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Seeking Common Ground in Dryland Systems: Steps Towards Adaptive Water Governance

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Abstract: Drylands are exposed to climate stressors, such as water scarcity, as well as societal stressors, including conflicts, which can make water governance unsuitable for the system's context. The emergence of adaptive water governance often takes places in these challenging contexts, but the process of achieving this style of governance requires a better consideration of system complexities. Using the Rio del Carmen watershed in Mexico as a case study, with primary data obtained through a questionnaire survey carried out with 217 farmers, this paper aims to identify the main complexities and needs to enable the emergence of adaptive water governance. We found that different groups of farmers converge in identifying system stressors and the main needs regarding water governance; yet, the ways these stressors are perceived differ between groups. The results indicate that contrasting perceptions are shaped by the different cultural roots and environmental conditions in the upper and lower parts of the watershed. This variation increases the difficulty in achieving collaboration and compromise when conflicts ensue. Reducing inequalities in the awareness of system stressors has the potential to enable adaptive water governance. This could be achieved through a peacebuilding technique with an appropriate cultural approach for the watershed's context in the early stages of a stakeholder engagement process.

Keywords: Mexico; social-ecological resilience; perceptions survey; agricultural systems; water scarcity; cultural sensitivity

1. Introduction

Drylands cover approximately 45% of the world's land surface [1,2]. Their human populations, consisting of the poorest and most marginalised people in the world [3] number 2.8 billion [2], with projections suggesting increases to 4 billion in the next 30 years [4]. Such growth increases pressure on limited water resources, reducing water ecosystem services (WES) that support natural resource-based livelihoods [5]. Moreover, drylands are highly conflict-prone areas [3] often exposed to environmental stressors like droughts and high temperatures [5]. This is a challenging context, as drylands' high climate variability can trigger larger impacts over the whole social-ecological system (SES), beyond the direct area of drought occurrence [6]. For instance, incidents of violent conflict in some places have been shown to increase by up to 45% when there are extreme droughts [4,7]. Looking to the near future, as drylands and their inhabitants are predicted to increase [4,8], so will other major issues such as poverty, migration, conflicts, and political instability [1].

Current notions of SES functioning show that contemporary conflicts are complex, and that societal (including cultural) and ecological (e.g., climate non-linearity) dynamics and interactions shape conflict occurrence [9]. The capacity to deal with these challenges and dynamics determines the risk of future conflicts [10]. However, traditional top-down and centralised water governance has often failed to address uncertainty and SES's changing conditions, leading to the collapse of WES and conflicts over access to them [11–13]. Adaptive water governance (AWG) has emerged as a way to foster adaptive capacity, moving from stiff and centralised water governance, towards more flexible, inclusive, and collaborative arrangements that can strengthen SES resilience in the face of uncertainty [11]. AWG is especially appropriate when conflicts and resource scarcity are increasing [14], and indeed, conflict is a common and sometimes necessary element of change [9]. Nevertheless, the literature suggests that social attributes such as perceptions and conflicts, which shape SES resilience, have not been properly captured [14]. These deficits need addressing to enable AWG. As drylands are more exposed to stressors such as conflicts and water scarcity than many other SES, finding ways to improve understanding and build resilience in that challenging context is paramount [15], yet, an important gap remains in terms of identifying the pertinent barriers and opportunities [16].

Given the gap in the literature on processes that seek to enable AWG in conflictive and water-scarce contexts, characterising dryland SES exposure, sensitivity, and adaptive capacity through a stakeholder lens, can unravel both the threats and the potential for moving towards AWG. This consideration is based on the understanding that (1) conflicts are commonly caused by opposing perceptions of needs, values, and interests [17] and that (2) identifying SES stressors and sensitivity is key to raising awareness of vulnerability, targeting adaptation strategies, and designing governance changes [18]. Moreover, understanding system stressors through stakeholders' perceptions is appropriate since societal influence over SES is shaped by how humans interact with the environment and understand ecological functioning [9,19]. Cognition of such SES complexities is important when facing uncertainty [18,20]. Addressing this challenge, we focus on understanding and differentiating between opposing perceptions and cultural constraints that undermine dryland adaptation, and the potential that stakeholders have to overcome their differences and enable AWG, using the Rio del Carmen watershed in Mexico as a case study. Our results show that perceptions are shaped by context-specific societal and ecological elements. In this sense, given that AWG is appropriate for a conflictive and resource-scarce context, we show that understanding SES threats through a stakeholder lens, has the potential to highlight key barriers and opportunities for enabling AWG. By doing so, we contribute solutions to one of the biggest dryland challenges: improving governance to support water management in conflictive and water-scarce contexts.

1.1. Literature Review

AWGs regimes are flexible, collaborative, and learning-based institutions, designed to adapt to changing relationships in society and between society and ecosystems, and which engage key stakeholders for an adaptive management of water resources and WES [21,22]. AWG has the potential to increase human adaptive capacity to better face non-linear and complex environmental changes [23]. To do so, the AWG conceptual framework establishes: (1) a legally binding authority and accountability to stakeholders; (2) that governance should operate with the institutional principles of flexibility, collaboration, iteration, and subsidiarity; and (3) that financial, technical and administrative resources are necessary for its sustainability [24]. In a dryland SES context with highly variable ecological conditions, such as extreme droughts and torrential rains [24,25], and social complexities, such as conflicts over water access [3,4], AWG is paramount to allowing SES functioning to continue [26]. Therefore, understanding exposure to stressors is important if AWG is to address them, especially if the SES shows sensitivity to them. Sensitivity considers the extent to which ecological functioning, human well-being, and livelihoods could be affected by exposure to SES stressors [15,27]. But also, sensitivity must be understood in terms of social fabric, as SES stressors have system-wide impacts on the social function of governance, and can undermine the system's adaptive capacity [28].

The literature claims that AWG is appropriate when an SES faces threats to social or ecological values, conflicts over scarce resources, or SES crises [29,30]. Since AWG aims to enhance the capacity of actors to cope with a diverse range of stressors, and to adapt or transform so they can continue to exist within the SES [31,32], dealing with potential conflicts and societal challenges that could arise when moving towards AWG is of great importance.

In the light of the above, tensions and conflicts need to be properly managed for engaging key stakeholders in a process that can potentially enable AWG [9,33]. Managing those tensions demands a better understanding of stakeholder perceptions since they shape collaboration and/or incompatible behaviours between stakeholders [26,34]. Moreover, perceptions influence decision-making processes [35,36] and affect human interaction with the environment [37]. In this sense, as adaptive capacity is based on collaboration, self-organisation, and learning to live with change [31,32], stakeholder perceptions must be recognised and incorporated in any engagement process. Unravelling stakeholder perceptions is thus paramount for understanding an intersubjective SES [17], and for identifying the main barriers to and opportunities in moving towards AWG [36].

