Towards adaptive water governance in dryland social-ecological systems: the case of the Rio del Carmen watershed

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The candidate confirms that the work submitted is his own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

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Abstract

Drylands are ecologically restricted by water scarcity, limiting the water ecosystem services that can contribute to human well-being. At the same time, the 2.5 billion people living in drylands are considered the poorest and most marginalized people in the world. Given this challenging context, drylands, as coupled social-ecological systems, are prone to suffer harm from non-linear stressors such as droughts, climate change, as well as the mismanagement of water ecosystem services, with important implications for livelihoods. Adaptive water governance has the potential to increase dryland resilience in the face of uncertainty, through institutional arrangements that enable flexibility, iteration, subsidiarity, and collaboration. However, when advancing adaptation efforts, water governance assessments and reforms tend to fail because of a lack of a comprehensive analysis of the social-ecological context and its complexities.

To provide important insights to strengthen dryland resilience, this thesis analyses water governance in the Rio del Carmen watershed in the Chihuahuan Desert, Mexico. Based on primary data from semi-structured interviews and survey research, this thesis explores how stakeholders perceive water ecosystem services and how water governance regulates their access; the governance vulnerabilities that undermine dryland adaptation; and the potential that stakeholders have to overcome them and enable adaptive water governance.

Results show that formal institutions that do not consider informal institutions (including stakeholder perceptions, farming practices, religious beliefs, and corruption) when addressing local needs, undermine the effectiveness of governance. In the Rio del Carmen watershed, this has led to impacts on both the environment and society in the form of water overexploitation, grassland loss, water mismanagement, legal breaches, and social clashes. Findings suggest that developing a common awareness about water ecosystem services among stakeholders has the potential to engage them and ultimately help establish a formal network guided by adaptive governance approaches. Accordingly, this thesis derives three principles for moving towards adaptive water governance, highlighting the need to recognise the exposure and sensitivity to societal and climate stressors, and to

adjust the institutional setting to these context-specific issues. The principles aim to enhance the implications of resilience theory for scholars and practitioners working on dryland resilience and adaptation, so the expansion and degradation of drylands can be better addressed.

Table of Contents

List of Tables

List of Figures

Abbreviations

AWG	Adaptive water governance
CONAGUA	Mexican National Water Commission
DOF	Mexican Federal Official Gazette
IMTA	Mexican Institute of Water Technology
INEGI	Mexican National Institute of Statistic and Geography
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
LAN	Mexican National Water Law
OECD	Organisation for Economic Co-operation and Development
SAGARPA	Mexican Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food
SEMARNAT	Mexican Ministry of the Environment and Natural Resources
SES	Social-ecological system
WES	Water ecosystem services

Chapter 1

Abstract

Given their challenging context, drylands are socially and environmentally prone to suffer harm from non-linear stressors, which may be of a social or ecological nature. Water governance regimes are often incompatible with social-ecological conditions in drylands, and this plays a major role in their exposure, sensitivity, and vulnerability to stressors. Using the Rio del Carmen watershed as a case study, this thesis aims to analyse water governance, identifying barriers and entry points in governance structure and processes, with a view to improving the system's adaptive capacity. Chapter 1 introduces the social-ecological system approach, resilience and vulnerability theory, the adaptive governance literature, methods, questions, and objectives, as well as the implications for increasing adaptive capacity in dryland systems, obtained from this case study. Moreover, this Chapter explains the structure of the thesis, and gives an overview of its content. The Chapter concludes by discussing the knowledge gaps addressed by the thesis, along with the contributions to literature obtained from this research.

1.1 Introduction

Drylands cover 45% of the world's land surface (Plaza et al., 2018; Prăvălie, 2016), which illustrates a worrisome increase with respect to the last estimation of 41% published in 2005 (Safriel et al., 2005). Accordingly, it is estimated that dryland populations have reached 2.8 billion (Plaza et al., 2018), and it is projected that this number will increase to 4 billion in the next 30 years (IPBES, 2018). This is important because dryland inhabitants are the poorest, least healthy, hungriest, and most marginalized people in the world, living in highly conflict-prone areas (Middleton et al., 2011), where water limitations make it difficult to secure water ecosystem services (WES) and human welfare (Prăvălie, 2016).

Globally, 50% of cropland and 74% of pastures are located in drylands (Plaza et al., 2018), however, drylands' capacity to support these livelihoods has diminished (IPBES, 2018). Drylands are particularly exposed to climate-stressors, such as droughts, which have nuanced negative effects on both livelihoods and the environment (Reed and Stringer, 2016), compromising the ecosystem and human subsistence (Huang et al., 2017). Governance failures to address climate-stressors according to local needs, have been restricting dryland development and endangering livelihoods. This is especially so where the unsuccessful approach to environmental uncertainty has been to try to fix and maintain the status quo instead of adapt (Davies et al., 2016). Dryland degradation is mainly human-induced, so in order to prevent, reduce and reverse degradation, allow dryland development while increasing drylands' resilience, modifying the governance of natural resources is required (IPBES, 2018). Indeed, water-related problems are directly related to water governance, for which, considering a different approach in governance regimes is paramount, yet presents major challenges (Loë and Patterson, 2017).

Water regulation is the overarching dryland ecosystem service which has a cascading effect on all dryland livelihoods (Safriel et al., 2005). The point of departure of this thesis is that shifting towards adaptive water governance that enhances WES conservation in the face of uncertainty could reduce dryland degradation and better support natural resource based livelihoods.

1.2 Major challenges in dryland development

Reynolds et al. (2007) highlight a set of biophysical and socioeconomic features that dominate dryland dynamics, called "dryland syndromes". These features consist of highly variable social-ecological conditions, low soil fertility, as well as the sparseness, remoteness, and lack of voice of their inhabitants. These factors have significant impacts on dryland livelihoods that are mainly natural resource based (Safriel et al., 2005). For instance, drylands' low fertility has negative impacts on both tillage and grazing, limiting productivity and increasing livelihood sensitivity to land degradation and economic instability (IPBES, 2018; Reynolds et al., 2007). Drylands' high climate variability, which includes periods of drought, is associated with an increase in violent conflicts (up to 45 percent (IPBES, 2018)), likewise, higher temperatures are associated with poverty, marginalisation and land degradation (Huang et al., 2016).

Overall climate change and land degradation have negative impacts on food security, water supply, and gross domestic product (Huang et al., 2017; IPBES, 2018). Therefore, as drylands and their inhabitants are predicted to increase (Huang et al., 2016; IPBES, 2018), so will other major issues such as poverty accentuation, migration, conflicts, and political instability (Prăvălie, 2016). Accordingly, climate change and land degradation contribute not only to violent conflicts over resource access, but also to migration. Estimates suggest that increasing desertification will potentially force 50 to 700 million people to migrate by 2050, and the consequences of this are unpredictable (IPBES, 2018). Addressing climate change and land degradation to target sustainability goals is complex as these issues are closely interlinked. Reducing dryland vulnerability to threats and increasing general resilience is paramount in this challenging context (Reed and Stringer, 2016) to allow drylands to increase their capacity for adaptation, learning, and transformation while maintaining their essential functions and natural resource-based livelihoods, in spite of dryland syndromes (Reed and Stringer, 2016). Understanding what makes a system resilient or vulnerable, especially in dryland contexts, requires a deeper analysis, especially given their implications for dryland development, and potential impacts of migration and conflicts which will extend beyond the drylands.

1.3 Resilience and vulnerability in drylands

In this thesis, resilience in drylands is defined as the ability to cope with a diverse range of stressors and shocks, and to adapt or transform in the face of uncertainty; in order to achieve development, human well-being, and secure the WES on which livelihoods directly rely (Barrett and Constas, 2014; Mortimore et al., 2009; Reed and Stringer, 2015). This thesis considers vulnerability of the social-ecological system (SES) to be the "propensity to suffer harm from exposure to external stresses and shocks" (Gunderson *et al.*, 2010, p. 52). If a dryland system is exposed, sensitive and unable to adapt effectively to change, then it will not be able to maintain its ecosystem functioning, to support its livelihoods, nor adapt to future changes, so it will become vulnerable (Reed and Stringer, 2016). Accordingly, these adaptive responses can range from incremental changes (e.g., ecological restoration) to transformational changes (e.g., moving from crops to an agro-pastoral system) when any of the ecological, economic or social structures become untenable (Gunderson et al., 2010; IPCC, 2014; O'Connell et al., 2016).

The relationship between resilience and vulnerability is complex. SES can be resilient and vulnerable at the same time, while some elements that can be considered as features of resilience, in reality, could be increasing SES vulnerability (Miller et al., 2010). This situation refers to the type of resilience that has been strengthened, and can include: specified resilience, which consists of the resilience of a part of the SES to specific stressors, or general resilience, which applies to the SES as a whole without considering any particular stressor (Gunderson et al., 2010). For instance, an agricultural community located in a dryland system may try to strengthen specified resilience of crop production to droughts, and this strategy could consist of increasing groundwater use for irrigation, similar to what has happened in this case study. However, there are two problems that can arise from these situations.

First, maintaining agricultural coping strategies for certain persisting social and economic conditions, undermines SES adaptive capacity, by hindering innovation and social learning (Miller et al., 2010). This case study shows that by strengthening specific agricultural resilience to variable rainfall and economic insecurity by investing in large agricultural developments, deep-water well equipment and profitable crops, agriculture has become highly vulnerable to water depletion in the context of no other livelihood options. Similarly, a case study in Mozambique showed that smallholder rural drought coping strategies, which were carried out to maintain their traditions and the status quo, like relying on birds and wild plants for consumption, increased vulnerability to climate change, reinforced poverty, and slowed collaboration to propose new strategies (Osbahr et al., 2008).

Secondly, when strategies are adopted at a farm or rural household level they tend to negatively impact general resilience at a wider scale, which may generate conflicts at local, regional, national or even international scale (Garrick, 2018). Accordingly, a lack of agricultural planning in the Rio del Carmen watershed, the case study in this thesis, has left the adoption of agricultural practices at the farmers' discretion, according to their own socio-economic portfolios, without considering the externalities that this may generate. Indeed, strategies that aim to strengthen specified resilience to particular stressors, but which adversely impact general resilience and increase SES vulnerability, are known as maladaptive (Barnett and O'Neill, 2010; Dixon and Stringer, 2015).

Superimposing specified resilience of the social or the ecological over each other also undermines general resilience, because in doing so, social-ecological interplay will not be properly captured (Nemec et al., 2014). Being purely environmentally sustainable, or, on the other hand, focusing on the resilience of human well-being, both present trade-offs and will increase the vulnerabilities of one or the other (Folke, 2016). For instance, the Endangered Species Act in the USA generally seeks to return already transformed ecosystems to previous ecological states, focusing on the restoration of habitat in order to conserve a single species, without considering the broader social, political, and economic implications that limits its effectiveness (DeCaro et al., 2017b). As a result, given its absolute prohibition approach, the Endangered Species Act is very unpopular with all natural resource users affected by its prohibitions, and this has produced a strong political backlash because it has been blamed for declining economic development (Arnold and Gunderson, 2013). Matching the governance scale to the relevant ecological scale is also an important issue that commonly undermines SES resilience (Chaffin et al., 2014b). In this regard, social resilience tends to be understood at one scale, often at that of the community, while ecosystem functioning means that extended ecological feedbacks affect a wider scale, like upstream/downstream problems at the watershed scale (Miller et al., 2010). Accordingly, general resilience at a scale that fits both the social and ecological components, is more appropriate when coping with and adapting to uncertainty (Chaffin et al., 2014b; Dixon and Stringer, 2015).

Resilience and vulnerability approaches are equally significant and complementary when analysing SES: resilience aims to secure future sustainability, while vulnerability seeks to identify opportunities for coping and adaptation (Miller et al., 2010). Accordingly, another similarity between both concepts refers to their approach. Specified resilience discusses the resilience "of what, to what", and understanding that working on this approach can potentially undermine general resilience is important (Gunderson et al., 2010). But equally important is to understand that defining "who is vulnerable to what" (Downing et al., 2006), plays a major role in our ability (or inability) to capture SES threats and stressors. When vulnerability is influenced by several intersecting social processes that have not been properly considered (IPCC, 2014), adaptation often fails to address the persistent and intractable stressors that increase SES vulnerability (Miller et al., 2010). For example, distrust in the authorities and political rivalry were identified as some of the main problems in Nepal's vulnerability to floods, as they were hindering the rule of law and state action to face climate change (Smith and Vivekananda, 2009). When assessing SES exposure to harm, the social dimension has only been integrated in terms of livelihoods or economic vulnerability, with focus often being placed on poverty (Downing et al., 2006). Exposure to harm has not been captured in terms of security, good social relations, peace of mind and spiritual experience as basic elements of human well-being (Díaz et al., 2015). This situation can be better understood by considering the conflict between the mining industry, indigenous communities, and the government in the sacred territory of Wirikuta, in Mexico. In the 1980s Mexico was undergoing a severe economic crisis. In order to access international credit, the World Bank, the Inter-American Development Bank, and the International Monetary Fund demanded that Mexico adopt neo-liberal policies (Stoltenborg and Boelens, 2016). The Mexican legal framework (e.g. the Mining Law and Foreign Investment Law) was substantially reformed to enable foreign investment, especially in the mining sector, by giving it the character of "public utility"[1] (Stoltenborg and Boelens, 2016). When a Canadian Mining Company was established in Wirikuta, fully supported by the government, despite the area being formally declared as an ecological and cultural area, an indigenous community called Huichol protested against the Mining Company since Wirikuta was an area of pilgrimage and of high religious value (Alfie Cohen, 2015). The Mining Company and the government offered money to the communities to settle the problem, yet, given the government's inability to safeguard the institutions, culture, and environment of the indigenous people, as well as engage in a dialogue with them, the situation resulted in long legal disputes (Alfie Cohen, 2015). This highlights that social vulnerability encompasses more than poverty and that adapting the legal framework to focus only on economic development, generates societal stressors that increase vulnerability to the loss of ethnicity, culture, and lifestyle. By integrating these elements and understanding their role in shaping vulnerability, we can have a better idea of their importance in shaping resilience.

[1] In case of public utility, the government has to carry out the necessary procedures, such as expropriation, to guarantee the provision of public services and satisfaction of collective needs such as health, education, economic development among others (LDE, 2012).

New concepts such as social fabric help to complement our understanding of what social vulnerability is in terms of solidarity, protection, human rights, ethnic composition, and regional values (Hábitat México, 2018). Yet, research in this regard is currently sparse.

The greater the integration of these elements when conducting a SES assessment, the greater the potential understanding of the relationship between resilience and vulnerability, and how climate and/or societal stressors can exacerbate each other (IPCC, 2014). For example, in the Klamath River, USA, climate stressors in the form of droughts, triggered legal, political and physical contestations between different productive sectors and indigenous communities, which took about 10 years to resolve (Chaffin et al., 2016, 2014a). At the same time, fragmented environmental governance as a consequence of these societal stressors, had several ecological impacts, like altering fish biological corridors, intensifying toxic algae blooms, and limiting water management (Chaffin et al., 2016). Knowing how to address both climate and societal stressors has important implications in dryland systems. Drylands are particularly sensitive to environmental change, and even small changes, like irregular precipitation, can have large impacts at SES scale (Huang et al., 2017), and in the occurrence of violent conflicts over water access (IPBES, 2018). Understanding SES stressors will allow us to address dryland vulnerabilities and strengthen resilience more holistically, by increasing adaptive capacity to manage change. Accordingly, increasing adaptive capacity requires WES conservation to allow ecological functioning to recover, to better support livelihoods, and so to increase human wellbeing in the drylands (Mortimore et al., 2009).

1.3.1. Water governance problems

In this thesis, water governance is defined as the social function that acts within a set of rules, practices, and processes, for regulating development, water management, and provision of WES at different scales and levels of society, guiding the WES towards a desirable state (Akhmouch and Clavreul, 2016; Pahl-Wostl, 2017). The element of "development" in this concept, highlights the premise that effective governance should facilitate development, yet, this can also present major economic and physical side effects or externalities (Rogers et al., 2003). Unsuitable development has led to several water-related problems like contamination, overexploitation, and degraded ecosystems that are attributed to governance failures (Loë and Patterson, 2017; Pahl-Wostl, 2017). The misleading assumption that development redresses social vulnerability, was already highlighted with the Wirikuta case presented in section 1.3. Among several issues that are creating this situation, is the lack of connection with other drivers, institutions, and actors that belong to other development sectors, like agriculture, energy, industry, and that are out of the scope of the water sector (Loë and Patterson, 2017). For instance, observing the same Klamath River case mentioned previously, we find that failed water governance connectivity with other sectors such as agriculture, salmon harvesting and hydropower, led to several social conflicts over WES (Chaffin et al., 2016). England et al. (2018b) conducted a policy assessment in southern Africa to find cross-sectoral common ground for Climate Compatible Development. Results indicated that aligning energy, forestry, agriculture, and water sectors bring great advantages for facing climate change, yet, they also identified some important barriers for this to happen, such as very rooted development paradigms or lack of resources (England et al., 2018b). As such, water governance needs to recognize mutual interdependencies between WES and other sectors, and avoid a water-centric perspective (Loë and Patterson, 2017). Chapter 2 of this thesis shows that in the Rio del Carmen watershed, there is a strong linkage between the illegal conversion of grassland to cropland, which has been increasing illegal water exploitation and water depletion. Water governance should capture all these complex processes that determine WES management for supporting livelihoods and ecosystem functioning (Pahl-Wostl, 2017). Nevertheless, an inappropriate integration between water supply and demand to meet all water needs, has been a central challenge to address in worldwide water crises (Akhmouch and Clavreul, 2016).

Unsuitable formal institutions and misconceptions about ecosystem functioning that are embedded in traditional water governance, have failed to address uncertainty and SES' changing conditions, which has led to the collapse of WES (DeCaro et al., 2017b; Smidt et al., 2016). Conventional governance regimes are known for operating with command-and-control mechanisms that are very limited for this complex and changing world (Armitage et al., 2009), as these approaches tend to oversimplify SES dynamics (DeCaro et al., 2017b). There are no universal solutions or panaceas to manage complex SES (Folke, 2016; Ostrom, 2007). Accordingly, linear conceptualizations of SES dynamics tend to undermine system adaptive capacity, as they do not consider day-to-day surprises and discontinuities (Armitage et al., 2009). For instance, in the Columbia River and the Everglades in the USA, water control structures were built to control water supply, provide flood control and hydropower. However, these top-down and linear governance approaches caused unexpected impacts, like decreased water runoff and the loss of fish species (Gunderson et al., 2016). Top-down governance rarely matches SES's scale needs, for which they commonly fail to provide effective solutions. They also fail to properly coordinate with key stakeholders across large-scale jurisdictional boundaries (Chaffin et al., 2014b). Governance regimes need to increase their horizontal interplay, policy coherence, and participation around what it is they seek to improve (e.g., increasing adaptation (England et al., 2018a)).

Uncertainty is inherent to SES complexities, so collaborative and learning processes in governance systems for increasing adaptive capacity offer useful ways to address it (Armitage et al., 2009). Top-down governance has lost political legitimacy as it lacks both inclusive and deliberative processes for policy design and implementation, as well as legal and institutional flexibility to accommodate dynamic systems (Akhmouch and Clavreul, 2016; Ahjond Garmestani and Benson, 2013). This is also found in Mexico, where water governance operates through river basin management with a comprehensive system of river basin organisations, councils and auxiliary bodies (OECD, 2013). However, it remains centralised and driven by a top-down approach, without clarity in the distribution of competences (OECD, 2013). Water governance in Mexico has not been able to ensure public participation in its management or decision-making processes (Murillo-Licea and Soares-Moraes, 2013) since its river basin councils lack the necessary legal, capacity, regulatory, human and economic resources to carry out their functions (OECD, 2013). Chapter 3 of this thesis illustrates the implications of this situation in greater depth.

Finally, the lack of stakeholder integration in traditional top-down governance approaches not only undermines adaptive capacity to face environmental change, but it also dismisses the need for and importance of integrating values, perceptions, and culture in the governance system. An example of this situation happened in Australia. Under the banner of poverty reduction and “good governance”, yet lacking context-sensitive approaches, the Federal Government intervened with aboriginal governance systems that used to operate using a multi-level approach with self-determined institutions (Moran and Elvin, 2009). With the goal to better support local development, the government took over resources management and local decision-making, disabling cooperation within these communities for achieving governance goals, and generating distrust with all non-Aboriginal employees (Moran and Elvin, 2009). This highlights that the neglect of culture and the lack of context-sensitive solutions are common governance problems (Armitage et al., 2009; Pahl-Wostl, 2017), and tend to marginalise local stakeholders, whose integration, given the cumulative knowledge they have of SES functioning, is paramount to increase system adaptive capacity (Chaffin et al., 2016; Díaz et al., 2015; Stringer et al., 2018).

1.3.2. Social-ecological lens for understanding system complexities

This thesis uses the most common definition of SES: a coupled system of ecosystems and human societies with reciprocal feedbacks and interdependence, which emphasizes the humans-in-nature perspective (Gunderson et al., 2010). In this regard, SES are more complex than just the sum of the social and the ecological, since their interrelations are constantly triggering new feedbacks contributing to the dynamics of the whole (Folke, 2016; Gunderson et al., 2010). Besides, the humans-in-nature perspective means that people are integrated within ecosystems, and acknowledges that human existence depends on nature, for which they (people) have an ethical obligation towards it (nature) (Okpara et al., 2018). Accordingly, the SES lens allows us to see societal influences as drivers of change, and how the environment responds to change in the face of growing human demand for natural resources (Carpenter et al., 2015; Folke, 2016).

Describing key social-ecological relationships helps to identify the interactions that can lead to desirable and undesirable outcomes (Figure 1.1), highlighting known controlling variables that can lead to positive synergies and avoid negative trade-offs (O'Connell et al., 2016). Nowadays, governments and foundations are increasing their investment in SES research, because understanding how ecological and social dynamics relate is paramount for achieving sustainability, and requires long-term thinking (Rissman and Gillon, 2017). Methodologies for analysing SES (e.g., through stakeholder analysis) are key for framing human-environment relationships, and these methodological choices will determine the research outcomes, and thus, their application (Miller et al., 2010). For instance, a SES approach can be used to explain or predict causal relationships, to qualitatively describe complex intertwining of SES phenomena, or to measure natural assets for defining SES pathways (Aumeeruddy-Thomas et al., 2012; Rissman and Gillon, 2017). Nonetheless, the importance of using a SES approach also relies on the need for understanding how exogenous and endogenous processes influence SES variables and dynamics (Gunderson et al., 2010; Rammel et al., 2007). This is paramount in drylands, as the interaction of slow (e.g. soil fertility) and more fluctuating (e.g. precipitation) variables, are key in shaping dryland dynamics (Reynolds et al., 2007). This draws a bigger picture, from a holistic viewpoint, to explain SES pathways. For instance, given they are situated in a (water) scarcity context, drylands have less capacity to recover from impacts when a threshold related to slow variables has been crossed, as seen in the Dust Bowl in the USA or the "sandification" problem in China (Reynolds et al., 2007). Crossing thresholds in drylands can lead to unpredictable outcomes and significant changes in the essential functions and structures that establish the dryland's identity (Stringer et al., 2017).

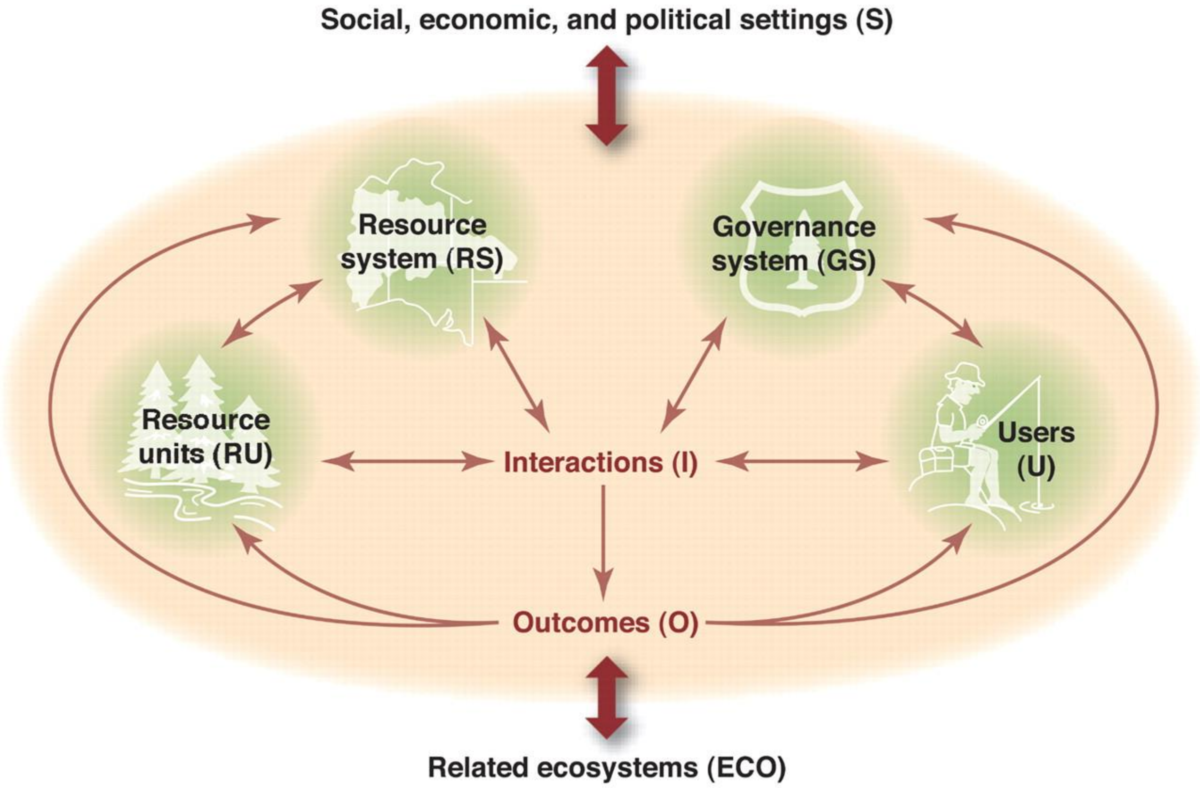

Figure 1.1 Relationships and key interactions within SES elements. Image obtained from Ostrom, (2009).

A SES lens is more likely to consider the human benefits obtained from the environment, and the negative impacts between humans and nature; yet, it does not truly consider relations among humans (Rissman and Gillon, 2017). Notwithstanding, for addressing dryland development challenges and strengthening their resilience, SES approaches need to "unpack relationships and interactions in social-ecological systems, livelihood portfolios and value chains" (p. 1956), by setting boundaries and identifying relevant stakeholders (Stringer et al., 2017). For instance, more than 80% of the negative impacts caused by droughts are on the agriculture sector (FAO, 2016). Dealing with drought is difficult because feedback between human activities and drought is incompletely understood, and as stated in section 1.2, the relative scarcity of precipitation can trigger larger impacts over the SES (Huang et al., 2017). Accordingly, in spite of traditional SES approaches that could explain or try to predict human-drought feedbacks, facing droughts and their impacts on agriculture requires understanding and identifying, for instance, societal and institutional potential to increase adaptation to climate change. Certainly, SES can have policy implications for improving resilience, e.g. by highlighting the agricultural practices that should be adopted for facing droughts, yet, this approach always faces cultural, epistemological and socioeconomic obstacles that hinder its application (Rissman and Gillon, 2017). Considering the main dryland livelihoods are natural resource-based, unpacking SES interactions where the impacts of the human relationships on the environment can be better understood is important, as they are drivers of change, but rarely assessed (Stringer et al., 2017). This can provide insights on how to accomplish institutional arrangements, in accordance with the ecosystem functioning for WES conservation; likewise, understanding whose decisions and what development practices have a major influence, is key for understanding SES pathways (O'Connell et al., 2016). In this regard, the ability to capture issues on power and politics through an SES lens is not simple, and as Rissman and Gillon, (2017) say, there is often a trade-off between focusing on SES linkages or complex societal dynamics. Nonetheless, power and politics are increasingly being incorporated into complex adaptive SES assessments, as they are a core element of SES governance (Folke, 2016). Accordingly, the sophistication of SES research has to increase, with new approaches for mitigating these potential trade-offs, for instance, by including causal analysis and a better understanding of the interplay between complex SES components (Rissman and Gillon, 2017). For instance, by drawing on ethno-biological data as well as historical documents and maps, Aumeeruddy-Thomas et al., (2012) were able to develop a social-ecological thick description of the decline and renewal of Languedoc-Roussillon´s forest, analysing the socio-political legacies, values, economies, and institutions shaping power and influencing courses of action in agriculture.

Human actions shape institutional structures in different ways based on their cultural constraints, so understanding culture is essential for increasing adaptive capacity and thus, in shaping resilience (Folke, 2016). SES vary across cultures and cosmo-visions that shape knowledge, including scientific and indigenous knowledge (Díaz et al., 2015). Schlüter et al. (2017) define knowledge as "the information and understanding an individual has about her social-ecological environment and her own behaviour within this context" (p. 25). In this regard, there are two procedural elements influencing people's behaviour: perceptions (the mental process by which individuals obtain information on SES functioning) and knowledge (what is claimed to be the 'truth' regarding what is perceived) (Schlüter et al., 2017).

Accordingly, this thesis uses the SES approach to explore how stakeholders in the Rio del Carmen watershed perceive WES (Chapter 2), how water governance regulates access to WES (Chapter 3), the governance vulnerabilities that undermine dryland adaptation (Chapter 4), and the potential that stakeholders have to overcome them and enable adaptive water governance (AWG) in the watershed (Chapters 2, 3, and 4). During the assessment, the thesis considers how human behaviour impacts the Rio del Carmen's water balance, highlighting, likewise, how the watershed has been responding to unsustainable agricultural practices, in terms of WES. Interpreting this social-ecological interaction, the thesis shows how entry points can be identified for increasing SES adaptive capacity by enabling AWG, which ultimately will strengthen the Rio del Carmen watershed's general resilience.

1.3.3. Adaptive water governance

Nowadays, water is no longer a resource managed to serve only human needs, as the complexities and variety of services and goods it provides, like maintaining biodiversity or soil formation, are now appreciated and valued in SES functioning (Cosens et al., 2018). Moreover, experiences from the Everglades and Columbia River in the USA, show that managers face two different forms of uncertainties: when addressing ecological issues like externalities in water flow manipulation, and when articulating and prioritising social differences in democratic processes (Gunderson et al., 2016). Given the need for more flexible, iterative and adaptive approaches to deal with constant environmental changes, and water governance problems described in section 1.2.1, some scholars have proposed AWG as a way to put resilience theory into practice so SES complexities can be addressed (Cosens et al., 2018; Ahjond Garmestani and Benson, 2013).

AWG is defined as flexible, collaborative, and learning-based institutions designed to adapt to changing relationships in society and between society and ecosystems, engaging key stakeholders for adaptive management of water resources and WES (Akamani, 2016; O'Connell et al., 2016). AWG is an alternative to the command-and-control paradigm of water resource management, addressing the social, legal, and institutional elements that enable adaptive ecosystem-based management (Akamani, 2016). This governance regime increases SES adaptive capacity and strengthens resilience, by embracing societal and environmental change, for which AWG implementation needs to be done under a SES lens to better capture this non-linearity (Akamani, 2016). Accordingly, AWG must operate on the scale(s) that better fit the social and ecological components, where institutional arrangements and ecosystem functioning are more compatible (Chaffin et al., 2014). By bringing together formal and informal institutions, AWG seeks to maintain the sustainability of WES for human well-being, and thus allow SES permanence (Chaffin et al., 2014b; Gunderson et al., 2016).

As for the limitations of this adaptive type governance, Cleaver and Whaley (2018) state that it still lacks a critical institutionalism approach that stresses the societal structures, power relations, and social norms shaping adaptation. Accordingly, critical institutionalism provides a better appreciation of the meaning and values underlying the social arrangements needed for increasing adaptation; and better reveals the hidden processes that may be obstacles to enable AWG. On the basis of the above, in this thesis, I take special care to emphasise emergence, engagement, learning, and collaborative processes, along with the legal and institutional setting needed for enabling AWG in the watershed.

The emergence of AWG consists of and describes how relatively spontaneous adaptive approaches arise in water governance, through creative processes initiated by key stakeholders (DeCaro et al., 2017b). Furthermore, the literature states that the emergence of AWG may also begin when threats to social or ecological values, conflicts over scarce resources, or SES crises, mobilize key stakeholders to drive institutional change (Cosens et al., 2014; Chaffin et al., 2014). Accordingly, it can be inferred that enabling AWG requires a social capital base, consisting of knowledge co-generation, collaboration, learning, stakeholder engagement, leadership and trust (Cosens et al., 2018).

Engaging the broadest range of stakeholders in decision-making and water management, is paramount for increasing social learning, collaboration, legitimacy and accountability, while reducing social difficulties, such as potential problems or conflictive perceptions (Akhmouch and Clavreul, 2016). However, while participatory processes hold promise for increasing efficiency and effectiveness in water governance, special attention must be paid to the social, cultural, institutional, and environmental context in which they are conducted (De Vente et al., 2016). For instance, reconciling conflicting perceptions with cultural sensitivity will increase the ownership of institutional arrangements, by involving a multiplicity of perspectives that collectively and creatively can develop new solutions for complex SES (De Vente et al., 2016). Stakeholder engagement therefore plays a major role in the emergence and sustainability of AWG (Akhmouch and Clavreul, 2016; Chaffin et al., 2016). Dietz (2013) states that we need to improve our social learning about facts, so we can align our perceptions with how the world really works, because our cognitive barriers to understanding SES complexities present a key limitation when facing climate change.

Social learning during stakeholder engagement is a continuous process, and the 'fuel' within the AWG gear as it not only has the potential to increase awareness over SES functioning, but also to identify how we can constantly improve water governance (Stringer et al., 2006). As highlighted in an assessment conducted in the Northwest Forest Plan that sets out land use in the Pacific Northwest in the USA, adaptive governance is not only about how to take current decisions, but how to learn about SES complexities so as to take more informed future decisions (Bormann et al., 2007). For that matter, social learning is not only stakeholder interaction for knowledge co-generation and exchange within AWG (Reed et al., 2010), it also helps in deliberation and negotiation of institutional arrangements for enhancing AWG, since these participatory processes improve the quality, legitimacy, and capacity of stakeholders in their decision-making (Dietz, 2013; Reed et al., 2010).

From the literature reviewed above, we can argue that well-organized groups with trusted actors, good collaboration, and learning processes with traditional and scientific knowledge, are important elements that can legitimise and drive institutional change (DeCaro et al., 2017b). Yet, it has been found that the interaction of policies, authorities and financing that reinforce the status quo, presents important barriers to the emergence of AWG, as governance systems are highly influenced by these fluctuating social and institutional factors (Akamani, 2016). So, in addition to stakeholder engagement, leadership, and trust building, advancing AWG requires an adaptive legal and institutional setting, and an assessment of societal influence over SES for a better understanding of leverage points and to identify “windows of opportunity” (Olsson et al., 2006, p.8). This will also help to identify the institutional, informational, social, cognitive or financial factors that hamper SES adaptive capacity, and the conditions that block movement toward AWG (Biesbroek et al., 2013). By way of illustration, as shown by Akhmouch and Clavreul, (2016) with an OECD survey conducted with 215 stakeholder groups within and outside the worldwide water sector, some of these barriers consist of:

- The lack of stakeholder leadership and political will to reduce social inequalities;

- Overlapping and contradictory formal institutions, with conflicting goals that hinder intersectional cooperation;

- The lack of economic resources to sustain stakeholder engagement, along with unqualified and uncommitted staff for these processes; and

- The lack of inclusion of vulnerable and marginalised groups.

Issues regarding the federal Administrative Procedure Act in the USA, also illustrate how legal adaptive barriers are commonplace in environmental management. Despite that environmental management has been delegated to the environmental agencies, assessment statutes like the National Environmental Policy Act, limit agencies’ self-organization and adaptation to emerging situations by requiring preceding assessments (e.g. cost-benefit or judicial reviews) before they can act (DeCaro et al., 2017b). This highlights how formal institutions play a major role in creating or hindering AWG. Nevertheless, there is a gap in the literature in terms of how legal frameworks can be leveraged to integrate an adaptive approach in the way they operate. It still unclear how legal and institutional principles can foster AWG, when complexities around scales, jurisdictions, and societies need to be linked for the emergence of effective cooperation (DeCaro et al., 2017b). While understanding and identifying social and ecological needs offers significant guidance for moving toward adaptation (Folke, 2016), SES assessments should also consider the legal and institutional changes needed to give formality, legitimacy, and adhesion of the AWG to the SES context (Ahjond Garmestani and Benson, 2013). Yet, as already stated in section 1.3.2, there are some weakness related to understanding human relations through the SES approach, like those regarding power and culture. Accordingly, and identifying these gaps and weaknesses, this thesis pays special attention to the complexities in institutional interplay, and the relationship between the institutional setting and the environment. In doing so, this research considers the scale failures and societal complexities that have been undermining participation and cooperation for increasing adaptation.

Given the challenges that lie in the design and implementation of formal institutions that can support AWG, DeCaro et al. (2017) have proposed some legal and institutional principles for adaptive governance (Table 1.1). They argue that these legal and institutional foundations may inform institutional design and work as a guide for the emergence and effectiveness of adaptive governance.

Table 1.1 Legal and Institutional principles proposed by DeCaro et al. (2017), for adaptive governance.

Legal principles	Institutional principles
Reflexive: Does not rely on static rules.	**Well-Defined Boundaries:** Political, institutional, and ecosystem boundaries of the SES.
Legal Sunsets: Planned periods of comprehensive evaluation.	**Participatory Decision Making:** Variety of stakeholder participatory methods and processes to influence, design, and implement water governance.

Legally Binding Authority: Polycentric authority institutionalized in binding legislation to make decisions and implement solutions.	**Internal Enforcement:** Internal mechanisms to monitor and enforce institutional compliance.
Legally Binding Responsibility: Formal definition and assignment of responsibility to resolve SES issues.	**Internal Conflict Resolution:** Internal mechanisms for neutral and transparent conflict resolution.
Tangible Support: Government assistance (resources, personnel, or inputs) to meet legally binding responsibilities.	

