives for overexploitation (Table 1). This water governance failure is a clear barrier to system adaptation, since degradation of WES substantially restricts dryland systems' adaptive capacity (Mortimore et al. 2009). Stakeholder participation is critical for increasing adaptability (Folke et al. 2005), hence, farmers have a significant role in the governance of WES, as they are selecting crops, removing grasslands and extracting water (Chaffin et al. 2014). As resource users, farmers must be involved in water regulation, cooperate in monitoring, participate in decision-making processes, collaborate and generate knowledge for improving water governance, however, there are barriers.

Lack of awareness about the importance of WES for the perpetuation of freshwater ecosystems has resulted in non-compliance with formal institutions that seek to protect the Rio del Carmen watershed, and their relevance is ignored. Informal institutions, like modern Mennonites' agricultural practices, have not changed despite the existing water legal framework because of a lack of awareness of ecological processes, and because "informal constraints that are culturally derived will not change immediately in reaction to changes in the formal rules" (North, 1990, p. 45). Hence, modifying stakeholders' perceptions by generating and sharing

knowledge is an entry point for enabling AWG, but also, an important principle that needs to be embedded to avoid undesired states and to better understand social processes (Stringer et al. 2017). Mennonites' beliefs and perceptions determine their intentions, which are externalized through their behaviours in order to obtain desired outcomes (Schlüter et al. 2017), like building family heritage through intensive farming practices. Most Mexican farmers like ejidatarios do not share those intentions because they have opposing perceptions about WES. This results in two incompatible behaviours creating a major obstacle for solving conflicts.

Co-creating knowledge between CONAGUA, Mennonites, and Mexican farmers offers potential for understanding decision-making behaviours and improving social learning, as well as engaging them in processes in which their perceptions are considered. Learning processes that allow a shared vision of the WES to be established, offer potential to facilitate collaboration between stakeholders (Medema et al. 2017). Collaboration is key as it can mitigate current conflicts, create networks, and enhance participation in decision-making: basic elements of adaptive governance (DeCaro et al. 2017).

Moreover, CONAGUA's lack of resources and its inability to enforce the law has led to a quasi-open access regime, where informal institutions have surpassed the formal institutions that seek to regulate water access. Accordingly, governance failures have driven some stakeholders to take action (Pahl-Wostl et al. 2010). El Barzon has been most active, looking to change the undesirable state by taking on a leadership role. Leadership is a critical factor for social learning (Garmestani and Benson 2013), but it needs to be directed towards creating networks and building trust between stakeholders, enabling collaboration and allowing emergence of an adaptive governance model (Chaffin et al. 2014). El Barzon have already taken the initiative to reconcile conflicts and collaborate with Mennonites, and currently, they have convened an inter-institutional roundtable to try to solve the problems. However, barriers in their processes have not allowed them to reach favourable results.

First, this is taking place in an “unmanageability” context, with lack of participation or "action" from key stakeholders in the watershed. This means El Barzon is framing and structuring the problem according to their own perceptions, without other stakeholder inputs (Pahl-Wostl et al. 2010), so their processes lack legitimacy, accountability and representativeness (Chaffin et al. 2014). Even though El Barzon is trying to remedy CONAGUA’s deficiencies in conserving WES, informal networks require legitimacy to design and implement formal measures that will address the problem (Österblom and Folke 2013). CONAGUA needs to start getting involved in these participatory processes and encourage the participation of Mennonites, which ultimately will increase acceptance of and compliance with formal institutions (Cosens 2013). Lack of participation and collaboration by Mennonites can be attributed to two issues: 1) stakeholders will not participate if they feel they are considered responsible for the problem, and 2) lack of awareness of water issues decreases stakeholders’ interest to participate (Medema et al. 2017).

Despite the potential for creating a common vision through knowledge co-creation, it is paramount that communication during these processes is facilitated by experts in community engagement and participatory processes; preserving that shared vision in situations with opposite views and conflicts between stakeholders (Medema et al. 2017). Besides El Barzon’s interest and leadership, capacities and resources from both Mennonites and CONAGUA are required for this collaborative process to succeed. Another barrier is El Barzon’s militant characteristics. Conceptual differences hinder good relationships with the other groups. However, developing mutual goals for addressing a collective problem should help to foster greater openness. An ejidatario said that “as an organization, we always bet on dialogue, sometimes with actions of civil resistance but always willing to make proposals and resolve the conflicts” (Mexican farmer A).

A similar situation was experienced in the Klamath River in the USA. After legal, political and physical conflicts over water access and no positive outcomes, key stakeholders took the lead to solve their problems by developing a common vision (Chaffin et al. 2016). To legitimize this process in the watershed, CONAGUA needs to play its role and establish a formal process that allows rapprochement between Mennonites and Mexican farmers. It needs to be clear for all stakeholders that water is finite and running low in the Rio del Carmen watershed. If economic profit is prioritised in the use of WES, it is necessary to have better control over water access, at least until a balance is achieved between recharge and extraction, and ultimately, to preserve the economic value of the watershed.

Unpacking the governance context is necessary to find the system's potential to apply AWG (Gunderson et al. 2016). Several structural and institutional complexities constitute obstacles (e.g. incompatible perceptions; poor management on CONAGUA's part). Knowledge co-creation is critical for increasing adaptability, but unravelling stakeholder perceptions and how they shape water access demonstrates how this process is a real and necessary entry point for enabling AWG. However, recognising the system's potential by understanding how society accesses and perceives WES, is only the first –necessary – step for enabling AWG in a water scarce context. Investigating the complexities of the relationships between governance actors, along with assessing the legal system that regulates the structures, capacities and processes of the governance system, are subsequent steps (Chaffin et al. 2016; Cosens et al. 2017), and would apply in both the Rio del Carmen and beyond.

5 Conclusion

Conservation of WES is imperative to build adaptive capacity in dryland systems. Success of AWG is based on recognition of the environmental state and stakeholders' perceptions of WES,

which ultimately indicate how and why water is accessed. This paper has three major conclusions. First, informal institutions like stakeholders' perceptions that are shaped by their cultural heritage can have a major influence, even more so than formal institutions. These perceptions of WES have led to the breach of formal institutions through illegal water exploitation and illegal conversion of grasslands, resulting in social and environmental crisis in the watershed.

Second, undesirable states can foster the emergence of leadership among stakeholders in order to change system conditions. For instance, the social movement "Defenders of the water of the Chihuahuan desert", where the grassroots organization El Barzon has participated actively in the conflicts over water access, has emerged as a consequence of this situation.

Third, even in SES with poor water management carried out by inefficient authorities, by unpacking societal perceptions and their underlying institutional context, entry points for enabling AWG can be found. It is important to be aware of the issues that led the system to an undesirable state in order to address and avoid them via participatory processes. Deeply rooted perceptions, lack of information and incompatibility among stakeholders are key barriers identified in the Rio del Carmen watershed. However, the ability of key stakeholders to unify and develop a common vision in the watershed is a pre-requisite to conserve WES and increase system adaptive capacity.

Acknowledgments

The first author acknowledges financial support from CONACYT-SECRETARIA DE ENERGIA-SUSTENTABILIDAD ENERGETICA Grant No. 439115.

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