2. Materials and Methods

2.1. The Rio del Carmen Watershed

The Rio del Carmen watershed is in Chihuahua, Mexico (Figure 1), and forms the case study focus of this paper. The main municipalities that make up the watershed are Ahumada, Buenaventura, Namiquipa, and Riva Palacio [38]. The watershed has four broad dryland biomes: grasslands, desert scrub, sandy desert vegetation, and forest [38]. The average annual rainfall ranges from 200 mm in the northern part (downstream) to 500 mm in the south (upstream) [38]. The Rio del Carmen is an endorheic watershed. [39]. Groundwater sources consist of 3 main aquifers that are overexploited: Santa Clara located upstream, and Flores-Magon—Villa Ahumada and Laguna de Patos, both of which are located downstream [24]. On the surface, the River Santa Clara later becomes the River Carmen, while in terms of hydraulic infrastructure, there is Las Lajas dam [40]. The National Water Commission (CONAGUA) is the government agency responsible for managing and issuing water rights, more than 90% of which are issued for agricultural purposes [41]. Accordingly, the main economic activity in the watershed is agriculture [38].

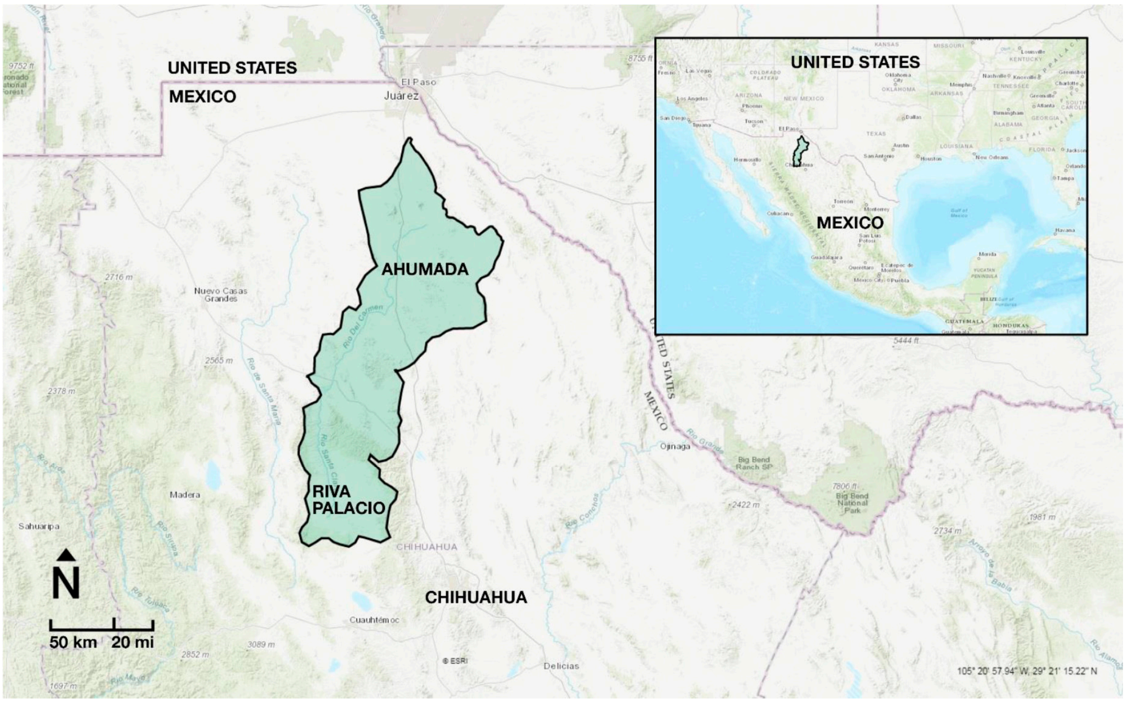

Figure 1. The Rio del Carmen watershed. Image obtained from the National Institute of Statistic and Geography of Mexico [42].

From around 1950, the Rio del Carmen watershed, specifically downstream, began experiencing a significant and disorganised increase in agricultural activity [43]. Given concerns about potential water depletion and the consequential impacts on agriculture, in 1957, an undefined period of restricted-access for new water exploitations was established [43]. This presidential decree had the following three main purposes: (1) establish restricted-access for surface water and groundwater, (2) order the construction of hydraulic infrastructure for agriculture in the area, and (3) establish Irrigation District El Carmen 089 to control agricultural development and access to hydraulic infrastructure [43]. Accordingly, a dam called Las Lajas with a capacity of 91.01 m^3 was built to be used by Irrigation District El Carmen 089 [38,40].

Irrigation Districts are institutional structures designed to support agricultural production, consisting of an agricultural surface, hydraulic infrastructure, the endowment of surface and groundwater, and legal protection for their activities [44]. Irrigation Districts need to be established through Presidential Decree, and have a hydraulic committee, including farmers, and a water district chief designated by CONAGUA [44]. Furthermore, they have their own regulations for the administration, operation, and conservation of land, agriculture, and water in the district [44]. Irrigation District El Carmen 089 is made up of two ejidos (agricultural communities that manage their land collectively), the ejido Benito Juarez and the ejido Constitucion. It has a total surface area of 20,815 ha, located downstream, and the main crops farmed by this district are chilli, pecans, cotton, alfalfa, and sorghum [40,45]. In general, the irrigation district does not have high-tech hydro-agricultural infrastructure, which leads to various inefficiencies in irrigation methods (including water leaks), generating an indiscriminate use of water [46]. Manzanares Rivera [47] states that ejidos' agricultural practices do not rely on intensive water use, and their production tends to be for self-consumption. However, Irrigation District El Carmen 089 has been characterised as having substantial agricultural production and a large expansion of its irrigated surface, which contradicts the ejidos' traditional agricultural production approach [48].

Upstream and downstream differences are not limited to climate conditions. Upstream areas are mainly occupied by a Mennonite agricultural community in contrast to the mostly Mexican traditional farmers found downstream [48]. In the early 20th century, Mennonites, a peaceful and secluded agricultural community originally from the Netherlands and Germany, were looking for new countries where they would be allowed to carry out their religious practices freely, so they made contact with the Mexican government [49]. In 1921, the President of Mexico issued a "privilegium", which consisted of a letter addressed to the representatives of the Old Colony Rheinland-Mennonite Church. While the Secretary of Agriculture and Development, and the Assistant Secretary for Foreign Affairs also signed the letter, it was never published in the Federal Official Gazette [50]. This letter gave freedom of worship, exemption from military service, the freedom to regulate their lands, and an autonomous school system without interference from the Mexican government to the Mennonite community, clearly contradicting the Political Constitution of the Mexican States [50]. Subsequently, between 1920 and 1930, Mennonites first established themselves in the Laguna de Bustillos watershed in Chihuahua before moving to other areas, like the Rio del Carmen watershed, as their population grew [48,49]. Although Mennonites acquire Mexican nationality by birth, Mennonite and Mexican traditional farmers differ in terms of their cultural identity [48,49].