Similar efforts have been found in the work published by Hill Clarvis et al. (2014), where iterativity, flexibility, connectivity, and subsidiarity were studied in different formal institutions (Figure 1.2). Here the authors aim to give more practical value to adaptive governance principles, by highlighting how they can act as a bridge between resilience theory and law.

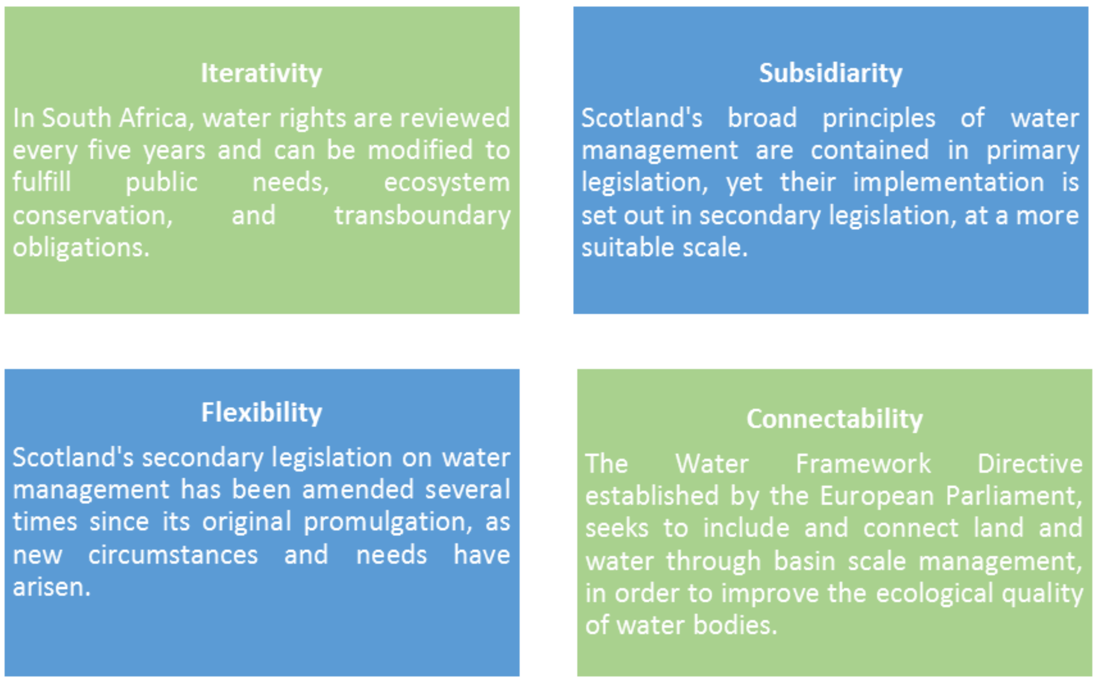

Figure 1.2 Examples obtained from Hill Clarvis et al. (2014), that illustrate the application of their adaptive governance principles in practice.

In accordance with the abovementioned literature, this thesis merges these legal and institutional principles and describes how AWG could look in the Rio del Carmen watershed context. The proposed AWG conceptual framework that is presented integrates the adaptive governance principles of 1) connectivity and subsidiarity, 2) legally binding authority and accountability, 3) iterativity and flexibility, and 4) financial, technical, and administrative resources. The potential of this conceptual framework also relies on the identified benefits of stakeholder engagement in water governance, like acceptability, knowledge co-generation, social equity, and institutional coherence (Akhmouch and Clavreul, 2016). Ultimately, as Garmestani and Benson, (2013) state, in integrating resilience science and adaptive governance, it is necessary to 1) delineate the suitable scale, 2) identify critical slow variables, 3) identify ecological thresholds, and 4) link ecological thresholds to legal thresholds to recalibrate them in the face of new information (iteration). Therefore, in addition to the proposed AWG conceptual framework, this thesis recognises the role that diverse stakeholder perceptions, institutional entry points, and context-specific needs play when moving forward adaptation. In doing so, this thesis also contributes to the research agenda established by Huitema et al., (2009) on adaptive governance. They state that more research is needed on how collaboration can be achieved and how challenges related to coordination and trust issues can be addressed; moreover, they ask specifically for more research on how transitions toward adaptive governance can be managed. Accordingly, this research provides important lessons and proposes three principles for moving towards AWG, which are valuable in advancing this research agenda.

1.4. Research framing, objectives and study site

My research framing revolves around AWG as a governance regime, and its potential to increase general resilience in drylands. Using resilience and vulnerability theory, the adaptive governance literature, and the SES approach, my research aim is to critically assess water governance in Mexico’s dryland social-ecological systems, with a view to identifying entry points for increasing adaptive capacity. When conducting the literature review for this research aim, I identified gaps in the literature regarding how AWG could be implemented in a dryland context. More specifically, these gaps can be sorted into three main considerations:

- How to analyse institutions in order to identify how they could be transformed and leveraged to enable AWG;

- The legal and institutional implications of restructuring dryland water governance when moving toward adaptation;

- The necessary approaches for fitting AWG to context-specific needs, like drylands' challenging context.

In view of the foregoing, to address my research aim I developed three research objectives, which, in turn, were accompanied with respective research questions (Table 1.2).

Table 1.2 Research objectives and questions.

Research Objectives	Research questions
Analyse the role of water as a key ecosystem service for human well-being and development.	Who are the key stakeholders in the Rio del Carmen watershed?
	Which communities and economic activities have access to water and why?
	How do different stakeholders in Rio del Carmen perceive WES?
Critically assess and describe how water governance regulates access to WES.	What is the legal and institutional structure of water governance in the watershed?
	How has water governance affected water availability and WES in the watershed and for whom?
	What kind of conflicts and trade-offs are taking place in the watershed and how are these shaped by institutional aspects?
Identify entry points that enable AWG in order to increase SES resilience.	Where are the vulnerabilities in current water governance in the Rio del Carmen watershed

	that undermine resilience?
	What potential does society have to enable AWG in the Rio del Carmen watershed?

The three research objectives were tackled in depth and each one resulted in publishable material (Table 1.3). Notwithstanding that each paper has its own discussion and conclusion, bringing together the findings from the three research objectives has wider implications. "The whole is greater than the sum of its parts", so analysing more holistically the findings obtained from each paper, generates a different and deeper composition than just analysing the results individually.

Table 1.3 Academic outputs according to each research objective.

Paper addressing the first research objective.	Lopez Porras, G., Stringer, L. C. and Quinn, C. H. (2018) 'Unravelling Stakeholder Perceptions to Enable Adaptive Water Governance in Dryland Systems', Water Resources Management. Springer Netherlands, 32(10), pp. 1–17. doi: 10.1007/s11269-018-1991-8.
Paper addressing the second research objective.	Lopez Porras, G., Stringer, L. C. and Quinn, C. H. (2019) 'Corruption and conflicts as barriers to adaptive governance: Water governance in dryland systems in the Rio del Carmen watershed', Science of The Total Environment[2]. Elsevier, 660, pp. 519–530. doi: 10.1016/J.SCITOTENV.2019.01.030.
Paper addressing the third research objective.	Lopez Porras, G., Stringer, L. C. and Quinn, C. H. (2019) 'Seeking common ground in dryland systems: steps towards adaptive water governance'. Under review in the Geographical Journal.

[2] This paper was selected in the Research Highlights featured in the 11th February issue of Nature Sustainability: Burnside, W. (2019) 'Corruption and exploitation', Nature Sustainability. Nature Publishing Group, 2(2), pp. 85–85.

Using the SES approach showed that strengthening dryland resilience by increasing adaptive capacity, requires more than just unravelling perceptions, resource availability, climate conditions, cultural constraints, and the institutional setting. Accordingly, putting in context the interaction of all these components is what allows the identification of barriers and entry points for moving toward adaptation, giving, as a result, a series of lessons that this thesis presents as "principles for enabling AWG in dryland systems". These principles are discussed in Chapter 5.

1.4.1. The Rio del Carmen watershed

This thesis focuses on a case study of the Rio del Carmen watershed (Figure 1.3), located in the Chihuahuan desert, in Chihuahua, Mexico, in order to unpack the issues discussed above. The Rio del Carmen watershed belongs to the Closed Northern Watersheds, within the Rio Bravo River Basin (INEGI, 2016a). It has an approximate surface area of 16,799 km^2, and the main municipalities that make up the watershed are Ahumada, Buenaventura, Namiquipa, and Riva Palacio (INEGI, 2016a). The watershed has four broad dryland biomes: grasslands, desert scrub, sandy desert vegetation, and forest (INEGI, 2016b). The average annual rainfall oscillates from 200 mm in the northern part (downstream) to 500 mm in the south (upstream), while the climate conditions vary from hyper-arid, semi-arid, semi-cold sub-humid, and arid to sub-humid (INEGI, 2016a). The Rio del Carmen is an endorheic watershed. On the surface, the Santa Clara River is the main surface water source beginning upstream, changing its name to the River Carmen when it reaches further downstream (INEGI, 2003). Upstream has an annual water runoff of 75.33 m^3y^{-1} while downstream runoff is 106.24 m^3y^{-1} (DOF, 2016a). Groundwater sources consist of 3 main aquifers: Santa Clara located upstream, Flores-Magon – Villa Ahumada located downstream, and Laguna de Patos, located downstream as well (INEGI, 2016b). Despite that official data regarding the magnitude of the deficit is not accurate, as a result of illegal water access and inefficient monitoring (see section 5.3 Research limitations and opportunities for further enquiry) these three aquifers are categorised as overexploited, and the amount of water granted through water rights is higher than the recharge capacity of each aquifer published by the government (DOF, 2018). More than 90% of water rights issued in the watershed are for agricultural purposes (CONAGUA, 2015a), with the National Water Commission (CONAGUA) the government agency responsible for managing and issuing water rights. Accordingly, the main economic activity in the watershed is agriculture (INEGI, 2016a).

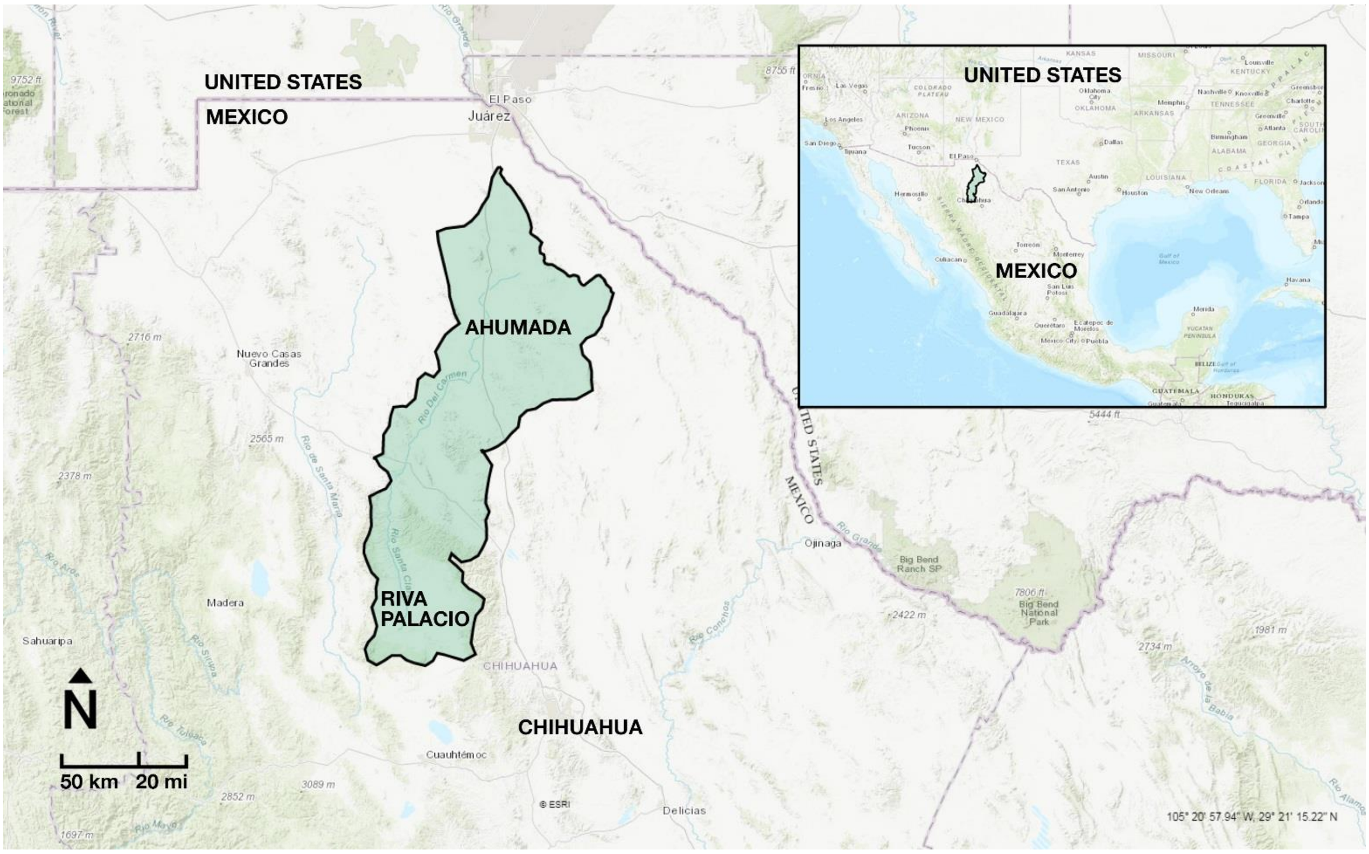

Figure 1.3 The Rio del Carmen watershed. Image obtained from INEGI (2016b).

Around 1950, the Rio del Carmen watershed, specifically downstream, started to experience a significant and disorganized increase in agricultural activity (DOF, 1957). Given concerns about potential water depletion and the consequential impacts on agriculture in the watershed, in 1957, an undefined period of restricted-access for new water exploitations was established (DOF, 1957). This presidential decree had 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 (DOF, 1957). 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 (INEGI, 2016a, 2003).

Irrigation Districts are institutional structures made up of physical and human capital designed for agricultural production, consisting of an agricultural surface, hydraulic infrastructure, the endowment of surface and groundwater, and legal protection for their activities (LAN, 2016). Irrigation Districts need to be established through Presidential Decree, and have a hydraulic committee including farmers and a water district chief designated by CONAGUA (LAN, 2016). Furthermore, they have their own regulations for the administration, operation, and conservation of land, agriculture and water in the district (LAN, 2016). Irrigation District El Carmen 089 is made up of two ejidos[3], 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 (CONAGUA, 2016a; INEGI, 2003). In general, the irrigation district does not have high-tech hydro-agricultural infrastructure, which leads to various inefficiencies in irrigation methods (like water leaks), generating an indiscriminate use of water (Yescas Diego, 2014). Manzanares Rivera (2016) states that ejidos' agricultural practices do not generate intensive use of water, 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 traditional agricultural production approach of ejidos' (Quintana, 2013).

Upstream and downstream differences are not limited to climate conditions; upstream is mainly occupied by a Mennonite agricultural community in contrast to mostly Mexican farmers found downstream (Quintana, 2013). In the early 20th century Mennonites, 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 (Bravo Peña et al., 2015). 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 (Carroll Janer, 2017). This letter gave freedom of worship, exemption from military service, freedom to regulate their lands, and an autonomous school system without interference from the Mexican government to the Mennonite

[3] Eijdos are agricultural communities that manage their land collectively.

community, clearly contradicting the Political Constitution of the Mexican States (Carroll Janer, 2017). Subsequently, between 1920 and 1930, Mennonites first established themselves in the Laguna de Bustillos watershed in Chihuahua, but given high rates of population growth, they had to move to other areas, like the Rio del Carmen watershed (Bravo Peña et al., 2015; Quintana, 2013).

Mennonite communities are characterized by their separation from the secular world, so they are isolated communities that provide their own education with strong religious connotations (Bravo Peña et al., 2015). The configuration of the landscape built upstream by the Mennonite community (Figure 1.4), 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 (Bravo Peña et al., 2015). Mennonites' ethos demands a life of effort and austerity to please God, so that in exchange God provides what is necessary for the community (Bravo Peña et al., 2015). However, modern Mennonite generations have migrated towards more profitable agriculture, with an unsustainable economic reorientation that has led to water overexploitation (Bravo Peña et al., 2015; Quintana, 2013). Manzanares Rivera, (2016) has described this new Mennonite agricultural model as *highly specialized 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 located, like the Santa Clara aquifer, are overexploited, which highlights the detachment that this model has with the ecological context where it is practiced (Manzanares Rivera, 2016; Quintana, 2013).

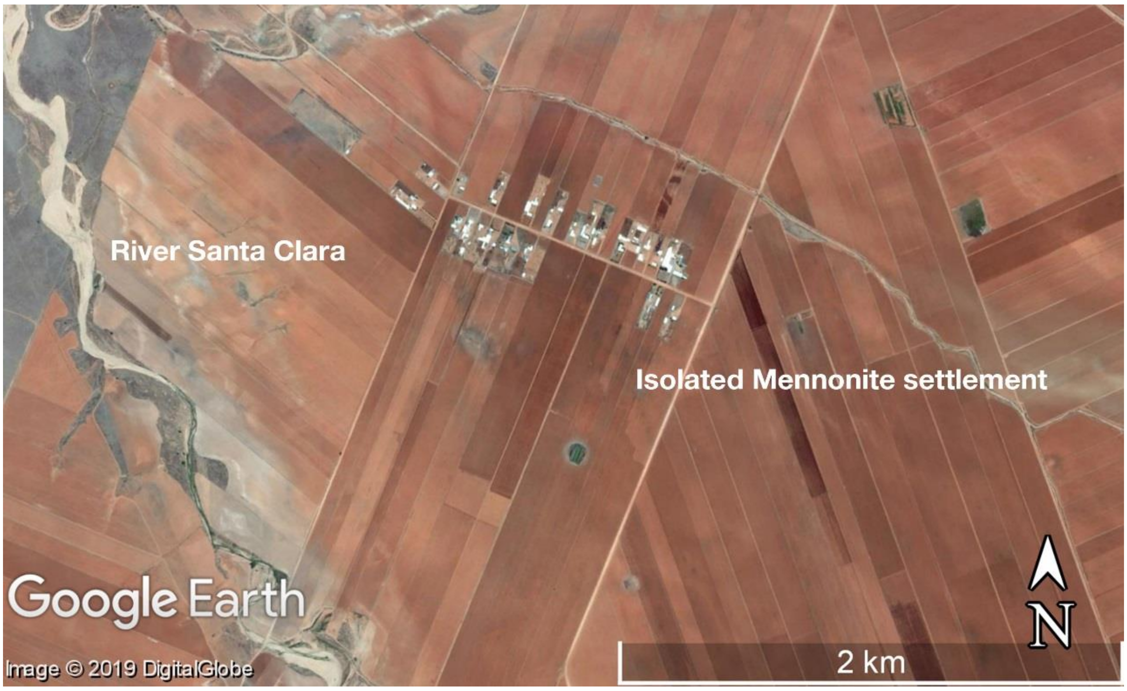

Figure 1.4 Mennonite settlement "Field 92" next to the River Santa Clara, that later becomes the River Carmen. Image obtained from Google, (2019).

Conflicts between upstream and downstream farmers started around 2010, when water levels of downstream groundwater exploitations started to drop considerably, along with reduced water runoff from the River Carmen (Quintana, 2013). Following this, a group of Mexican farmers detected numerous Mennonite water exploitations, protected by false water rights and rigged with the collusion of some CONAGUA officials (Athie, 2016; Quintana, 2013). It was pointed out by the Mexican farmers that there were 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 (IMTA, 2019). This situation provoked the downstream farmers, some of them affiliated to a grassroots organization called El Barzon, to give rise to a social movement called "defenders of the water of the Chihuahuan desert", which represented more than 3,000 Mexican farmers (Quintana, 2013). The fundamental demands of this group were:

1) That CONAGUA should enforce the law and stop illegal water exploitation in the watershed;

2) That PROFEPA[4] should prosecute the illegal conversion of grasslands to croplands that was taking place upstream;

3) That SAGARPA[5] should not grant any kind of support or subsidy to farmers who illegally access water; and

4) That the CFE[6] should stop providing electricity to illegal exploitations in the watershed (Quintana, 2013).

Given the lack of attention to the demands of the self-proclaimed “defenders of the water of the Chihuahuan Desert”, El Barzon, which is a militant activist organization, in coordination with other rural organizations, 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 (IMTA, 2019; Quintana, 2013). These acts of protest included occupation of government offices, highways, and even aggression against government officials until finally they could coordinate with CONAGUA, and help in the identification and demolition of some illegal water wells and dams placed to divert the flow of the river (IMTA, 2019; Quintana, 2013). At this point, the Mennonites began to demand that the Governor of Chihuahua and the President of Mexico stop the aggression against their community, arguing that justice cannot be selective and that CONAGUA should also inspect downstream illegal exploitations (IMTA, 2019). Nevertheless, given organized 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 (IMTA, 2019). To date, despite several attempts to solve this situation, illegal water access, corruption, and conflicts continue to permeate the SES dynamics of the Rio del Carmen watershed.

Against this background, Chapters 2, 3, and 4 go deeper by analysing the informal institutions including different stakeholder perceptions and farming practices driven by culture, formal and informal institutional interplay, as well as the interactions between the governance system and the ecological system, highlighting the impacts on WES in the watershed. In doing so, as stated in section 1.2.2, this thesis presents not only the human

[4] PROFEPA is the acronym in Spanish for the Federal Attorney for Environmental Protection.
[5] SAGARPA is the acronym in Spanish for the Ministry of Agriculture and Rural Development.
[6] CFE is the acronym in Spanish for the Federal Electricity Commission.

benefits obtained from the environment and the negative impacts on the water balance, but also the societal and institutional potential to increase system adaptive capacity, considering cultural and socioeconomic barriers to enabling AWG. For this, the research design, which includes qualitative and quantitative methods for data collection and analysis, was designed for understanding these SES complexities.

While there are particular aspects of this case study that are grounded in the local context, the environmental and societal complexities found there, are emblematic of the conditions and problems found across dryland systems. For example, the vegetation in the Rio del Carmen watershed, consisting of grassland, desert scrub, and forest, is consistent with the dominant habitat types found in drylands. Average rainfall and climate conditions in the watershed are also representative of many drylands globally. Moreover, societies that are dependent on the natural resource base, as in Rio del Carmen, dominate dryland areas (Safriel et al., 2005). As such, conflicts over water access are commonly found in these water-scarce systems where access to resources is critical for livelihoods (IPBES, 2018). For instance, agricultural water use is the dominant global water use (Koch et al., 2016), as well as in Rio del Carmen, so the findings and lessons obtained from this thesis increase our understanding and potential for addressing dryland complexities related to agriculture and water scarcity more broadly. In addition, better policies, strategies and sustainable water management are needed to address dryland complexities, and they can only be achieved by cooperation, not by the conflict that is often the situation in many drylands all around the globe (Koch et al., 2016). Therefore, this analysis of Rio del Carmen´s water conflicts, farming practices, water overexploitation, and social clashes, will provide important insights that will be useful for other drylands facing similar challenges. In addition, this case study contributes to broader AWG discussions about the most appropriate scale of operation, by showing how the river basin scale, at which most AWG studies are carried out (B. A. Cosens et al., 2014), is not necessarily the most appropriate. Accordingly, findings obtained from this case study will contribute to the literature on both drylands and AWG.

1.5. Methodology, Methods, Data

This thesis uses a case study approach to carry out an intensive study of the current water governance in the Rio del Carmen watershed, with the intention of finding entry points for increasing adaptive capacity. As stated by Zainal, (2007) some advantages of using a case study approach are:

- Data is not isolated from its context. On the contrary, it is examined within the situation where it takes place.

- Qualitative and quantitative methods are allowed.

- It helps to explore and explain the real world complexities that are possibly not captured with other approaches.

This case study supports some assumptions, like the already described top-down governance failures; moreover, it provides explanations of SES phenomena through the integration of new concepts in resilience theory, like "societal stressors", utilised in other case studies. Nevertheless, data from this thesis is not used for testing or measuring resilience in drylands, rather it seeks to build a theory regarding how AWG can be enabled in the case study dryland context, and potentially beyond. The case study approach is very valuable for theory building, especially in its first stages as this thesis proposes (Flyvbjerg, 2006). Therefore, interpretive case research is important as it allows modification of the research questions as necessary, derivation of more contextualised and richer interpretation of phenomena, and analysis from multiple stakeholder perspectives (Bhattacherjee, 2012; Reed et al., 2009). None of this would be possible if instead, I used a positivist method, which is more appropriate for theory testing than theory building (Bhattacherjee, 2012). Consequently, the case study approach was found appropriate for this thesis, as it allowed the unravelling of the Rio del Carmen watershed complexities with a holistic approach to real-life events. For instance, addressing the research questions with data obtained from an important plurality of stakeholders, and other sources (e.g., secondary data) allowed me to present a clearer narrative to solve the “how and why” questions, that emerged when analysing rooted issues in water governance. Accordingly, the contribution from this approach also relies on the qualitative detail produced when describing SES complexities, through real-life situations in a real-life environment, allowing an in-depth understanding of the reasons that motivated the strategies proposed for addressing SES problems (Zainal, 2007). For instance, based on this and other case studies, this thesis provides a good qualitative explanation of what motivated the design of the three principles for moving towards AWG, which would not be possible using a different approach.

The most appropriate philosophical position for case study research in the Rio del Carmen watershed, is the standpoint of critical realism (Easton, 2010). Critical realism recognises that: 1) the influence of human perception shapes reality, and 2) the outcomes of interactions between the heterogeneous systems that set up the world are difficult to predict, but their tendencies can be researched (Evely et al., 2008). This ties in directly with epistemology of adaptive governance, which seeks to learn about the SES complexities in order to take more informed future decisions. According to Easton (2010) critical realism "makes the ontological assumption that there is a reality but that it is usually difficult to apprehend" (p. 128). Once again, critical realism's ontology fits with the thesis research framing, as it supports the need for a holistic assessment of the results, as presented in the three papers described in section 1.3. Capturing how the institutional (formal and informal) interacts with the ecological system, and results in different events, behaviours, or impacts over the whole SES, puts into perspective and shows the incentives and problems associated with water governance that have led to water overexploitation. Moreover, competing explanations of these events and behaviours are necessary to ensure a more accurate interpretation (Easton, 2010), which is effectively achieved by properly integrating and highlighting conflicting stakeholder perspectives. This allows the construction of a narrative produced from different data gathered from different collection methods (quantitative and qualitative) explaining the social interpretation of SES functioning, and from this, the identification of entry points for enabling AWG. With the implications that this entails, this epistemology assumes that social phenomena "construe rather than construct the world" (Easton, 2010, p.122), and that this interpretation is not only descriptive but also constitutive of the real world (Easton, 2010).

Of this, Sayer (2010) and Easton (2010) identify several assumptions of critical realism:

- Objects or entities are fundamental elements in the critical realism explanation since they configure the world;

- These objects and entities are properly structured and endowed with causal powers and liabilities capable of generating events;

- The events or outcomes are the external and visible behaviour that has to be described and investigated by the researcher. The aim of critical realism is an explanation, answering to the causality of those events; and

- There is a reality independent of observers which overlaps with the social construction that we create, and researchers need to understand and explain those situations.

This creates important methodological advantages for this research, as it allows a deep and multi-perspective understanding of how water is accessed and regulated in the Rio del Carmen watershed. Comparing different explanations and perspectives we can obtain reasoned judgments[7] and therefore, more objective descriptions of the reality (Easton, 2010). This philosophical validation is of great significance for this thesis, as each stakeholder has a different version of the situation in the Rio del Carmen watershed, so an approach that facilitates the integration of all perspectives is of utmost importance. The selection of research and analysis methods is based on this philosophical position, where a mixed methodological approach was needed in order to conduct a comprehensive analysis of water governance in the watershed, to gain and exhibit a deep understanding of its social context and environmental conditions. In doing so, I used multiple methods of data collection, such as interviews, survey research, documents, and secondary data (Bhattacherjee, 2012).

For instance, understanding how resilience and vulnerability are perceived to support decision-making needs a qualitative approach to unravel local perceptions and knowledge, while quantitative methods can be used to assess socioeconomic and environmental stresses (Miller et al., 2010). In this thesis, a mixed methodological stance

[7] "Judgemental rationality means that we can publically discuss our claims about reality as we think it is, and marshal better or worse arguments on behalf of those claims. By comparatively evaluating existing arguments, we can arrive at reasoned, though provisional, judgements about what reality is objectively like; about what belongs to that reality and what does not" (Archer et al., 2004, p.2).

drawing on qualitative and quantitative data was helpful in generating a unique insight into social-ecological complexities, which would not have been possible using either method separately, with each method compensating for the weakness of the other, in line with the critical realism that underlies this study. Chapters 2, 3 and 4 all contain more specific details about the research designs and methods used for addressing each research objective. Nonetheless, below is a general description of the sampling, data collection methods, and analysis as a whole.

1.5.1 Sampling and data collection

Data used in this thesis was collected from two phases of fieldwork with ethical approval AREA 16-148 (Appendix I) granted by the Research Ethics Committee of the University of Leeds. Secondary data sources were also used. In accordance with ethical approval, prior to any interview, a consent form was signed by each participant, indicating that they understood the nature of the research, what the data would be used for, and how anonymity would be maintained. For survey research, as the inclusion/exclusion criteria consisted of people with agricultural water rights in the Rio del Carmen watershed, participants' names were not necessary, so verbal consent was obtained by asking respondents if they agreed to participate in the survey, in line with the ethical approval gained. Stakeholder analysis was used as an underlying process for conducting the water governance assessment in the watershed (Reed et al., 2009). With this approach, I was able to: 1) define the system features, 2) identify who had a stake in those aspects, and 3) investigate the relationships, leadership, decision-making, and inequalities within the system (Prell et al., 2009).

First, from the 6th June to 6th July 2017 I undertook scoping fieldwork in the Rio del Carmen watershed, as well as the municipality of Chihuahua as that is where government offices are located. During this month I conducted scoping interviews with 13 participants, in Spanish, using a preliminary stakeholder list as a guide (Table 1.4) and an interview protocol (Appendix II), developed based on information from Quintana (2013), Manzanares Rivera (2016), and my prior experience in the area. In order to avoid a biased sample, I used a snowball sampling approach, conducting the interviews in parallel with each stakeholder group, and asking them to identify new participants for each category. Furthermore, by having these multiple starting points I reduced the selection bias commonly associated with snowball sampling (Sulaiman-Hill and Thompson, 2011). The scoping fieldwork was key in providing an initial sample to inform the second phase of fieldwork, as participants were allowed to increase the list in every category by nominating and classifying other participants.

Table 1.4 Stakeholder preliminary list.

Category	Stakeholder group
Federal Government	- National Water Comission (CONAGUA). - Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA). - Ministry of Environment and Natural Resources (SEMARNAT)
State Government	- Ministry of Rural Development. - Ministry of Urban Development and Ecology.
Local authorities	- Hydronometric Station "La Trasquila 08-28"
Universities	- Faculty of Zootechnics and Ecology of the Autonomous University of Chihuahua - Faculty of Agrotechnological Sciences of the Autonomous University of Chihuahua
NGOs and civil society organizations	- World Wildlife Fund - The Nature Conservancy - El Barzon - Pronatura
Trade or Industry Groups	- Silos del Campo, S.P.R. de R.L. de C.V.
Communities	- Mennonites - Ejidos - Private ranchers

Data collected from the scoping interviews gave the inputs for the published paper "Unravelling Stakeholder Perceptions to Enable Adaptive Water Governance in Dryland Systems", which constitutes Chapter 2 of this thesis.

From the 4th December 2017 to 1st May 2018 the second phase of fieldwork took place. During the first three months (from December 2017 to February 2018) I conducted a questionnaire survey (Appendix IV) with 217 farmers in the Rio del Carmen watershed. The aim was to obtain farmers' views on water exploitation, legal water access, droughts, agricultural livelihoods, crime, conflicts, corruption, crop types, coordination and law enforcement, and the main problems and emerging needs in the watershed. Data obtained from the survey research was used predominantly to write the manuscript "Seeking common ground in dryland systems: steps towards adaptive water governance" found in Chapter 4. It also provided the topics that were integrated into the following round of semi-structured interviews.

The survey sample had to involve participants related to water access and water ecosystem services in the watershed, so it could not be based on simple random sampling. Accordingly, to avoid non-probability sampling that could be subject to a sampling bias, a stratified sampling approach was used (Bhattacherjee, 2012). Stratified sampling also complemented the stakeholder analysis, putting boundaries on the category of communities by showing which ejidos and Mennonite colonies could be considered stakeholder groups. The sample size was delimited by dividing the water users into subgroups, where the population size consisted of the number of water rights for agriculture, aquaculture, livestock and domestic use, located in the main aquifers within the Rio del Carmen watershed, and ascribed to the public registry of water rights. Moreover, the sample needed to be based on legal water rights, regardless of the illegal water access (either because the water right is apocryphal or because the farmer extracts more water than is allowed by the water right). There is no certainty about the number of false water rights in the watershed so they could not be integrated into the survey sample. Although in practice these false rights might skew the sample size in each subgroup, illegal water access was not captured in the final sampling, and only participants with water rights were included when conducting the survey.

In March 2017, all CONAGUA's 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, and after using several filters to find which rights corresponded to the selected water uses in each of the main aquifers within the watershed, it was found that CONAGUA had registered 494 water use rights, as summarised in Table 1.5.

Table 1.5 Agricultural water uses by aquifer.

Aquifer	Water use rights	Percentage of total rights
Flores-Magon - Villahumada	268	54.25
Santa Clara	131	26.51
Laguna de Patos	95	19.24
	Total: 494	Total: 100

Each aquifer –subgroup- was considered a stratum, and simple random sampling took place within each one when carrying out the survey (Bhattacherjee, 2012). With a population size of 494 right holders, I used a sample size calculator (SurveyMonkey, 2017), with 95% confidence level, and 5% of margin of error, as these percentages are considered acceptable by survey researchers (Barlett et al., 2001; DataStar, 2008). The result of the calculation gave a sample size of 217 water rights, allocated proportionally in each stratum according to their ascribed water rights (Table 1.6). However, since access to the Mennonite community located in the Santa Clara aquifer (upstream) was complex, given distrust related to water access issues, a Mennonite assistant was recruited during the survey to better address this situation. In accordance with ethical approval, the assistant was briefed on the ethical issues, security, risk, and trained regarding how to conduct the survey. With this, I sought to mitigate any potential bias during the survey process, for instance, by explaining how our positionality and the way we frame a question can affect the survey outcomes. Despite hiring a Mennonite assistant for facilitating approach with upstream farmers, the achieved sample was 55, and so the downstream sample size is slightly larger (Table 1.6).

Table 1.6 Proportional and Final Stratified Sample.

Strata	Proportional Stratified Sampling	Final Stratified Sampling
Flores-Magon – Villahumada	117	117

Santa Clara	58	55
Laguna de Patos	42	45
	Total: 217	Total: 217

Finally, from February to April 2018, I conducted another round of semi-structured interviews in the same locations as the scoping fieldwork, also for which stakeholders' consent was sought before initiating the interview. The sample was based on the nominations provided during the scoping interviews, complemented with snowball (Reed et al., 2009) and purposeful sampling (Patton, 1999), in order to increase the stakeholder list with participants who would provide important information. The final sample resulted in 27 stakeholders (Table 1.7). Interviews were conducted in parallel in each stakeholder category in order to ensure full representation from all the categories. The interview protocol (Appendix III) was designed with information obtained from the scoping fieldwork and with preliminary results from the survey; again, the interviews were conducted in Spanish.

Table 1. 7 Stakeholder list from second phase of fieldwork.

Stakeholder Category	Farmers	Government officials	Consultants	NGO	Academic
Sector representatives	Mennonite community	National Water Commission	Agricultural management	World Wide Fund for Nature	Faculty of Zootechnics and Ecology of the Autonomous University of Chihuahua
	Mexican farmers	Secretariat of Environment and Natural Resources	Legal advice		
		Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food	Agricultural products and trade		
		State Coordination of Civil Protection			

1.5.2 Data analysis

As the interviews were recorded in Spanish, they were transcribed into English for their analysis. Qualitative data from both rounds of interviews were first deductively coded (Bernard, 2011; Luna-Reyes and Andersen, 2003), using NVivo 2011 for Windows, in categories established according to adaptive governance literature, categorising stakeholders' quotes accordingly for their analysis (Reed et al., 2009). Afterward, secondary data was collected and deductively coded with the same categories, allowing the comparison, complementation, and validation of both qualitative datasets (Kohlbacher, 2006; Patton, 1999). The main secondary data sources for triangulating with the qualitative data were these Government of Mexico's websites: https://datos.gob.mx/; www.infomexdf.org.mx/; www.gob.mx/conagua; www.dof.gob.mx; www.diputados.gob.mx/LeyesBiblio/; and http://gaia.inegi.org.mx/. Finally, using content analysis (Bernard, 2011) with the social-ecological rich description method, the qualitative datasets were used to produce a narrative of the causal analysis and the interplay of complex institutional and ecological components (Rissman and Gillon, 2017).

For the survey research, also conducted in Spanish, results were translated into English, and then compiled in Microsoft Excel 2013. The survey aim was to obtain the farmers' views on several water governance issues, along with the main problems and needs in the watershed. Data regarding stakeholders' perceptions were analysed quantitatively according to the frequency they were mentioned (Kohlbacher, 2006) and simple descriptive statistics were compiled. In addition, a chi-square test of independence was carried out on the stakeholders' perceptions (Mcdonald, 2014), using the CHISQ.TEST function in Microsoft Excel 2013, with the null hypothesis that there was no significant difference in perceptions between Mennonites and Mexican farmers. Finally, survey results regarding the main needs and problems in the watershed, were analysed with an incidence and severity index approach (Quinn et al., 2003), in order to identify common ground between the Mexican farmer and Mennonite stakeholder groups. Secondary data, including information regarding climate conditions and water availability, was obtained from the same Government of Mexico's websites as listed previously. Survey findings were then complemented and triangulated with secondary data, to increase robustness and ensure validity. The set of all these results provided sufficient information for characterising the watershed's exposure, sensitivity, and adaptive capacity.