Mennonite communities are characterised by their separation from the secular world, so they are isolated communities that provide their own education with strong religious connotations [49]. The configuration of the landscape built upstream by the Mennonite community (Figure 2), is intrinsically related to their cultural identity. They have found in agriculture an activity that allows them to isolate themselves geographically, which is also reflected in the shape of their human settlements [49]. Mennonites' ethos demands a life of effort and austerity to please God, so that in exchange God provides that which is necessary for the community [49]. However, modern Mennonites have migrated towards more profitable agriculture, with an unsustainable economic reorientation that has led to water overexploitation [48,49]. Manzanares Rivera, [47] has described this new Mennonite agricultural model as a highly specialised emerging development, which consists of a participatory model at the community level, with a cooperative dynamic that ranges from the acquisition of land, seeds, and irrigation technology, to the sale of the product in the market. The problem is that, at least in the state of Chihuahua, all the aquifers where these agricultural models are in operation, like the Santa Clara aquifer, are overexploited, which highlights the detachment that this model has with the ecological context where it is practiced [47,48].

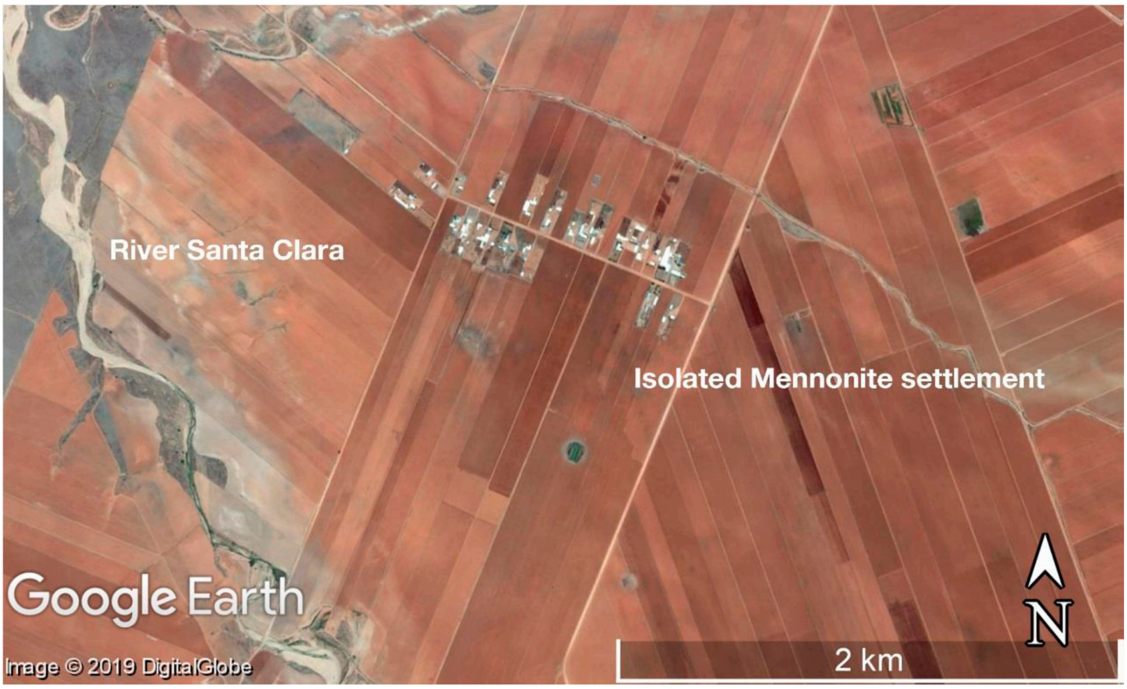

Figure 2. Mennonite settlement "Field 92" next to the River Santa Clara, that later becomes the River Carmen. Image obtained from Google [51].

Conflicts between upstream (Mennonites) and downstream (traditional Mexican) farmers started in the Rio Del Carman watershed in 2010, when water levels in downstream groundwater exploitations started to drop considerably, along with reduced water runoff in the River Carmen [48]. Following this, a group of Mexican farmers detected numerous Mennonite water exploitations that were protected by false water rights and rigged with the collusion of some CONAGUA officials [48,52]. Mexican farmers identified more than 200 illegal wells and 150 illegal dams in the watershed, and they had evidence that, for at least the last 10 years, CONAGUA officials had been charging between 12,000 and 25,000 US dollars for each apocryphal water right [53]. This situation led downstream farmers, some of which were affiliated to a grassroots militant activist organisation called El Barzon, to create a social movement called "defenders of the water of the Chihuahuan Desert", which represented more than 3000 Mexican farmers [48]. The fundamental demands of this group were that the government should:

1. Enforce the law and stop illegal water exploitation in the watershed;
2. Prosecute the illegal conversion of grasslands to croplands that was taking place upstream;
3. Not grant any kind of support or subsidy to farmers who illegally access water; and
4. Stop providing electricity to illegal exploitations in the watershed [48].

When these demands were not met, El Barzon, in coordination with other rural organisations, such as the Peasant Democratic Front and the National Peasant Confederation, began to carry out direct action to force the authorities to take them more seriously [48,53]. These acts of protest included the occupation of government offices, highways, and even aggression against government officials, until finally CONAGUA agreed to work with them in the identification and demolition of illegal water wells and dams placed to divert the flow of the river [48,53]. However, some members of El Barzon also began to burn crops that were being irrigated with illegal water exploitations [24,53]. At this point, Mennonites demanded that the Governor of Chihuahua and the President of Mexico stop the aggression against their community, arguing that CONAGUA should also inspect downstream illegal exploitations [53]. Given the widespread organised crime, the lack of judicial warrants, the lack of economic resources, and the lack of political will, amongst other issues, the closure of illegal water exploitations in the watershed could not continue [53]. To date, despite several attempts, principally from El Barzon, which has met with the Mennonite Central Committee and with several government agencies to resolve the situation and stop water overexploitation, illegal water access, corruption, and conflicts continue to permeate the SES dynamics of the Rio del Carmen watershed [36,48].

2.2. Data Collection

A questionnaire survey (Supplementary Materials) was conducted in Spanish in the Rio del Carmen watershed. From December 2017–February 2018 we surveyed the Mennonite community and the Mexican farmers located in the municipalities of Ahumada, Buenaventura (both downstream), Namiquipa, and Riva Palacio (both upstream). Questions considered water exploitation, legal water access, droughts, agricultural livelihoods, crime, conflicts, corruption, crop types, coordination, law enforcement, and the main problems and emerging needs in the watershed. Stratified sampling was used [54]. Accordingly, Table 1 shows a summary of Sections 2.2 and 2.3 regarding the collection and analysis methods used in this paper.

Table 1. Methods used for collecting and analysing the data needed for answering the main research questions.

Research Question	Data Collection	Data Analysis
Where are the vulnerabilities in current water governance in the Rio del Carmen watershed that undermine resilience?	For exposure: survey research and secondary data on drought indicators.	Frequency analysis on survey results regarding climate perceptions and secondary data regarding drought indicators.
	For sensitivity: survey research and secondary data on social conflicts, water availability and crop yields.	Incidence and severity index on survey results regarding the main problems in the watershed and frequency analysis on secondary data regarding the conflicts and crop yields.
	For adaptive capacity: survey research and secondary data on agricultural expansion.	Frequency analysis and chi-square test of independence on survey results regarding stakeholder perceptions. Frequency analysis on secondary data regarding agricultural expansion.
What potential does society have to enable AWG in the Rio del Carmen watershed?	Survey research.	Incidence and severity index on survey results regarding the main needs in the watershed.

The sample size was delimited by the number of water rights issued in the watershed and ascribed to the public registry of water rights. In March 2017, public water records were downloaded from the Mexican Government website https://datos.gob.mx/busca/dataset/concesiones-asignaciones-permisos-otorgados-y-registros-de-obras-situadas-en-zonas-de-libre-alu. Rights issued in the Rio del Carmen watershed were filtered to select those that were for agricultural use. A total of 494 rights were identified and ascribed: Flores-Magon—Villa Ahumada (downstream) had 268, Santa Clara (upstream) had 131, and Laguna de Patos (downstream) had 95. Each aquifer was considered a stratum, and simple random sampling took place within each [54]. With a population size of 494 water rights, using a sample size calculator [55], a 95% confidence level, and a 5% margin of error [56], the total sample size was 217, divided as: Flores-Magon—Villa Ahumada 117, Santa Clara 58, and Laguna de Patos 42.

However, because access to the Mennonite community located in the Santa Clara aquifer (upstream) was complex given their cultural preference not to engage with outsiders, the achieved sample was 55, and so the final sample was: Flores-Magon—Villa Ahumada 117, Santa Clara 55, and Laguna de Patos 45. Verbal consent was obtained, complying with ethical approval granted at the authors' institution.

During December 2018–February 2019, secondary data on agricultural production, water rights, crop yields, agricultural expansion, conflicts, water availability, and climate conditions were collected from the websites https://www.gob.mx/conagua, http://ocam.imta.mx/inicio.html, http://201.116.60.187/index.html, https://www.inegi.org.mx/, http://mosemm.conagua.gob.mx/, and http://www.dof.gob.mx/, all of which are maintained by the Federal Government of Mexico. The secondary information gained was used to complement the survey data.

2.3. Data Analysis

The results were translated into English in March–April 2018 and were transcribed and analysed using Microsoft Excel 2013. Along with the secondary data, we made a quantifiable estimation of vulnerability considering: (1) the SES's exposure to societal and climate stressors, (2) its sensitivity to structural change due to that exposure and, (3) its adaptive capacity to maintain SES stability during exposure [15,31]. Exposure to climate stressors was examined using survey results on climate change perceptions, along with the secondary data on drought indicators in Mexico obtained from http://mosemm.conagua.gob.mx/. Accordingly, perceptions on climate change were quantitatively analysed according to the frequency with which they were identified by the participants, and drought data was graphically represented according to the indices that mark if it is an extreme or exceptional drought. This allowed us to see which climate stressors are perceived as relevant, and how severe the droughts (as a climate stressor) were in the watershed. Next, using the survey results, we identified which problems were considered as major threats by the participants. This allowed us to characterise stakeholder perceptions on the watershed´s sensitivity to suffering harm, by ranking the problems according to their severity and incidence. To do this, we used an incidence and severity index approach [57]. In the survey, participants were asked to list and rank, with no limitations, the main problems in the Rio del Carmen watershed. Using the formula $Sj = 1 + (r - 1)/(n - 1)$, where Sj is the severity value, r is the rank, and n is the total number of problems mentioned by the respondent, we calculated their severity. This was done with every participant, then the average severity index was calculated for each problem by summing the Sj values of that problem and then dividing by the number of people who mentioned it. For the incidence index, the total number of times a problem was mentioned was divided by the total number of responses, producing a number ranging from zero (no incidence) to one (highest incidence). Accordingly, the incidence lets us know how commonly identified the problem is, while the severity index constitutes the perception of sensitivity to suffering harm from those problems. Afterwards, from the press and documentary database of water-related conflicts located on the government website (http://ocam.imta.mx/inicio.html) we identified the number of clashes in the watershed related to corruption, conflicts, water overexploitation, and its illegal access. This allowed us to identify if the SES was sensitive enough to stressors to generate violent conflicts among the agricultural communities in the watershed. Finally, with secondary data on water availability, and crop yields, we examined sensitivity by exploring how water overexploitation and droughts specifically affect water availability and agricultural production.

The investigation of the adaptive capacity used survey results that captured farmers' perceptions. As we said in Section 1.1, collaboration is a foundational element of adaptive capacity. By revealing how opposing perceptions have been inhibiting the collaboration between agricultural communities, we can understand the perceptions' influence on adaptive capacity. This allowed us to investigate how similar or different upstream/downstream perceptions are to one another and thus why collaboration has not been achieved. Accordingly, survey data regarding stakeholders' perceptions were analysed quantitatively according to frequency [58]. A chi-square test of independence was carried out [59], with the null hypothesis that both communities are equal in relation to their perceptions. Using frequency values from each group's perceptions, we calculated the expected values and then, using the CHISQ.TEST function from Microsoft Excel 2013, we calculated *p*-values for each perception. Using secondary data on agricultural expansion in the watershed, we then explored the extension of the agricultural frontier as an adaptation strategy and its effectiveness in facing climate stressors.

AWG has to operate in an institutional setting in which collaboration and self-organisation can take place. To identify common ground that allows collaboration, survey data related to the main needs in the watershed was analysed using incidence and severity indices [57]. The methodology is the same as with the identification of the main problems in the watershed, but this time, we asked the surveyed to list and rank the main needs in the watershed. Accordingly, results on the main needs highlight potential to use common needs among the agricultural communities as a route to facilitate collaboration in the watershed. Finally, to validate our survey results, secondary data on agricultural plantations, climate conditions, water granted, water availability, and natural recharge were analysed qualitatively, enabling data validation through methodological triangulation [60]. In this sense, for data validation, we verified that the survey results were consistent with the information obtained from secondary data and the literature on agricultural communities and water governance in the study site (e.g., [47,48,52]). The contradictions detected from survey results (e.g., Mennonites´ perceptions on corruption) were addressed through a complementary approach, highlighting what those differences were and analysing them in context [61]. This allowed us to understand and resolve those contradictions.

3. Results

3.1. Where Are the Vulnerabilities in Current Water Governance in the Rio del Carmen Watershed That Undermine Resilience?

3.1.1. Exposure

Here, we consider only the exposure to environmental stressors identified in the survey that can be supported by secondary data. Between 1997 and 2017, droughts increased, particularly in the downstream area of the watershed (Figures 3 and 4). Downstream areas have also experienced more severe droughts in recent years, while the most significant upstream drought period was from 1999 to 2000 (Figure 4). These differences between upstream and downstream climate conditions are reflected in perceptions, with more Mexican farmers (located downstream) perceiving droughts as a climate stressor.

Figure 3. Percentage of the upstream and downstream area affected by (**a**) exceptional and (**b**) extreme drought, from 1997 to 2017. Information obtained from the National Water Commission (CONAGUA) and the National Autonomous University of Mexico (UNAM), [62].