1.5.3. Contributions from the Rio del Carmen watershed case study

Putting the findings together, the information presented in this thesis makes contributions to understanding water governance in Mexico, and to the adaptive governance and dryland development literature. First, it demonstrates that Mexican water governance and its institutional scales have failed to ensure the conservation of water resources and WES, and to guarantee the human right of access to water[8]. Moreover, this thesis integrates resilience research (which favours ecologically bounded scales), and vulnerability research (which tends to consider socially defined scales (Miller et al., 2010)). By combining both concepts, and putting them in context with the legal and institutional structure of Mexican water governance, this research shows that the watershed scale is more suitable for understanding SES dynamics. Furthermore, this thesis shows how finding the right scale, per se, is a leverage point, as all governance issues, along with the legal, social, ecological, and institutional entry points for enabling AWG, seem to be connected. For instance, upstream-downstream water runoff, water overexploitation, the restricted-access decree, the water rights system, social incompatibilities, WES functioning, corruption, all these issues overlap at this scale, and in the same way as the identified entry points. When strengthening SES resilience, there are always tensions between social and ecological scales (Miller et al., 2010), and although this thesis does not seek to establish blueprints, it shows how capturing the main social-ecological interactions can lead to the identification of the appropriate scale.

This thesis also shows that analysing legal frameworks for enabling AWG, provides important insights for leveraging all the legal and institutional tools, which would lay the

[8] According to the thesis VI.3o.A.1 CS (10a.) of Mexico's Supreme Court, which includes the agricultural water use within the human right of access to water.

foundations of AWG in the studied area. This is important for the adaptive governance literature since, as this thesis shows, even centralised and top-down water governance has elements that can be used to move towards adaptation. Similar work was presented by Cosens, (2015), where an examination of water management in the Lake Eyre Basin, Australia, was conducted in light of AWG principles. However, that work did not establish the legal feasibility for and implications of formally establishing AWG. Conversely, this thesis helps guide the legal framework necessary to enable AWG.

Characterising the Rio del Carmen watershed's vulnerabilities has laid the groundwork for determining that drylands are not only exposed to climate stressors, or that social vulnerabilities are economically exclusive. For instance, according to the United Nations Development Programme, the main municipalities that make up the Rio del Carmen watershed (see section 1.3.1), have a high human development index (PNUD, 2014). This index is determined by education, health, and income indicators, from which, societally, it could be inferred that the watershed is not vulnerable. However, this thesis determines that in terms of human well-being, by incorporating the elements of good social relations, security, and peace of mind (Díaz et al., 2015), the watershed is societally vulnerable. This finding contributes to a more comprehensive understanding of dryland livelihoods, expanding the elements and stressors that must be considered in dryland development. Additionally, it contributes to the identification and differentiation of what is vulnerable and what is resilient, in a dryland context.

Finally, the Rio del Carmen watershed case study shows why it is important to know how WES are perceived and accessed, to understand the formal and informal institutions for water governance, and to understand the role of societal factors in shaping resilience, for improving the system's adaptive capacity. These contributions are discussed in more detail in Chapter 5.

1.6 Thesis structure

This thesis is composed of 5 chapters in compliance with the alternative thesis format established by the University of Leeds:

- Chapter 1. This introductory chapter, which contains the introduction, literature review and an outline of the methodology;

- Chapter 2. This consists of the pre-proof stage manuscript "Unravelling Stakeholder Perceptions to Enable Adaptive Water Governance in Dryland Systems", published in Water Resources Management;

- Chapter 3. This consists of the pre-proof stage manuscript "Corruption and conflicts as barriers to adaptive governance: Water governance in dryland systems in the Rio del Carmen watershed", published in Science of the Total Environment;

- Chapter 4. This consists of the pre-proof stage manuscript "Seeking common ground in dryland systems: steps towards adaptive water governance", submitted to The Geographical Journal; and

- Chapter 5. This is the discussion chapter, which consists of the discussion and conclusion sections.

1.7 References

Akamani, K. 2016. Adaptive Water Governance: Integrating the Human Dimensions into Water Resource Governance. *Journal of Contemporary Water Research & Education*. **158**(1), pp.2–18.

Akhmouch, A. and Clavreul, D. 2016. Stakeholder Engagement for Inclusive Water Governance: 'Practicing WhatWe Preach' with the OECD Water Governance Initiative. *Water (Switzerland)*. **8**(5), pp.1–17.

Alfie Cohen, M. 2015. Conflictos socio-ambientales: la minería en Wirikuta y Cananea. *El Cotidiano*. (191), pp.97–108.

Archer, M.S., Collier, A. and Porpora, D. V. 2004. *Transcendence: critical realism and God* [Online]. Routledge. [Accessed 3 April 2017]. Available from: https://books.google.co.uk/books?hl=es&lr=&id=YA0L2yzkc0QC&oi=fnd&pg=PP1&dq=

Transcendence+collier&ots=s-pCRvnPHY&sig=xTSqPlJNq0zfHxa0KEFKUBlmCfc&redir_esc=y#v=onepage&q=rationality&f=false.

Armitage, D.R., Plummer, R., Berkes, F., Arthur, R.I., Charles, A.T., Davidson-Hunt, I.J., Diduck, A.P., Doubleday, N.C., Johnson, D.S., Marschke, M., McConney, P., Pinkerton, E.W. and Wollenberg, E.K. 2009. Adaptive co-management for social–ecological complexity. *Frontiers in Ecology and the Environment*. **7**(2), pp.95–102.

Arnold, C.A. (Tony) and Gunderson, L. 2013. Adaptive Law and Resilience.

Athie, K. 2016. *El Agua, ayer y hoy* [Online] (Centro de Estudios Sociales y de Opinion Publica, ed.). Mexico City: Camara de Diputados LXIII Legislatura. Available from: http://www5.diputados.gob.mx/index.php/camara/Centros-de-Estudio/CESOP/Estudios-e-Investigaciones/Libros/El-Agua-Ayer-y-Hoy.

Aumeeruddy-Thomas, Y., Therville, C., Lemarchand, C., Lauriac, A. and Richard, F. 2012. Resilience of Sweet Chestnut and Truffle Holm-Oak Rural Forests in Languedoc-Roussillon, France: Roles of Social-Ecological Legacies, Domestication, and Innovations. *Ecology and Society*. **17**(2), p.art12.

Barlett, J.E., Kotrlik, J.W. and Higgins, C.C. 2001. Organizational research: Determining appropriate sample size in survey research. *Information Technology, Learning, and Performance Journal; Spring*. **19**(1).

Barnett, J. and O'Neill, S. 2010. Maladaptation. *Global Environmental Change*. **20**(2), pp.211–213.

Barrett, C.B. and Constas, M.A. 2014. Toward a theory of resilience for international development applications. *Proceedings of the National Academy of Sciences of the United States of America*. **111**(40), pp.14625–30.

Bernard, H.R. 2011. *Research methods in anthropology : qualitative and quantitative approaches* [Online] 5th ed. Maryland: AltaMira. [Accessed 3 October 2017]. Available from: https://books.google.co.uk/books?hl=es&lr=&id=WhKYqATAySwC&oi=fnd&pg=PR1&dq=Research+methods+in+anthropology:+qualitative+and+quantitative+approaches&ot

s=6ArlvvOWzL&sig=dKTz4NAWqyXfqpbNsXAeTcGmOu0#v=snippet&q=deductive&f=false.

Bhattacherjee, A. 2012. *Social Science Research: Principles, Methods, and Practices* [Online] Book 3. (Textbooks Collection, ed.). Textbooks Collection. [Accessed 22 February 2017]. Available from: http://scholarcommons.usf.edu/oa_textbookshttp://scholarcommons.usf.edu/oa_textbooks/3.

Biesbroek, G.R., Klostermann, J.E.M., Termeer, C.J.A.M. and Kabat, P. 2013. On the nature of barriers to climate change adaptation. *Regional Environmental Change*. **13**(5), pp.1119–1129.

Bormann, B.T., Haynes, R.W. and Martin, J.R. 2007. Adaptive Management of Forest Ecosystems: Did Some Rubber Hit the Road? *BioScience*. **57**(2), pp.186–191.

Bravo Peña, L.C., Alatorre Cejudo, L.C., Díaz Caravantes, R., Wiebe, L. and Moreno Murrieta, R. 2015. Cultura y Apropiación del Espacio: Diferencias en los Paisajes Culturales de Menonitas y Mestizos de Chihuahua, México. *Journal of Latin American Geography*. **14**(2), pp.77–100.

Carpenter, S.R., Booth, E.G., Gillon, S., Kucharik, C.J., Loheide, S., Mase, A.S., Motew, M., Qiu, J., Rissman, A.R., Seifert, J., Soylu, E., Turner, M. and Wardropper, C.B. 2015. Plausible futures of a social-ecological system: Yahara watershed, Wisconsin, USA. *Ecology and Society*. **20**(2), p.art10.

Carroll Janer, I.E. 2017. *La gente que nos alimenta. Herencia, parentesco y sangre entre los menonitas de la Vieja Colonia en el ejido Salamanca al sur del estado de Quintana Roo en México*.[Online] Escuela Nacional de Antropologia e Historia. [Accessed 13 March 2019]. Available from: https://www.academia.edu/34007404/La_gente_que_nos_alimenta._Herencia_parentesco_y_sangre_entre_los_menonitas_de_la_Vieja_Colonia_en_el_ejido_Salamanca_al_sur_del_estado_de_Quintana_Roo_en_México.

Chaffin, B.C., Craig, R.K. and Gosnell, H. 2014a. RESILIENCE, ADAPTATION, AND TRANSFORMATION IN THE KLAMATH RIVER BASIN SOCIAL-ECOLOGICAL SYSTEM. *51*

Idaho Law Review 1.

Chaffin, B.C., Garmestani, A.S., Gosnell, H. and Craig, R.K. 2016. Institutional networks and adaptive water governance in the Klamath River Basin, USA. *Environmental Science & Policy*. **57**, pp.112–121.

Chaffin, B.C., Gosnell, H. and Cosens, B.A. 2014b. A decade of adaptive governance scholarship: Synthesis and future directions. *Ecology and Society*. **19**(3), p.56.

Cleaver, F. and Whaley, L. 2018. Understanding process, power, and meaning in adaptive governance: A critical institutional reading. *Ecology and Society*. **23**(2), p.49.

CONAGUA 2015. Comisión Nacional del Agua. Disponibilidad por Acuíferos. [Accessed 22 June 2018]. Available from: http://sigagis.conagua.gob.mx/gas1/sections/Disponibilidad_Acuiferos.html.

CONAGUA 2016. Comisión Nacional del Agua. Estadísticas agrícolas de los distritos de riego. *Comisión Nacional del Agua*. [Online]. [Accessed 10 December 2018]. Available from: https://www.gob.mx/conagua/documentos/estadisticas-agricolas-de-los-distritos-de-riego.

Cosens, B. 2015. *Application of the Adaptive Water Governance Project to the management of the Lake Eyre Basin and its connections to the Great Artesian Basin, Report to Flinders University and the Goyder Institution* [Online]. Adelaide, South Australia. [Accessed 10 February 2017]. Available from: http://goyderinstitute.org/index.php?id=53.

Cosens, B., Gunderson, L., Allen, C., Benson, M., Cosens, B., Gunderson, L., Allen, C. and Benson, M.H. 2014. Identifying Legal, Ecological and Governance Obstacles, and Opportunities for Adapting to Climate Change. *Sustainability*. **6**(4), pp.2338–2356.

Cosens, B.A., Gunderson, L. and Chaffin, B. 2014. The Adaptive Water Governance Project: Assessing Law, Resilience and Governance in Regional Socio-Ecological Water Systems Facing a Changing Climate. *51 Idaho Law Review 1*.

Cosens, B.A., Gunderson, L. and Chaffin, B.C. 2018. Introduction to the Special Feature Practicing Panarchy: Assessing legal flexibility, ecological resilience, and adaptive governance in regional water systems experiencing rapid environmental change. *Ecology and Society*. **23**(1), p.4.

DataStar 2008. What Every Researcher Should Know About Statistical Significance.

Davies, J., Barchiesi, S., Ogali, C.J., Welling, R., Dalton, J. and Laban, P. 2016. *Water in drylands: Adapting to scarcity through integrated management*. Gland, Switzerland: IUCN.

DeCaro, D.A., Chaffin, B.C., Schlager, E., Garmestani, A.S. and Ruhl, J.B. 2017. Legal and institutional foundations of adaptive environmental governance. *Ecology and Society*. **22**(1), p.32.

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Báldi, A., Bartuska, A., Baste, I.A., Bilgin, A., Chan, K.M., Figueroa, V.E., Duraiappah, A., Fischer, M., Hill, R., Koetz, T., Leadley, P., Lyver, P., Mace, G.M., Martin-Lopez, B., Okumura, M., Pacheco, D., Pascual, U., Pérez, E.S., Reyers, B., Roth, E., Saito, O., Scholes, R.J., Sharma, N., Tallis, H., Thaman, R., Watson, R., Yahara, T., Hamid, Z.A., Akosim, C., Al-Hafedh, Y., Allahverdiyev, R., Amankwah, E., Asah, S.T., Asfaw, Z., Bartus, G., Brooks, L.A., Caillaux, J., Dalle, G., Darnaedi, D., Driver, A., Erpul, G., Escobar-Eyzaguirre, P., Failler, P., Fouda, A.M.M., Fu, B., Gundimeda, H., Hashimoto, S., Homer, F., Lavorel, S., Lichtenstein, G., Mala, W.A., Mandivenyi, W., Matczak, P., Mbizvo, C., Mehrdadi, M., Metzger, J.P., Mikissa, J.B., Moller, H., Mooney, H.A., Mumby, P., Nagendra, H., Nesshover, C., Oteng-Yeboah, A.A., Pataki, G., Roué, M., Rubis, J., Schultz, M., Smith, P., Sumaila, R., Takeuchi, K., Thomas, S., Verma, M., Yeo-Chang, Y. and Zlatanova, D. 2015. The IPBES Conceptual Framework — connecting nature and people. *Current Opinion in Environmental Sustainability*. **14**, pp.1–16.

Dietz, T. 2013. Bringing values and deliberation to science communication. *Proceedings of the National Academy of Sciences of the United States of America*. **110 Suppl**(Supplement 3), pp.14081–7.

Dixon, J. and Stringer, L. 2015. Towards a Theoretical Grounding of Climate Resilience Assessments for Smallholder Farming Systems in Sub-Saharan Africa. *Resources*. **4**(1), pp.128–154.

DOF 1957. ACUERDO que establece el Distrito de Riego de El Carmen, en San Buenaventura y Villa Ahumada, Chih., y declara de utilidad pública la construcción de las obras que lo formen y la adquisición de los terrenos necesarios para alojarlas y operarlas. , pp.4–5. [Accessed 31 July 2017]. Available from: http://dof.gob.mx/nota_to_imagen_fs.php?cod_diario=188731&pagina=5&seccion=0.

DOF 2018. Diario Oficial de la Federación. ACUERDO por el que se actualiza la disponibilidad media anual de agua subterránea de los 653 acuíferos de los Estados Unidos Mexicanos, mismos que forman parte de las Regiones Hidrológico-Administrativas que se indican. [Accessed 22 June 2018]. Available from: http://www.dof.gob.mx/nota_detalle.php?codigo=5510042&fecha=04/01/2018.

DOF 2016. Diario Oficial de la Federacion. ACUERDO por el que se actualiza la disponibilidad media anual de las aguas nacionales superficiales de las 757 cuencas hidrológicas que comprenden las 37 regiones hidrológicas en que se encuentra dividido los Estados Unido. [Accessed 2 November 2018]. Available from: http://dof.gob.mx/nota_detalle.php?codigo=5443858&fecha=07/07/2016.

Downing, T.E., Aerts, J., Soussan, J., Barthelemy, O., Bharwani, S., Hinkel, J., Ionescu, C., Klein, R.J.T., Mata, L., Matin, N., Moss, S., Purkey, D. and Ziervogel, G. 2006. *Integrating social vulnerability into water management. NeWater Working Paper No. 5* [Online]. [Accessed 19 February 2019]. Available from: www.newater.info.

Easton, G. 2010. Critical realism in case study research. *Industrial Marketing Management*. **39**(1), pp.118–128.

England, M.I., Dougill, A.J., Stringer, L.C., Vincent, K.E., Pardoe, J., Kalaba, F.K., Mkwambisi, D.D., Namaganda, E. and Afionis, S. 2018. Climate change adaptation and cross-sectoral policy coherence in southern Africa. *Regional Environmental Change*. **18**(7), pp.2059–2071.

England, M.I., Stringer, L.C., Dougill, A.J. and Afionis, S. 2018. How do sectoral policies support climate compatible development? An empirical analysis focusing on southern Africa. *Environmental Science & Policy*. **79**, pp.9–15.

Evely, A.C., Fazey, I., Pinard, M. and Lambin, X. 2008. The influence of philosophical perspectives in integrative research: A conservation case study in the Cairngorms National Park. *Ecology and Society*. **13**(2).

FAO 2016. *Food and Agriculture Organization of the United Nations. Increasing the resilience of agricultural livelihoods* [Online]. Rome, Italy. [Accessed 16 August 2018]. Available from: http://www.fao.org/3/a-i5615e.pdf.

Flyvbjerg, B. 2006. Five Misunderstandings About Case-Study Research. *Sage Publications*. **12**(2), pp.219–245.

Folke, C. 2016. Resilience (Republished). *Ecology and Society*. **21**(4), p.44.

Garmestani, A. and Benson, M. 2013. A Framework for Resilience-based Governance of Social-Ecological Systems. *Ecology & Society*. **18**(1), p.9.

Garrick, D. 2018. Decentralisation and drought adaptation: Applying the subsidiarity principle in transboundary river basins. *International Journal of the Commons*. **12**(1), p.301.

Google 2019. Google Earth. . **Image Land**(Data SIO, NOAA, US Navy, NGA, GEBCO).

Gunderson, L., Kinzig, A., Allyson, Q., Walker, B., Cundhill, G., Beier, C., Crona, B. and Bodin, O. 2010. Assessing Resilience in Social-Ecological Systems : Workbook for Practitioners. Version 2.0.

Gunderson, L.H., Cosens, B. and Garmestani, A.S. 2016. Adaptive governance of riverine and wetland ecosystem goods and services. *Journal of Environmenal Management*. **183**, pp.353–360.

Hábitat México 2018. El tejido social. Hábitat para la Humanidad México. [Accessed 19 February 2019]. Available from: https://www.habitatmexico.org/article/el-tejido-social.

Hill Clarvis, M., Allan, A. and Hannah, D.M. 2014. Water, resilience and the law: From general concepts and governance design principles to actionable mechanisms. *Environmental Science and Policy*. **43**, pp.98–110.

Huang, J., Li, Y., Fu, C., Chen, F., Fu, Q., Dai, A., Shinoda, M., Ma, Z., Guo, W., Li, Z., Zhang, L., Liu, Y., Yu, H., He, Y., Xie, Y., Guan, X., Ji, M., Lin, L., Wang, S., Yan, H. and Wang, G. 2017. Dryland climate change: Recent progress and challenges. *Reviews of Geophysics*.

55(3), pp.719–778.

Huang, J., Yu, H., Guan, X., Wang, G. and Guo, R. 2016. Accelerated dryland expansion under climate change. *Nature Climate Change*. **6**(2), pp.166–171.

Huitema, D., Mostert, E. and Pahl-wostl, C. 2009. Adaptive Water Governance : Assessing the Institutional Prescriptions of Adaptive (Co-) Management from a Governance Perspective and Defining a Research Agenda. . **14**(1), p.26.

IMTA 2019. Instituto Mexicano de Tecnología del Agua. Observatorio de Conflictos por el Agua en México. [Accessed 30 January 2019]. Available from: http://ocam.imta.mx/inicio.html.

INEGI 2016a. *Instituto Nacional de Estadística y Geografía. Estudio de información integrada de la Cuenca Río Santa Clara y Lago Las Flores* [Online]. Aguascalientes, Mexico. [Accessed 21 January 2019]. Available from: www.inegi.org.mx.

INEGI 2016b. Mapa Digital de México V6.1. Instituto Nacional de Estadistica y Geografia. [Accessed 14 February 2017]. Available from: https://gaia.inegi.org.mx/mdm6/?v=bGF0OjI1Ljc5MTU5LGxvbjotMTAyLjE0NTY1LHo6MixsOmMxMTFzZXJ2aWNpb3N8dGMxMTFzZXJ2aWNpb3M=.

INEGI 2003. *Síntesis de Información geográfica del estado de Chihuahua* [Online]. Aguascalientes, Mexico. [Accessed 26 January 2017]. Available from: http://internet.contenidos.inegi.org.mx/contenidos/productos/prod_serv/contenidos/espanol/bvinegi/productos/historicos/2104/702825224332/702825224332_12.pdf.

IPBES 2018. *Summary for policymakers of the assessment report on land degradation and restoration of the Intergovernmental SciencePolicy Platform on Biodiversity and Ecosystem Services. R. Scholes, L. Montanarella, A. Brainich, N. Barger, B. ten Brink, M. Cantele, B.* [Online]. IPBES secretariat, Bonn, Germany. [Accessed 25 September 2018]. Available from: www.ipbes.net.

IPCC 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]* [Online]. Geneva, Switzerland: IPCC. [Accessed 20 February 2019]. Available from: http://www.ipcc.ch.

Koch, M., Missimer, T., Koch, M. and Missimer, T.M. 2016. Water Resources Assessment and Management in Drylands. *Water*. **8**(6), p.239.

Kohlbacher, F. 2006. The Use of Qualitative Content Analysis in Case Study Research. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*. **7**(1), pp.1–30.

LAN 2016. Ley de Aguas Nacionales. Diaro Oficial de la Federacion. CÁMARA DE DIPUTADOS DEL H. CONGRESO DE LA UNIÓN. [Accessed 13 February 2017]. Available from: http://www.diputados.gob.mx/LeyesBiblio/pdf/16_240316.pdf.

LDE 2012. *LEY DE EXPROPIACIÓN. Diaro Oficial de la Federacion. CÁMARA DE DIPUTADOS DEL H. CONGRESO DE LA UNIÓN.* [Online]. [Accessed 2 April 2019]. Available from: http://www.diputados.gob.mx/LeyesBiblio/pdf/35.pdf.

Loë, R.C. de and Patterson, J.J. 2017. RETHINKING WATER GOVERNANCE: MOVING BEYOND WATER-CENTRIC PERSPECTIVES IN A CONNECTED AND CHANGING WORLD. *Natural Resources Journal*. **57**(1), pp.75–100.

Luna-Reyes, L.F. and Andersen, D.L. 2003. Collecting and analyzing qualitative data for system dynamics: methods and models. *System Dynamics Review*. **19**(4), pp.271–296.

Manzanares Rivera, J.L. 2016. Hacer florecer al desierto: Análisis sobre la intensidad de uso de los recursos hídricos subterráneos y superficiales en Chihuahua, México. *Cuadernos de Desarrollo Rural*. **13**(77), pp.35–61.

Mcdonald, J.H. 2014. *Handbook of Biological Statistics* [Online] 3rd ed. Baltimore, Maryland: Sparky House Publishing. [Accessed 6 December 2018]. Available from: http://www.biostathandbook.com/HandbookBioStatThird.pdf.

Middleton, N., Stringer, L., Goudie, A. and Thomas, D. 2011. *The Forgotten Billion MDG Achievement in the Drylands* [Online]. New York. [Accessed 9 March 2017]. Available from: http://www.unccd.int/Lists/SiteDocumentLibrary/Publications/Forgotten Billion.pdf.

Miller, F., Osbahr, H., Boyd, E., Thomalla, F., Bharwani, S., Ziervogel, G., Walker, B., Leeuw, S. Van Der, Hinkel, J., Downing, T., Folke, C. and Nelson, D. 2010. Resilience and Vulnerability: Complementary or Conflicting Concepts? . **15**(3), p.11.

Moran, M. and Elvin, R. 2009. Coping with Complexity: Adaptive Governance in Desert Australia. *GeoJournal*. **74**(5), pp.415–428.

Mortimore, M., Anderson, S., Cotula, L., Davies, J., Faccer, K., Hesse, C., Mortin, J., Nyangena, W., Skinner, J. and Wolfangel, C. 2009. *Dryland opportunities: a new paradigm for people, ecosystems and development* [Online]. IUCN, Gland, Switzerland; IIED, London, UK and UNDP/DDC, Nairobi, Kenya: IUCN. Available from: http://trove.nla.gov.au/work/160629536?q&versionId=175115005.

Murillo-Licea, D. and Soares-Moraes, D. 2013. El péndulo de la gobernabilidad y la gobernanza del agua en México. *Tecnologia y Ciencias del Agua*. **4**(3), pp.149–163.

Nemec, K.T., Chan, J., Hoffman, C., Spanbauer, T.L., Hamm, J.A., Allen, C.R., Hefley, T., Pan, D. and Shrestha, P. 2014. Assessing Resilience in Stressed Watersheds. *Ecology and Society*. **19**(1), p.34.

O'Connell, D., Abel, N., Grigg, N., Maru, Y., Butler, J., Cowie, A., Stone-Jovicich, S., Walker, B., Wise, R., Ruhweza, A., Pearson, L., Ryan, P. and Stafford Smith, M. 2016. Designing projects in a rapidly changing world - Guidelines for embedding resilience, adaptation and transformation into sustainable development projects. , p.112.

OECD 2013. *Making Water Reform Happen in Mexico, OECD Studies on Water, OECD Publishing* [Online]. Available from: http://dx.doi.org/10.1787/9789264187894-en.

Okpara, U.T., Stringer, L.C., Akhtar-Schuster, M., Metternicht, G.I., Dallimer, M. and Requier-Desjardins, M. 2018. A social-ecological systems approach is necessary to achieve land degradation neutrality. *Environmental Science & Policy*. **89**, pp.59–66.

Olsson, P., Gunderson, L.H., Carpenter, S.R., Ryan, P., Lebel, L., Folke, C. and Holling, C.S. 2006. Shooting the Rapids: Navigating Transitions to Adaptive Governance of Social-Ecological Systems. *Ecology and Society*. **11**(1), p.18.

Osbahr, H., Twyman, C., Neil Adger, W. and Thomas, D.S.G. 2008. Effective livelihood adaptation to climate change disturbance: Scale dimensions of practice in Mozambique. *Geoforum*. **39**(6), pp.1951–1964.

Ostrom, E. 2007. A diagnostic approach for going beyond panaceas. *Proceedings of the*

National Academy of Sciences of the United States of America. **104**(39), pp.15181–7.

Ostrom, E. 2009. A General Framework for Analyzing Sustainability of Social-Ecological Systems. . **325**(5939), pp.419–422.

Pahl-Wostl, C. 2017. An Evolutionary Perspective on Water Governance: From Understanding to Transformation. *Water Resources Management*. **31**(10), pp.2917–2932.

Patton, M.Q. 1999. Enhancing the quality and credibility of qualitative analysis. *Health services research*. **34**(5 Pt 2), pp.1189–208.

Plaza, C., Zaccone, C., Sawicka, K., Méndez, A.M., Tarquis, A., Gascó, G., Heuvelink, G.B.M., Schuur, E.A.G. and Maestre, F.T. 2018. Soil resources and element stocks in drylands to face global issues. *Scientific Reports*. **8**(1), p.13788.

PNUD 2014. *Programa de las Naciones Unidas para el Desarrollo. Índice de Desarrollo Humano Municipal en México: nueva metodología* [Online]. Mexico. [Accessed 16 February 2017]. Available from: www.undp.org.mx/desarrollohumano.

Prăvălie, R. 2016. Drylands extent and environmental issues. A global approach. *Earth-Science Reviews*. **161**, pp.259–278.

Prell, C., Hubacek, K. and Reed, M. 2009. Stakeholder Analysis and Social Network Analysis in Natural Resource Management. *Society & Natural Resources*. **22**(6), pp.501–518.

Quinn, C.H., Huby, M., Kiwasila, H. and Lovett, J.C. 2003. Local perceptions of risk to livelihood in semi-arid Tanzania. *Journal of Environmental Management*. **68**(2), pp.111–119.

Quintana, V.M. 2013. Nuevo orden alimentario y disputa por el agua en el norte de México. *Apuntes: Revista de Ciencias Sociales*. **40**(73), pp.175–202.

Rammel, C., Stagl, S. and Wilfing, H. 2007. Managing complex adaptive systems — A co-evolutionary perspective on natural resource management. *Ecological Economics*. **63**(1), pp.9–21.

Reed, M.S., Evely, A.C., Cundill, G., Fazey, I., Glass, J., Laing, A., Newig, J., Parrish, B., Prell, C., Raymond, C. and Stringer, L.C. 2010. What is Social Learning? *Ecology and Society*.

15(4), p.r1.

Reed, M.S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C.H. and Stringer, L.C. 2009. Who’s in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management*. **90**(5), pp.1933–1949.

Reed, M.S. and Stringer, L.C. 2015. *Climate change and desertification: anticipating, assessing & adapting to future change in drylands* [Online] (Agropolis International & G. CCEE, eds.). Cancun, Mexico: 3rd UNCCD Scientific Conference. Available from: http://www.unccd.int/en/programmes/Science/Conferences/Documents/3sc_unccd_impulse-report.pdf.

Reed, M.S. and Stringer, L.C. 2016. *Land Degradation, Desertification and Climate Change: Anticipating, assessing and adapting to future change* [Online]. London: Routledge. [Accessed 20 February 2019]. Available from: https://www.taylorfrancis.com/books/9780203071151.

Reynolds, J.F., Smith, D.M.S., Lambin, E.F., Turner, B.L., Mortimore, M., Batterbury, S.P.J., Downing, T.E., Dowlatabadi, H., Fernández, R.J., Herrick, J.E., Huber-Sannwald, E., Jiang, H., Leemans, R., Lynam, T., Maestre, F.T., Ayarza, M. and Walker, B. 2007. Global desertification: building a science for dryland development. *Science (New York, N.Y.)*. **316**(5826), pp.847–51.

Rissman, A.R. and Gillon, S. 2017. Where are Ecology and Biodiversity in Social-Ecological Systems Research? A Review of Research Methods and Applied Recommendations. *Conservation Letters*. **10**(1), pp.86–93.

Rogers, P., Hall, A.W., Van de Meene, S.J., Brown, R.R. and Farrelly, M. a. 2003. *Effective Water Governance Global Water Partnership Technical Committee (TEC)* [Online]. Available from: http://dx.doi.org/10.1016/j.gloenvcha.2011.04.003%5Cnwww.gwpforum.org.

Safriel, U., Adeel, Z., Niemeijer, D., Puigdefabregas, J., White, R., Lal, R., Winslow, M., Ziedler, J., Prince, S., Archer, E., King, C., Shapiro, B., Wessels, K., Nielsen, T., Portnov, B., Reshef, I., Thonell, J., Lachman, E. and Mcnab, D. 2005. *Chapter 22 Dryland Systems.*

Ecosystems and Human Well-being: Current State and Trends. Volume 1, findings of the Responses Working Group of the Millennium Ecosystem Assessment. [Online] (N. Hassan R., Scholes, R., Ash, ed.). Washington, D.C., USA.: Island Press. Available from: https://www.millenniumassessment.org/documents/document.291.aspx.pdf.

Sayer, A. 2010. *Method in Social Science, Revised 2nd Edition* Second Edi. (T. & Francis, ed.). Oxfordshire: Taylor & Francis Group.

Schlüter, M., Baeza, A., Dressler, G., Frank, K., Groeneveld, J., Jager, W., Janssen, M.A., McAllister, R.R.J., Müller, B., Orach, K., Schwarz, N. and Wijermans, N. 2017. A framework for mapping and comparing behavioural theories in models of social-ecological systems. *Ecological Economics*. **131**, pp.21–35.

Smidt, S.J., Haacker, E.M.K., Kendall, A.D., Deines, J.M., Pei, L., Cotterman, K.A., Li, H., Liu, X., Basso, B. and Hyndman, D.W. 2016. Complex water management in modern agriculture: Trends in the water-energy-food nexus over the High Plains Aquifer. *Science of The Total Environment*. **566**–**567**, pp.988–1001.

Smith, D. and Vivekananda, J. 2009. *Climate change, conflict and fragility. Understanding the linkages, shaping effective responses* [Online]. London. [Accessed 1 April 2019]. Available from: www.international-alert.org.

Stoltenborg, D. and Boelens, R. 2016. Disputes over land and water rights in gold mining : the case of Cerro de San Pedro , Mexico. *Water International*. **41**(3), pp.447–467.

Stringer, L., Dougill, A., Fraser, E., Hubacek, K., Prell, C. and Reed, M. 2006. Unpacking "participation" in the adaptive management of social–ecological systems: a critical review. *Ecology and Society*. **11**(2), p.39.

Stringer, L.C., Quinn, C.H., Le, H.T. V., Msuya, F., Pezzuti, J., Dallimer, M., Afionis, S., Berman, R., Orchard, S.E. and Rijal, M.L. 2018. A New Framework to Enable Equitable Outcomes: Resilience and Nexus Approaches Combined. *Earth's Future*. **6**(6), pp.902–918.

Stringer, L.C., Reed, M.S., Fleskens, L., Thomas, R.J., Le, Q.B. and Lala-Pritchard, T. 2017. A New Dryland Development Paradigm Grounded in Empirical Analysis of Dryland Systems Science. *Land Degradation & Development*. **28**(7), pp.1952–1961.

Sulaiman-Hill, C.M. and Thompson, S.C. 2011. Sampling challenges in a study examining refugee resettlement. *BMC International Health and Human Rights*. **11**(1), p.2.

SurveyMonkey 2017. Sample Size Calculator. [Accessed 7 March 2017]. Available from: https://www.surveymonkey.com/mp/sample-size-calculator/.

De Vente, J., Reed, M.S., Stringer, L., Valente, S. and Newig, J. 2016. How does the context and design of participatory decision making processes affect their outcomes? Evidence from sustainable land management in global drylands. *Ecology and Society*. **21**(2), p.24.

Yescas Diego, F. 2014. *Valoración económica del agua en el módulo uno del Distrito de Riego 089 "El Carmen" en el Estado de Chihuahua, a través de los costos de obtención y de la productividad marginal.*[Online] INSTITUCIÓN DE ENSEÑANZA E INVESTIGACIÓN EN CIENCIAS AGRÍCOLAS. [Accessed 11 March 2019]. Available from: https://text-mx.123dok.com/document/wyeep10y-valoracion-economica-del-agua-en-el-modulo-uno-del-distrito-de-riego-089-el-carmen-en-el-estado-de-chihuahua-a-traves-de-los-costos-de-obtencion-y-de-la-productividad-marginal.html.

Zainal, Z. 2007. Case study as a research method. *Jurnal Kemanusiaan*. **9**.

Chapter 2

UNRAVELLING STAKEHOLDER PERCEPTIONS TO ENABLE ADAPTIVE WATER GOVERNANCE IN DRYLAND SYSTEMS

This chapter is the accepted manuscript of Lopez Porras, G., Stringer, L.C. and Quinn, C.H. 2018. Unravelling Stakeholder Perceptions to Enable Adaptive Water Governance in Dryland Systems. Water Resources Management. 32(10), pp.1–17. http://link.springer.com/10.1007/s11269-018-1991-8.

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-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

2.1 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 (DOF, 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). Nonetheless, as Huitema et al., (2009) have stated, approaches to capitalise on opportunities for enabling AWG, for instance, by creating an institutional setting where stakeholders can collaborate and establish learning processes, are still unclear, for which more research is needed. Moreover, not much attention has been paid to the role perceptions play during these processes, yet, this is of paramount importance as they shape stakeholders' interactions between them and the environment (DeCaro et al., 2017a; Schlüter et al., 2017).

Accordingly, to better establish the importance of stakeholder perceptions when aiming toward a more collaborative and iterative type of water governance, 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).

2.2 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 (Athie, 2016; Quintana, 2013).

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., 2017a). 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, ensuring all views were captured.

An interview protocol (Appendix II) 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).

2.3 Results

2.3.1 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[9]. 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).

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

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 (Athie, 2016; Murillo-Licea and Soares-Moraes, 2013), 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).

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 into 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 (Burnett, 2015; Quintana, 2013). 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*[10] *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 as damaging to the watershed or those who live in it; on the contrary, they see their activities as 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*

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

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 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[11] and private farmers. Many of these farmers are organized into an Irrigation District called El Carmen 089, created in 1957 when 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 (DOF, 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 coordinate actions with CONAGUA to demolish dams and close wells. However,

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

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 was 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).

2.3.2 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, 2015b).

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 invest 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, with 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 2.1):

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[12] 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 (Athie, 2016; Murillo-Licea and Soares-Moraes, 2013), 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 inspection visits they should make… We cannot properly manage water with the limited personnel we have (CONAGUA official D).

[12] 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 (Athie, 2016; Quintana, 2013).

Table 2. 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 exploitation to the Irrigation District, and water availability does not meet the minimum required by law.	*"Mennonites have many legal advisers, they have filed requests for defence to stop administrative processes against them"* (CONAGUA official B).	Some Mexican farmers have begun to break the law, as they have witnessed there are no consequences for doing so.
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*"	"*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).

	(CONAGUA official C).		
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.

2.3.3 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*[13] *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:

> *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 2.1) 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 the 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

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

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 2.1).

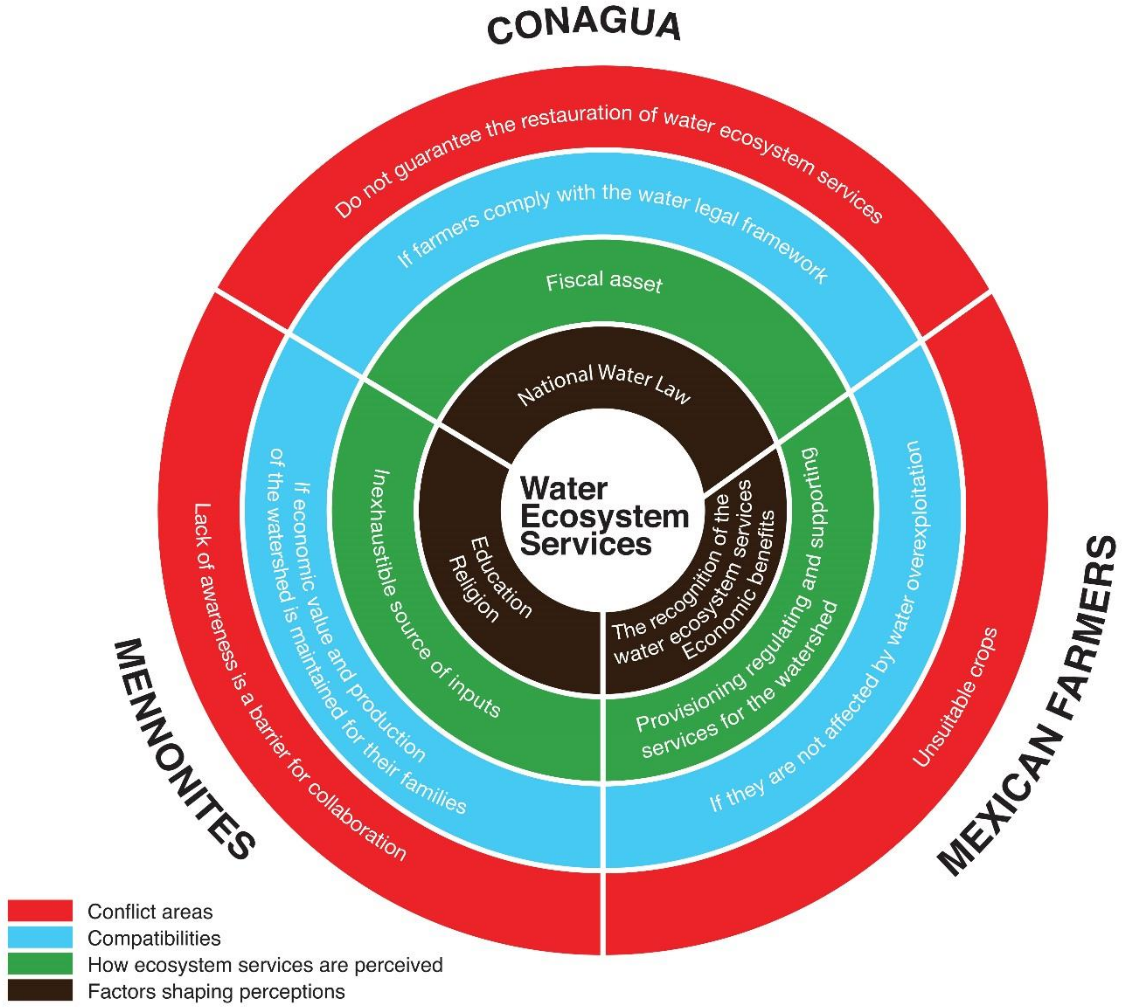

Figure 2.1 Stakeholder perceptions, compatibilities and conflict areas for restoration of water ecosystem services.

2.4. 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 2.1). 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., 2014b). 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., 2017a). 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., 2017b).

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 (AS 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., 2014b). 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., 2014b). 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., 2017a).

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., 2017a). 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.

2.5. 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.

2.6. References

Akamani, K. 2016. Adaptive Water Governance: Integrating the Human Dimensions into Water Resource Governance. *Journal of Contemporary Water Research & Education*. **158**(1), pp.2–18.

Athie, K. 2016. *El Agua, ayer y hoy* [Online] (Centro de Estudios Sociales y de Opinion

Publica, ed.). Mexico City: Camara de Diputados LXIII Legislatura. Available from: http://www5.diputados.gob.mx/index.php/camara/Centros-de-Estudio/CESOP/Estudios-e-Investigaciones/Libros/El-Agua-Ayer-y-Hoy.

Bernard, H.R. 2011. *Research methods in anthropology : qualitative and quantitative approaches* [Online] 5th ed. Maryland: AltaMira. [Accessed 3 October 2017]. Available from: https://books.google.co.uk/books?hl=es&lr=&id=WhKYqATAySwC&oi=fnd&pg=PR1&dq=Research+methods+in+anthropology:+qualitative+and+quantitative+approaches&ots=6ArlvvOWzL&sig=dKTz4NAWqyXfqpbNsXAeTcGmOu0#v=snippet&q=deductive&f=false.

Bhattacherjee, A. 2012. *Social Science Research: Principles, Methods, and Practices* [Online] Book 3. (Textbooks Collection, ed.). Textbooks Collection. [Accessed 22 February 2017]. Available from: http://scholarcommons.usf.edu/oa_textbookshttp://scholarcommons.usf.edu/oa_textbooks/3.

Burnett, V. 2015. Mennonite Farmers Prepare to Leave Mexico, and Competition for Water. *The New York Times*. [Online], p.A6. [Accessed 6 October 2017]. Available from: https://www.nytimes.com/2015/11/17/world/americas/mennonite-farmers-prepare-to-leave-mexico-and-competition-for-water.html.

Chaffin, B.C., Garmestani, A.S., Gosnell, H. and Craig, R.K. 2016. Institutional networks and adaptive water governance in the Klamath River Basin, USA. *Environmental Science & Policy*. **57**, pp.112–121.

Chaffin, B.C., Gosnell, H. and Cosens, B.A. 2014. A decade of adaptive governance scholarship: Synthesis and future directions. *Ecology and Society*. **19**(3), p.56.

CJF 2016. Consejo de la Judicatura Federal. Respuesta a solicitud de informacion 0320000157416. [Accessed 3 October 2017]. Available from: http://www.plataformadetransparencia.org.mx/web/guest/inicio?p_p_id=buscadoresportlet_WAR_buscadoresportlet&p_p_lifecycle=0&p_p_state=maximized&p_p_mode=view&p_p_col_id=column-

2&p_p_col_count=2&_buscadoresportlet_WAR_buscadoresportlet_action=buscardoresPo.

CONABIO 2014. *Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. La biodiversidad en Chihuahua: Estudio de Estado.* [Online]. Mexico. Available from: http://www.biodiversidad.gob.mx/region/EEB/pdf/Chihuahua_Final_Web.pdf.

CONAGUA 2015. Disponibilidad por Acuíferos: Comision Nacional del Agua. [Accessed 11 September 2017]. Available from: https://www.gob.mx/conagua/acciones-y-programas/chihuahua-74904.

Cosens, B. 2015. *Application of the Adaptive Water Governance Project to the management of the Lake Eyre Basin and its connections to the Great Artesian Basin, Report to Flinders University and the Goyder Institution* [Online]. Adelaide, South Australia. [Accessed 10 February 2017]. Available from: http://goyderinstitute.org/index.php?id=53.

Cosens, B.A. 2013. Legitimacy, adaptation, and resilience in ecosystem management. *Ecology and Society*. **18**(1), p.3.

Cosens, B.A., Craig, R.K., Hirsch, S.L., Arnold, C.A. (Tony), Benson, M.H., DeCaro, D.A., Garmestani, A.S., Gosnell, H., Ruhl, J.B. and Schlager, E. 2017. The role of law in adaptive governance. *Ecology and Society*. **22**(1), p.30.

Davies, J., Barchiesi, S., Ogali, C.J., Welling, R., Dalton, J. and Laban, P. 2016. *Water in drylands: Adapting to scarcity through integrated management*. Gland, Switzerland: IUCN.

DeCaro, D.A., Arnold, C.A. (Tony), Frimpong Boamah, E. and Garmestani, A.S. 2017a. Understanding and applying principles of social cognition and decision making in adaptive environmental governance. *Ecology and Society*. **22**(1), p.33.

DeCaro, D.A., Chaffin, B.C., Schlager, E., Garmestani, A.S. and Ruhl, J.B. 2017b. Legal and institutional foundations of adaptive environmental governance. *Ecology and Society*. **22**(1), p.32.

Diario Oficial de la Federacion 2015. ACUERDO por el que se actualiza la disponibilidad media anual de agua subterránea de los 653 acuíferos de los Estados Unidos Mexicanos, mismos que forman parte de las regiones hidrológico-administrativas que se indican. *Director General de la Comisión Nacional del Agua, Órgano Administrativo Desconcentrado de la Secretaría de Medio Ambiente y Recursos Naturales*. [Online]. [Accessed 3 August 2017]. Available from: http://dof.gob.mx/nota_detalle.php?codigo=5389380&fecha=20/04/2015.

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Báldi, A., Bartuska, A., Baste, I.A., Bilgin, A., Chan, K.M., Figueroa, V.E., Duraiappah, A., Fischer, M., Hill, R., Koetz, T., Leadley, P., Lyver, P., Mace, G.M., Martin-Lopez, B., Okumura, M., Pacheco, D., Pascual, U., Pérez, E.S., Reyers, B., Roth, E., Saito, O., Scholes, R.J., Sharma, N., Tallis, H., Thaman, R., Watson, R., Yahara, T., Hamid, Z.A., Akosim, C., Al-Hafedh, Y., Allahverdiyev, R., Amankwah, E., Asah, S.T., Asfaw, Z., Bartus, G., Brooks, L.A., Caillaux, J., Dalle, G., Darnaedi, D., Driver, A., Erpul, G., Escobar-Eyzaguirre, P., Failler, P., Fouda, A.M.M., Fu, B., Gundimeda, H., Hashimoto, S., Homer, F., Lavorel, S., Lichtenstein, G., Mala, W.A., Mandivenyi, W., Matczak, P., Mbizvo, C., Mehrdadi, M., Metzger, J.P., Mikissa, J.B., Moller, H., Mooney, H.A., Mumby, P., Nagendra, H., Nesshover, C., Oteng-Yeboah, A.A., Pataki, G., Roué, M., Rubis, J., Schultz, M., Smith, P., Sumaila, R., Takeuchi, K., Thomas, S., Verma, M., Yeo-Chang, Y. and Zlatanova, D. 2015. The IPBES Conceptual Framework — connecting nature and people. *Current Opinion in Environmental Sustainability*. **14**, pp.1–16.

DiCicco-Bloom, B. and Crabtree, B.F. 2006. The qualitative research interview. *Medical Education*. **40**(4), pp.314–321.

DOF 1957. ACUERDO que establece el Distrito de Riego de El Carmen, en San Buenaventura y Villa Ahumada, Chih., y declara de utilidad pública la construcción de las obras que lo formen y la adquisición de los terrenos necesarios para alojarlas y operarlas. , pp.4–5. [Accessed 31 July 2017]. Available from: http://dof.gob.mx/nota_to_imagen_fs.php?cod_diario=188731&pagina=5&seccion=0.

DOF 1976. RESOLUCION sobre dotación de aguas, solicitada por vecinos del poblado denominado Benito Juarez, antes Enriquez y Punta de Alamos, Municipio de Buenaventura, Chih. *El Presidente Constitucional de los Estados Unidos Mexicanos*.

[Online]. [Accessed 8 September 2017]. Available from: http://www.dof.gob.mx/nota_detalle.php?codigo=4833085&fecha=05/01/1976.

Folke, C. 2016. Resilience (Republished). *Ecology and Society*. **21**(4), p.44.

Folke, C., Hahn, T., Olsson, P. and Norberg, J. 2005. ADAPTIVE GOVERNANCE OF SOCIAL-ECOLOGICAL SYSTEMS. *Annual Review of Environment and Resources*. **30**(1), pp.441–473.

Forouzani, M., Karami, E., Zamani, G.H. and Moghaddam, K.R. 2013. Agricultural water poverty: Using Q-methodology to understand stakeholders' perceptions. *Journal of Arid Environments*. **97**, pp.190–204.

Garmestani, A. and Benson, M. 2013. A Framework for Resilience-based Governance of Social-Ecological Systems. *Ecology & Society*. **18**(1), p.9.

Grizzetti, B., Lanzanova, D., Liquete, C., Reynaud, A. and Cardoso, A.C. 2016. Assessing water ecosystem services for water resource management. . **61**, pp.194–203.

Gunderson, L.H., Cosens, B. and Garmestani, A.S. 2016. Adaptive governance of riverine and wetland ecosystem goods and services. *Journal of Environmenal Management*. **183**, pp.353–360.

Huang, J., Yu, H., Guan, X., Wang, G. and Guo, R. 2015. Accelerated dryland expansion under climate change. *Nature Climate Change*. **6**(October), pp.1–22.

Huitema, D., Mostert, E. and Pahl-wostl, C. 2009. Adaptive Water Governance : Assessing the Institutional Prescriptions of Adaptive (Co-) Management from a Governance Perspective and Defining a Research Agenda. . **14**(1), p.26.

INEGI 2003. *Síntesis de Información geográfica del estado de Chihuahua* [Online]. Aguascalientes, Mexico. [Accessed 26 January 2017]. Available from: http://internet.contenidos.inegi.org.mx/contenidos/productos/prod_serv/contenidos/espanol/bvinegi/productos/historicos/2104/702825224332/702825224332_12.pdf.

Knieper, C., Holtz, G., Kastens, B. and Pahl-Wostl, C. 2010. Analysing water governance in heterogeneous case studies—Experiences with a database approach. *Environmental Science & Policy*. **13**(7), pp.592–603.

Kohlbacher, F. 2006. The Use of Qualitative Content Analysis in Case Study Research. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*. **7**(1), pp.1–30.

Manzanares Rivera, J.L. 2016. Hacer florecer al desierto: Análisis sobre la intensidad de uso de los recursos hídricos subterráneos y superficiales en Chihuahua, México. *Cuadernos de Desarrollo Rural*. **13**(77), pp.35–61.

Martin-Ortega, J., Ferrier, R., Gordon, I. and Khan, S. 2015. *Water Ecosystem Services: A Global Perspective* [Online]. Cambridge: Cambridge University Press. [Accessed 5 October 2017]. Available from: http://unesdoc.unesco.org/images/0024/002447/244743e.pdf.

Medema, W., Adamowski, J., Orr, C., Furber, A., Wals, A. and Milot, N. 2017. Building a Foundation for Knowledge Co-Creation in Collaborative Water Governance: Dimensions of Stakeholder Networks Facilitated through Bridging Organizations. *Water*. **9**(1), p.60.

Mortimore, M., Anderson, S., Cotula, L., Davies, J., Faccer, K., Hesse, C., Mortin, J., Nyangena, W., Skinner, J. and Wolfangel, C. 2009. *Dryland opportunities: a new paradigm for people, ecosystems and development* [Online]. IUCN, Gland, Switzerland; IIED, London, UK and UNDP/DDC, Nairobi, Kenya: IUCN. Available from: http://trove.nla.gov.au/work/160629536?q&versionId=175115005.

Murillo-Licea, D. and Soares-Moraes, D. 2013. El péndulo de la gobernabilidad y la gobernanza del agua en México. *Tecnologia y Ciencias del Agua*. **4**(3), pp.149–163.

North, D.C. 1990. *Institutions, institutional change, and economic performance* [Online]. Cambridge: Cambridge University Press. [Accessed 5 September 2017]. Available from: http://admin.cambridge.org/gb/academic/subjects/politics-international-relations/political-economy/institutions-institutional-change-and-economic-performance#Z2tkQfZ58LXFGHS5.97.

Österblom, H. and Folke, C. 2013. Emergence of global adaptive governance for stewardship of regional marine resources. *Ecology and Society*. **18**(2), p.4.

Pahl-Wostl, C., Holtz, G., Kastens, B. and Knieper, C. 2010. Analyzing complex water governance regimes: The Management and Transition Framework. *Environmental Science and Policy*. **13**(7), pp.571–581.

Prell, C., Reed, M.S., Racin, L. and Hubacek, K. 2010. Competing structure, competing views: The role of formal and informal social structures in sahping stakeholder perceptions. *Ecology and Society*. **15**(4), p.34.

Quintana, V.M. 2013. Nuevo orden alimentario y disputa por el agua en el norte de México. *Apuntes: Revista de Ciencias Sociales*. **40**(73), pp.175–202.

Reed, M.S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C.H. and Stringer, L.C. 2009. Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management*. **90**(5), pp.1933–1949.

Safriel, U., Adeel, Z., Niemeijer, D., Puigdefabregas, J., White, R., Lal, R., Winslow, M., Ziedler, J., Prince, S., Archer, E., King, C., Shapiro, B., Wessels, K., Nielsen, T., Portnov, B., Reshef, I., Thonell, J., Lachman, E. and Mcnab, D. 2005. *Chapter 22 Dryland Systems. Ecosystems and Human Well-being: Current State and Trends. Volume 1, findings of the Responses Working Group of the Millennium Ecosystem Assessment.* [Online] (N. Hassan R., Scholes, R., Ash, ed.). Washington, D.C., USA.: Island Press. Available from: https://www.millenniumassessment.org/documents/document.291.aspx.pdf.

Schlüter, M., Baeza, A., Dressler, G., Frank, K., Groeneveld, J., Jager, W., Janssen, M.A., McAllister, R.R.J., Müller, B., Orach, K., Schwarz, N. and Wijermans, N. 2017. A framework for mapping and comparing behavioural theories in models of social-ecological systems. *Ecological Economics*. **131**, pp.21–35.

SEMARNAT 2017. Secretaria de Medio Ambiente y Recursos Naturales. Respuesta a solicitud de informacion 0001600286117.

Stringer, L.C., Reed, M.S., Fleskens, L., Thomas, R.J., Le, Q.B. and Lala-Pritchard, T. 2017. A New Dryland Development Paradigm Grounded in Empirical Analysis of Dryland Systems Science. *Land Degradation & Development*. **28**(7), pp.1952–1961.

Young, O.R. 2010. Institutional dynamics: Resilience, vulnerability and adaptation in environmental and resource regimes. *Global Environmental Change*. **20**(3), pp.378–385.

Chapter 3

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

This chapter is the accepted manuscript of Lopez Porras, G., Stringer, L.C. and Quinn, C.H. 2019. Corruption and conflicts as barriers to adaptive governance: Water governance in dryland systems in the Rio del Carmen watershed. Science of The Total Environment. 660, pp.519–530. https://www.sciencedirect.com/science/article/pii/S0048969719300361.

Abstract

Water governance in the Rio del Carmen watershed has failed to achieve sustainable water use, generating social conflicts, water overexploitation, and grassland loss. This leaves it unable to adapt and learn, to reconcile different stakeholder perspectives and to adequately respond to uncertainty. Adaptive water governance regulates water access through flexible, inclusive and innovative institutions, increasing system adaptive capacity in the face of uncertainty. This is necessary for water-scarce systems since they suffer context-specific exposure to land degradation and climate change. This research focuses on how water governance regulates water access in the Rio del Carmen watershed, Mexico, identifying key legal and institutional features that could increase adaptation and secure water resources in the long-term. 27 semi-structured interviews were conducted with key stakeholders in the watershed, in order to understand the water governance structure and its system dynamics. It was found that water mismanagement, overexploitation, and conflicts over access to water are due to the lack of application and neglect of formal rules. Results indicate that breaches of the legal framework are commonplace, permitted by corruption of both former and current government officials. Many farmers have institutionalized this corruption in order to access water; increasing social conflicts and hindering any type of planning or water management, which, in turn, continues to affect the ecological conditions of the watershed. By understanding the governance system, its structure and the interactions that weaken and bypass formal institutions to the detriment of water resources, stakeholder engagement has emerged as an entry point for enabling collaboration and acceptance of

formal institutions. This process has the potential to create a formal network, as a Watershed Committee, that could be honoured in practice through the efficacy of this engagement.

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

3.1. Introduction

Drylands are expanding as a result of environmental change and mismanagement (Huang et al., 2017). Resulting droughts, desertification and degradation accentuate the emergence of often violent conflicts in these regions (IPBES, 2018). Adaptive capacity in dryland systems is the ability to develop innovative solutions to face unpredictable changes or disturbances in a water-scarce context (Folke, 2016; Reed and Stringer, 2015). Adaptive water governance (AWG) seeks to foster this adaptive capacity through knowledge generation, flexibility, cross-scale collaboration and subsidiarity, as basic principles that can increase system resilience (Hill Clarvis et al., 2014). A central challenge in increasing drylands' resilience is the conservation of societal benefits obtained from freshwater sources, also known as water ecosystem services (WES), as they are the basis for maintaining multiple ecosystem functions and sustaining and improving human well-being (Davies et al., 2016; Pravalie, 2016). WES conservation needs proactive management of natural processes, if they are to sustain dryland livelihoods (WWAP, 2018). However, in dryland systems like the Rio del Carmen watershed in Mexico, where agriculture is the predominant livelihood activity, the mismanagement of WES has resulted in social conflicts and ecological degradation (Lopez Porras et al., 2018), which generate a loss of resilience and increase vulnerability (Reed and Stringer, 2015).

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

In order to improve human well-being and increase system resilience in drylands, access to WES needs to be regulated within an inclusive and integrated water governance regime (Aylward et al., 2005). This requires a feasible legal and institutional structure with the underlying elements of learning, connectivity, collaboration, flexibility, and subsidiarity (Figure 3.1), where WES access can be adjusted according to the system needs in the face of uncertainty (DeCaro et al., 2017b; Hill Clarvis et al., 2014). Sarker (2013) highlights how collaboration and users' autonomy to manage their resources, supported by the financial, technological and legal resources that the state can grant, increases efficiency in water governance. AWG offers one route towards these features (Cosens et al., 2018). However, as found in Australia's Murray Darling Basin, where the excessive use of water resources for agriculture led to environmental degradation and water quality problems, water reforms and their implementation is highly challenging in dryland systems that have institutional problems and conflicted interests (Alexandra, 2018). More information is needed regarding the potential for restructuring dryland water governance and the implications for AWG (DeCaro et al., 2017b). Furthermore, more research with policy implications is needed, where findings can be translated into real institutional constructs, which ultimately will show how legal frameworks can be leveraged to enable AWG.

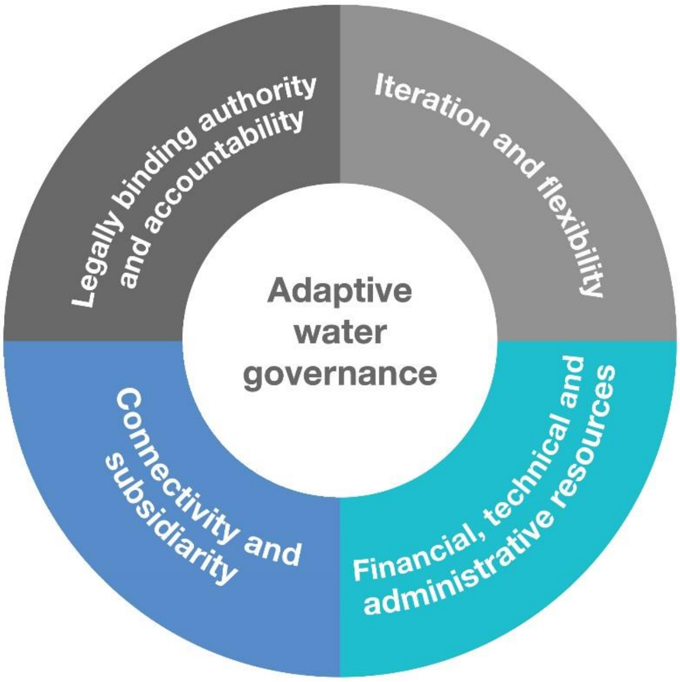

Figure 3.1 Adaptive water governance conceptual framework.

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

3.2. Study area and methodology

3.2.1 The Rio del Carmen watershed

The Rio del Carmen watershed (Figure 3.2) is located in the driest area of the Chihuahuan desert, in Chihuahua, Mexico (Quintana, 2013). Its vegetation, average rainfall, and climate conditions (Figure 3.3) are representative of many dryland systems (Safriel et al., 2005). It is composed of 3 main aquifers: Santa Clara (upstream), Flores-Magon – Villa Ahumada and Laguna de Patos (both downstream). More than 90% of water from these aquifers is used for agricultural purposes (CONAGUA, 2015a), producing mainly chilli, pecans, cotton, alfalfa, sorghum, and maize (Lopez Porras et al., 2018). However, the three aquifers are considered to be overexploited (DOF, 2018). The most important river is the River Carmen, whose waters are retained in the Las Lajas dam with a capacity of 91.01 million m^3 (INEGI, 2003).

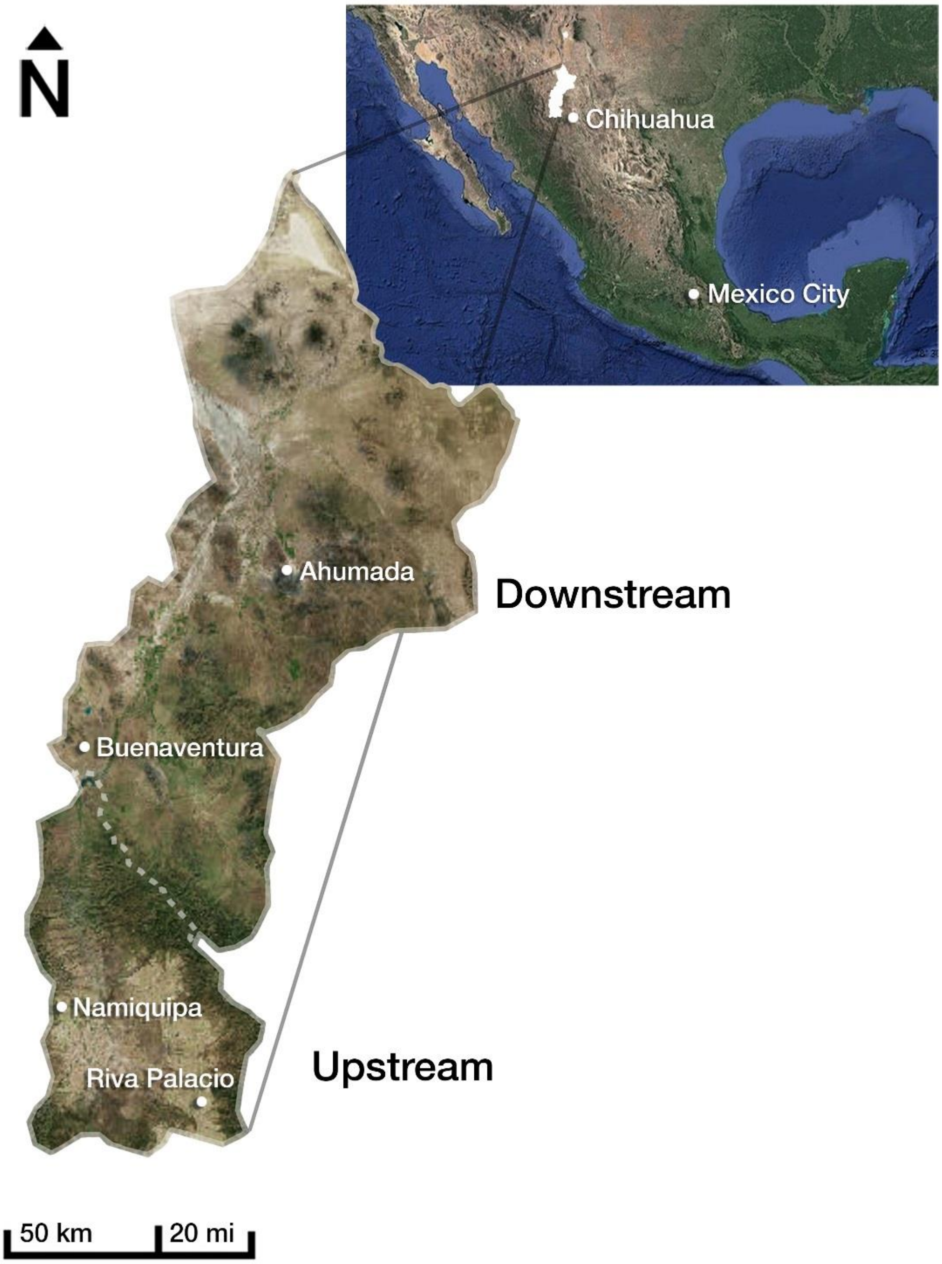

Figure 3.2 Location and upstream and downstream divisions in the Rio del Carmen watershed. Images obtained from INEGI, (2016).

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

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

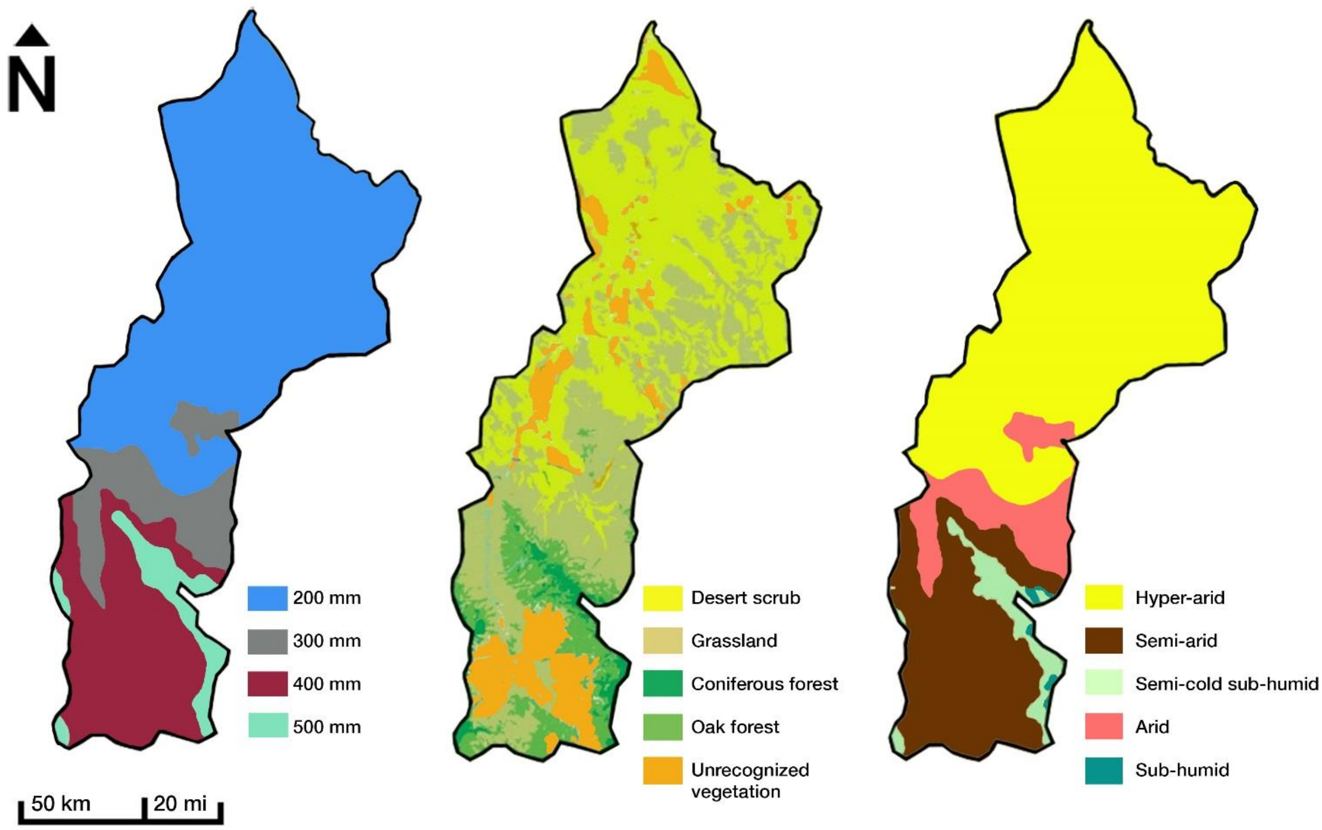

Figure 3.3 Precipitation, vegetation cover and climate conditions in the Rio del Carmen watershed. Maps modified from information obtained from INEGI (2016).

3.2.2 Research design and methods

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

3.2.2a. Sampling

A combination of snowball (Reed et al., 2009) and purposeful sampling (Patton, 1999) approaches was then used, asking interviewees to identify and nominate other stakeholders that would provide significant information regarding water governance in the

Rio del Carmen watershed. The snowball sample had multiple starting points, beginning with an interview in each stakeholder category in order to avoid a biased sample (Seale, 2012; Sulaiman-Hill and Thompson, 2011). In qualitative research, sample size and participant selection do not require representativeness or statistical significance to legitimize the findings (Luna-Reyes and Andersen, 2003; Reed et al., 2009). Instead, to obtain in-depth qualitative data, the purposeful sample allowed us to better understand the governance system in the Rio del Carmen watershed, by obtaining in-depth insights from relevant stakeholders rather than generating generalized data from a population subset (Patton, 1999). The stakeholder nominations resulted in a sample of 27 interviews with representatives of the main sectors related to water access and agriculture in the watershed (Table 3.1), consisting of 14 farmers, 7 government officials, 4 consultants, 1 NGO and 1 academic.

Table 3. 1 Description of the organisations and sector representation from each stakeholder category.

Stakeholder Category	Farmers	Government officials	Consultants	NGO	Academic
Sector representatives	Mennonite community	National Water Commission	Agricultural management	World Wide Fund for Nature	Faculty of Zootechnics and Ecology of the Autonomous University of Chihuahua
	Mexican farmers	Secretariat of Environment and Natural Resources	Legal advice		
		Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food	Agricultural products and trade		
		State Coordination of Civil Protection			

3.2.2b. Data collection

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

3.2.2c. Analysis

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

Transcripts were analysed using NVivo 11 for Windows using the content analysis method (Bernard, 2011) based on a deductive coding technique (Luna-Reyes and Andersen, 2003), where coding categories where determined on the basis of the adaptive governance literature (Cosens et al., 2018). The resulting codes were: agriculture, economic and social drivers, environmental change, institutional and structural features, water management, WES access, trade-offs, conflicts, entry points for adaptation, and legal compliance. During the process, indicative stakeholder quotes were structured in a matrix of codes (Figure 3.4) in order to test the accuracy of the coding process. Secondary data on aspects including water availability, legal provisions such as the restricted-access decree, and pecan production in the watershed, were obtained from the Federal Government of Mexico's websites: https://www.gob.mx/conagua; www.dof.gob.mx; http://gaia.inegi.org.mx/; http://www.diputados.gob.mx/LeyesBiblio/; and https://datos.gob.mx/. Secondary data was analysed using the same coding criteria as the interviews in order to facilitate data validation (Patton, 1999). The data obtained from the semi-structured interviews and the secondary data were compared, and triangulated with other sources related to water governance in the Rio del Carmen watershed, such as Athie, (2016); Burnett, (2015); Manzanares Rivera, (2016); and Quintana, (2013). By doing this, we avoided the weakness associated with the use of a single data collection method (Patton, 1999). This also helped to validate and verify the results, by corroborating the consistencies of the data and identifying where the differences were (Chi, 1997). The explanation of the governance system started from the integration of the coding matrix using the system narrative method (Luna-Reyes and Andersen, 2003). This qualitative method "allows for causal analysis and exploration of the interplay of complex system components" (Rissman and Gillon, 2017, p. 90). For contradictions during the cross-data validity checks, a complementary approach was used since differences did not necessarily refute each other, so they were analysed in context and were included to demonstrate the perception of each interviewee (May, 2010).

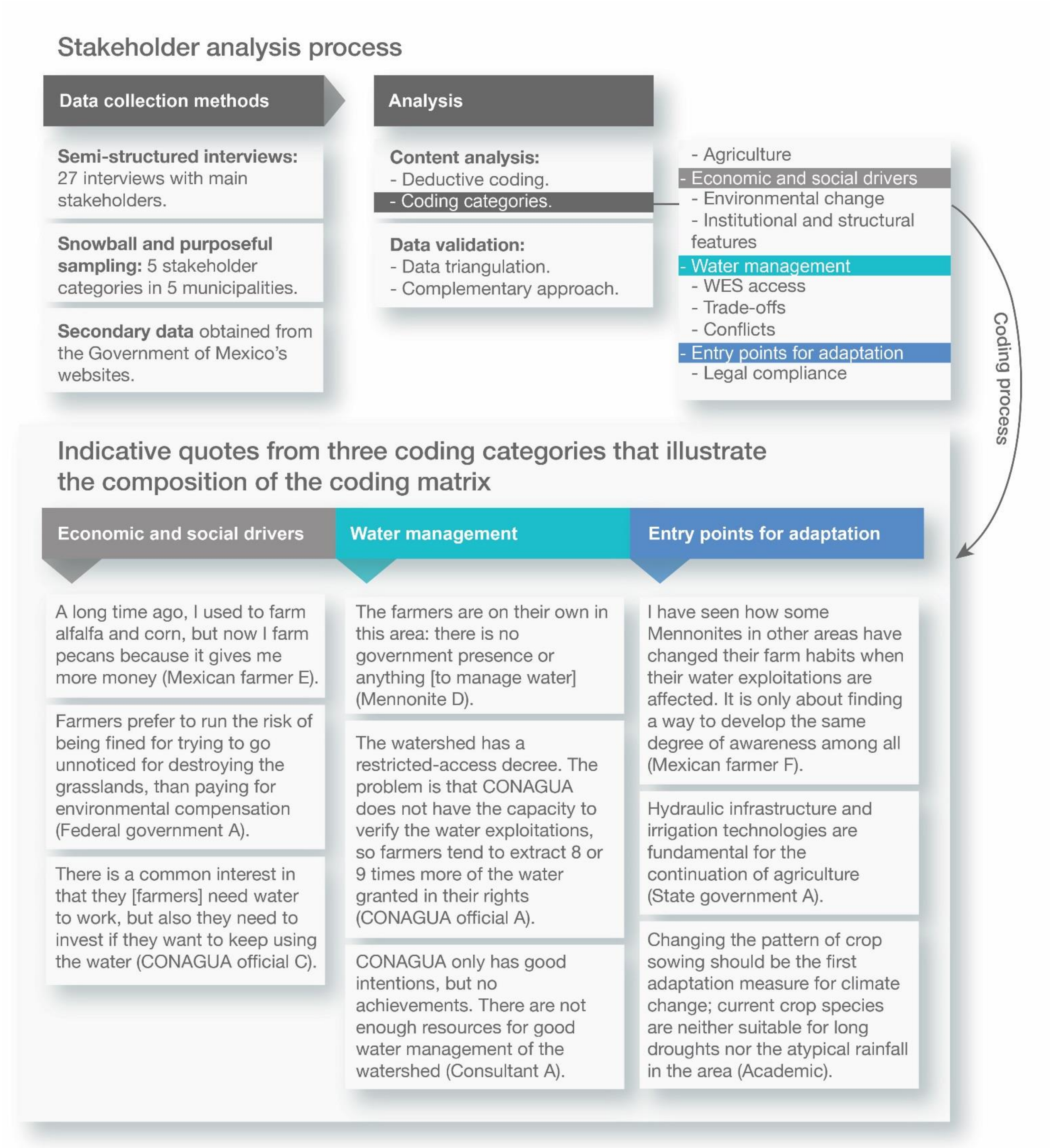

Figure 3.4 Stakeholder analysis process and coding process with three indicative quotes from three coding categories that illustrate the composition of the coding matrix.