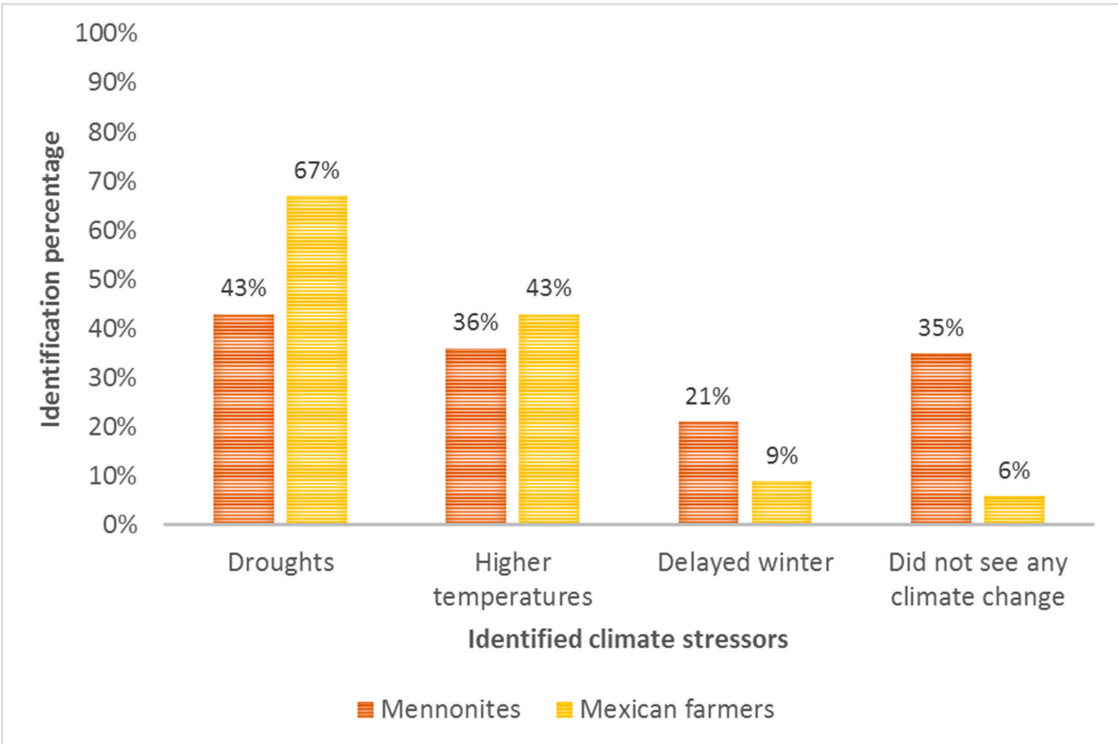

Figure 4. Survey results when the 217 participants were asked if they had seen any change in the climate conditions in the Rio del Carmen watershed between 1997 and 2017.

This evidence indicates that Mennonite and Mexican farmers' perceptions of climate change differ, because, in effect, the climate conditions upstream and downstream are different and hence their exposure to climate stressors, in this case drought, are different.

3.1.2. Sensitivity

According to our survey results, where we asked participants to list and rank the main problems in the watershed, we found that both farmer groups agree that the main problems are water overexploitation, illegal water access, droughts, corruption, and the breaching of the law (Figure 5). The higher in the graph, the greater the perceived incidence of the 'problem' during the survey, and the more to the right, the greater the perceived severity of the 'problem'. Most problems are of a social nature, for which the emergence of violent conflict can be used as an indicator of sensitivity to those societal stressors. According to a press and documentary database of water-related conflicts from 2012 to 2014, 16 incidents were recorded related to corruption, conflicts, water overexploitation and its illegal access [53]. This highlights that, regardless of its capacity to adapt to those stressors, water governance in the watershed is sensitive enough to the exposure of the identified problems in Figure 5 to generate social clashes.

Figure 5. Scatter plot that displays the problems identified by Mexican farmers (circles) and Mennonites (triangles) according to their severity and incidence. The severity index ranges from 0 (least severe) to 2 (most severe); the incidence index ranges from 0 (not mentioned) to 1 (most mentioned).

Although drought was identified as a problem, and evidence shows it is a climate stressor (Figure 3), its negative impact on water regulation and supply can only be validated for surface water, because from 2013 to 2018, no data showing variation in groundwater recharge had been published by the Mexican Government. As Table 2 shows, from 2013 to 2018, groundwater availability had been measured only by considering the changes in groundwater allocation through property rights, as if the climate dynamics that affect groundwater recharge were linear and stationary. However, perceptions over variations in water supply (Table 3) and conflicts over water overexploitation [53], confirm that the negative impacts on WES have been experienced by some stakeholders.

Table 2. Summary of the water sources in the watershed according to information published in the Mexican Official Journal of the Federation [39,63–67]. Figures are given in cubic meters per year.

Santa Clara Aquifer (Upstream)	Annual Groundwater Recharge	Groundwater Allocated	Groundwater Availability
2013	59.40	71.51	−12.11
2015	59.40	71.81	−12.41
2018	59.40	72.23	−12.83
Flores Magon-Villa Ahumada Aquifer (Downstream)	**Annual Groundwater Recharge**	**Groundwater Allocated**	**Groundwater Availability**
2013	137.50	247.77	−110.27
2015	137.50	247.88	−110.38
2018	137.50	253.81	−116.31
Laguna de Patos Aquifer (Downstream)	**Annual Groundwater Recharge**	**Groundwater Allocated**	**Groundwater Availability**
2013	11.00	10.67	0.32
2015	11.00	10.76	0.23
2018	11.00	37.14	−26.14
Upstream	**Water Runoff**	**Surface Water Allocated**	**Surface Water Availability**
2009	123.53	1.06	88.93
2013	74.74	0.86	44.91
2016	75.33	4.45	42.62
Downstream	**Water Runoff**	**Surface Water Allocated**	**Surface Water Availability**
2009	248.53	57.14	191.40
2013	174.22	57.13	117.09
2016	170.37	57.13	113.23

Table 3. Survey results that present the different perceptions between the Mennonites and the Mexican farmers in the Rio del Carmen watershed, over the same issues and the same period of time (1997–2017), with the *p*-value of the chi-square test for independence. Three asterisks mean that there is a significant difference between perceptions of the two groups of farmers, so the null hypothesis that states that that both communities are equal in relation to their perceptions cannot be accepted.

Survey Question	Mennonites		Mexican Farmers		*p*-Value of the Chi-Square Test for Independence.
	Yes	No	Yes	No	
Have you noticed any variation in the supply of water from your exploitations?	6	49	152	10	$p < 0.001$ ***
Have you noticed any deterioration in the Rio del Carmen watershed grasslands?	23	32	143	19	$p < 0.001$ ***
Have you been involved in any conflict over water access?	3	52	126	36	$p < 0.001$ ***
Have you seen any illegal water exploitation in the watershed?	9	46	122	40	$p < 0.001$ ***
Have you witnessed any act of corruption in relation to access to water in the watershed?	6	49	105	57	$p < 0.001$ ***

In terms of agriculture's sensitivity to drought, during 2012–2015, key crop yields saw minimal increases, except for maize, which suffered a significant decrease (Figure 6). Likewise, the total agricultural yield of Irrigation District El Carmen 089 has remained constant, ranging from 23.10 tons/ha in 2011 to 23.70 tons/ha in 2015 [45]. However, Table 2 shows that groundwater allocation (which is mainly for agriculture [38]) has been increasing from 2013–2018 and that upstream surface water allocated has substantially increased between 2009 and 2016. Moreover, from 2012 to 2015, in the same municipalities, the area sown with drought resistant varieties increased by 26,160 ha, and the fertilized surface increased by 23,994 ha [68,69]. The lack of yield increase, and in the case of maize, a yield decline, suggests that these investments in improving agriculture, along with the increasing water allocation for agricultural purposes, have only managed to maintain the status quo.

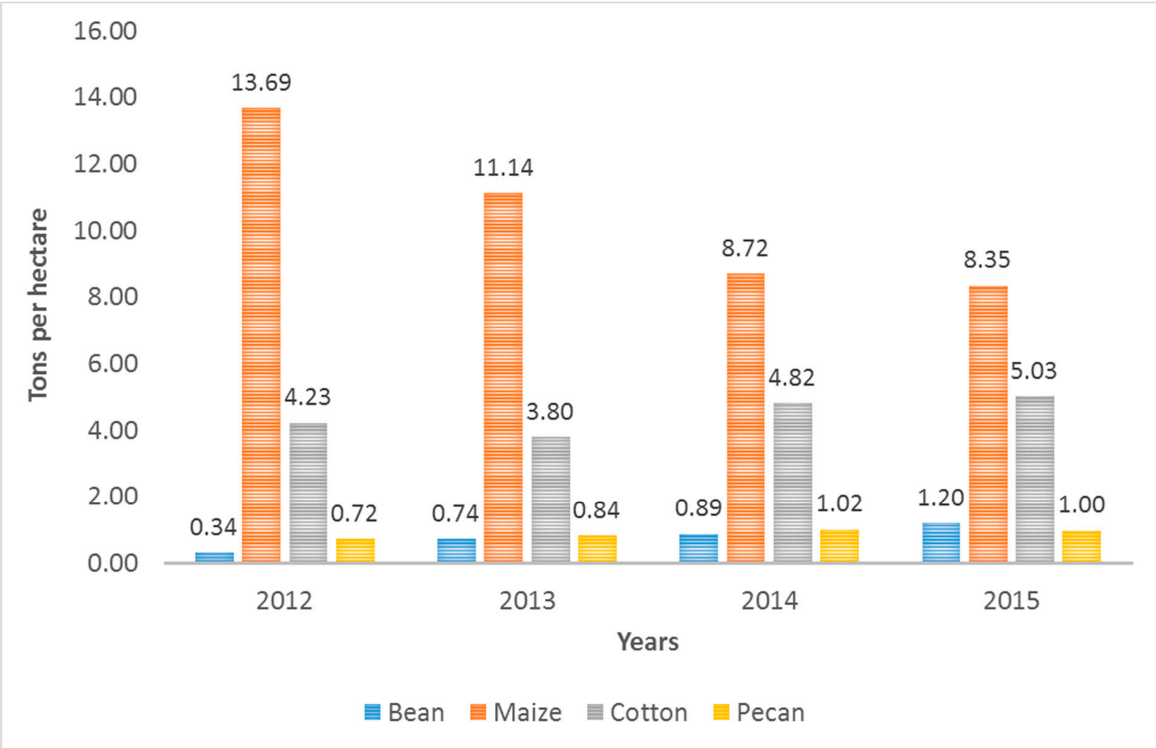

Figure 6. Main crop yields in key municipalities in the Rio del Carmen watershed from 2012–2015. Information obtained from INEGI, [68–71].

3.1.3. Adaptive Capacity

As stated in Section 1.1, adaptive capacity is founded on collaboration and self-organisation. Therefore, analysing stakeholder perceptions that allow or hinder collaboration and self-organisation, on which adaptive capacity is based is, important. Table 3 shows the results of the survey analysis of perceptions, in which a significant difference in perceptions between the agricultural communities is found. Most Mennonites said that they had not experienced water variation or deterioration, or seen conflict, corruption or illegal water exploitation, in stark contrast to responses from Mexican farmers.

It is important to put these results in context, since the Mennonites are a close knit and isolated community. Accepting that they have witnessed of an act of corruption would mean acknowledging that they have seen someone in their community committing it; this would transgress their intimate social cohesion [49]. Nevertheless, Mennonites do recognise a corruption problem in the watershed as a whole (Figure 5).

Livelihood aspirations for increasing agricultural production have led to maladaptive actions. Although yields have not increased despite investments in improved seeds and fertilizers (Figure 6), the agricultural frontier in the same municipalities has extended (Figure 7).

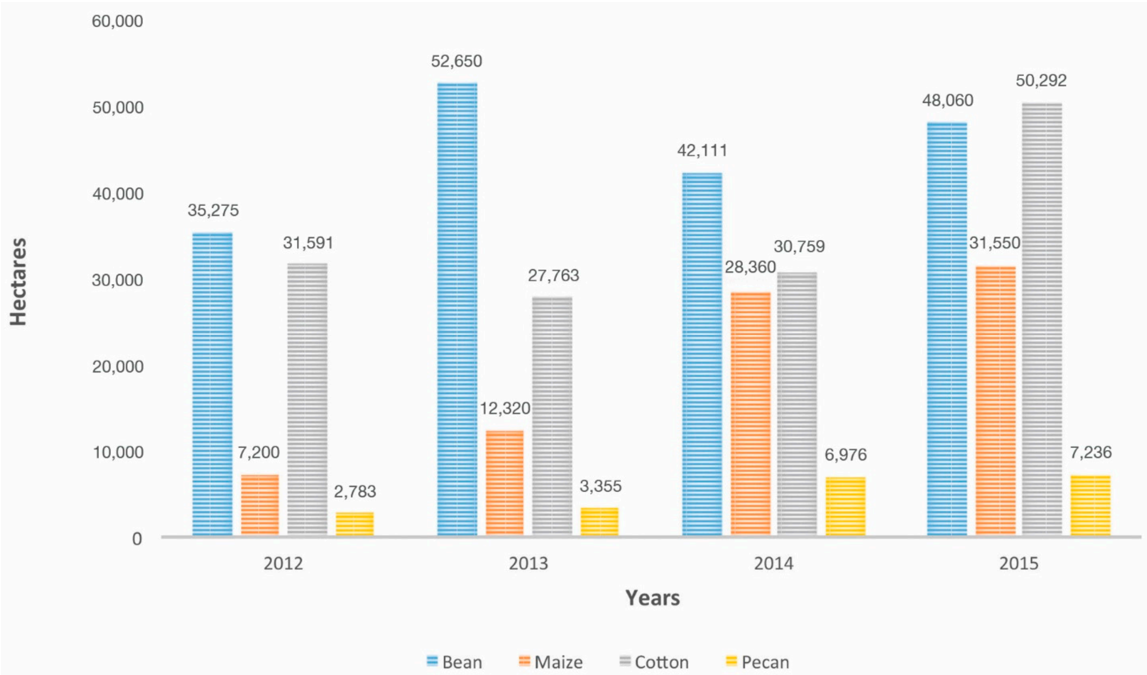

Figure 7. Hectares sown with the main crops in the key municipalities that make up the Rio del Carmen watershed, from 2012–2015. Information obtained from INEGI, [68–71].