3.3. Results

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

3.3.1a. Legal and institutional structure

Article 27 of the Political Constitution of Mexico establishes that the State is the original owner of water resources located within national territory. The use or exploitation of water can only be made through concessions granted by the federal government, consisting of extraction permits in free access areas or water rights in regulated or restricted-areas. The establishment of this water-rights system dates back to 1894, when, aiming to increase economic development in an orderly way, Mexico implemented this system through a very centralised and top-down governance regime (Athie, 2016). Given government inefficiencies in water management at state and municipal scales, Mexico underwent structural reforms in the 1980s (Athie, 2016). This led to the creation of the National Water Commission (CONAGUA) in 1989, establishing it as the government agency responsible for the national water management (Mussetta, 2009). CONAGUA's framework of action is regulated by 3 legal instruments: the National Water Law published in the Federal Official Gazette on 1st December 1992, the Regulation of the National Water Law published in the same Gazette on 12nd January 1994, and the Interior Regulation of the National Water Commission published in the Gazette on 30th November 2006.

Under the premise that by increasing participation in public affairs, governments can be more flexible, decentralised, and inclusive, CONAGUA established river basin water governance (Mussetta, 2009). Accordingly, CONAGUA's structure encompasses 3 governance levels: National, Regional Hydrological-Administrative, and State level. The administrative units that relate to Rio del Carmen watershed governance are the River Basin Councils (Regional level), the Chihuahua Local Directorate (State level), and the Irrigation District El Carmen 089 (regulated at the State level). Nonetheless, having a comprehensive legal structure and a governance regime that on paper increases public participation, has not been enough to improve Mexican water governance, because in its operation, various deficiencies have generated social and environmental crises (Athie, 2016; Mussetta, 2009).

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

At State level is the Chihuahua Local Directorate. The Directorates are the local organisations representative of CONAGUA´s water management throughout the Mexican states, applying its policies, strategies, programs, and actions (CONAGUA official C, interview transcript). Regarding water management in the watershed, "*CONAGUA has been trying to address the farmers' claims and has been monitoring the piezometric level of the watershed*" (CONAGUA official B). Nonetheless, interviewees noted that the Local Directorate lacks human and economic resources in its management. For example, "*The technical data for water resources is not obtained according to the procedures that the law dictates. There are only 5 or 6 inspectors in Chihuahua State and they never go to the Rio del Carmen watershed to verify and measure water access*" (Consultant D). The National Water Law establishes that restricted access areas like the Rio del Carmen watershed should have a comprehensive watershed management program and participatory processes for designing and implementing Mexican Official Standards that regulate water access. Also, this law envisages the creation of organizations such as Watershed Committees or Technical Committees of Underground Water, among other formal institutions, for enabling participatory water management according to the specific water-system needs. The Local Directorate is the starting point for these processes. However, "*the Local Directorate has not designed any watershed management programme; its bad reputation has caused it to lose acceptance in the watershed and therefore it has had less presence in the area*" (CONAGUA official A). Likewise, "*there are always isolated requests to increase the watershed's regulation: these are people* [farmers] *worried about their work, but nothing has been done*" (CONAGUA official C).

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

3.3.1b. Societal complexity in the governance system

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

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

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

3.3.2a. Agriculture and WES access

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

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

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

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

3.3.2b. Social and ecological impacts

Water availability is defined by the volume that can be extracted without affecting the water and ecosystem balance (CONAGUA, 2015a), so from this perspective, ecological thresholds in water-based SES are crossed through water depletion. Underground water is getting towards that point as it is alarmingly overexploited (Figure 3.5). "*In the last 4 years the water levels in the aquifer have been decreasing. We have had to deepen the wells which is very expensive, but also we are already drawing very deep water*" (Mexican farmer G). The watershed has surface water availability (Figure 3.5), nonetheless, the construction of illegal dams upstream is causing serious alterations to the water balance. "*30 years ago, we had surface water flow of 100 million* m^3y^{-1}*, and in 2012 we discovered that the surface water flow had dropped to 66 million* m^3y^{-1}" (CONAGUA official A). Given illegal water access

(Figure 3.5), there are no reliable data regarding water access and its availability. Again, this is an important barrier to any agricultural planning in the watershed.

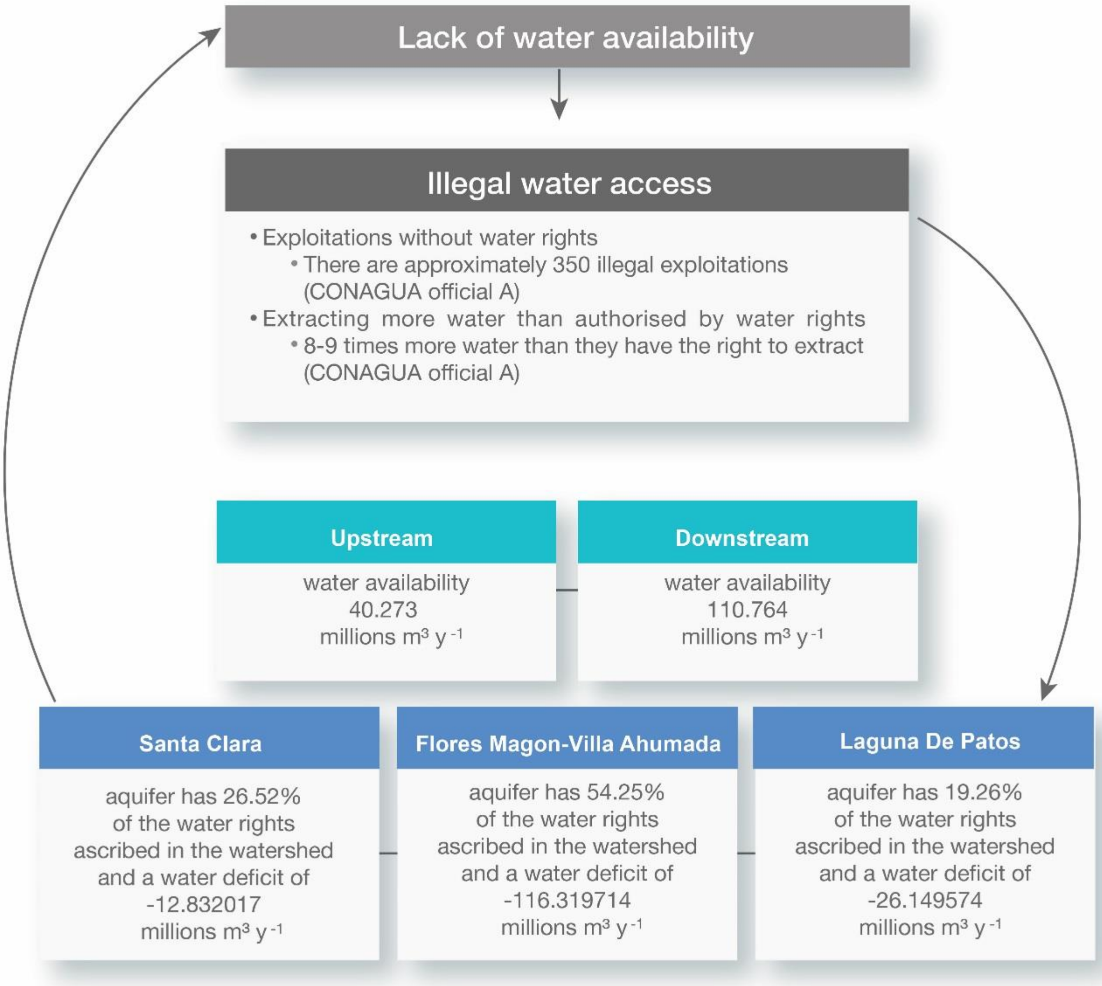

Figure 3.5 Socio-ecological water interactions in the Rio del Carmen watershed. Data obtained from DOF, (2016), DOF, (2018) and CONAGUA official A.

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

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

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

3.3.3a. Corruption and conflicts as barriers

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

> "*CONAGUA has created a black market for water rights, and the worst thing is that despite being the only way to get them, many are false and they ask for money so they can continue exploiting water illegally*" (Mexican farmer A).
>
> *"When we go for help, they* [CONAGUA] *tell us that our water right is false, they charge us money to regularize our exploitations and then it turns out that what they sold us is also false, and still, they extort us by asking for money so as not to remove*

our exploitations" (Mennonite A).

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

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

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

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

3.3.3b. Side effects of social conflicts

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

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

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

Despite these attempts and proposals from some Mexican farmers to improve the management of the Rio del Carmen watershed, coordination with CONAGUA has not been achieved. "*The problem is that the stakeholders with more influence* [CONAGUA officials] *and more economic resources* [Mennonite farmers] *are benefited by the status quo*"

(Consultant D). This power asymmetry strengthens unsuitable institutional conditions and incentivises corruption, given the niche of impunity that is created, as a Mexican farmer stated:

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

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

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

3.4. Discussion

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

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

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

- Be iterative and flexible in order to adjust water governance in the face of uncertainty. These uncertainties include precipitation variability and unanticipated changes in land coverage (Sietz et al., 2017).

- Give legally binding authority and accountability to stakeholders, to allow locally appropriate decision-making and encourage collaboration.

- Have financial, technical and administrative powers to self-govern WES in the watershed.

- Embrace connectivity and subsidiarity, so that different centres of activity can concur at the watershed scale, with local standards and policies.

In light of this, it is clear that the administrative river basin scale established by the National Water Law does not fit with the required elements for AWG, or with the social and ecological needs in the watershed. River Basin Councils are failed water organizations without representativeness (OECD, 2013). The distance to and the lack of participation of the Rio del Carmen stakeholders in the Rio Bravo River Basin Council, is a barrier to the connectivity and subsidiarity that AWG requires. Governance problems are often different between local watershed scale and the wider river basin system (B. Cosens et al., 2014). This has been found to be the case elsewhere, such as in the Murray Darling Basin in Australia, where the large-basin scale and institutional complexity create bureaucratic obstacles that have undermined water governance and the implementation of water reforms (Alexandra, 2018). Indeed, bureaucracy and institutional inefficiency is a problem that increases CONAGUA's corruption (Athie, 2016). In this regard, despite the attempt to decentralize water governance through the creation of these councils, CONAGUA is still a centralised and top-down agency with no political stability, and no control over corruption (Murillo-Licea and Soares-Moraes, 2013). Decentralization as an attempt to increase the effectiveness of water governance does not solve corruption, and any governance reform in this sense can be prejudicial to the SES (Pahl-Wostl and Knieper, 2014).

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

3.4.2 Agriculture in a dryland context

Crop expansion and unsuitable agriculture are direct drivers of land degradation and water depletion (IPBES, 2018; Marston et al., 2015). Improving dryland agriculture is of paramount importance, since desertification, an extreme form of dryland degradation (Reed and Stringer, 2015), already affects around 70% of the world's agricultural drylands (Winslow et al., 2004). In this regard, desertification is a potential problem in the Rio del Carmen watershed, since the Chihuahuan Desert has been suffering from grassland loss and soil degradation (Caracciolo et al., 2016; PMARP, 2012). However, the crops that are being sown in the watershed are unsuitable given its precipitation and climate conditions (Figure 3.3), and water overexploitation (Quintana, 2013). As in the Limarí Basin in Chile, the absence of agricultural planning in dryland watersheds increases water scarcity and thus conflicts over water access, creating the self-produced problem of agricultural drought (Urquiza and Billi, 2018). In the Rio del Carmen watershed depletion levels are increasing and water flow decreasing. Surface irrigation is not suitable in a water-scarce context (Becerra et al., 2006), and there are better technologies than sprinkler irrigation for maize, like subsurface drip irrigation (Olague et al., 2006).

Accordingly, proactive WES-based governance is key to avoid watershed degradation, and to address the global challenges of climate change adaptation and contemporary water management problems (WWAP, 2018). A governance system that adjusts agricultural production and crop selection according to the dryland context is needed in order to avoid desertification and support the restoration of degraded soil (IPBES, 2018). This has been done elsewhere in Mexico, such as in the Nazas watershed in the north. This demonstrates that it is possible to establish water assets for agricultural planning in drylands, as long as there is an organized network at the necessary scale, with reliable data on water access, crop species, and land that is being sown (Sanchez Cohen et al., 2018). However, the Rio del Carmen does not yet have these aspects in place. Current governance problems will not change if current conflicts and corruption continue to permeate the social setting, because collaboration will be not achieved.

3.4.3 Entry points and barriers for AWG

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

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

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

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

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

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

For such a committee to be formulated, stakeholder engagement is needed, with the acceptance of the of costs and benefits that this brings with it (Akhmouch and Clavreul, 2016). The identified barriers for the stakeholder engagement include that those who are accessing water illegally do not have incentives to collaborate, since submitting voluntarily to this process will represent large losses in their agricultural investments, similar to a commons problem where individual benefits outweigh collective benefits (Hardin, 1968). However, this risks the livelihoods of those who use water legally, so farmers with water rights need to take leadership and drive institutional change (Pahl-Wostl and Knieper, 2014).

The success of collaboration will depend on the acceptance of trade-offs that arise during the engagement. For farmers, this could consist of voluntarily restricting water access or stopping sowing certain crops; from CONAGUA this might mean giving farmers some licences or authorizations regarding water verification and management. But as demonstrated by the Southern Ocean case, an informal network that effectively engages the stakeholders in resource management, has the potential to evolve and be endowed with legal formality, in order to formally establish AWG (AS Garmestani and Benson, 2013).

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

3.5. Conclusion

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

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

3.6. References

Akhmouch, A. and Clavreul, D. 2016. Stakeholder Engagement for Inclusive Water Governance: 'Practicing WhatWe Preach' with the OECD Water Governance Initiative. *Water (Switzerland)*. **8**(5), pp.1–17.

Alexandra, J. 2018. Evolving Governance and Contested Water Reforms in Australia's Murray Darling Basin. *Water*. **10**(2), p.113.

Anthonj, C., Diekkrüger, B., Borgemeister, C. and Thomas Kistemann 2019. Health risk perceptions and local knowledge of water-related infectious disease exposure among Kenyan wetland communities. *International Journal of Hygiene and Environmental Health*. **222**(1), pp.34–48.

Armitage, D.R., Plummer, R., Berkes, F., Arthur, R.I., Charles, A.T., Davidson-Hunt, I.J., Diduck, A.P., Doubleday, N.C., Johnson, D.S., Marschke, M., McConney, P., Pinkerton, E.W. and Wollenberg, E.K. 2009. Adaptive co-management for social–ecological complexity. *Frontiers in Ecology and the Environment*. **7**(2), pp.95–102.

Athie, K. 2016. *El Agua, ayer y hoy* [Online] (Centro de Estudios Sociales y de Opinion Publica, ed.). Mexico City: Camara de Diputados LXIII Legislatura. Available from: http://www5.diputados.gob.mx/index.php/camara/Centros-de-Estudio/CESOP/Estudios-e-Investigaciones/Libros/El-Agua-Ayer-y-Hoy.

Aylward, B., Bandyopadhyay, J., Belausteguigotia, J.-C., Börkey, P., Cassar, A., Meadors, L., Saade, L., Siebentritt, M., Stein, R., Tognetti, S., Tortajada, C., Allan, T., Bauer, C., Bruch, C., Guimaraes-Pereira, A., Kendall, M., Kiersch, B., Landry, C., Mestre Rodriguez, E., Meinzen-Dick, R., Moellendorf, S., Pagiola, S., Porras, I., Ratner, B., Shea, A., Swallow, B., Thomich, T. and Voutchkov, N. 2005. *Chapter 7 Freshwater Ecosystem Services. Ecosystems and Human Well-being: Policy Responses. Volume 1, findings of the Responses Working Group of the Millennium Ecosystem Assessment.* [Online] (F. R. Robert Constanza, Pedro Jacobi, ed.). Washington, D.C., USA. [Accessed 11 September 2018]. Available from: https://www.millenniumassessment.org/documents/document.312.aspx.pdf.

Becerra, M., Sainz, J. and Muñoz, C. 2006. Los conflictos por aguaen México.Diagnóstico y análisis. *Gestión y Política Pública*. **XV**(1), pp.111–143.

Bernard, H.R. 2011. *Research methods in anthropology : qualitative and quantitative approaches* [Online] 5th ed. Maryland: AltaMira. [Accessed 3 October 2017]. Available from: https://books.google.co.uk/books?hl=es&lr=&id=WhKYqATAySwC&oi=fnd&pg=PR1&dq=Research+methods+in+anthropology:+qualitative+and+quantitative+approaches&ots=6ArlvvOWzL&sig=dKTz4NAWqyXfqpbNsXAeTcGmOu0#v=snippet&q=deductive&f=false.

Bhattacherjee, A. 2012. *Social Science Research: Principles, Methods, and Practices* [Online] Book 3. (Textbooks Collection, ed.). Textbooks Collection. [Accessed 22 February 2017]. Available from: http://scholarcommons.usf.edu/oa_textbookshttp://scholarcommons.usf.edu/oa_textbooks/3.

Burnett, V. 2015. Mennonite Farmers Prepare to Leave Mexico, and Competition for Water. *The New York Times*. [Online], p.A6. [Accessed 6 October 2017]. Available from: https://www.nytimes.com/2015/11/17/world/americas/mennonite-farmers-prepare-to-leave-mexico-and-competition-for-water.html.

Capon, S.J., Lynch, A.J.J., Bond, N., Chessman, B.C., Davis, J., Davidson, N., Finlayson, M., Gell, P.A., Hohnberg, D., Humphrey, C., Kingsford, R.T., Nielsen, D., Thomson, J.R., Ward, K. and Nally, R. Mac 2015. Regime shifts, thresholds and multiple stable states in freshwater ecosystems; a critical appraisal of the evidence. *Science of The Total Environment*. **534**, pp.122–130.

Caracciolo, D., Istanbulluoglu, E., Noto, L.V. and Collins, S.L. 2016. Mechanisms of shrub encroachment into Northern Chihuahuan Desert grasslands and impacts of climate change investigated using a cellular automata model. *Advances in Water Resources*. **91**, pp.46–62.

Chi, M.T.H. 1997. Quantifying Qualitative Analyses of Verbal Data: A Practical Guide. *Journal of the Learning Sciences*. **6**(3), pp.271–315.

Collet, K. 2004. Una agricultura de regadío racional: El Salobral - Albacete (España). *Papeles de Geografía*. (39), pp.43–58.

CONAGUA 2013. *Comisión Nacional del Agua, Programa de Medidas Preventivas y de Mitigación de la Sequía (PMPMS) Consejo de Cuenca del Río Bravo (CC-R Bravo)* [Online]. Mexico. [Accessed 25 June 2018]. Available from: http://www.pronacose.gob.mx/pronacose14/contenido/documentos/11RioBravo.pdf.

CONAGUA 2015a. Comisión Nacional del Agua. Disponibilidad por Acuíferos. [Accessed 22 June 2018]. Available from: http://sigagis.conagua.gob.mx/gas1/sections/Disponibilidad_Acuiferos.html.

CONAGUA 2015b. *Comisión Nacional del Agua. Estadísticas Agrícolas de los Distritos de Riego Año Agrícola 2013-2014* [Online]. Mexico. [Accessed 28 June 2018]. Available from: http://www.conagua.gob.mx/CONAGUA07/Publicaciones/Publicaciones/SGIH-6-15.pdf.

CONAGUA 2016. Consejos de Cuenca: Comisión Nacional del Agua. [Accessed 4 June 2018]. Available from: https://www.gob.mx/conagua/documentos/consejos-de-cuenca.

Cosens, B., Gunderson, L., Allen, C., Benson, M., Cosens, B., Gunderson, L., Allen, C. and Benson, M.H. 2014. Identifying Legal, Ecological and Governance Obstacles, and Opportunities for Adapting to Climate Change. *Sustainability*. **6**(4), pp.2338–2356.

Cosens, B.A., Gunderson, L. and Chaffin, B.C. 2018. Introduction to the Special Feature Practicing Panarchy: Assessing legal flexibility, ecological resilience, and adaptive governance in regional water systems experiencing rapid environmental change. *Ecology and Society*. **23**(1), p.4.

Davies, J., Barchiesi, S., Ogali, C.J., Welling, R., Dalton, J. and Laban, P. 2016. *Water in drylands: Adapting to scarcity through integrated management*. Gland, Switzerland: IUCN.

DeCaro, D.A., Chaffin, B.C., Schlager, E., Garmestani, A.S. and Ruhl, J.B. 2017. Legal and institutional foundations of adaptive environmental governance. *Ecology and Society*. **22**(1), p.32.

DOF 2016. ACUERDO por el que se actualiza la disponibilidad media anual de las aguas nacionales superficiales de las 757 cuencas hidrológicas que comprenden las 37 regiones hidrológicas en que se encuentra dividido los Estados Unidos Mexicanos. [Accessed 23 August 2017]. Available from: http://dof.gob.mx/nota_detalle.php?codigo=5428971&fecha=08/03/2016.

DOF 1957. ACUERDO que establece el Distrito de Riego de El Carmen, en San Buenaventura y Villa Ahumada, Chih., y declara de utilidad pública la construcción de las obras que lo formen y la adquisición de los terrenos necesarios para alojarlas y operarlas. , pp.4–5. [Accessed 31 July 2017]. Available from: http://dof.gob.mx/nota_to_imagen_fs.php?cod_diario=188731&pagina=5&seccion=0.

DOF 2018. Diario Oficial de la Federación. ACUERDO por el que se actualiza la disponibilidad media anual de agua subterránea de los 653 acuíferos de los Estados Unidos Mexicanos, mismos que forman parte de las Regiones Hidrológico-Administrativas que se indican. [Accessed 22 June 2018]. Available from: http://www.dof.gob.mx/nota_detalle.php?codigo=5510042&fecha=04/01/2018.

Folke, C. 2016. Resilience (Republished). *Ecology and Society*. **21**(4), p.44.

Garmestani, A. and Benson, M. 2013. A Framework for Resilience-based Governance of Social-Ecological Systems. *Ecology & Society*. **18**(1), p.9.

Google 2018. Google Maps directions for driving from the Chihuahua Local Directorate of CONAGUA, to the Rio Bravo River Basin Council. [Accessed 25 September 2018]. Available from: https://www.google.co.uk/maps/dir/Avenida+Universidad+3300,+Magisterial+Universidad,+31200+Chihuahua,+Chih.,+Mexico/Edificio+Bisa,+Gral.+Jerónimo+Treviño+Pte.+4

09,+Centro,+64000+Monterrey,+N.L.,+Mexico/@27.0489497,-104.327531,8z/data=!3m1!4b1!4m.

Hardin, G. 1968. The tragedy of the commons. The population problem has no technical solution; it requires a fundamental extension in morality. *Science (New York, N.Y.)*. **162**(3859), pp.1243–8.

Hill Clarvis, M., Allan, A. and Hannah, D.M. 2014. Water, resilience and the law: From general concepts and governance design principles to actionable mechanisms. *Environmental Science and Policy*. **43**, pp.98–110.

Huang, J., Li, Y., Fu, C., Chen, F., Fu, Q., Dai, A., Shinoda, M., Ma, Z., Guo, W., Li, Z., Zhang, L., Liu, Y., Yu, H., He, Y., Xie, Y., Guan, X., Ji, M., Lin, L., Wang, S., Yan, H. and Wang, G. 2017. Dryland climate change: Recent progress and challenges. *Reviews of Geophysics*. **55**(3), pp.719–778.

INEGI 2016. Mapa Digital de México V6.1. Instituto Nacional de Estadistica y Geografia. [Accessed 14 February 2017]. Available from: https://gaia.inegi.org.mx/mdm6/?v=bGF0OjI1Ljc5MTU5LGxvbjotMTAyLjE0NTY1LHo6MixsOmMxMTFzZXJ2aWNpb3N8dGMxMTFzZXJ2aWNpb3M=.

INEGI 2003. *Síntesis de Información geográfica del estado de Chihuahua* [Online]. Aguascalientes, Mexico. [Accessed 26 January 2017]. Available from: http://internet.contenidos.inegi.org.mx/contenidos/productos/prod_serv/contenidos/espanol/bvinegi/productos/historicos/2104/702825224332/702825224332_12.pdf.

IPBES 2018. *Summary for policymakers of the assessment report on land degradation and restoration of the Intergovernmental SciencePolicy Platform on Biodiversity and Ecosystem Services. R. Scholes, L. Montanarella, A. Brainich, N. Barger, B. ten Brink, M. Cantele, B.* [Online]. IPBES secretariat, Bonn, Germany. [Accessed 25 September 2018]. Available from: www.ipbes.net.

LAN 2016. Ley de Aguas Nacionales. Diaro Oficial de la Federacion. CÁMARA DE DIPUTADOS DEL H. CONGRESO DE LA UNIÓN. [Accessed 13 February 2017]. Available from: http://www.diputados.gob.mx/LeyesBiblio/pdf/16_240316.pdf.

Lopez Porras, G., Stringer, L.C. and Quinn, C.H. 2018. Unravelling Stakeholder Perceptions to

Enable Adaptive Water Governance in Dryland Systems. *Water Resources Management*. **32**(10), pp.1–17.

Luna-Reyes, L.F. and Andersen, D.L. 2003. Collecting and analyzing qualitative data for system dynamics: methods and models. *System Dynamics Review*. **19**(4), pp.271–296.

Manzanares Rivera, J.L. 2016. Hacer florecer al desierto: Análisis sobre la intensidad de uso de los recursos hídricos subterráneos y superficiales en Chihuahua, México. *Cuadernos de Desarrollo Rural*. **13**(77), pp.35–61.

Marston, L., Konar, M., Cai, X. and Troy, T.J. 2015. Virtual groundwater transfers from overexploited aquifers in the United States. *Proceedings of the National Academy of Sciences of the United States of America*. **112**(28), pp.8561–6.

May, V. 2010. *Realities Toolkit #12. What to do with contradictory data?* [Online]. Morgan Centre, University of Manchester. [Accessed 19 July 2018]. Available from: http://hummedia.manchester.ac.uk/schools/soss/morgancentre/toolkits/12-toolkit-contradictory-data.pdf.

Middleton, N., Stringer, L., Goudie, A. and Thomas, D. 2011. *The Forgotten Billion MDG Achievement in the Drylands* [Online]. New York. [Accessed 9 March 2017]. Available from: http://www.unccd.int/Lists/SiteDocumentLibrary/Publications/ForgottenBillion.pdf.

Mortimore, M., Anderson, S., Cotula, L., Davies, J., Faccer, K., Hesse, C., Mortin, J., Nyangena, W., Skinner, J. and Wolfangel, C. 2009. *Dryland opportunities: a new paradigm for people, ecosystems and development* [Online]. IUCN, Gland, Switzerland; IIED, London, UK and UNDP/DDC, Nairobi, Kenya: IUCN. Available from: http://trove.nla.gov.au/work/160629536?q&versionId=175115005.

Murillo-Licea, D. and Soares-Moraes, D. 2013. El péndulo de la gobernabilidad y la gobernanza del agua en México. *Tecnologia y Ciencias del Agua*. **4**(3), pp.149–163.

Mussetta, P. 2009. Participación y gobernanza . El modelo de gobierno del agua en México. *Espacios Públicos*. **12**(25), pp.66–84.

OECD 2013. *Making Water Reform Happen in Mexico, OECD Studies on Water, OECD*

Publishing [Online]. Available from: http://dx.doi.org/10.1787/9789264187894-en.

Olague, J., Montemayor, J., Bravo, S., Fortis, M., Aldaco, A. and Ruiz, E. 2006. Características agronómicas y calidad del maíz forrajero con riego sub-superficial. *Revista Mexicana de Ciencias Pecuarias*. **44**(3), pp.351–357.

Österblom, H. and Folke, C. 2013. Emergence of global adaptive governance for stewardship of regional marine resources. *Ecology and Society*. **18**(2), p.4.

Pahl-Wostl, C. 2017. An Evolutionary Perspective on Water Governance: From Understanding to Transformation. *Water Resources Management*. **31**(10), pp.2917–2932.

Pahl-Wostl, C. and Knieper, C. 2014. The capacity of water governance to deal with the climate change adaptation challenge: Using fuzzy set Qualitative Comparative Analysis to distinguish between polycentric, fragmented and centralized regimes. *Global Environmental Change*. **29**, pp.139–154.

Patton, M.Q. 1999. Enhancing the quality and credibility of qualitative analysis. *Health services research*. **34**(5 Pt 2), pp.1189–208.

PMARP 2012. *Plan Maestro de la Alianza Regional para la Conservación de los Pastizales del Desierto Chihuahuense* [Online] (J. C. Guzman-Aranda, J. Hoth, & H. Berlanga, eds.). Montreal, Canada. Available from: http://rmbo.org/v3/Portals/0/Documents/International/Master_Plan_Chihuahua_jan2012.pdf.

Pravalie, R. 2016. Drylands extent and environmental issues. A global approach. *Earth-Science Reviews*. **161**, pp.259–278.

Quintana, V.M. 2013. Nuevo orden alimentario y disputa por el agua en el norte de México. *Apuntes: Revista de Ciencias Sociales*. **40**(73), pp.175–202.

Reed, M.S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C.H. and Stringer, L.C. 2009. Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management*. **90**(5), pp.1933–1949.

Reed, M.S. and Stringer, L.C. 2015. *Climate change and desertification: anticipating, assessing & adapting to future change in drylands* [Online] (Agropolis International & G. CCEE, eds.). Cancun, Mexico: 3rd UNCCD Scientific Conference. Available from: http://www.unccd.int/en/programmes/Science/Conferences/Documents/3sc_unccd_impulse-report.pdf.

Rissman, A.R. and Gillon, S. 2017. Where are Ecology and Biodiversity in Social-Ecological Systems Research? A Review of Research Methods and Applied Recommendations. *Conservation Letters*. **10**(1), pp.86–93.

Safriel, U., Adeel, Z., Niemeijer, D., Puigdefabregas, J., White, R., Lal, R., Winslow, M., Ziedler, J., Prince, S., Archer, E., King, C., Shapiro, B., Wessels, K., Nielsen, T., Portnov, B., Reshef, I., Thonell, J., Lachman, E. and Mcnab, D. 2005. *Chapter 22 Dryland Systems. Ecosystems and Human Well-being: Current State and Trends. Volume 1, findings of the Responses Working Group of the Millennium Ecosystem Assessment.* [Online] (N. Hassan R., Scholes, R., Ash, ed.). Washington, D.C., USA.: Island Press. Available from: https://www.millenniumassessment.org/documents/document.291.aspx.pdf.

Sanchez Cohen, I., Inzunza Ibarra, M., Esquivel Arriaga, G., Cerano Paredes, J., Velasquez Valle, M., Bueno Hurtado, P. and Ojeda Bustamante, W. 2018. The impact of climatic patterns on runoff and irrigation water allocation in an arid watershed of northern Mexico. *Meteorology Hydrology and Water Management*. **6**(2), pp.59–66.

Sarker, A. 2013. THE ROLE OF STATE-REINFORCED SELF-GOVERNANCE IN AVERTING THE TRAGEDY OF THE IRRIGATION COMMONS IN JAPAN. *Public Administration*. **91**(3), pp.727–743.

Seale, C. 2012. *Researching society and culture* [Online]. SAGE Publications. [Accessed 25 October 2018]. Available from: https://books.google.co.uk/books?id=jLAjZJGNGgAC&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false.

Sietz, D., Fleskens, L. and Stringer, L.C. 2017. Learning from Non-Linear Ecosystem Dynamics Is Vital for Achieving Land Degradation Neutrality. *Land Degradation & Development*. **28**(7), pp.2308–2314.

Sifuentes, E., Samaniego, J., Anaya, A., Nuñez, J., Valdez, B., Gutierrez, R., Ruelas, J. and Macias, J. 2015. Programación del riego en nogal pecanero (Carya illinoinensis), mediante un modelo integral basado en tiempo térmico. *Revista mexicana de ciencias agrícolas*. **6**(8), pp.1893–1902.

Smidt, S.J., Haacker, E.M.K., Kendall, A.D., Deines, J.M., Pei, L., Cotterman, K.A., Li, H., Liu, X., Basso, B. and Hyndman, D.W. 2016. Complex water management in modern agriculture: Trends in the water-energy-food nexus over the High Plains Aquifer. *Science of The Total Environment*. **566**–**567**, pp.988–1001.

Sulaiman-Hill, C.M. and Thompson, S.C. 2011. Sampling challenges in a study examining refugee resettlement. *BMC International Health and Human Rights*. **11**(1), p.2.

Urquiza, A. and Billi, M. 2018. Water markets and social–ecological resilience to water stress in the context of climate change: an analysis of the Limarí Basin, Chile. *Environment, Development and Sustainability*., pp.1–23.

Wiek, A. and Larson, K.L. 2012. Water, People, and Sustainability-A Systems Framework for Analyzing and Assessing Water Governance Regimes. *Water Resources Management*. **26**, pp.3153–3171.

Winslow, M., Shapiro, B., Thomas, R. and Shetty, S.V.. 2004. *Desertification, drought, poverty and agriculture: research lessons and opportunities*.[Online] Aleppo, Syria; Patancheru, India; and Rome, Italy: International Center for Agricultural Research in the Dry Areas (ICARDA), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and the UNCCD Global Mechanism (GM). [Accessed 2 October 2018]. Available from: www.icarda.org,.

WWAP 2018. *United Nations World Water Assessment Programme/UN-Water. The United Nations World Water Development Report 2018: Nature-Based Solutions for Water.* [Online]. Paris. [Accessed 24 September 2018]. Available from: www.unesco.org/open-access/.

Chapter 4

SEEKING COMMON GROUND IN DRYLAND SYSTEMS: STEPS TOWARDS ADAPTIVE WATER GOVERNANCE.

This chapter is the submited manuscript of Lopez Porras, G., Stringer, L.C. and Quinn, C.H. (2019). Seeking common ground in dryland systems: steps towards adaptive water governance. Under review in the Geographical Journal.

Abstract

Dryland systems are exposed to climate stressors such as water scarcity, but also to societal stressors such as inequality, that as a whole, can make water governance unsuitable for the system context. Adaptive water governance seeks to understand and embed a system's particular features into its management to increase resilience in the face of uncertainty and exposure to stress. Using the Rio del Carmen watershed in the Chihuahuan desert, Mexico, as a case study, this paper aims to understand the role of societal factors in shaping social-ecological system resilience in order to allow the emergence of adaptive water governance. A questionnaire survey was carried out with 217 farmers to identify system vulnerabilities in relation to water governance, and find areas of conflict and common ground. We found that different groups of farmers converge in identifying the main needs regarding water governance, as well as the climate and societal stressors that are affecting the watershed, yet the ways these stressors are perceived differ between groups. Results indicate that contrasting perceptions are shaped by the different environmental conditions in upper and lower parts of the watershed, and the different cultural roots of agricultural communities. These lines of variation increase the difficulty in achieving collaboration and compromise when conflicts ensue. Reducing inequalities in awareness about climate and societal stressors has the potential to build system resilience. This could be achieved through a peacebuilding technique with an appropriate cultural approach for the agricultural communities that reside in the watershed. If this is conducted in the early stages of a stakeholder engagement process, conflicting perceptions can be addressed and potentially

settled. Ultimately, this will allow the institutionalization of adaptive water governance and could increase dryland socio-ecological system resilience, providing important insights on how to deal with context when advancing adaptation.

4.1. Introduction

Drylands cover approximately 45% of the world's land surface (Plaza et al., 2018; Prăvălie, 2016). Their human populations number 2.8 billion people (Plaza et al., 2018), with projections suggesting increases to 4 billion in the next 30 years (IPBES, 2018). Such growth increases pressure on limited water resources, reducing water ecosystem services (WES) that support natural resource-based livelihoods (Schlaepfer et al., 2017). This does not mean that drylands are per se vulnerable; ecological attributes like rich biodiversity, crop and livestock production can make them resilient (Mortimore et al., 2009; Stringer et al., 2017). However, they face high exposure to environmental stressors, like droughts and high temperatures (Schlaepfer et al., 2017). Accordingly, vulnerability is determined by the sensitivity or extent to which WES and dryland livelihoods can change or disappear given exposure to those stressors (Reed and Stringer, 2016). Understanding relationships between resilience and vulnerability in drylands is paramount for securing livelihoods (Webb et al., 2017).

Looking at drylands as coupled social-ecological systems (SES) integrates human influences as a driver of change in development pathways, and in the environmental responses and modifications to WES (Carpenter et al., 2015; Okpara et al., 2018). This allows us to understand how human-caused disturbances affect drylands, better capturing the relationships between resilience and vulnerability (Dixon and Stringer, 2015; Gunderson et al., 2010). Furthermore, it allows us to reveal the societal factors that systematically place stress on the SES (Pichler and Brad, 2016).

Balancing different aspects of dryland resilience and vulnerability requires integrating the social complexities associated with context in the development of effective water governance. This is important since cultural constraints shape people´s perceptions of how SES work, influencing coping and adaptation to SES stressors, highlighting the role of perceptions and cultural sensitiveness when aiming to increase adaptive capacity (Engle, 2011; Lopez Porras et al., 2018). Adaptive water governance (AWG) has emerged as a way to foster adaptive capacity, moving from stiff and centralized water governance, towards more flexible, inclusive, and collaborative institutional arrangements that can strengthen SES resilience (DeCaro et al., 2017b). Literature claims that the emergence of AWG tends to begin when threats to social or ecological values, conflicts over scarce resources, or SES crises, mobilise key stakeholders to drive institutional change (Chaffin et al., 2014b; B. Cosens et al., 2014). Nevertheless, this institutional change requires acceptability, knowledge co-generation, social equity, and institutional coherence, which can be achieved through stakeholder engagement (Akhmouch and Clavreul, 2016; Lopez Porras et al., 2019). In drylands, stakeholder engagement for enabling AWG must consider and be sensitive to water scarcity and to competitiveness over its access; yet, approaches to fitting AWG to these social and ecological complexities are still unclear.

Characterising dryland exposure, sensitivity, and adaptive capacity through a stakeholder lens, can define how AWG could emerge and better fit dryland needs (Baca et al., 2014; Downing et al., 2005). Indeed, cognition of SES complexities is a key aspect when facing uncertainty (Dietz, 2013; Downing et al., 2005). The role that informal institutions, such as perceptions play for enabling AWG is paramount, as they shape collaboration and/or incompatible behaviours between stakeholders (Cosens et al., 2018; Lopez Porras et al., 2018; Schlüter et al., 2017). Opposing perceptions of how to move from undesirable states of governance can be dealt with through peacebuilding processes (Aggestam & Sundell-Eklund, 2014; Hileman et al., 2016), which increase the possibility of achieving and sustaining AWG. Addressing this challenge, we focus on understanding governance challenges that undermine dryland adaptation, and the potential that stakeholders have to overcome them and enable AWG, using the Rio del Carmen watershed as a case study. By doing so, we contribute solutions to one of the biggest dryland challenges: securing natural resource dependent livelihoods.

4.2. Methods and Research Design

4.2.1 The Rio del Carmen watershed

The Rio del Carmen watershed is in Chihuahua, Mexico. Precipitation is 200-300 mm with a hyper-arid climate downstream, with precipitation 400-500 mm and a semi-arid and semi-cold sub-humid climate upstream. The watershed comprises 3 aquifers that are overexploited (DOF, 2018). On the surface, the River Santa Clara later becomes the River Carmen, and in terms of hydraulic infrastructure, there is Las Lajas dam (INEGI, 2003). More than 90% of water in the watershed is used for agriculture, especially beans, maize, wheat, cotton, pecans, alfalfa, chili and other vegetables (Lopez Porras et al., 2018). There are two main agricultural communities: i) the Mexican farmers (downstream), most of whom are organized into an Irrigation District called El Carmen 089; and ii) the Mennonite farmers (upstream), a peaceful and secluded agricultural community, whose lifestyle is based on religious Anabaptism of 1500 from Central-Eastern Europe, where they are originally from (Bravo Peña et al., 2015). In the 1950s, due to increasing agriculture in the area, an undefined period of restricted-access for new water exploitations was established to secure agricultural continuity and conserve WES (DOF, 1957). However, climate change, illegal water access, illegal land use conversion from grasslands to farmlands, and unsuitable crop cultivation, threaten the future of agricultural livelihoods (Quintana, 2013).

Accordingly, social tensions emerged in 2010 when Mexican farmers noticed that groundwater was being rapidly depleted, alongside their abilities to exploit water on their farms. When they discovered the upstream agricultural development carried out by the Mennonites, the Mexican farmers self-organized to address the situation. They took action against the National Water Commission (CONAGUA) for water mismanagement, and the Mennonite community for blocking the water flow downstream (Quintana, 2013). The Mennonites defended themselves, and maintained their agricultural activities despite the social clashes (Quintana, 2013). Later, the Mexican farmers found that many of the Mennonites' upstream water exploitations were illegal, but the Mennonites were initially protected by the corruption of CONAGUA officials who had sold them false water rights

(Lopez Porras et al., 2019). Many of those illegal exploitations are now protected as a result of legal requests for defence. Such protection allows them water access without any water right until the trials are over, increasing the concerns of Mexican farmers about ongoing WES loss (Lopez Porras et al., 2019). This situation has exacerbated tensions between CONAGUA, the Mennonites and the Mexican farmers and provides the socio-cultural context to the study area.

4.2.2 Data collection

A questionnaire survey (Appendix IV) 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 and law enforcement, and the main problems and emerging needs in the watershed. Stratified sampling was used (Bhattacherjee, 2012).

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. 494 rights were identified and ascribed: Flores-Magon – Villa Ahumada (downstream) had 268, Santa Clara (upstream) had 131, and Laguna de Patos (upstream) had 95. Each aquifer was considered a stratum, and simple random sampling took place within each (Bhattacherjee, 2012). With a population size of 494 water rights, using a sample size calculator (SurveyMonkey, 2017), 95% confidence level and 5% margin of error (Barlett et al., 2001), 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, 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, January, and February 2019, secondary data on agricultural production, water rights, water availability, and climate conditions were collected from the websites https://www.gob.mx/conagua, http://201.116.60.187/index.html, https://www.inegi.org.mx/, and http://www.dof.gob.mx/, which are maintained by the Federal Government of Mexico, and used to complement the survey data.

4.2.3 Data analysis

Results were translated into English in March-April 2018, and transcribed and analysed using Microsoft Excel 2013. Along with the secondary data, we obtained a quantifiable estimation of vulnerability considering: 1) the SES's exposure to suffer harm, 2) its sensitivity to structural change due to that exposure and, 3) its adaptive capacity to maintain SES stability during exposure (Engle, 2011; Reed and Stringer, 2016). Exposure was examined using survey results on climate change perceptions, supported by official drought data to identify the climate stressors. Next, using the survey results regarding the main problems in the watershed and secondary data on conflicts, water availability, and yield stressors, we examined sensitivity by exploring how the various stressors specifically affect water governance, WES, and agricultural production. Investigating adaptive capacity used survey results that captured farmers' perceptions, alongside secondary data on agricultural expansion, highlighting features and maladaptations. Survey data regarding stakeholders' perceptions were analysed quantitatively according to frequency (Kohlbacher, 2006). A chi-square test of independence was carried out (Mcdonald, 2014), with the null hypothesis that both communities are equal in relation to their perceptions. Using frequency values from each group's perceptions (Table 4.2) we calculated the expected values, then using the CHISQ.TEST function from Microsoft Excel 2013 we calculated P values for each perception.

Survey data related to problems and priorities in water governance were analysed with an incidence and severity index approach (Quinn et al., 2003). In the survey, participants were asked to list and rank, with no limitations, the main problems and main needs in the water governance of 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 (or needs) mentioned by the respondent, we calculated their severity. This was done with every participant, then the average severity index was calculated for each problem (or need) by summing the Sj values of that problem (or need), 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). Secondary data on agricultural plantations, climate conditions, water granted, water availability, and natural recharge were analysed qualitatively, supporting data validation through methodological triangulation (Patton, 1999). We verified the consistency of survey results with secondary data and the literature on agricultural communities and water governance in Mexico, in the Chihuahuan desert, and the Rio del Carmen watershed (e.g. Athie (2016); Bravo Peña et al. (2015); and Quintana, (2013)). Contradictions were addressed through a complementary approach, highlighting what those differences were and analysing them in context (May, 2010).

4.3. Results

4.3.1 Where are the vulnerabilities in current water governance in the Rio del Carmen watershed that undermine resilience?

4.3.1a. Exposure

Here, we consider only the exposure to environmental stressors identified in the survey which can be supported by secondary data. Findings confirmed that from 1997 to 2017, droughts increased, particularly in the downstream area (Figure 4.1 and Figure 4.2). Given differences in downstream and upstream climatic conditions, more Mexican farmers perceived droughts as a climate stressor.

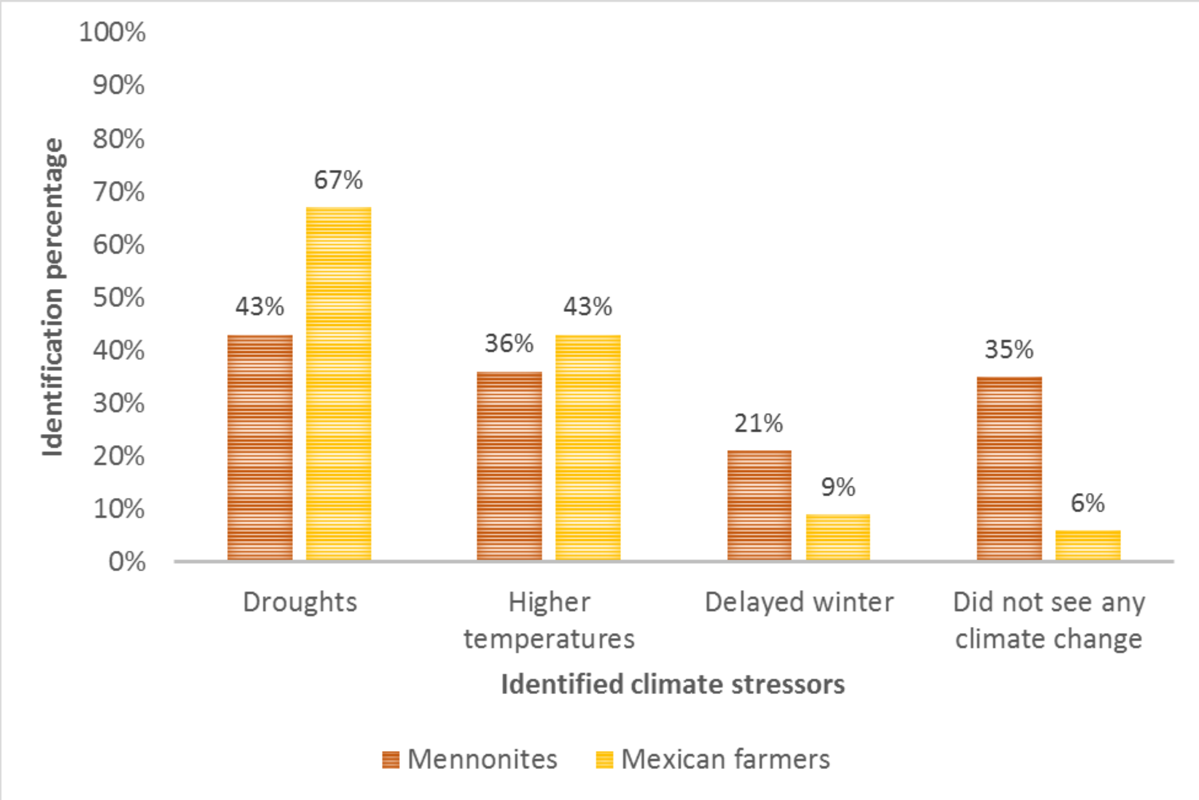

Figure 4.1 Survey results when the 217 participants were asked if they had seen any change in the climate conditions in the Rio del Carmen watershed from 1997 to 2017.

Downstream areas have experienced more severe droughts in recent years, while the greatest upstream drought period was from 1999 -2000 (Figure 4.2).

Figure 4.2 Percentage of (a) the upstream and (b) downstream area affected by exceptional, extreme, severe, or moderate drought, and abnormally dry, from 1997 to 2017. Information obtained from CONAGUA and UNAM, (2019).

This confirms exposure to climate stressors, showing that Mennonite and Mexican farmers' perceptions of climate change differ, because in effect, the climate conditions upstream and downstream are different.

4.3.1b. Sensitivity

This considers the extent to which WES, human well-being, and livelihoods could be affected by exposure to stressors (Baca et al., 2014; Reed and Stringer, 2016). Both farmer groups agree the main problems are water overexploitation, illegal water access, droughts, corruption, and breach of law (Figure 4.3). Accordingly, most problems are of a social nature. Sensitivity must be understood in terms of social fabric, as these societal stressors are generating system-wide impacts on the social function of water governance in the watershed, undermining its adaptive capacity. 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 (IMTA, 2019). This highlights how sensitive the water governance is, as exposure to the identified problems in Figure 4.3 is a continuous risk that has resulted in several social clashes (IMTA, 2019).

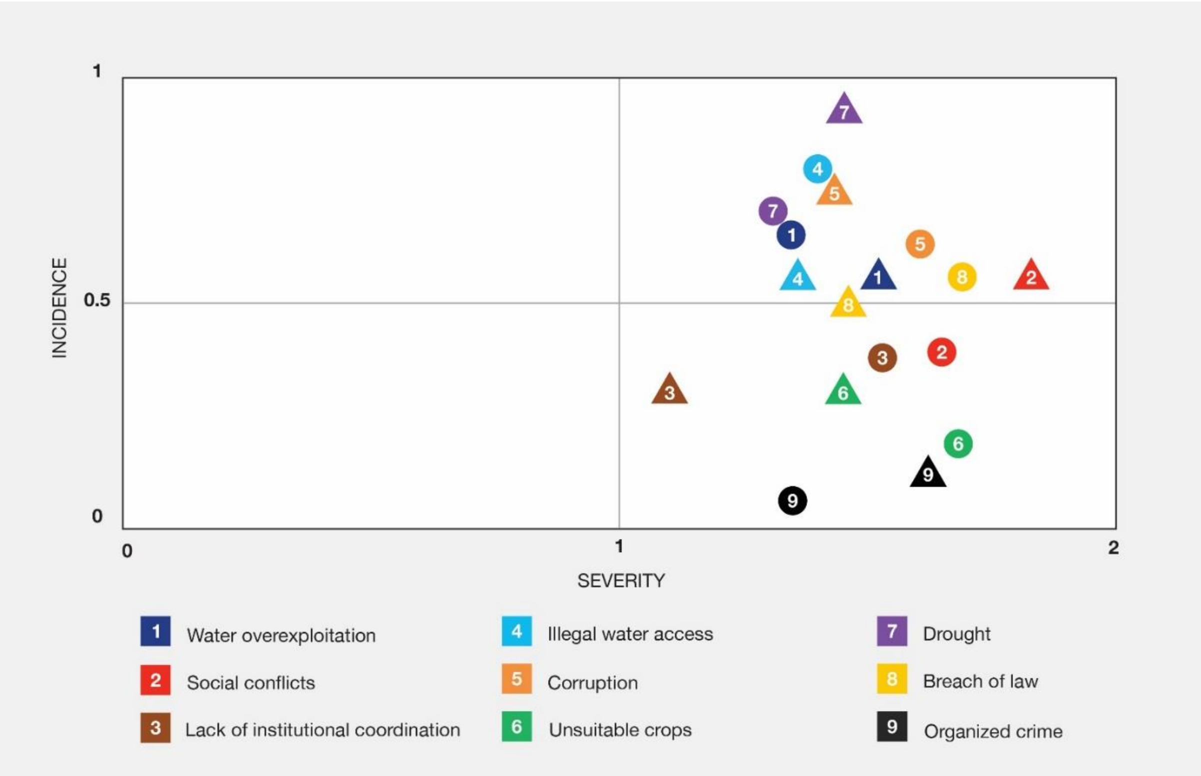

Figure 4.3 Scatter plot that displays the problems identified by Mexican farmers (circles) and Mennonites (triangles) according to their severity and incidence. The severity index ranges from 0 (least severe) to 2 (most severe); the incidence index ranges from 0 (not mentioned) to 1 (most mentioned).

Although drought was also identified as a problem, and evidence shows it is a climate stressor, its negative impact on water regulation and supply is only validated in surface water, because from 2013 to 2018, no variation in groundwater recharge was published by the Mexican Government (Table 4.1). However, perceptions over variations in water supply (Table 4.2) and conflicts over water overexploitation (IMTA, 2019), confirm negative impacts on WES have been experienced by some stakeholders. In terms of agriculture's sensitivity to drought, from 2012-2015, key crop yields saw minimal increases, except for maize, which suffered a significant decrease (Figure 4.4). Likewise, the total agricultural production 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 (CONAGUA, 2016a).

Table 4.1 Summary of the water sources in the watershed according to information published in DOF, (2018), (2016), (2015), (2013a), (2013b), (2009). Figures are given in cubic meters per year.

Santa Clara aquifer (upstream)	Annual groundwater recharge	Groundwater allocated	Groundwater availability (green) or deficit (red)
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 or deficit
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 or deficit
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 or deficit
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 or deficit
2009	248.53	57.14	191.40
2013	174.22	57.13	117.09
2016	170.37	57.13	113.23

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 (INEGI, 2015, 2012). Despite investments in improving agriculture and attempts to reduce its sensitivity to climate stressors, there has not been any significant yield improvement, with a substantial decrease for maize.

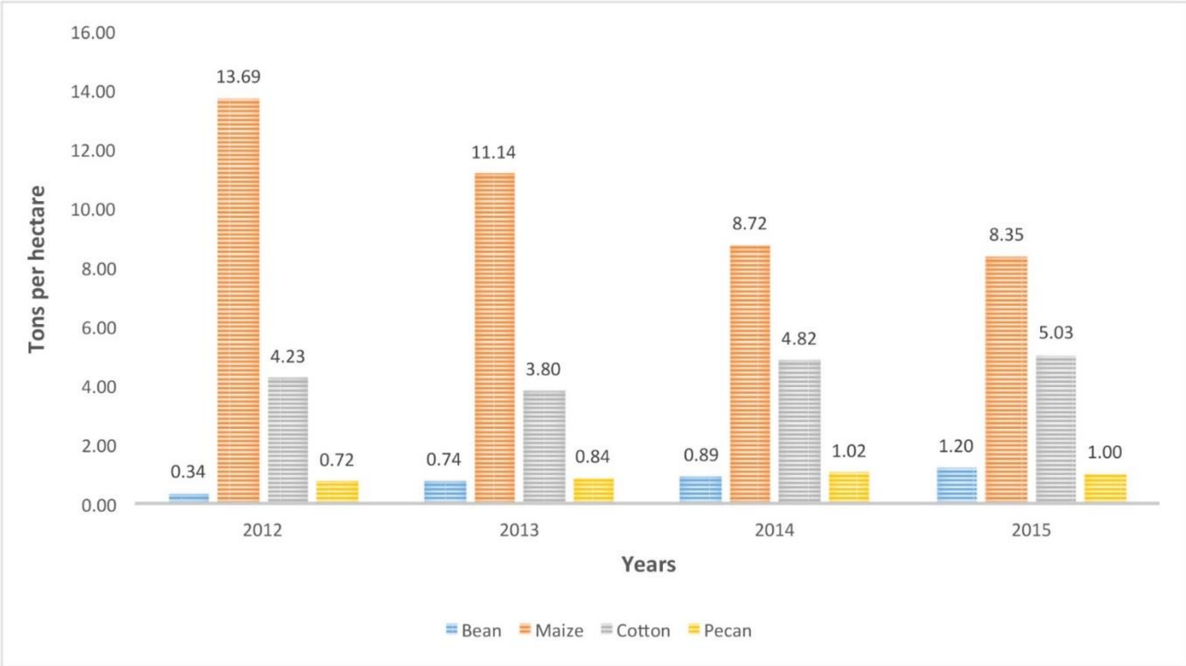

Figure 4.4 Main crop yields in key municipalities in the Rio del Carmen watershed from 2012-2015. Information obtained from INEGI, (2015), (2014), (2013), (2012).

4.3.1c. Adaptive capacity

Adaptive capacity refers to the capacity of actors to cope with a diverse range of stressors, and to adapt or transform, based on collaboration, self-organization, and learning to live with change, so they can continue to exist within the SES (Engle, 2011; Folke, 2016). However, in the Rio del Carmen watershed, conflicting perceptions have undermined adaptive capacity, inhibiting farmers' collaboration (Table 4.2).

Table 4.2 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 which 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	$p<0.001$ ***

Table 4.2 shows a significant difference in perceptions between the agricultural communities. Most Mennonites said they have not taken part in or seen any of these issues,

as opposed to the Mexican farmers' answers that they have witnessed corruption, conflicts and illegal water access in the watershed.

It is important these results are discussed in context, since the Mennonites are a close knit and isolated community. Accepting being a witness of an act of corruption would mean acknowledging they had seen someone in their community committing it; this would transgress their intimate social cohesion (Bravo Peña et al., 2015). Nevertheless, Mennonites do recognise a corruption problem in the watershed (Figure 4.3).

Regarding adaptation strategies, livelihood aspirations for increasing agricultural production have led to maladaptive actions. Although yields have not increased despite investments in improved seeds and fertilizers (Figure 4.4), the agricultural frontier in the same municipalities has extended (Figure 4.5).

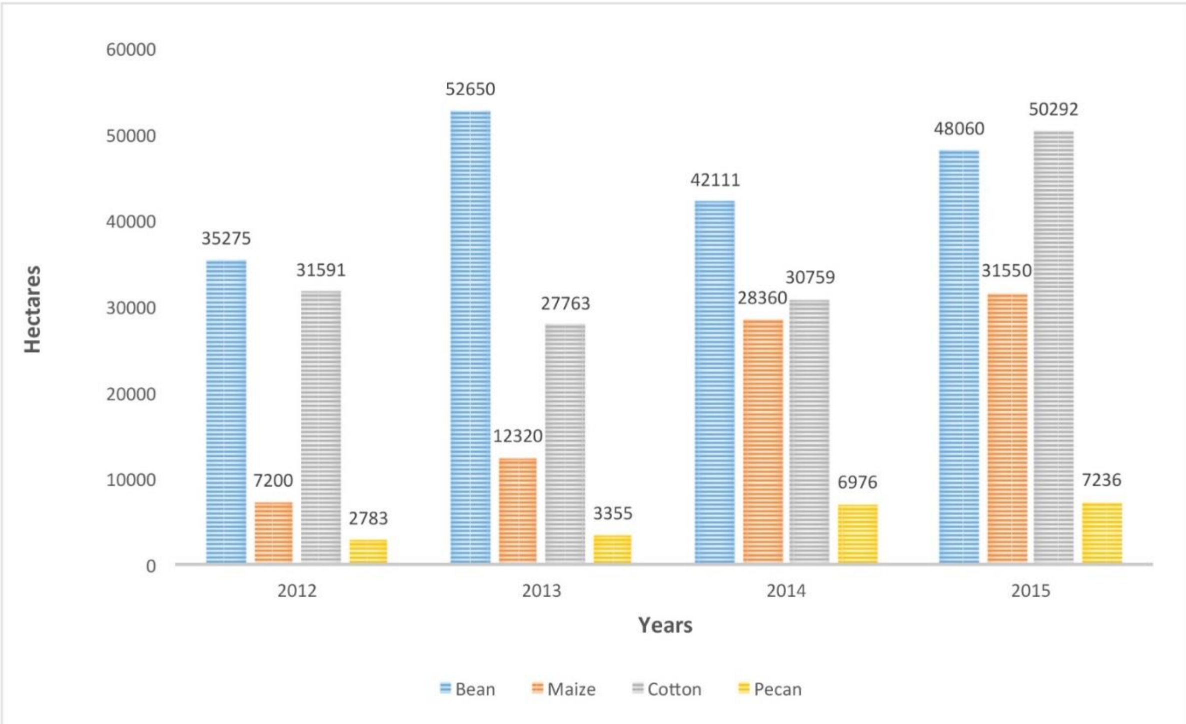

Figure 4.5 Hectares sown with the main crops in the key municipalities that make up the Rio del Carmen watershed, from 2012-2015. Information obtained from INEGI, (2015), (2014), (2013), (2012).

The most prominent indicator of this maladaptation is seen in maize. In 4 years, its agricultural frontier increased by 338%, (Figure 4.5) but yields decreased by 39% (Figure

4.4). Moreover, climate stressors have influenced the over-dependency on already overexploited groundwater. Table 4.1 showed there is surface water availability to meet the water needs in the watershed. However, it is unlikely that annual runoff will be constant year after year, given the great drought variations (Figure 4.2), so groundwater is a safer bet. Furthermore, Las Lajas dam is the only hydraulic infrastructure that can guarantee agriculture water needs, yet, the Irrigation District El Carmen 089 has the main, almost exclusive, water access rights (DOF, 1976; INEGI, 2003). This situation has generated maladaptation for securing water supplies among the remaining farmers, causing aquifer overexploitation.

4.3.2 What potential does society have to enable AWG in the Rio del Carmen watershed?

Enabling collaboration necessary for AWG first requires the identification of common ground between the watershed's agricultural communities. Figure 4.6 shows the main needs for water governance in the watershed according to both communities.

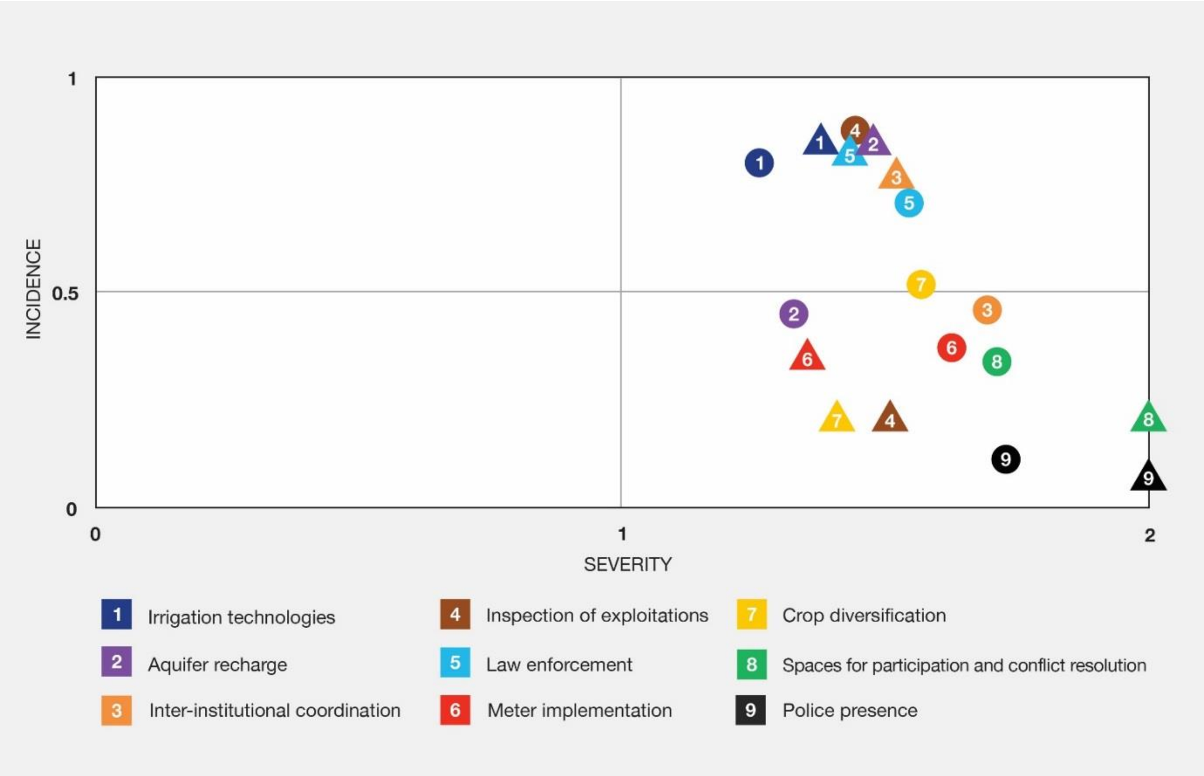

Figure 4.6 Scatter graph that displays the needs identified by Mexican farmers (circles) and Mennonites (triangles) according to their severity and incidence. The severity index

ranges from 0 (least severe) to 2 (most severe), the incidence index ranges from 0 (not mentioned) to 1 (most mentioned).

Irrigation technologies and law enforcement emerge as an area of agreement, offering potential to address the system's sensitivity to climate and societal stressors accordingly. Using the identified needs as entry points for reconciling the contrasting perceptions between communities should be straightforward as it could benefit everyone's livelihoods. Nevertheless, special attention must be paid to other informal institutions so that this can be achieved (section 3.1.3).

4.4. Discussion

Understanding dryland vulnerabilities by characterising exposure, sensitivity, and adaptive capacity, and identifying the changes needed according to the context, provides insights for more informed pathways towards AWG. This underscores the importance of understanding the social influence within SES in terms of increasing resilience. We have shown that despite the watershed's exposure to drought and water overexploitation, stakeholders´ perceptions and behavioural norms are diverse, with significant differences between Mennonite and Mexican farmers. This is because the ways stakeholders experience social-ecological interplay is shaped by environmental conditions and cultural constraints (Quinn et al., 2003). Mennonites do not experience the same climate stressors at the same intensity as Mexican farmers, besides, as part of their culture and faith, many Mennonites do not recognise groundwater overexploitation, and consider God will provide unlimited water (Lopez Porras et al., 2018). Conversely, Mexican farmers recognise, experiment, and care about drought and groundwater overexploitation, because they had to modify their water exploitations and deepen their wells (Lopez Porras et al., 2019).

Climate stressors have led to maladaptation, as demonstrated through land use changes that expanded the agricultural frontier and increased reliance on groundwater. There has not been a significant yield improvement (Figure 4.4), so, to increase agricultural production, farmers converted Chihuahuan desert grasslands to farmland, mostly illegally (Lopez Porras et al., 2018). Moreover, farmers' reliance on groundwater as a drought adaptation is maladaptive at the watershed scale, causing aquifer depletion. A similar case is 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 (Garrick, 2018). In the Rio del Carmen watershed, these maladaptive strategies could be addressed through AWG, yet, several social complexities present barriers to moving this forward.

The integration of societal stressors with vulnerability characterisation provides a valuable understanding of social influences over SES resilience. It highlights that social vulnerability is not only about poverty and marginalisation, as the absence of good social relations, security, and peace increase vulnerability in terms of human well-being (Díaz et al., 2015). Moreover, our findings help to increase understanding of vulnerability, by including other intersecting social processes that are the differential factors between vulnerability and exposure to climate change (IPCC, 2014). SES exposure is not only environment-related (IPCC, 2014). In the Rio del Carmen watershed, societal stressors resulted in social clashes, dam destruction, and the burning of crops (IMTA, 2019; Lopez Porras et al., 2018). However, these are not exclusively linked to resource scarcity, as the stressors are institutionally embedded in, e.g., intensive agriculture's externalities or the adoption of corrupt practices (Lopez Porras et al., 2019). This is similar to the situation in southeast Asia, where forestry, water, and mining sectors generated several societal stressors, e.g. human rights violations and unequal distributions of costs and benefits, resulting in conflicts and violent rebellions (Pichler and Brad, 2016). Addressing both climate and societal stressors is paramount for advancing adaptation.

Stakeholders in the Rio del Carmen have shown sympathy towards important elements of AWG. Mexican farmers have been most interested in solving water overexploitation, showing leadership by having meetings with the Mennonite Central Committee (Lopez Porras et al., 2018), while Mennonites demonstrated adaptive capacity through balancing flexibility and stability, keeping their cultural identity under changing contexts (when emigrating from Europe to America), through an adaptation process called "selective modernity" (Bravo Peña et al., 2015; Roessingh and Boersma, 2011). However, absence of a cultural approach to the Mennonites when dealing with illegal water access and its overexploitation, has meant a lack of positive results (Lopez Porras et al., 2018). The restricted access decree in the watershed should protect legal water exploitations (DOF, 1957). Under this decree, Mexican farmers with water rights feel entitled and have had inflexibility when trying to resolve conflicts over water access (Lopez Porras et al., 2019). Despite that, legal contests have favoured the Mennonites, so pressure on overexploited groundwater continues, with an increasing impact on the Mexican farmers (Lopez Porras et al., 2019). Understanding the Mennonites' cultural approach and leveraging it, is necessary to progress adaptation.

Another identified societal stressor is corruption (Figure 4.3), which plays a major role in the lack of collaboration. Corruption has been exacerbating inequalities between agricultural communities in terms of water access, and who is affected by water overexploitation (Quintana, 2013). No one wants corruption; Mennonites do not like having been victims of it; yet, circumstances have led them to be part of it (Lopez Porras et al., 2019). However, 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 (Roessingh and Boersma, 2011). Expecting that they are going to reveal who is responsible for corruption or illegal water access within their community is unrealistic, explaining the survey results in Table 4.2. These findings demonstrate that confrontation and incrimination between the agricultural communities to address the Rio del Carmen watershed's vulnerabilities has been a poor choice of actions, worsening the situation (Lopez Porras et al., 2019). Again, this underscores the need for cultural references when approaching the Mennonite community.

AWG principles, such as learning and collaboration for achieving adaptation through common goals (e.g. irrigation technology and law enforcement), have potential to address corruption, by aligning the communities' incentives for addressing the watershed's problems (Søreide and Truex, 2013). However, collaboration also depends on achieving greater equity between communities, developing similar levels of awareness about the climate and societal stressors among them. Developing 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 (De Vente et al., 2016). Common needs identified by both agricultural communities (Figure 4.6) are beneficial to enhance the exchange of ideas and views, to deliberate and negotiate solutions to common problems as part of a learning process (Reed et al., 2010). Accordingly, social learning co-generates ecological knowledge for addressing the climate stressors, while understanding how to cooperate and collaborate with conflicting stakeholders to address the societal stressors (Stringer et al., 2006). 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 (Stringer et al., 2006). Collaboration enables stakeholders to devise and develop suitable and multi-perspective solutions (De Vente et al., 2016), meaning stakeholder engagement is appropriate for developing solutions to commonly identified problems (Akhmouch and Clavreul, 2016; Søreide and Truex, 2013). Nonetheless, Mennonites nor CONAGUA officials will participate in any collaborative process if they are seen as the source of the corruption problem (Medema et al., 2017b).

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 (Aggestam and Sundell-Eklund, 2014; Interpeace, 2016). AWG principles need to be embedded in building peace in terms of adaptation to future adversities, instead of taking a conflict approach that will increase vulnerability (Interpeace, 2016). A first step is to identify leadership among the agricultural communities (Interpeace, 2016). This is straightforward since the Irrigation District is a structured organization formed by irrigation associations and a water district chief (Lopez Porras et al., 2019), while the Mennonite community is very closely connected through religion and family, with a community head that has representativeness, legitimacy, and accountability (Bravo Peña et al., 2015; Roessingh and Boersma, 2011). Then, focusing on common needs and problems that bring people together despite the conflicts, by highlighting and recognizing each communities' capacities, it sets the stage for a peacebuilding process (Interpeace, 2016). This is especially important in drylands with extreme droughts, like the Rio del Carmen watershed, because during long low rainfall periods, violent conflicts can increase up to 45% (IPBES, 2018). 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 and increase resilience.

4.5. Conclusion

AWG offers potential to increase SES resilience 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 doing so, it is necessary to acknowledge the roles of exposure, sensitivity and adaptive capacity, which set the balance of vulnerability and resilience within the system, and determine the capabilities for enabling AWG. The Rio del Carmen watershed case provides important insights on how to unravel SES components in order to understand what shapes resilience, what is undermining it, and how context-specific procedures can be designed, offering important insights 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. 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 an enduring and suitable AWG.

4.6. References

Aggestam, K. and Sundell-Eklund, A. 2014. Situating water in peacebuilding: revisiting the Middle East peace process. *Water International*. **39**(1), pp.10–22.

Akhmouch, A. and Clavreul, D. 2016. Stakeholder Engagement for Inclusive Water Governance: 'Practicing WhatWe Preach' with the OECD Water Governance Initiative. *Water (Switzerland)*. **8**(5), pp.1–17.

Athie, K. 2016. *El Agua, ayer y hoy* [Online] (Centro de Estudios Sociales y de Opinion Publica, ed.). Mexico City: Camara de Diputados LXIII Legislatura. Available from: http://www5.diputados.gob.mx/index.php/camara/Centros-de-

Estudio/CESOP/Estudios-e-Investigaciones/Libros/El-Agua-Ayer-y-Hoy.

Baca, M., Läderach, P., Haggar, J., Schroth, G. and Ovalle, O. 2014. An integrated framework for assessing vulnerability to climate change and developing adaptation strategies for coffee growing families in Mesoamerica. *PloS ONE*. **9**(2), p.e88463.

Barlett, J.E., Kotrlik, J.W. and Higgins, C.C. 2001. Organizational research: Determining appropriate sample size in survey research. *Information Technology, Learning, and Performance Journal; Spring*. **19**(1).

Bhattacherjee, A. 2012. *Social Science Research: Principles, Methods, and Practices* [Online] Book 3. (Textbooks Collection, ed.). Textbooks Collection. [Accessed 22 February 2017]. Available from: http://scholarcommons.usf.edu/oa_textbookshttp://scholarcommons.usf.edu/oa_textbooks/3.

Bravo Peña, L.C., Alatorre Cejudo, L.C., Díaz Caravantes, R., Wiebe, L. and Moreno Murrieta, R. 2015. Cultura y Apropiación del Espacio: Diferencias en los Paisajes Culturales de Menonitas y Mestizos de Chihuahua, México. *Journal of Latin American Geography*. **14**(2), pp.77–100.

Carpenter, S.R., Booth, E.G., Gillon, S., Kucharik, C.J., Loheide, S., Mase, A.S., Motew, M., Qiu, J., Rissman, A.R., Seifert, J., Soylu, E., Turner, M. and Wardropper, C.B. 2015. Plausible futures of a social-ecological system: Yahara watershed, Wisconsin, USA. *Ecology and Society*. **20**(2), p.art10.

Chaffin, B.C., Gosnell, H. and Cosens, B.A. 2014. A decade of adaptive governance scholarship: Synthesis and future directions. *Ecology and Society*. **19**(3), p.56.

CONAGUA 2016. Comisión Nacional del Agua. Estadísticas agrícolas de los distritos de riego. *Comisión Nacional del Agua*. [Online]. [Accessed 10 December 2018]. Available from: https://www.gob.mx/conagua/documentos/estadisticas-agricolas-de-los-distritos-de-riego.

CONAGUA and UNAM 2019. Comision Nacional del Agua y Universidad Nacional Autonoma de Mexico. Monitor de Sequía Multivariado en México (MoSeMM). [Accessed 28 January 2019]. Available from: http://201.116.60.187/index.html.

Cosens, B., Gunderson, L., Allen, C., Benson, M., Cosens, B., Gunderson, L., Allen, C. and Benson, M.H. 2014. Identifying Legal, Ecological and Governance Obstacles, and Opportunities for Adapting to Climate Change. *Sustainability*. **6**(4), pp.2338–2356.