The most prominent indicator of this maladaptation is seen in maize. In 4 years, its agricultural frontier increased by 338%, (Figure 7) but yields decreased by 39% (Figure 6). Moreover, climate stressors have influenced over-dependency on already overexploited groundwater. Table 2 shows that there is surface water availability to meet water needs in the watershed. However, it is unlikely that annual runoff will be consistent year on year given the risk of drought (Figure 4), so groundwater is considered a safer bet by most farmers. Furthermore, Las Lajas dam is the only hydraulic infrastructure that can guarantee agricultural water needs, yet, the Irrigation District El Carmen 089 has almost exclusive water access rights [40,72] which means that many farmers have no choice but to rely on decreasing groundwater reserves.

3.2. What Potential Does Society Have to Enable AWG in the Rio del Carmen Watershed?

Enabling the collaboration necessary for AWG first requires the identification of common ground between the watershed's agricultural communities. To do this, survey participants were asked to list and rank the main needs in the watershed. Results are shown in Figure 8 according to their importance and incidence.

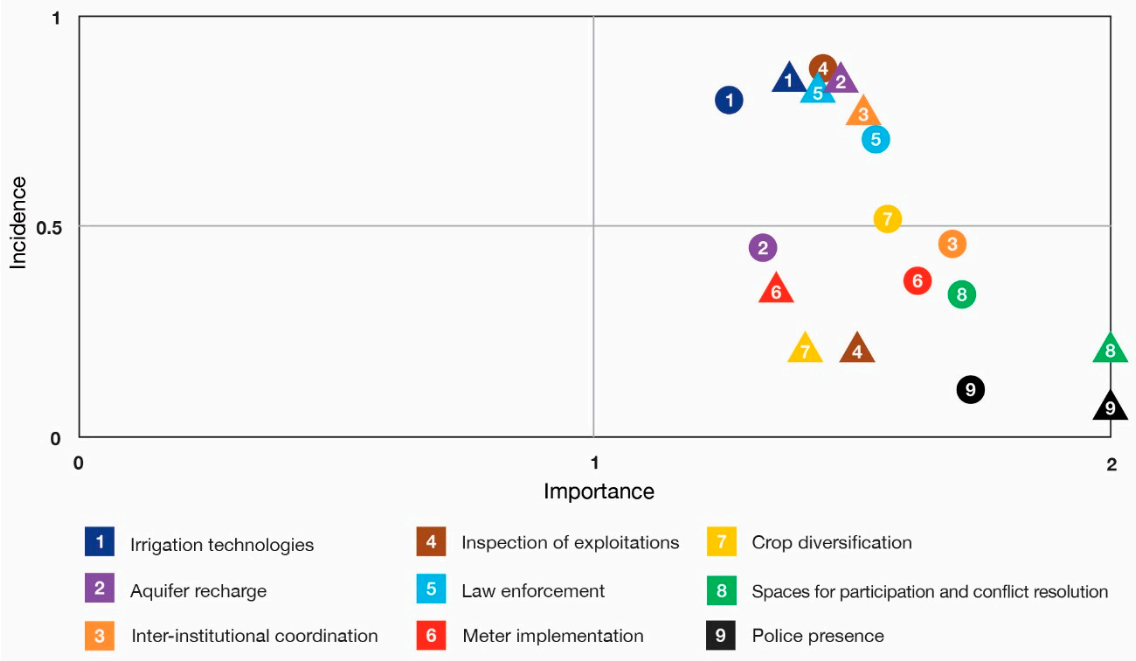

Figure 8. A scatter graph that displays the needs identified by Mexican farmers (circles) and Mennonites (triangles) according to their importance and incidence. The importance index ranges from 0 (least important) to 2 (most important), and the incidence index ranges from 0 (not mentioned) to 1 (most mentioned).

Irrigation technologies (need 1) and law enforcement (need 5) emerge as areas of agreement; they were mentioned with a similar level of incidence, and ranked at a similar level of importance (Figure 8), offering potential to address the system's sensitivity to climate and societal stressors accordingly.

4. Discussion

Unravelling dryland exposure, sensitivity, and adaptive capacity, as well as identifying the changes needed according to the context, provides insights for more informed pathways towards AWG. Characterising the Rio del Carmen watershed's vulnerabilities through a stakeholder lens has laid the groundwork for determining that dryland SESs are not only exposed to climate stressors and have helped to identify inequalities in awareness and conflicting perceptions that might act as barriers to AWG.

Despite the Rio Del Carmen watershed's exposure to drought and water overexploitation, we found that stakeholders´ perceptions and behavioural norms are diverse, with significant differences between Mennonite and Mexican farmers. This is because, as stated in Section 2.1, the ways stakeholders experience social–ecological interplay is shaped by both environmental conditions and cultural constraints [57]. Our results show that Mennonites do not experience the same climate stressors at the same time and intensity as Mexican farmers (Figures 3 and 4). Additionally, as part of their culture and faith, many Mennonites do not believe that groundwater can be overexploited, believing that God will provide unlimited water [36]. Conversely, the results show that although Mexican farmers have increased their agricultural activity to sustain yields (see Section 3.1.2), they also recognise drought and groundwater overexploitation, because they have had to modify their water exploitations and deepen their wells in response to reduced water availability [24].

Climate stressors have led to maladaptation, as demonstrated through land-use changes that have expanded the agricultural frontier and increased reliance on groundwater. We found that these changes did not lead to a significant yield improvement (Figure 6). So, to increase agricultural production, farmers have converted the Chihuahuan desert grasslands to farmland, with the literature indicating this has mostly been done illegally [36]. Moreover, farmers' reliance on groundwater as a drought adaptation is maladaptive at the watershed scale, causing aquifer depletion [73]. A similar case can be found in the Rio Grande Basin, where farmers' groundwater exploitation as a drought buffer caused legal disputes between the states of Texas and New Mexico because it was leading to aquafer depletion [73]. In the Rio del Carmen watershed, these maladaptive strategies could be addressed through AWG, yet, several social complexities present barriers to achieving this, for instance, the societal stressors that are leading to social clashes in the area.

The integration of societal stressors within a vulnerability characterisation provides a valuable understanding of social influences over SES adaptation. In this case study, it is shown that if an SES is sensitive enough to societal stressors, such as illegal water access, corruption, and the breaching of the law, it will lead to social clashes, undermining human adaptive capacity in terms of collaboration and self-organisation. It highlights that social vulnerability is not only about poverty and marginalisation, because the absence of good social relations, security and peace all increase vulnerability in terms of human well-being [37]. Moreover, our findings help to increase our understanding of vulnerability by including other intersecting social processes (e.g., the interaction between opposing perceptions and illegal water access) that are the differential factors between the vulnerability to climate change and the vulnerability to SES stressors [74]. Exposure to SES stressors is not only environment-related [74]. As reported in Section 2.1, in the Rio del Carmen watershed, societal stressors have caused 16 conflict incidents in two years, consisting of social clashes, dam destruction, and the burning of crops, illustrating the fragile context of conflict dynamics [33]. Nevertheless, societal stressors are not exclusively linked to resource scarcity, as they are institutionally embedded in, e.g., intensive agriculture's externalities or the adoption of corrupt practices [24]. This is similar to the situation in Southeast Asia, where forestry, water, and mining sectors have generated several societal stressors, e.g., human rights violations and unequal distributions of costs and benefits, resulting in conflicts and violent rebellions [75]. Addressing both climate and societal stressors is thus paramount for advancing adaptation.

Another identified societal stressor is corruption (Figure 5), which plays a major role in the lack of collaboration. Corruption has been exacerbating inequalities between agricultural communities in terms of water access and has played a key role in determining who is affected by water overexploitation [48]. No one wants corruption. Mennonites do not like that they were victims of it, but since they were deceived into buying apocryphal water rights by some CONAGUA officials, sustaining a relationship based on corruption is the only way through which some of them can continue farming [24]. This explains why Mennonites said that they had not witnessed an act of corruption (Table 3): claiming otherwise implies that the participant or someone close to them has been part of it. Trusting that the community will take care of its members is a basic element of Mennonite culture and of the construction of its collective identity [49,76]. Expecting that they will reveal who is responsible for corruption or illegal water access within their community is unrealistic [48]. Again, this does not mean that Mennonites do not recognise corruption as a problem, because as Figure 5 shows, they do, but stating they have witnessed corruption carries other implications, which explains the survey results in Table 3. Given societal complexities like this, confrontation and incrimination between the agricultural communities only worsens the situation [24]. The absence of a culturally sensitive approach to the Mennonites, and the lack of recognition of opposing perceptions (Table 3) when dealing with illegal water access and its overexploitation, has meant a lack of positive results [36,52]. Such cultural insensitivity undermines the extrapolation of proven solutions to diverse conflict settings [10]. Understanding the Mennonites' cultural approach is necessary to allow a rapprochement between these communities [49]. Nevertheless, identifying common ground between both agricultural communities as a starting point for this rapprochement is the first step.

Principles identified in the AWG framework, such as learning and collaboration for achieving adaptation through common goals (e.g., irrigation technology and law enforcement), have the potential to address societal stressors, by aligning the two communities' incentives to address the watershed's problems [77]. Collaboration also depends on achieving greater equity between communities, allowing them to develop similar levels of awareness about the climate at wider scales (Figure 4) and to better understand the societal stressors they face (Figure 5). Developing a more equal awareness is of great significance, because if Mennonites think they will not get the same benefits as the Mexican farmers, they may not have the same incentives to collaborate [78]. Identifying common needs between agricultural communities (Figure 8) enhances the exchange of ideas and views, to deliberate and negotiate solutions to common problems as part of a learning process [79]. Accordingly, social learning co-generates ecological knowledge to address climate stressors, while building an understanding of how to cooperate and collaborate with conflicting stakeholders to address the societal stressors [80]. This will not necessarily modify cultural constraints or trigger change, but can establish the institutional setting to advance adaptation by adjusting agricultural livelihoods to the watershed´s context through social learning [80]. Learning will also require, for instance, collaboration to address monitoring deficiencies on groundwater recharge (Table 2) to support adjustment of farming practices to ecological conditions. Collaboration enables stakeholders to devise and develop suitable and multi-perspective solutions [78], meaning that stakeholder engagement is appropriate for developing solutions to commonly identified problems [77,81], similar to the ones shown in Figure 5. Nonetheless, neither Mennonites nor CONAGUA officials will participate in any collaborative process if they are seen as the source of the corruption problem or responsible for current disputes [82].

Peace is not the absence of conflict, but the ability to manage and transform it [13]. In the Rio del Carmen watershed, this means the ability to manage opposing perceptions (Table 3) in order to allow agriculture to continue. Peacebuilding comprises different strategies, ranging from negotiations, mediation, and conflict resolution, to institutional strengthening and economic development [10,13]. Understanding this is important, especially in dryland contexts where there is a lot of competition for scarce resources [3]. A peacebuilding process as a starting point for enabling AWG could potentially reconcile the agricultural communities in the watershed in a non-conflictual way, addressing the root of the disagreements, and building common frames, needs, and interests [10,33]. AWG principles need to be embedded in peacebuilding in terms of adaptation to future adversities, rather than taking a conflict approach that will increase vulnerability [33]. Considering peacebuilding to enable AWG is important, as AWG emergence often takes place in undesirable states of governance and a conflictive context, delaying any transition to another governance regime. For instance, in the in the Klamath River, USA, it took about 10 years to resolve legal, political, and physical contestations between different productive sectors and indigenous communities in order to allow the emergence of adaptive governance [83,84]. A first step in peacebuilding for adaptive governance is to identify leadership among the agricultural communities [33]. This is straightforward since the Irrigation District is a structured organization formed by irrigation associations and a water district chief [24], while the Mennonite community is very closely connected through religion and family, with a community head that has representativeness, legitimacy, and accountability [49,76]. Then, focusing on common needs and problems that bring people together despite the conflicts, by highlighting and recognising each communities' capacities, sets the stage for a peacebuilding process [33]. This is especially important in drylands with extreme droughts, like the Rio del Carmen watershed. Hence, identifying vulnerabilities, problems, and needs, as we have here, is key for starting a peacebuilding process grounded in stakeholder engagement, which can ultimately enable AWG.

5. Conclusions

AWG offers potential to increase the dryland SES adaptive capacity by addressing both climate and societal stressors. Understanding the role of societal factors in shaping SES resilience provides important insights for defining context-specific AWG. In seeking to achieve AWG, it is necessary to acknowledge stakeholder perceptions of exposure, sensitivity, and adaptive capacity, as this highlights the potential for enabling AWG and system needs. The Rio del Carmen watershed case provides important insights on how to unravel SES components in order to understand exposure to societal and climate stressors, and how context-specific procedures can be designed to overcome them. Such insights offer important guidance for other watersheds globally.

The Rio del Carmen dryland context is challenging: livelihoods rely on overexploited groundwater; it has nuanced exposure to droughts; and it has illegal water access, corruption, inequality, and legal breaches that are exacerbating existing conflicts over water access. Nevertheless, irrigation technologies and law enforcement are common needs in the watershed that can be leveraged to initiate stakeholder engagement as part of a process of peacebuilding. Conflicts and cultural differences require a peacebuilding process in the early stages of stakeholder engagement. This requires working on and developing common frames, needs, and interests, in order to achieve enduring and suitable AWG.

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