Cosens, B.A., Gunderson, L. and Chaffin, B.C. 2018. Introduction to the Special Feature Practicing Panarchy: Assessing legal flexibility, ecological resilience, and adaptive governance in regional water systems experiencing rapid environmental change. *Ecology and Society*. **23**(1), p.4.

DeCaro, D.A., Chaffin, B.C., Schlager, E., Garmestani, A.S. and Ruhl, J.B. 2017. Legal and institutional foundations of adaptive environmental governance. *Ecology and Society*. **22**(1), p.32.

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Báldi, A., Bartuska, A., Baste, I.A., Bilgin, A., Chan, K.M., Figueroa, V.E., Duraiappah, A., Fischer, M., Hill, R., Koetz, T., Leadley, P., Lyver, P., Mace, G.M., Martin-Lopez, B., Okumura, M., Pacheco, D., Pascual, U., Pérez, E.S., Reyers, B., Roth, E., Saito, O., Scholes, R.J., Sharma, N., Tallis, H., Thaman, R., Watson, R., Yahara, T., Hamid, Z.A., Akosim, C., Al-Hafedh, Y., Allahverdiyev, R., Amankwah, E., Asah, S.T., Asfaw, Z., Bartus, G., Brooks, L.A., Caillaux, J., Dalle, G., Darnaedi, D., Driver, A., Erpul, G., Escobar-Eyzaguirre, P., Failler, P., Fouda, A.M.M., Fu, B., Gundimeda, H., Hashimoto, S., Homer, F., Lavorel, S., Lichtenstein, G., Mala, W.A., Mandivenyi, W., Matczak, P., Mbizvo, C., Mehrdadi, M., Metzger, J.P., Mikissa, J.B., Moller, H., Mooney, H.A., Mumby, P., Nagendra, H., Nesshover, C., Oteng-Yeboah, A.A., Pataki, G., Roué, M., Rubis, J., Schultz, M., Smith, P., Sumaila, R., Takeuchi, K., Thomas, S., Verma, M., Yeo-Chang, Y. and Zlatanova, D. 2015. The IPBES Conceptual Framework — connecting nature and people. *Current Opinion in Environmental Sustainability*. **14**, pp.1–16.

Dixon, J. and Stringer, L. 2015. Towards a Theoretical Grounding of Climate Resilience Assessments for Smallholder Farming Systems in Sub-Saharan Africa. *Resources*. **4**(1), pp.128–154.

DOF 2013a. ACUERDO por el que se actualiza la disponibilidad media anual de agua subterránea de los 653 acuíferos de los Estados Unidos Mexicanos, mismos que forman parte de las regiones hidrológico-administrativas que se indican. *Diario Oficial de la*

Federacion. [Online]. [Accessed 10 December 2018]. Available from: http://dof.gob.mx/nota_detalle.php?codigo=5327360&fecha=20/12/2013.

DOF 2015. ACUERDO por el que se actualiza la disponibilidad media anual de agua subterránea de los 653 acuíferos de los Estados Unidos Mexicanos, mismos que forman parte de las regiones hidrológico-administrativas que se indican. *Diario Oficial de la Federación*. [Online]. [Accessed 10 December 2018]. Available from: http://dof.gob.mx/nota_detalle.php?codigo=5389380&fecha=20/04/2015.

DOF 2016. ACUERDO por el que se actualiza la disponibilidad media anual de las aguas nacionales superficiales de las 757 cuencas hidrológicas que comprenden las 37 regiones hidrológicas en que se encuentra dividido los Estados Unidos Mexicanos. [Accessed 23 August 2017]. Available from: http://dof.gob.mx/nota_detalle.php?codigo=5428971&fecha=08/03/2016.

DOF 2009. ACUERDO por el que se actualiza la disponibilidad media anual de las aguas superficiales en las cuencas hidrológicas Río del Carmen 1, Río del Carmen 2, mismas que forman parte de la Región Hidrológica número 34 Cuencas Cerradas del Norte. *Diario Oficial de la Federación*. [Online]. [Accessed 10 December 2018]. Available from: http://www.dof.gob.mx/nota_detalle.php?codigo=5077750&fecha=19/01/2009.

DOF 2013b. ACUERDO por el que se actualiza la disponibilidad media anual de las aguas superficiales en las cuencas hidrológicas Río del Carmen 1, Río del Carmen 2, mismas que forman parte de la Región Hidrológica número 34 Cuencas Cerradas del Norte. *Diario Oficial de la Federación*. [Online]. [Accessed 10 December 2018]. Available from: http://www.dof.gob.mx/nota_detalle.php?codigo=5308662&fecha=31/07/2013.

DOF 1957. ACUERDO que establece el Distrito de Riego de El Carmen, en San Buenaventura y Villa Ahumada, Chih., y declara de utilidad pública la construcción de las obras que lo formen y la adquisición de los terrenos necesarios para alojarlas y operarlas. , pp.4–5. [Accessed 31 July 2017]. Available from: http://dof.gob.mx/nota_to_imagen_fs.php?cod_diario=188731&pagina=5&seccion=0.

DOF 2018. Diario Oficial de la Federación. ACUERDO por el que se actualiza la disponibilidad media anual de agua subterránea de los 653 acuíferos de los Estados Unidos

Mexicanos, mismos que forman parte de las Regiones Hidrológico-Administrativas que se indican. [Accessed 22 June 2018]. Available from: http://www.dof.gob.mx/nota_detalle.php?codigo=5510042&fecha=04/01/2018.

DOF 1976. RESOLUCION sobre dotación de aguas, solicitada por vecinos del poblado denominado Benito Juarez, antes Enriquez y Punta de Alamos, Municipio de Buenaventura, Chih. *El Presidente Constitucional de los Estados Unidos Mexicanos*. [Online]. [Accessed 8 September 2017]. Available from: http://www.dof.gob.mx/nota_detalle.php?codigo=4833085&fecha=05/01/1976.

Downing, T.E., Patwardhan, A., Authors, C., Klein, R.J.T., Mukhala, E., Stephen, L., Winograd, M. and Ziervogel, G. 2005. Assessing Vulnerability for Climate Adaptation [Accessed 5 November 2018]. Available from: http://www4.unfccc.int/nap/Country Documents/General/apf technical paper03.pdf.

Engle, N.L. 2011. Adaptive capacity and its assessment. *Global Environmental Change*. **21**(2), pp.647–656.

Folke, C. 2016. Resilience (Republished). *Ecology and Society*. **21**(4), p.44.

Garrick, D. 2018. Decentralisation and drought adaptation: Applying the subsidiarity principle in transboundary river basins. *International Journal of the Commons*. **12**(1), p.301.

Gunderson, L., Kinzig, A., Allyson, Q., Walker, B., Cundhill, G., Beier, C., Crona, B. and Bodin, O. 2010. Assessing Resilience in Social-Ecological Systems : Workbook for Practitioners. Version 2.0.

IMTA 2019. Instituto Mexicano de Tecnología del Agua. Observatorio de Conflictos por el Agua en México. [Accessed 30 January 2019]. Available from: http://ocam.imta.mx/inicio.html.

INEGI 2012. *Instituto Nacional de Estadística y Geografía. Anuario estadístico de Chihuahua 2012* [Online]. Aguascalientes, Mexico. [Accessed 22 January 2019]. Available from: www.inegi.org.mx.

INEGI 2013. *Instituto Nacional de Estadística y Geografía. Anuario estadístico y geográfico* *de Chihuahua 2013* [Online]. Aguascalientes, Mexico. [Accessed 22 January 2019]. Available from: www.inegi.org.mx.

INEGI 2014. *Instituto Nacional de Estadística y Geografía. Anuario estadístico y geográfico de Chihuahua 2014* [Online] (Instituto Nacional de Estadistica y Geografia, ed.). Aguascalientes, Mexico. [Accessed 10 December 2018]. Available from: https://books.google.co.uk/books?id=XGBUDwAAQBAJ&pg=PP2&lpg=PP2&dq=anuario+estadistico+y+geografico+de+chihuahua&source=bl&ots=zBM6cEhKpB&sig=AFogrY4_pizXCFGZ1JyPy_XTv5M&hl=en&sa=X&ved=2ahUKEwjDlOGi95TfAhVJyYUKHTVLBEs4ChDoATACegQICBAB#v=onepage&q=anuario%25.

INEGI 2015. *Instituto Nacional de Estadística y Geografía. Anuario estadístico y geográfico de Chihuahua 2015* [Online] (Instituto Nacional de Estadística y Geografía, ed.). Aguascalientes, Mexico. [Accessed 10 December 2018]. Available from: www.inegi.org.mx.

INEGI 2003. *Síntesis de Información geográfica del estado de Chihuahua* [Online]. Aguascalientes, Mexico. [Accessed 26 January 2017]. Available from: http://internet.contenidos.inegi.org.mx/contenidos/productos/prod_serv/contenidos/espanol/bvinegi/productos/historicos/2104/702825224332/702825224332_12.pdf.

Interpeace 2016. *Using resilience to build peace – Practice brief: resilience and peacebuilding* [Online]. Geneva, Switzerland. [Accessed 21 August 2018]. Available from: https://www.interpeace.org/wp-content/uploads/2016/06/Practice_Brief-Resilience_and_Peacebuilding-A4-v3.pdf.

IPBES 2018. *Summary for policymakers of the assessment report on land degradation and restoration of the Intergovernmental SciencePolicy Platform on Biodiversity and Ecosystem Services. R. Scholes, L. Montanarella, A. Brainich, N. Barger, B. ten Brink, M. Cantele, B.* [Online]. IPBES secretariat, Bonn, Germany. [Accessed 25 September 2018]. Available from: www.ipbes.net.

IPCC 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]* [Online]. Geneva, Switzerland:

IPCC. [Accessed 20 February 2019]. Available from: http://www.ipcc.ch.

Kohlbacher, F. 2006. The Use of Qualitative Content Analysis in Case Study Research. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*. **7**(1), pp.1–30.

Lopez Porras, G., Stringer, L.C. and Quinn, C.H. 2019. Corruption and conflicts as barriers to adaptive governance: Water governance in dryland systems in the Rio del Carmen watershed. *Science of The Total Environment*. **660**, pp.519–530.

Lopez Porras, G., Stringer, L.C. and Quinn, C.H. 2018. Unravelling Stakeholder Perceptions to Enable Adaptive Water Governance in Dryland Systems. *Water Resources Management*. **32**(10), pp.1–17.

May, V. 2010. *Realities Toolkit #12. What to do with contradictory data?* [Online]. Morgan Centre, University of Manchester. [Accessed 19 July 2018]. Available from: http://hummedia.manchester.ac.uk/schools/soss/morgancentre/toolkits/12-toolkit-contradictory-data.pdf.

Mcdonald, J.H. 2014. *Handbook of Biological Statistics* [Online] 3rd ed. Baltimore, Maryland: Sparky House Publishing. [Accessed 6 December 2018]. Available from: http://www.biostathandbook.com/HandbookBioStatThird.pdf.

Medema, W., Adamowski, J., Orr, C., Furber, A., Wals, A., Milot, N., Medema, W., Adamowski, J., Orr, C., Furber, A., Wals, A. and Milot, N. 2017. Building a Foundation for Knowledge Co-Creation in Collaborative Water Governance: Dimensions of Stakeholder Networks Facilitated through Bridging Organizations. *Water*. **9**(1), p.60.

Mortimore, M., Anderson, S., Cotula, L., Davies, J., Faccer, K., Hesse, C., Mortin, J., Nyangena, W., Skinner, J. and Wolfangel, C. 2009. *Dryland opportunities: a new paradigm for people, ecosystems and development* [Online]. IUCN, Gland, Switzerland; IIED, London, UK and UNDP/DDC, Nairobi, Kenya: IUCN. Available from: http://trove.nla.gov.au/work/160629536?q&versionId=175115005.

Okpara, U.T., Stringer, L.C., Akhtar-Schuster, M., Metternicht, G.I., Dallimer, M. and Requier-Desjardins, M. 2018. A social-ecological systems approach is necessary to achieve land degradation neutrality. *Environmental Science & Policy*. **89**, pp.59–66.

Patton, M.Q. 1999. Enhancing the quality and credibility of qualitative analysis. *Health services research*. **34**(5 Pt 2), pp.1189–208.

Pichler, M. and Brad, A. 2016. Political ecology and socio-ecological conflicts in Southeast Asia. *ASEAS-Österreichische Zeitschrift für Südostasienwissenschaften*. **9**(1), pp.1–10.

Plaza, C., Zaccone, C., Sawicka, K., Méndez, A.M., Tarquis, A., Gascó, G., Heuvelink, G.B.M., Schuur, E.A.G. and Maestre, F.T. 2018. Soil resources and element stocks in drylands to face global issues. *Scientific Reports*. **8**(1), p.13788.

Prăvălie, R. 2016. Drylands extent and environmental issues. A global approach. *Earth-Science Reviews*. **161**, pp.259–278.

Quinn, C.H., Huby, M., Kiwasila, H. and Lovett, J.C. 2003. Local perceptions of risk to livelihood in semi-arid Tanzania. *Journal of Environmental Management*. **68**(2), pp.111–119.

Quintana, V.M. 2013. Nuevo orden alimentario y disputa por el agua en el norte de México. *Apuntes: Revista de Ciencias Sociales*. **40**(73), pp.175–202.

Reed, M.S., Evely, A.C., Cundill, G., Fazey, I., Glass, J., Laing, A., Newig, J., Parrish, B., Prell, C., Raymond, C. and Stringer, L.C. 2010. What is Social Learning? *Ecology and Society*. **15**(4), p.r1.

Reed, M.S. and Stringer, L.C. 2016. *Land Degradation, Desertification and Climate Change: Anticipating, assessing and adapting to future change* [Online]. London: Routledge. [Accessed 20 February 2019]. Available from: https://www.taylorfrancis.com/books/9780203071151.

Roessingh, C. and Boersma, K. 2011. ‘We are growing Belize’: modernisation and organisational change in the Mennonite settlement of Spanish Lookout, Belize. *International Journal of Entrepreneurship and Small Business*. **14**(2), p.171.

Schlaepfer, D.R., Bradford, J.B., Lauenroth, W.K., Munson, S.M., Tietjen, B., Hall, S.A., Wilson, S.D., Duniway, M.C., Jia, G., Pyke, D.A., Lkhagva, A. and Jamiyansharav, K. 2017. Climate change reduces extent of temperate drylands and intensifies drought in deep soils. *Nature Communications*. **8**, p.14196.

Schlüter, M., Baeza, A., Dressler, G., Frank, K., Groeneveld, J., Jager, W., Janssen, M.A., McAllister, R.R.J., Müller, B., Orach, K., Schwarz, N. and Wijermans, N. 2017. A framework for mapping and comparing behavioural theories in models of social-ecological systems. *Ecological Economics*. **131**, pp.21–35.

Søreide, T. and Truex, R. 2013. Multi-stakeholder Groups for Better Sector Performance: A Key to Fighting Corruption in Natural-Resource Governance? *Development Policy Review*. **31**(2), pp.203–217.

Stringer, L., Dougill, A., Fraser, E., Hubacek, K., Prell, C. and Reed, M. 2006. Unpacking "participation" in the adaptive management of social–ecological systems: a critical review. *Ecology and Society*. **11**(2), p.39.

Stringer, L.C., Reed, M.S., Fleskens, L., Thomas, R.J., Le, Q.B. and Lala-Pritchard, T. 2017. A New Dryland Development Paradigm Grounded in Empirical Analysis of Dryland Systems Science. *Land Degradation & Development*. **28**(7), pp.1952–1961.

SurveyMonkey 2017. Sample Size Calculator. [Accessed 7 March 2017]. Available from: https://www.surveymonkey.com/mp/sample-size-calculator/.

De Vente, J., Reed, M.S., Stringer, L., Valente, S. and Newig, J. 2016. How does the context and design of participatory decision making processes affect their outcomes? Evidence from sustainable land management in global drylands. *Ecology and Society*. **21**(2), p.24.

Webb, N.P., Marshall, N.A., Stringer, L.C., Reed, M.S., Chappell, A. and Herrick, J.E. 2017. Land degradation and climate change: building climate resilience in agriculture. *Frontiers in Ecology and the Environment*. **15**(8), pp.450–459.

Chapter 5

DISCUSSION AND CONCLUSIONS BASED ON THE RIO DEL CARMEN WATERSHED

Abstract

If current development pathways do not change, future prospects for the drylands are worrisome: potential large-scale migration, increasing water scarcity and land degradation, growing poverty and marginalisation, along with a great loss of key ecosystem services that allows drylands' social-ecological functioning. Strengthening dryland resilience will help secure human well-being and water ecosystem services. This can be achieved by increasing adaptive capacity through an adaptive model of water governance. Adaptation nevertheless requires the identification of the barriers and entry points that, correspondingly, can obstruct or enable Adaptive Water Governance. By discussing the findings presented in previous chapters, Chapter 5 presents the identified barriers and entry points in the Rio del Carmen watershed for enabling Adaptive Water Governance, proposing three principles for moving towards adaptation in drylands. The Chapter concludes by discussing the limits of the Rio del Carmen case study, opportunities for further research, and the implications of this thesis for dryland systems.

5.1 Introduction

Chapters 2, 3, and 4 tackle each research objective presented in Chapter 1. Summarising those findings we can recognise four main challenges that are undermining the watershed's resilience:

1) Informal institutions (e.g., perceptions and farming practices) have a major influence on SES adaptation;

2) Informal institutions are shaped by cognitive processes linked to the social and ecological surroundings;

3) Lack of compatibility both within and between formal and informal institutions makes water governance unsuitable; and

4) The scale of water governance does not fit with the SES need for WES conservation.

A linear and straightforward connection between these governance problems, provides an elementary narrative of the main barriers to increasing the Rio del Carmen watershed's adaptive capacity. However, given the intricate SES complexities, understanding the implications and reinforcing feedbacks resulting from the constant interactions between the problems, requires a comprehensive analysis of the evidence presented in previous chapters. In this regard, to better analyse these governance problems and the barriers hindering AWG, it is important to review them according to their historical context, to understand why formal and informal institutions are not compatible, and why water governance in the watershed has not achieved WES conservation (Duarte et al., 2014).

According to Mussetta, (2009), water governance in Mexico has had two phases. First was the "water leviathan", in the first half of the 20th century, where water was a synonym of development and the Federation, through the former Ministry of Hydraulic Development, prioritised and boosted agricultural development through the construction of large hydraulic infrastructure, like dams and irrigation systems. To formalise water management and the agricultural sector in a single structure, the Ministry of Hydraulic Development then became the Ministry of Agriculture and Hydraulic Resources, which had centralised authority over water resources, and was a key component in Mexican economic development (Mussetta, 2009). Nevertheless, as a consequence of the deterioration of water resources, the Government changed from a hydraulic policy to a water policy, creating CONAGUA (as a decentralised agency of the Ministry of the Environment and Natural Resources) and introducing sustainable development into its operational framework (Athie, 2016; Mussetta, 2009). In doing so, the National Water Law was created, postulating as fundamental principles: integrated water management, public participation, legal security for granted water rights, water conservation, and the recognition that the basin and the aquifers are the suitable scale for water management (Athie, 2016). However, previous commitment to agriculture as an economic trigger without considering water availability, especially in the country's northern drylands, led to several social conflicts over water access (Athie, 2016).

With this preamble, it is possible to discuss the main issues that are taking place in the Rio del Carmen watershed. First, as already stated in Chapter 1 section 1.2, strengthening specified resilience focusing on economic development, raises societal stressors and increases other vulnerabilities by exposing human well-being to social clashes and human rights violations. Economic development is not a synonym for less vulnerability, especially when formal institutions are designed with detachment from reality, as they will be predestined to fail in light of unforeseen problems (Nemec et al., 2014). This does not mean that economic development necessarily increases societal stressors, but it highlights the need for a more holistic approach, for instance as England et al. (2018) stated, by seeking triple wins in terms of adaptation, mitigation, and development. This is especially important in drylands, as their exposure to desertification, land degradation, and drought, can cause other important aspects of human well-being that influence SES vulnerability, to be lost sight of. Mexico's desire for an agricultural boom meant that comprehensive agricultural planning was left to one side, and so it did not foresee the externalities that this would generate. These were discussed in previous chapters, and include water overexploitation and growing enmity among upstream and downstream farmers. Even though there is a different approach for water management currently, CONAGUA is still very centralised and lacks cross-sectoral cooperation, public participation, and transparency (Murillo-Licea and Soares-Moraes, 2013; OECD, 2013). In view of this, the roots of the SES complexities surrounding the Rio del Carmen watershed can be better understood as follows:

1) The Mennonite community was invited to increase agriculture in Mexico's drylands, granting them total freedom to manage their lands;

2) Water scarcity awareness caused the government to create the Las Lajas Dam, an Irrigation District, and a restricted-access decree for new water exploitations;

3) Great losses of grasslands ensued given their conversion to croplands, water overexploitation, social conflicts, and the government is unable to solve the problem.

CONAGUA has water policy instruments and an institutional structure, that on paper, opens the doors to inclusion of the principles of AWG, as was discussed in Chapter 3. Nevertheless, CONAGUA has not used all its legal and institutional tools to adapt and solve the emerging problems, or if it has done so, it has done it ineffectively. For instance, a watershed's restricted-access decree that does not consider the establishment of the Mennonite community upstream, illustrates how formal institutions are inefficient. This centralised approach, alienated from context-specific needs (such as cultural sensitivity) for addressing water overexploitation, shows how the mismatch between formal and informal institutions leads to unsuitable governance regimes. Moreover, as water governance regimes entail the set of institutions that structure the governance system (Pahl-Wostl, 2017), this institutional mismatch with the watershed scale has a major influence over water overexploitation, social clashes, and threats to human rights, making water governance unsuitable.

Consequently, the combination of these issues escalated into a wider self-reinforced problem (Figure 5.1), similar to what Enfors, (2013) called a "social-ecological trap", where external drivers (droughts) have interacted with key system variables (institutional inefficiency, cultural plurality, etc.) to shape a development trajectory that is leading to WES loss.

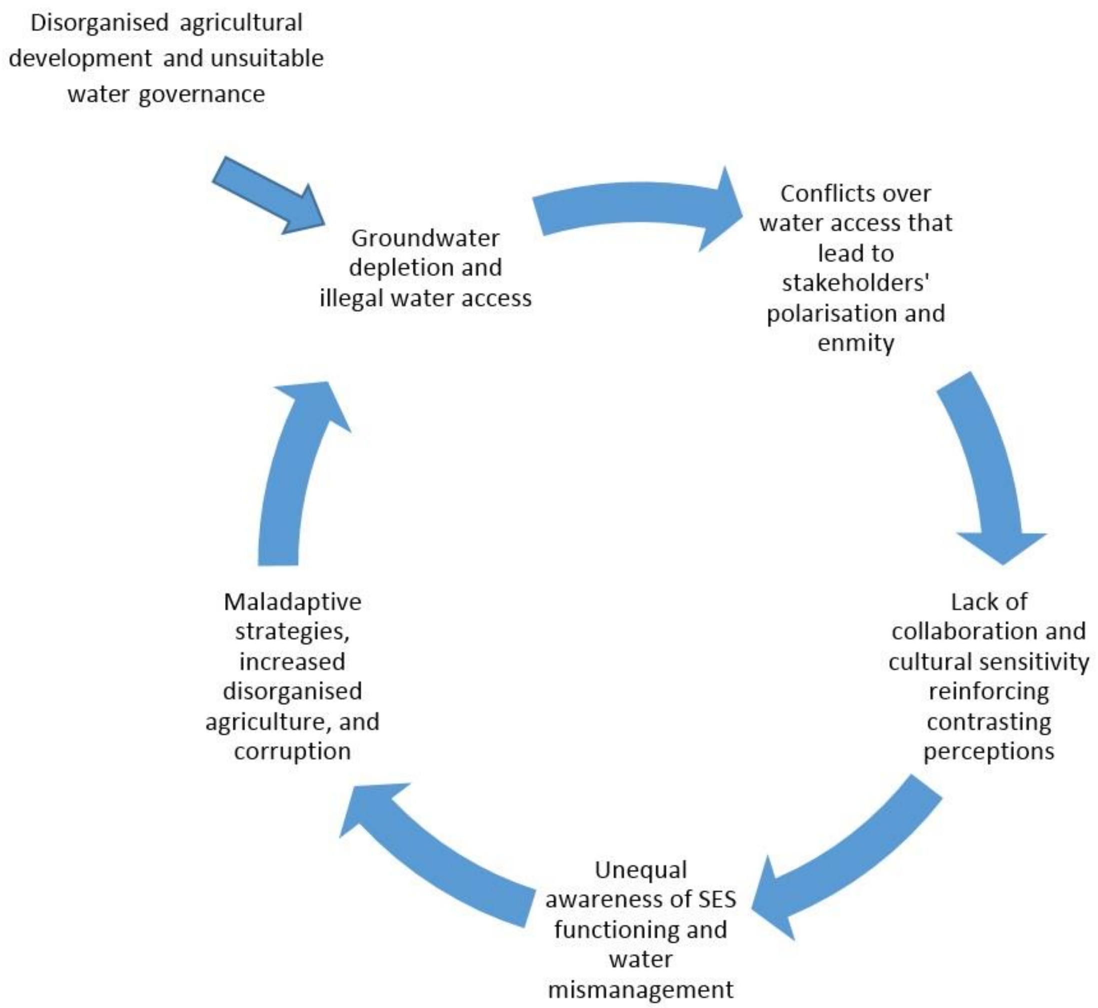

Figure 5.1 Vicious circle development trajectory in the Rio del Carmen watershed

The development trajectory identified in Figure 5.1 summarises the gestational process of the social-ecological crisis, showing the main barriers to AWG in the Rio del Carmen watershed, as represented in each node. As stated in previous chapters, these barriers consist of corruption, contrasting perceptions, illegal water access, unequal awareness of ecological functioning, social clashes, and water mismanagement.

In the literature different solutions have been proposed to address this kind of vicious circle. Enfors, (2013), proposes the identification of mechanisms with the potential to destabilise the feedback loops, such as a change in farming practices which has cascading effects on water balance, soil moisture, and then, yield. There are also the leverage points for intervention proposed by Meadows, (1997) which "are places within a complex system where a small shift in one thing can produce big changes" (p.1). Moreover, Chaffin et al., (2014b) and Olsson et al., (2006) include the concept of "windows of opportunity" as interventions (e.g. a disruptive political election) or fortuitous events (e.g. a natural disaster) that can boost a change towards AWG. Nevertheless, questions regarding the effectiveness of these concepts, concerning how to step in or achieve the needed institutional setting for successfully moving towards AWG, are still unclear (Chaffin et al., 2014b). Addressing this gap, in this thesis it was decided to use the term "entry points", given the need to identify input areas or gateways in the SES, which are strategic to step in to in order to address a problem or trigger a change. Therefore, entry points for increasing adaptive capacity could consist of points of agreement between stakeholders, leadership, a suitable area for participation, or a stage in a process that can open a window of opportunity, to increase the likelihood of successful AWG. Moreover, to ensure a successful governance transition, these entry points also aim to identify where to intervene in the legal and institutional setting, to prepare the SES for sustainable AWG.

Chapters 2, 3, and 4, correspondingly, identify entry points for enabling feasible, legitimate, and sustainable AWG in the Rio del Carmen watershed. In doing so, I analysed the main stakeholders, key leadership, and their relationships, through a stakeholder analysis process (Reed et al., 2009), that highlighted the societal elements with the potential to increase adaptive capacity, so the entry points can be leveraged. Among these elements, I found the leadership of the Mexican farmers, the balance between flexibility and stability from the Mennonites, and the representativeness, legitimacy, and accountability which the leaders from both groups have. Although these societal features sympathise with the constituent elements of AWG, they are being hindered by the barriers that restrict movement towards adaptation (the nodes described in Figure 5.1), increasing the watershed's exposure to SES stressors. The goal when identifying entry points for enabling AWG is to overcome those barriers that are undermining SES resilience, which is especially important in a dryland context, as they have nuanced exposure to climate stressors and tend to suffer conflicts over resource access (IPBES, 2018; Middleton et al., 2011). Therefore, these entry points were framed according to their nature:

1) Concordance: By working on common needs and problems, the exchange of ideas, views, and solutions will be easier and will increase the likelihood of collaboration.

2) Key stakeholder actions: Farmers with water rights need to take leadership and drive institutional change to secure their livelihoods, by leveraging existing elements of AWG in the watershed (e.g., leadership, accountability, flexibility).

3) Structure: The legal concept of a "Watershed Committee" established in the National Water Law, is an institutional construct with the potential to be shaped with AWG principles in the watershed.

As has been outlined in previous chapters, working on common needs, increasing social-ecological awareness, and identifying key leadership is needed for establishing stakeholder engagement with the potential for enabling AWG. Chapter 4 highlights the feasibility of achieving these conditions (equality, clear leadership, and areas of agreement) by suggesting use of a peacebuilding process in the early stages of stakeholder engagement. In this way, although AWG is not guaranteed, the likelihood of addressing the watershed´s societal complexities is increased and so the potential for enabling AWG. Indeed, peacebuilding to enable AWG is important, as AWG emergence often takes place in undesirable states of governance and in contexts characterised by conflict, delaying any transition to another governance regime (Chaffin et al., 2014b). For instance, as aforementioned, in the Klamath River, USA, it took about 10 years to resolve legal, political and physical contestations between different productive sectors and indigenous communities, to allow the emergence of adaptive governance (Chaffin et al., 2016, 2014a). Consequently, peacebuilding is an important starting point, and the first two entry points have the potential to achieve it, reconciling relationships among both agricultural communities and CONAGUA. Nevertheless, as stated in Chapter 2, the situation in the Rio del Carmen watershed is taking place in an "unmanageability" context, where several attempts to bring the stakeholders together have failed, given the distrust and accusations of blame among them. On this, it is important to highlight that Mexican farmers´ attitudes towards the Mennonite community need to change, because while many Mennonites can lack ecological awareness, the lack of a culturally sensitive approach shows that Mexican farmers lack societal awareness. Thereof, a major challenge to enable AWG in the Rio del Carmen watershed lies in the rapprochement between the stakeholders, since this will put the entry points ´on the table´ to allow institutional change. Again, to increase the likelihood of a successful rapprochement, peacebuilding experts should facilitate communication from the outset. This will allow stakeholder engagement, where farmers can get involved in the decision-making and management of water resources at the watershed scale, increasing acceptance of formal institutions and trade-offs. Lastly, this engagement needs to continuously co-produce knowledge to keep stakeholders´ perceptions aligned, address emerging threats, and allow social learning for addressing climate and societal stressors. If these positive results are obtained, the engagement can be potentially reinforced by the stakeholders, ensuring its durability, legitimacy, and accountability (Reed et al., 2010).

The third entry point refers to leveraging current legal and institutional tools, to look for formalisation of any stakeholder engagement or agreement in the Rio del Carmen watershed, principally, the watershed scale has been found to be the most appropriate scale for water management, where many social and ecological issues interact. Chapter 3 indicates the main features of the Watershed Committees, and how they can be shaped to integrate AWG principles. Accordingly, key stakeholders should use legal mechanisms to enforce the procedural requirements for enabling participation, and indeed, Chapter 3 has shown how some farmers have successfully used legal contestations in their favour. For this effect, articles 14 and 14 BIS of the National Water Law, establish that CONAGUA has to promote and support public participation in the decision-making and execution of water policies, providing the necessary support and resources for doing so (LAN, 2016). Indeed, strategic litigation through the courts, based on human-rights arguments, could help to push CONAGUA to create this Watershed Committee by also leveraging CONAGUA´s obligations towards the creation and promotion of citizen involvement in water management. Although this could be a slower way, if there is a lack of political will, it is a reliable strategy for enabling a Watershed Committee that operates under the AWG principles. Strategic litigation has been used all around the globe, for creating frameworks on which governments must design, implement and monitor concrete actions to safeguard human rights (UN, 2007). In Mexico specifically, strategic litigation has resulted in policy instruments such as ecological development programs; and human rights defenders place trust in this strategy to have an impact on public policies (UN, 2007). This thesis has found that these entry points have a greater chance of success, nevertheless, this does not prevent any other legal strategy or resources from providing formality and legitimacy to AWG in the watershed.

5.2 Principles for moving towards adaptive water governance

This thesis aims to contribute to the literature and practice of water governance when moving towards adaptation, with special emphasis on dryland systems. As has been discussed in Chapters 2, 3, and 4, this can be achieved by adjusting the institutional setting, according to, and by understanding, stakeholder perceptions, SES attributes, and the properties that maintain dryland functioning. Deductive interpretation of the findings obtained from this case study, allowed the elucidation of three interdependent principles (Table 5.1) that aim to increase the value and the implications of this thesis, for resilience theory and adaptive governance literature in drylands.

Table 5.1 Principles for moving towards adaptive water governance

Principle 1	Water governance must consider informal institutions when aiming to support adaptation.
Principle 2	Compliance with and enforcement of rules are the means through which a system's functioning can continue.
Principle 3	Context shapes the guidelines for a transition towards adaptation.

5.2.1 Water governance must consider informal institutions when aiming to support adaptation

It is currently understood that informal authorities and institutions play a major role in water governance, for which increasing public-private coordination and participation has been sought for the benefit of all stakeholders (Rogers et al., 2003). Informal institutions refer to norms of behaviour that are ruled by culture, such as traditions, religious beliefs, perceptions, and moral values (Pejovich, 1999). Accordingly, informal institutions guide decision-making processes (Kaufmann et al., 2018; North, 1990). They affect the way societies interact with their environment (e.g. in obtaining benefits from nature), and the experience resulting from this shapes their perspectives on the relationship between nature and good quality of life (Díaz et al., 2015).

However, another example of an informal institution is corruption (Kaufmann et al., 2018). Corruption is a cross-cultural reality present in all societies, and has different forms, e.g., the omission of action in terms of challenging a problem (Leitao, 2016) or, in the sense referred to here, the abuse or misuse of power (Søreide and Truex, 2013) that undermines SES resilience. Corruption hinders the rule of law, innovation[14], and leads to water overexploitation; however, addressing corruption is complex as it is shaped by several economic, historical, social, political, and cultural factors (Iza and Stein, 2009; Leitao, 2016). Many illegal and informal activities arise as the only alternatives to tedious and unnecessary bureaucracies (Rogers et al., 2003), as higher corruption is often related to more red tape (Kaufmann et al., 2018). So, even though corruption cannot be removed, especially from highly centralised government agencies with very entrenched corruption such as CONAGUA (Athie, 2016; OECD, 2013), it must be reduced at least to a point where it does not increase SES vulnerability (e.g., via water depletion, grassland loss, or violent conflicts as a result of illegal water access). In this regard, as stated in Chapter 3, drylands with high levels of corruption can mitigate this problem through stakeholder engagement for enabling local water management embedded with transparency, legitimacy, and accountability (Iza and Stein, 2009; Søreide and Truex, 2013).

This thesis claims that informal institutions (such as perceptions and corruption) give important insights into the system's functioning and societal influences over social-ecological crises (e.g., water depletion and social disaggregation). Moreover, it shows that WES are valuable in terms of how they are perceived, which in turn, determines how they are accessed. But when stakeholders with opposite perceptions share common pool resources like water, and formal institutions do not foresee this situation, water access can give rise to overexploitation and social conflicts; besides, corruption tends to worsen this situation by boosting system exposure to these stressors (Leitao, 2016). This illustrates why the objectives set by formal institutions, as in WES conservation, will not succeed if they do not consider the complexities around informal institutions, such as corruption or cultural inequalities (Pahl-Wostl and Knieper, 2014).

Huitema et al. (2009) say that informal institutions comprise "the power relations and practices that have developed and the rules that are followed in practice" (p. 2). This is

[14] Described in Chapter 3 as a constitutive element of adaptive capacity.

influenced by several social, productive, environmental and political factors that increase institutional complexity when aiming at adaptation (Cortez Lara, 2010; Huitema et al., 2009). Accordingly, public participation and actions of local stakeholders are fundamental for driving institutional change and dealing with societal complexities, even if these are large-scale SES (Cortez Lara, 2010). Although this raises a concern about the assignment of governance responsibilities, the AWG principle of subsidiarity emerges as a suitable solution for better considering informal institutions in governance regimes (Garrick, 2018). By allowing institutional design and implementation at the lowest or more suitable scale, water governance will take better account of local circumstances (Hill Clarvis et al., 2014). Subsidiarity has the potential to develop locally appropriate rules and standards for water management, allowing each organisational unit to have its own and well-matched regulations, within the context of governance and government at a larger scale (Cosens et al., 2017; Garrick, 2018). This thesis has shown that informal institutions such as perceptions of WES, shape the way stakeholders behave to achieve their goals and obtain desired outcomes (Schlüter et al., 2017).

Better integration of informal institutions, like perceptions and cultural differences within governance regimes increase the acceptance, legitimacy, and subsequent cooperation that will enable AWG (DeCaro et al., 2017a). Better consideration of noxious informal institutions, like corruption, allows us to recognise when the authority endowed with formality to address corruption has failed, and to reveal second-best solutions (Søreide and Truex, 2013). Water governance systems whose formal institutions are centralised and alien to SES dynamics or local context, are weakly enforced and have a poor and undermined rule of law, which facilitates corruption (Leitao, 2016; Rogers et al., 2003). Conversely, strong and suitable institutions mean strong rule of law supported by civil society, with clear rules of conduct; where values and norms of behaviour play a major role in the compliance with and enforcement of rules (Leitao, 2016; Pejovich, 1999; Rogers et al., 2003).

5.2.2 Compliance with and enforcement of rules are the means through which a system's functioning can continue

Rules facilitate SES goals: they give structure and order, avoiding the chaos that could emerge from uncertainty and non-linearity (Peterson, 2018). If rules must consider informal institutions, they should aim for mutual betterment, and therefore, stakeholders should be willing to meet their obligations; nonetheless, when someone fails to comply, enforcement is necessary to provide security for other stakeholders (Iza and Stein, 2009). Rules, to be effective, not only must adequately punish corruption, overexploitation, illegal water access, and breach of law, but also need to contemplate incentives for WES conservation, for instance, by establishing a compensation system for incorporating the most suitable irrigation technologies, or for compliance with water conservation standards. This is based on the assumption that to influence human behaviour, rules must 1) foresee positive (rewards) and negative (penalties) consequences (Doménech Pascual, 2015), 2) be developed in relation to people's needs, and 3) be designed in context with the SES reality (DeCaro et al., 2017a).

As mentioned earlier, rules need to match the appropriate scale, fostering local creativity and innovation because problems are scale-dependent, and rules are better enforced and designed using local knowledge, which also increases their legitimacy and acceptance (Cosens et al., 2017; Ahjond Garmestani and Benson, 2013). In doing so, rules should be limited to those strictly necessary, as this will require fewer resources for law enforcement, besides, bad and unnecessary rules diminish respect for good rules (Peterson, 2018). High costs and complexities in law enforcement make for a failed rule of law (Rogers et al., 2003), negatively impacting the SES. This has been shown in this thesis, where the incapacity of formal authorities to address SES needs, such as WES and grassland conservation, through the enforcement of formal institutions, hinders achievement of the rules' functional aims and fosters SES vulnerability.

As *water governance must consider informal institutions when aiming to support adaptation* (principle 1), rules must be developed with similar levels of awareness about the climate and societal stressors among the stakeholders. This thesis shows that inequalities in awareness led to the breach of law, because stakeholders do not acknowledge the benefits of WES conservation, so they do not have the same incentives to collaborate. Therefore, there is a lack of certainty about the achievement of the objectives (e.g. increasing adaptive capacity or WES conservation) and a lack of full understanding of why the regulations are established. It is common for societies threatened by uncertainty to feel conflict over rule adherence, ("strict rules and laws are a good thing if others, not myself, follow them"(p.399)) when they are not conscious of the consequences of not fulfilling their obligations (Kaufmann et al. 2018). Uncertainty and unequal awareness of the negative outcomes of our actions, lead to decreased pro-social behaviour and promote selfishness (Kappes et al., 2018).

In the Rio del Carmen watershed, water users want their human right to access water to be respected, but many do not comply with the obligations and responsibilities that the water law has established, finding it inconvenient or inapplicable for them. This thesis claims that this kind of "doublethink" emerges from the lack of clarity over what the threats are, what is aimed for, and how it will be achieved at a watershed scale. If stakeholders are uncertain about whether their farming practices are causing water depletion or not, they are more likely to keep overexploiting the water resources. However, perceptions of social norms establish that if comparable levels of awareness and values are developed, negative outcomes can be identified, agreed, and so avoided (Kappes et al., 2018). Therefore, more certainty about the negative effects of agriculture on WES conservation, and how this affects rights to access water, will clarify the rules’ functional aims and the importance of respecting them.

Suitable rules require common goals so as to establish priorities and thus a hierarchy of values, which has the potential to reconcile opposing perceptions, create a shared value system, and so create a cultural alignment that stabilises interactions between stakeholders, enhancing their collaboration (Peterson, 2018). People ask for rules that can mitigate uncertainty (Kaufmann et al., 2018); so, for the system to continue functioning, formal institutions should embed the elements of iterativity, flexibility, connectivity, and subsidiarity, in order to increase adaptive capacity in the face of uncertainty (DeCaro et al., 2017b; Hill Clarvis et al., 2014).

5.2.3 Context shapes the guidelines for a transition towards adaptation

Increasing adaptation through governance regimes requires a deep understanding of the social influence over SES, in order to adjust rules according to the system identity and create sustainable resource management (Kerner et al., 2014). Ways to enable AWG vary according to each context (De Vente et al., 2016); for instance, in a dryland context, that means managing resource scarcities and addressing the weaknesses that undermine adaptive capacity (Balbo et al., 2016). Chapter 1 explains why adaptation is key to reduce vulnerability and increase resilience; additionally, Chapter 4 highlights that drylands may not be exclusively exposed to climate but also to societal stressors. So, even though adaptation has a nuanced association to climate change (Folke, 2016; Garrick, 2018), it should not be limited to the capacity to respond (by adjusting or transforming) to climate, but also to societal impacts on the SES. Entry points for increasing adaptive capacity in drylands by enabling AWG, can only be identified under that premise.

Chapter 4 showed that stakeholders identified water overexploitation, illegal water access, droughts, corruption, and breach of law as the main problems in the watershed. It was later discussed that opposing perceptions, lack of cultural sensitivity, overdependence on groundwater, unequal awareness, and social conflicts are also important elements of the Rio del Carmen watershed's governance. Although this thesis does not seek to measure the impacts of those stressors, it can be qualitatively observed that the number of societal stressors surpasses those of climate. This takes greater relevance given the increasingly conflictive context in drylands, where increasing poverty, lack of food, migration, land degradation, water scarcity and its "weaponization"[15] generate an enormous social toll and negatively impact SES; and the effects of these issues will transcend national borders (IPBES, 2018; Werrell and Femia, 2017). Equal consideration of dryland exposure to climate and societal stressors appreciates that adaptation is not a blueprint, while failed adaptation means failed understanding of SES stressors.

This Chapter frames three entry points for enabling AWG in the Rio del Carmen watershed, identified as 1) concordance, 2) stakeholder actions, and 3) structure; based on an interpretation of the watershed's dynamics, needs, and problems. These are entry points

[15] When in water-scarce contexts, water access is used to exercise and impose power (King, 2015).

for context-specific issues that no panaceas can predict when aiming to enable AWG. Nonetheless, it clearly shows how *context shapes the guidelines for a transition towards adaptation*. This means that besides the options for adapting to climate change, for instance, those that were presented by the IPCC (2014), the inherent complexity of SES requires consideration of non-environmental factors that influence vulnerability, and to which it also has to be adaptive. Knowing what to do and how to do it when aiming to increase adaptation, requires unpacking the co-adapting SES processes, components, and dynamics that are shaping its development pathway (Rammel et al., 2007; Stringer et al., 2017).

Successful transitions are based on a correct interpretation of the role of societal factors in shaping SES resilience, so as to include all the voices and values that will allow and reinforce AWG (Chaffin et al., 2014b). To define suitable AWG for a system's context that will potentially increase SES resilience, we need to understand system dynamics, resilience attributes, and vulnerabilities (Downing et al., 2005; Engle, 2011). That is, unravelling context-specific components shaping SES pathways, facilitates a transition to AWG (Engle, 2011) by identifying how governance regimes should match local geographic and social conditions (e.g., location, physical assets, and procedures) for increasing adaptation (Garrick, 2018).

5.3 Research limitations and opportunities for further enquiry

This thesis assesses water governance in the Rio del Carmen watershed, identifying entry points for increasing adaptive capacity by enabling AWG. The research contributes to understanding of how AWG might emerge in water-scarce contexts, and how governance regimes can be restructured to allow WES conservation and secure natural resource dependent livelihoods. In this thesis I used a case study approach, duly justified in Chapter 1, which explains its advantages and convenience, nevertheless, a first limitation of this approach is its wider applicability. Despite using a mixed methodological approach to mitigate limitations of both qualitative and quantitative data when conducting this research, inherent limitations to the case study cannot be eliminated.

Firstly, data collected from stakeholders may contain hidden assumptions that, even though they were validated through triangulation and cross-data validity checks to corroborate their consistencies and resolve any contradictions, findings cannot be necessarily upscaled to be considered applicable to other cases. In this regard, policy implications are limited to the watershed as these entry points were identified for context-specific issues (as stated in section 5.2.3). Furthermore, this research was funded by the Mexican Government through the National Council of Science and Technology, and the application of the findings provided by this research will be at the discretion of that institution.

Secondly, the single-case study allows for an in-depth understanding of an SES phenomenon (Luna-Reyes and Andersen, 2003; Reed et al., 2009), and it is through this context-dependent knowledge and experience, that researchers move from basic general knowledge to become experts (Flyvbjerg, 2006). However, the evidence presented from a single-case approach is not robust as that presented from multiple-case research, which is characterised by allowing a comparison of similarities and differences with other cases (Heale and Twycross, 2018). The decision to use a case study approach for theory building (Chapter 1, section 1.4) was supported by the resourcing and timeframes for the research linked to the duration of a PhD, and meant that a decision was made to focus on depth in a single case, rather than breadth and multiple cases. The natural step now is to move from theory building, to use a multiple-case study approach for theory testing.

Thirdly, there is a limitation related to data availability. After an exhaustive search, information regarding grassland loss and degradation in the Rio del Carmen watershed was not found. Consequently, I filed two official requests (in Spanish) to obtain that information through the National Transparency Platform of the National Institute of Transparency, Information Access and Protection of Personal Data. The first one took place in February 2017, addressed to the Ministry of Environment and Natural Resources, and the second was filed on July 2017 to the National Forest Commission; nonetheless, both government agencies said they did not have the information requested. Another data limitation consists of the groundwater recharge information published by CONAGUA from 2013 to 2018, through the Federal Official Gazette. Apparently, aquifer recharge has not changed in those 5 years, regardless of the droughts that have hit the watershed from 1997-2017 (information presented in Chapter 4), affecting and limiting the ability to really know the magnitude of the water deficit. This lack of clarity was also highlighted in Chapter 2, where statements from CONAGUA officials differed: one stating that CONAGUA has been monitoring groundwater quality and no variation or deterioration has been detected, while the other official said the watershed has been suffering worrisome overexploitation. Again, drought occurrences make evident the watershed had to undergo some variation. Moreover, there is a lack of monitoring highlighted by many stakeholders (including CONAGUA officials). Accordingly, there is no public data available that could be collected for addressing these inconsistencies. Coupled with the lack of monitoring, the number of false water rights do not allow accurate measurement of the depleting water levels and the real number of exploitations in the watershed. This also influenced the sample size when designing the survey research, as previously stated in Chapter 1 section 1.4.1. These issues are not only applicable to the research presented in this thesis, but represent a wider challenge in terms of understanding water dynamics within dryland systems. Although the collected data allowed me to characterise and understand the societal influence over the SES, these limitations impede more in-depth exploration of the ecological conditions of the Rio del Carmen watershed. Moreover, the same limitations apply to data regarding agricultural production in the watershed from 2015 onwards. As shown, there is a great need for the government to increase the monitoring and measurement of natural resources, their availability, their extraction, and to obtain data on agricultural production, making this information available so we can better address social-ecological challenges in the area.

A final limitation consists of the lack of clarity in the expected trade-offs for enabling AWG in the Rio del Carmen watershed. It was stated in Chapter 3 that during stakeholder engagement, some costs and benefits would arise (e.g., voluntarily restricting water access to allow WES conservation) and the success of this engagement depends on the acceptance of those trade-offs. However, in this thesis, there is no assessment of the benefits and losses that can arise with stakeholder engagement. A clear description of these trade-offs would provide strong incentives to policymakers, government officials, and practitioners to push for the appropriate changes in policy.

To address these limitations, further research that identifies the trade-offs of stakeholder engagement, with a cost-benefit analysis that integrates the risk of failure to move towards adaptation, is required. This would strengthen the policy implications of the work. Finally, further research must be conducted using a multi-case approach to test the wider applicability of the three principles for moving towards AWG. This will allow comparison and assessment of the similarities and differences among case studies when identifying entry points, and is necessary to advance theory and testing of the principles as to how AWG can be enabled in dryland contexts.

5.4. Conclusions and reflections on the thesis implications on dryland systems

Natural resource based livelihoods in dryland systems are often taking place in a context of poverty, marginalisation, and violence over resource access. They are particularly exposed to climate stressors, like droughts, and other SES stressors of a societal nature, which increase complexities when aiming to increase resilience. It has been highlighted that in water-scarce contexts, WES conservation is paramount for maintaining different ecosystem functions that will sustain and improve human well-being. Accordingly, increasing adaptive capacity to develop innovative solutions in a water-scarce context, is key for addressing the sensitivity of WES and dryland livelihoods to the potential impacts of climatic and societal stressors. Increasing adaptive capacity strengthens SES resilience.

Using the Rio del Carmen watershed as a case study for identifying barriers and entry points for moving towards adaptation by enabling AWG, has provided valuable insights for resilience theory, adaptive governance, and the dryland development literature. The case study presented here explores the complex relationship between resilience and vulnerability, illustrating how strengthening specified resilience focused on economic development, can increase overall SES vulnerability. This has major implications in drylands, since the urgency of addressing increasing poverty, marginalisation and migration problems, can lead to strategies that will only negatively impact these dryland livelihoods. In this regard, this thesis also highlights how maladaptive strategies at the farm scale can aggregate and accumulate, leading to significant negative impacts at a watershed scale, risking all natural resource based livelihoods in the area. This shows how a lack of awareness and collaboration in drylands has nuanced effects given their water-scarce context.

Furthermore, this case study analysed how dryland exposure is not climate-exclusive, as there are problems of a social nature that increase SES vulnerability. Improper integration of the societal influence within a SES, hinders correct characterisation of what makes it vulnerable or resilient, and thus, our ability to identify barriers and entry points for increasing adaptive capacity. I found that according to concepts such as human well-being and even social fabric, social vulnerability encompasses more than poverty, and unravelling it requires a more in-depth interpretation of SES vulnerability and resilience. Consequently, the thesis advocates for greater integration of the concept of "societal stressors" in the resilience literature, describing the societal factors that are systematically causing stress on the SES, and whose effects and impacts on the SES can be as dangerous as natural hazards (e.g. through dam destruction and the burning of crops). The concept seeks to expand our appreciation of vulnerability and resilience in SES, and similarly, that social vulnerability assessments in drylands should not be limited to considering marginalisation, famine or poverty. Increasing adaptive capacity to strengthen dryland resilience requires a more holistic approach, that accurately expresses the SES stressors that are undermining human well-being and increasing WES loss, among which, corruption and illegal water access are highlighted in this research.

Finally, the process and methodologies used in this research can be used in other case studies with water-scarce contexts, when identifying barriers and entry points for enabling AWG is intended. The process employed in the Rio del Carmen watershed shows how in-depth a governance system assessment has to be in order to obtain useful insights for enabling AWG. It has been stated several times in this thesis that problems and solutions are context-dependent, so the identified barriers and entry points will vary in each case study. Nonetheless, the implications of this research entail showing how stakeholders, legal frameworks, and institutional structures can be potentially leveraged for enabling AWG. The thesis proposed three principles for moving towards AWG, which aim to provide lessons concerning how AWG can be enabled, considering the peculiarities of each SES, and mapping out what established AWG could look like. But more deeply, the principles proposed in this thesis were derived with the intention to enhance the implications of this research for scholars and practitioners that aim to facilitate AWG. The principles seek to clarify, regardless of the context or SES features, how AWG can be successfully enabled, with a nuanced approach in dryland systems.

5.5 References

Athie, K. 2016. *El Agua, ayer y hoy* [Online] (Centro de Estudios Sociales y de Opinion Publica, ed.). Mexico City: Camara de Diputados LXIII Legislatura. Available from: http://www5.diputados.gob.mx/index.php/camara/Centros-de-Estudio/CESOP/Estudios-e-Investigaciones/Libros/El-Agua-Ayer-y-Hoy.

Balbo, A.L., Gómez-Baggethun, E., Salpeteur, M., Puy, A., Biagetti, S. and Scheffran, J. 2016. Resilience of small-scale societies: a view from drylands. *Ecology and Society*. **21**(2), p.art53.

Chaffin, B.C., Craig, R.K. and Gosnell, H. 2014a. RESILIENCE, ADAPTATION, AND TRANSFORMATION IN THE KLAMATH RIVER BASIN SOCIAL-ECOLOGICAL SYSTEM. *51 Idaho Law Review 1*.

Chaffin, B.C., Garmestani, A.S., Gosnell, H. and Craig, R.K. 2016. Institutional networks and adaptive water governance in the Klamath River Basin, USA. *Environmental Science & Policy*. **57**, pp.112–121.

Chaffin, B.C., Gosnell, H. and Cosens, B.A. 2014b. A decade of adaptive governance scholarship: Synthesis and future directions. *Ecology and Society*. **19**(3), p.56.

Cortez Lara, A. 2010. Reflexiones teórico-metodológicas sobre la cultura de sustentabilidad en el manejo de aguas transfronterizas del bajo río Colorado. *Culturales*. **6**(12), p.34.

Cosens, B.A., Craig, R.K., Hirsch, S.L., Arnold, C.A. (Tony), Benson, M.H., DeCaro, D.A., Garmestani, A.S., Gosnell, H., Ruhl, J.B. and Schlager, E. 2017. The role of law in adaptive governance. *Ecology and Society*. **22**(1), p.30.

DeCaro, D.A., Arnold, C.A. (Tony), Frimpong Boamah, E. and Garmestani, A.S. 2017. Understanding and applying principles of social cognition and decision making in adaptive environmental governance. *Ecology and Society*. **22**(1), p.33.

DeCaro, D.A., Chaffin, B.C., Schlager, E., Garmestani, A.S. and Ruhl, J.B. 2017. Legal and institutional foundations of adaptive environmental governance. *Ecology and Society*. **22**(1), p.32.

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Báldi, A., Bartuska, A., Baste, I.A., Bilgin, A., Chan, K.M., Figueroa, V.E., Duraiappah, A., Fischer, M., Hill, R., Koetz, T., Leadley, P., Lyver, P., Mace, G.M., Martin-Lopez, B., Okumura, M., Pacheco, D., Pascual, U., Pérez, E.S., Reyers, B., Roth, E., Saito, O., Scholes, R.J., Sharma, N., Tallis, H., Thaman, R., Watson, R., Yahara, T., Hamid, Z.A., Akosim, C., Al-Hafedh, Y., Allahverdiyev, R., Amankwah, E., Asah, S.T., Asfaw, Z., Bartus, G., Brooks, L.A., Caillaux, J., Dalle, G., Darnaedi, D., Driver, A., Erpul, G., Escobar-Eyzaguirre, P., Failler, P., Fouda, A.M.M., Fu, B., Gundimeda, H., Hashimoto, S., Homer, F., Lavorel, S., Lichtenstein, G., Mala, W.A., Mandivenyi, W., Matczak, P., Mbizvo, C., Mehrdadi, M., Metzger, J.P., Mikissa, J.B., Moller, H., Mooney, H.A., Mumby, P., Nagendra, H., Nesshover, C., Oteng-Yeboah, A.A., Pataki, G., Roué, M., Rubis, J., Schultz, M., Smith, P., Sumaila, R., Takeuchi, K., Thomas, S., Verma, M., Yeo-Chang, Y. and Zlatanova, D. 2015. The IPBES Conceptual Framework — connecting nature and people. *Current Opinion in Environmental Sustainability*. **14**, pp.1–16.

Doménech Pascual, G. 2015. Por qué y cómo hacer análisis económico del Derecho. *Revista de Administración Pública*. **0**(195), pp.99–133.

Downing, T.E., Patwardhan, A., Authors, C., Klein, R.J.T., Mukhala, E., Stephen, L., Winograd, M. and Ziervogel, G. 2005. Assessing Vulnerability for Climate Adaptation [Accessed 5 November 2018]. Available from: http://www4.unfccc.int/nap/Country Documents/General/apf technical paper03.pdf.

Duarte, R., Pinilla, V. and Serrano, A. 2014. Looking backward to look forward: water use and economic growth from a long-term perspective. *Applied Economics*. **46**(2), pp.212–224.

Enfors, E. 2013. Social–ecological traps and transformations in dryland agro-ecosystems: Using water system innovations to change the trajectory of development. *Global*

Environmental Change. **23**(1), pp.51–60.

England, M.I., Stringer, L.C., Dougill, A.J. and Afionis, S. 2018. How do sectoral policies support climate compatible development? An empirical analysis focusing on southern Africa. *Environmental Science & Policy*. **79**, pp.9–15.

Engle, N.L. 2011. Adaptive capacity and its assessment. *Global Environmental Change*. **21**(2), pp.647–656.

Flyvbjerg, B. 2006. Five Misunderstandings About Case-Study Research. *Sage Publications*. **12**(2), pp.219–245.

Folke, C. 2016. Resilience (Republished). *Ecology and Society*. **21**(4), p.44.

Garmestani, A. and Benson, M. 2013. A Framework for Resilience-based Governance of Social-Ecological Systems. *Ecology & Society*. **18**(1), p.9.

Garrick, D. 2018. Decentralisation and drought adaptation: Applying the subsidiarity principle in transboundary river basins. *International Journal of the Commons*. **12**(1), p.301.

Heale, R. and Twycross, A. 2018. What is it? Examples of case studies What is a case study? Research made simple. . **21**.

Hill Clarvis, M., Allan, A. and Hannah, D.M. 2014. Water, resilience and the law: From general concepts and governance design principles to actionable mechanisms. *Environmental Science and Policy*. **43**, pp.98–110.

Huitema, D., Mostert, E. and Pahl-wostl, C. 2009. Adaptive Water Governance : Assessing the Institutional Prescriptions of Adaptive (Co-) Management from a Governance Perspective and Defining a Research Agenda. . **14**(1), p.26.

IPBES 2018. *Summary for policymakers of the assessment report on land degradation and restoration of the Intergovernmental SciencePolicy Platform on Biodiversity and Ecosystem Services. R. Scholes, L. Montanarella, A. Brainich, N. Barger, B. ten Brink, M. Cantele, B.* [Online]. IPBES secretariat, Bonn, Germany. [Accessed 25 September 2018]. Available from: www.ipbes.net.

IPCC 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and*

III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)] [Online]. Geneva, Switzerland: IPCC. [Accessed 20 February 2019]. Available from: http://www.ipcc.ch.

Iza, A. and Stein, R. 2009. *Rule - Reforming water governance* [Online]. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources. [Accessed 13 May 2019]. Available from: www.iucn.org/publications.

Kappes, A., Nussberger, A.-M., Faber, N.S., Kahane, G., Savulescu, J. and Crockett, M.J. 2018. Uncertainty about the impact of social decisions increases prosocial behaviour. *Nature Human Behaviour*. **2**(8), pp.573–580.

Kaufmann, W., Hooghiemstra, R. and Feeney, M.K. 2018. Formal institutions, informal institutions, and red tape: A comparative study. *Public Administration*. **96**(2), pp.386–403.

Kerner, D.A., Thomas, J.S., Kerner, D.A. and Thomas, J.S. 2014. Resilience Attributes of Social-Ecological Systems: Framing Metrics for Management. *Resources*. **3**(4), pp.672–702.

King, M.D. 2015. The Weaponization of Water in Syria and Iraq. *The Washington Quarterly*. **38**(4), pp.153–169.

LAN 2016. Ley de Aguas Nacionales. Diaro Oficial de la Federacion. CÁMARA DE DIPUTADOS DEL H. CONGRESO DE LA UNIÓN. [Accessed 13 February 2017]. Available from: http://www.diputados.gob.mx/LeyesBiblio/pdf/16_240316.pdf.

Leitao, A. 2016. Corruption and the Environment. *Journal of Socialomics*. **5**(3), p.5.

Luna-Reyes, L.F. and Andersen, D.L. 2003. Collecting and analyzing qualitative data for system dynamics: methods and models. *System Dynamics Review*. **19**(4), pp.271–296.

Meadows, D.H. 1997. Places to intervene in a system (in increasing order of effectiveness). *Whole Earth*. (91), pp.78–84.

Middleton, N., Stringer, L., Goudie, A. and Thomas, D. 2011. *The Forgotten Billion MDG Achievement in the Drylands* [Online]. New York. [Accessed 9 March 2017]. Available from: http://www.unccd.int/Lists/SiteDocumentLibrary/Publications/Forgotten

Billion.pdf.

Murillo-Licea, D. and Soares-Moraes, D. 2013. El péndulo de la gobernabilidad y la gobernanza del agua en México. *Tecnologia y Ciencias del Agua*. **4**(3), pp.149–163.

Mussetta, P. 2009. Participación y gobernanza . El modelo de gobierno del agua en México. *Espacios Públicos*. **12**(25), pp.66–84.

Nemec, K.T., Chan, J., Hoffman, C., Spanbauer, T.L., Hamm, J.A., Allen, C.R., Hefley, T., Pan, D. and Shrestha, P. 2014. Assessing Resilience in Stressed Watersheds. *Ecology and Society*. **19**(1), p.34.

North, D.C. 1990. *Institutions, institutional change, and economic performance* [Online]. Cambridge: Cambridge University Press. [Accessed 5 September 2017]. Available from: http://admin.cambridge.org/gb/academic/subjects/politics-international-relations/political-economy/institutions-institutional-change-and-economic-performance#Z2tkQfZ58LXFGHS5.97.

OECD 2013. *Making Water Reform Happen in Mexico, OECD Studies on Water, OECD Publishing* [Online]. Available from: http://dx.doi.org/10.1787/9789264187894-en.

Olsson, P., Gunderson, L.H., Carpenter, S.R., Ryan, P., Lebel, L., Folke, C. and Holling, C.S. 2006. Shooting the Rapids: Navigating Transitions to Adaptive Governance of Social-Ecological Systems. *Ecology and Society*. **11**(1), p.18.

Pahl-Wostl, C. 2017. An Evolutionary Perspective on Water Governance: From Understanding to Transformation. *Water Resources Management*. **31**(10), pp.2917–2932.

Pahl-Wostl, C. and Knieper, C. 2014. The capacity of water governance to deal with the climate change adaptation challenge: Using fuzzy set Qualitative Comparative Analysis to distinguish between polycentric, fragmented and centralized regimes. *Global Environmental Change*. **29**, pp.139–154.

Pejovich, S. 1999. *The effects of the interaction of formal and informal institutions on social stability and economic development* [Online]. Published by the Center for Economic Personalism. [Accessed 8 January 2019]. Available from:

https://www.marketsandmorality.com/index.php/mandm/article/view/624.

Peterson, J.B. 2018. *12 rules for life: An antidote to chaos* [Online]. Toronto, Canada: Random House Canada. Available from: www.penguinrandomhouse.ca.

Rammel, C., Stagl, S. and Wilfing, H. 2007. Managing complex adaptive systems — A co-evolutionary perspective on natural resource management. *Ecological Economics*. **63**(1), pp.9–21.

Reed, M.S., Evely, A.C., Cundill, G., Fazey, I., Glass, J., Laing, A., Newig, J., Parrish, B., Prell, C., Raymond, C. and Stringer, L.C. 2010. What is Social Learning? *Ecology and Society*. **15**(4), p.r1.

Reed, M.S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C.H. and Stringer, L.C. 2009. Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management*. **90**(5), pp.1933–1949.

Rogers, P., Hall, A.W., Van de Meene, S.J., Brown, R.R. and Farrelly, M. a. 2003. *Effective Water Governance Global Water Partnership Technical Committee (TEC)* [Online]. Available from: http://dx.doi.org/10.1016/j.gloenvcha.2011.04.003%5Cnwww.gwpforum.org.

Schlüter, M., Baeza, A., Dressler, G., Frank, K., Groeneveld, J., Jager, W., Janssen, M.A., McAllister, R.R.J., Müller, B., Orach, K., Schwarz, N. and Wijermans, N. 2017. A framework for mapping and comparing behavioural theories in models of social-ecological systems. *Ecological Economics*. **131**, pp.21–35.

Søreide, T. and Truex, R. 2013. Multi-stakeholder Groups for Better Sector Performance: A Key to Fighting Corruption in Natural-Resource Governance? *Development Policy Review*. **31**(2), pp.203–217.

Stringer, L.C., Reed, M.S., Fleskens, L., Thomas, R.J., Le, Q.B. and Lala-Pritchard, T. 2017. A New Dryland Development Paradigm Grounded in Empirical Analysis of Dryland Systems Science. *Land Degradation & Development*. **28**(7), pp.1952–1961.

UN 2007. *EL LITIGIO ESTRATÉGICO EN MÉXICO: la aplicación de los derechos humanos a* *nivel práctico* [Online]. Mexico City. Available from: www.hchr.org.mx.

De Vente, J., Reed, M.S., Stringer, L., Valente, S. and Newig, J. 2016. How does the context and design of participatory decision making processes affect their outcomes? Evidence from sustainable land management in global drylands. *Ecology and Society*. **21**(2), p.24.

Werrell, C. and Femia, F. 2017. *EPICENTERS OF CLIMATE AND SECURITY: THE NEW GEOSTRATEGIC LANDSCAPE OF THE ANTHROPOCENE* [Online]. [Accessed 2 May 2019]. Available from: www.climateandsecurity.org.

Appendix

Appendix I. Ethical approval AREA 16-148

The Secretariat
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UNIVERSITY OF LEEDS

Gabriel Lopez

Sustainability Research Institute

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University of Leeds

Leeds, LS2 9JT

ESSL, Environment and LUBS (AREA) Faculty Research Ethics Committee

University of Leeds

2 October 2019

Dear Gabriel,

Title of study:	**Assessing water governance in Mexico's semi-arid grassland systems, with a view to identifying entry points for improving resilience.**
Ethics reference:	**AREA 16-148**

I am pleased to inform you that the above research application has been reviewed by the ESSL, Environment and LUBS (AREA) Faculty Research Ethics Committee and following receipt of your response to the Committee's initial comments, I can confirm a favourable ethical opinion as of the date of this letter. The following documentation was considered:

Document	Version	Date
AREA 16-148 Ethical Review clarification.docx	1	23/05/17
AREA 16-148 Ethical Review Form GL.doc	2	23/05/17
AREA 16-148 High-Risk Assessment GL.docx	1	08/05/17
AREA 16-148 Appendix 1.docx	1	08/05/17
AREA 16-148 Appendix 2.docx	1	08/05/17
AREA 16-148 Appendix 3.docx	1	08/05/17
AREA 16-148 Appendix 4.docx	1	08/05/17

Please notify the committee if you intend to make any amendments to the information in your ethics application as submitted at date of this approval as all changes must receive ethical approval prior to implementation. The amendment form is available at http://ris.leeds.ac.uk/EthicsAmendment.

Please note: You are expected to keep a record of all your approved documentation and other documents relating to the study, including any risk assessments. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited. There is a checklist listing examples of documents to be kept which is available at http://ris.leeds.ac.uk/EthicsAudits.

We welcome feedback on your experience of the ethical review process and suggestions for improvement. Please email any comments to ResearchEthics@leeds.ac.uk.

Yours sincerely

Jennifer Blaikie

Senior Research Ethics Administrator, the Secretariat

On behalf of Dr Kahryn Hughes, Chair, AREA Faculty Research Ethics Committee

CC: Faculty Research & Innovation Office/ Student's supervisor(s)

Appendix II. Interview protocol for scoping fieldwork

1) Interviewee's background

For Communities:

- What are your name and occupation?

- How long have you been living in the Rio del Carmen watershed?

- How long have you been engaged in agricultural activities within the watershed?

- What type of agricultural activities do you carry out?

For the other categories:

- Can you tell me your name, job title, organisation and duties?

- How is your job related to the grasslands and water governance in the Rio del Carmen watershed?

2) Stakeholders in the Rio del Carmen watershed

- Can you tell me if the categories in the preliminary stakeholder list are accurate? How can you improve it?

- Which other stakeholders should be in each category on that list? Can you introduce me to them or give me their contact details?

3) Water access for agricultural practices

For Communities:

- How and when did you get your agricultural water rights?

Has your access to water has changed since you obtained your rights?

- Do you think that water access for agricultural users in Rio del Carmen watershed is fair? Why?

- Do you think that economic or political aspects have affected the way in which access to water takes place? Why?

- Have you sought to increase your access to water since you obtained your water right? Why?

- Is there any season of the year where greater access to water is required?

- If yes, do you accede to the required volume during those seasons?

For the other categories:

- Do you think that water access regulation in Rio del Carmen watershed can improve for agricultural users?

- If yes, how can it be improved?

- Do you think that water access for agricultural use in Rio del Carmen watershed is fair for people who access or want to access it? Why?

- Do you think that the way in which access to water takes place have been influenced by some stakeholders?

- If yes, can you explain how does this occur?

- How many people have lost their agricultural water rights since 1994 and for what reasons?

4) Water value and water ecosystem services value

For Communities:

- What is the relation between water access for agricultural use and the grasslands in the Rio del Carmen watershed?

- How do you think the agricultural water use affects the ecological processes in the Rio del Carmen watershed?

- What kind of benefits (direct and indirect) does water provides to the agriculture in the Rio del Carmen watershed?

- Which of those benefits do you think are more important?

- Considering current water availability, do you think that agriculture in the Rio del Carmen watershed can continue in the long term, for example, 20 years?

For the other categories:

- What is the relation between water access for agricultural use and the grasslands in the Rio del Carmen watershed?

- How do you think the agricultural water use affects the ecological processes in the Rio del Carmen watershed?

- What kind of benefits (direct and indirect) does water provides to the agriculture in the Rio del Carmen watershed?

- Considering current water availability, do you think that agriculture in the Rio del Carmen watershed can continue in the long term, for example, 20 years?

5) The governance of water

- Which of the categories on the preliminary stakeholder list do you consider have communication and coordination roles in terms of water governance?

- Has information been generated and shared among these categories on how to improve water use in the watershed?

- Have you participated in a decision-making process about water use in the watershed?

- What have been the effects of water management in the Rio del Carmen watershed and the impacts on livelihoods within it?

6) Conflicts and trade-offs in water use

- What do you think are the reasons for the conflicts over water access?

- How many conflicts have arisen since 1994 due water access for agricultural use in the Rio del Carmen watershed? Do you remember some approximate dates?

- Has any attempt been made to resolve these conflicts?

- What do you think are the positive and negative influences of the extraction of agricultural water over the different kind of livelihoods in the Rio del Carmen watershed?

Appendix III. Interview protocol for second fieldwork

Interviewee background

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

If yes, can you explain your activities?

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

For the farmers

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

Why did you select those crops?

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

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

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

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

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

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

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

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

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

For the other stakeholders

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

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

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

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

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

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

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

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

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

For the farmers

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

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

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

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

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

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

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

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

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

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

For the other stakeholders

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

What could be another strategy to address the overexploitation?

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

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

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

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

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

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

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

For the farmers

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

How are the conflicts over water access affecting you?

Do you know how it has affected other farmers too?

What are the main obstacles to collaboration in the watershed?

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

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

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

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

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

For the other stakeholders

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

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

What are the main obstacles to collaboration in the watershed?

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

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

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

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

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

Appendix IV. Survey questionnaire

This survey is being carried out as part of the research *Assessing water governance in Mexico's semi-arid grassland systems, with a view to identifying entry points for improving resilience*. Consent for the use of data from the survey is implied by participating in it.

Your name is not required, so individual responses would not be used in any way. The main output from this research will be a PhD thesis to be submitted to the University of Leeds, UK in 2019. Additionally, the results of the research will be used in academic publications and conference presentations.

1. Do you have an agricultural water right in the Rio del Carmen watershed?

Yes (__)No (__)

2. How many cubic meters per year is your water right?

____

3. How many hectares of cultivation do you have?

____

4. Which of these agricultural groups do you belong to? You can mark more than one.

Ejido member (__) Irrigation module (__)

Irrigation unit (__) Mennonite (__) Other________________________________

5. What are your crops in the current growing season? You can mark more than one.

Chile (__) Alfalfa (__) Walnut (__) Cotton (__) Corn (___) Other____________

6. Have you seen any deterioration on the Rio del Carmen watershed grasslands in the last 20 years?

Yes (__) No (__) (If No, go to question 8).

7. Why do you think grasslands have deteriorated?

Droughts (__) Illegal change of land (__) water exploitation (__)

Overgrazing (__) Loss of soil and vegetation (__)

Other____

8. Have there been any changes in your water exploitation over the last 20 years?

Yes (__) No (__) (If No, go to question 11).

9. Why do you think you have changed your exploitation? You can mark more than one.

Drought (__) Illegal water exploitation (__) Excess of right holders (__)

Inadequate crops (__) Other____

10. What have you done to remedy it if it is not a desirable change?

Deepen the exploitation (__) Relocate the exploitation (__) Use two exploitations (__)

Other____

11. Have you seen any change in the climate conditions in the Rio del Carmen watershed over the last 20 years? You can mark more than one.

Heat increase (__) More drought (__) Atypical rain (__) Delayed winter (__)

Other_____________________________________ No (__) (If No, go to question 10).

12. How have these changes in climate affected your agricultural activities?

Less water availability (__) Agricultural cycle lag (__) Less agricultural production (__)

Increases in production costs (__) Other____

13. Have you been involved in some personal conflict or social clash with other agricultural rights holders derived from the use of water in the watershed?

Yes (__) No (__) (If No, go to question 16).

14. Why did this conflict arise?

Water overuse (__) Illegal exploitation (__) A modification in the exploitation (__)

Other____

15. Has the conflict been resolved?

The problem was solved by individuals (__)   It was solved through an organization[16] (__)

Is in resolution process (__)   It has not been solved (__)

16. Have you seen any illegal water exploitation in the Rio del Carmen watershed?

Yes (__)   No (__)   (If No, go to question 18).

17. Have you reported it to CONAGUA?

Yes (__)   No (__)

18. Have you ever been a victim or have been threatened by organised crime in the Rio del Carmen watershed?

I have been a victim (__)   I have been threatened (__)   No (__)

19. Have you noticed any act of corruption concerning the use of water in the watershed?

Yes (__)   No (__)   (If No, go to question 21).

20. What was that act of corruption?

Obtaining a water right (__)   Avoid an inspection process or a fine (__)

Water right modification (__)   Other____

21. Have you participated in any collaboration or decision-making processes regarding water management in the Rio del Carmen watershed?

Yes (__)   No (__)   (If No, go to question 23).

22. What authorities, organizations or individuals participated in this process?

CONAGUA (__)   CFE (__)   SEMARNAT (__)   PROFEPA (__)

SEGOB (__)   Barzon (__)   Irrigation District (__)

Mennonite Central Committee (__)   Other____

23. Please rank from 1 to 5 the main problems in the watershed (1 the most important).

Water overexploited (___)   Illegal water exploitation (___)   Droughts (___)

[16] Name of the organization____

Conflicts over water use (___)   Corruption (___)   Breach of the law (___)

Lack of coordination with the authorities (___)   Crops that are not suitable (___)

Organized crime (___)   Other (___) ____

24. Please rank from 1 to 5 the main needs in the watershed (1 the most important).

Irrigation technologies (___)   Law enforcement (___)   Aquifer recharge (___)

Meter implementation (___)   Inter-institutional coordination (___)   Crop diversification (___)

Inspection of exploitations (___)   Spaces for participation and conflict resolution (___)

Police presence (___)   Other (___) ____