Reframing Conservation and Resource Management from *Ejidatario* Needs Assessment in Cuatro Ciénegas, MX

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Contents

Abstract

The Cuatro Ciénegas Basin (CCB) is one of the most diverse wetland ecosystems in North America, however unsustainable development and water use threatens the basin's biota and human populations alike. Conservation and natural resource management plans (CNMP) have focused on biophysical and ecological preservation of the CCB, however they fail to address the social complexities of the basin. This has resulted in mostly unsuccessful CNMPs, continued resource degradation, and increased stakeholder tension. Social dynamics are for the most part undocumented and must be better understood to ensure inclusive, equitable, and sustainable development of CNMPs. Because small, communal farmers (*ejidatarios*) are historically marginalized and highly vulnerable to shifts in natural resources, it is critical to incorporate them in decision making processes. This study describes *ejidatario* challenges and perspectives that can be integrated into future CNMPs to help reduce negative impacts on *ejidatario* livelihoods. Participatory, semi-structured interviews and grounded theory tools were used to promote *ejidatario* narratives in the research process. Results reveal how social conflict, lack of funding, and insufficient infrastructure and technology inhibit stakeholder collaboration and adoption of more sustainable farm management practices. Increased engagement in CNMPs can empower *ejidatarios* by shifting the power regime of traditionally structured resource management to one that is more inclusive of marginalized groups. These insights can be used to guide the development of more socially equitable CNMPs, promoting their overall success.

Introduction

Understanding the needs of local populations in fragile ecosystems is critical to developing sustainable, holistic conservation and natural resource management plans (CNMP). This is particularly applicable to historically marginalized groups whose livelihoods stand to be greatly impacted by shifts in natural resource availability. I look at the Cuatro Ciénegas Basin (CCB) as an example of how incorporating small, communal farmers (*ejidatarios*) into CNMP development can lead to more sustainable outcomes. The CCB is one of the most diverse desert wetlands in North America, but current agricultural activities in the region are unsustainable and threaten ecosystem health (Minckley, 1992; Pronatura Noreste, 2018; Souza et al., 2006). Traditionally water management agencies and NGOs develop top-down CNMPs which are primarily focused on biophysical preservation and do not adequately consider *ejidatario* needs, thus increasing stakeholder tensions and rendering CNMPs predominantly unsuccessful. A new

model that better addresses the complicated socio-environmental dynamics in the CCB would lead to more successful CNMP implementation. In this paper, I argue that this can be achieved through increased *ejidatario* engagement in CNMP development and decision-making processes.

Numerous geological and ecological academic studies have been performed in the CCB, but little research exists describing the basin's social dynamics. A 1997 study and 2016 study provide a foundational understanding of different stakeholder viewpoints, however there is not a focused description of *ejidatarios* (Ortiz Acosta & Romo Aguilar, 2016; Valeria, 1997). Addressing this gap in information will clarify how *ejidatarios* can be more engaged in CNMP decision-making processes. Here, we present a qualitative needs assessment of *ejidatarios* in the CCB and report how findings can help guide more equitable CNMPs.

Goals & Objectives

The goal of this study was to provide an assessment of *ejidatario* challenges and opinions through a literature review and grounded theory analysis so that their ideas can play a larger role in directly informing future CNMPs. I accomplished this through 3 main objectives: (1) understand how *ejidatarios* value the CCB's natural resources in relation to their personal wellbeing (2) identify barriers, needs, and prospective solutions to improving *ejidatario* livelihoods (3) describe *ejidatario* perceptions of other CCB stakeholders. Objectives were understood using a participatory approach, allowing *ejidatario* commentary to guide data collection.

Natural Landscape

The CCB is a 1,200 km square valley that sits in the heart of the state of Coahuila in northern Mexico. Centered in the middle of the Chihuahuan Desert, the basin has an arid climate receiving only about 200 mm of annual precipitation and experiencing cold winters dropping below freezing and hot summer temperatures reaching 44 C (Mamer & Newton, 2017; Montiel-gonzález et al., 2018). Most precipitation occurs in the mountains surrounding the CCB; the Sierra Madera range borders the north and the Sierra San Marcos rage cuts straight up the center splitting the basin into two triangles.

Along with much of central North America, the CCB was covered by a shallow sea during Jurassic and Cretaceous periods (Mamer & Newton, 2017). As faults reversed, marine sediments left behind the topography we see today (McKee et al., 1990). The karstic geology

allows for a shallow, highly permeable aquifer (Mamer & Newton, 2017) and existing faults permit groundwater effluent to the surface (Evans, 2005).

An abundance of springs exist in the CCB due to groundwater and surface water interactions (Felstead et al., 2015; Wolaver, 2008). These springs have manifested themselves in pools (*pozas*) varying in space, surface area, depth, biodiversity, and chemistry (Evans, 2005; Wolaver, 2008). Between 300-500 turquoise-blue *pozas* have been reported making the basin one of two remaining fragile desert wetland ecosystems in North America, and the highest spring density in the Chihuahuan Desert (Felstead et al., 2015; Mamer & Newton, 2017; Minckley, 1992). Pozas and Río Mezquite (the CCB's main river) are the main surface water features in the CCB. Under natural conditions, the CCB is a closed system with evapotranspiration being the only outflow (Adolfo et al., 2018).

Desertification, mountain formation, and hydrogeological dynamics enabled evolution to occur in isolation, creating a desert oasis in terms of water and life (Souza et al., 2012). An abundance of plants, animals and microbes live in the poza's microecosystems which rely on continuous water flow. The CCB's biodiversity, with over 70 endemic species, has been compared to that of the Galapagos and has drawn national and international attention to the basin (Souza et al., 2012). Scientists and researchers have cited the CCB as an invaluable window into understanding early evolution of life on Earth and possibly other planets (Souza et al., 2006, 2012). The CCB was declared an "Área Natural Protegida¨ (ANP) by Mexico in 1994, it is recognized as a high priority site for conservation by UNESCO, and is a Ramsar "Wetland of International Importance" (Lillo et al., 1999; Souza et al., 2012). Often described as an ecological oasis, the combination of unique hydrologic features and immense biodiversity are what make the CCB truly special.

Human Development

In recent decades, changes in the CCB's hydrologic characteristics have caused controversy. Water levels in some pozas, including Poza Churince and Poza Becerra, have periodically declined with some pozas experiencing seasonal disappearance. Laguna Grande, which was once a terminal lake, steadily decreased in surface area until it vanished completely in 2010 (Berris personal commentary, 2019; Mamer & Newton, 2017). Hydrologic disconnectivity in Rio Mesquite is visible in dry river segments that once connected pozas (Berris personal commentary, 2019).

Groundwater overdraft, surface water depletion, and drought have been cited as possible sources of hydrologic degradation with blame placed primarily on agricultural activities. Agriculture has been predominant in the CCB for centuries, but spatial and social shifts in the early 1900s significantly changed crop composition. While cotton, grapes, maize, and wheat were primarily grown up until the 1930s, alfalfa was established throughout the CCB and surrounding areas as a result of modern agricultural technologies (Lillo et al., 1999). Industrial-scale agricultural development for alfalfa, driven by high demand for dairy fodder, began in the Ocampo valley to the north in the 1980s, and in the Hundido Valley to the southwest in the early 2000's (Mamer & Newton, 2017). Although alfalfa has a large water requirement of 1200-1500 liters per kg (Senamhi et al., 2012), it's still the region's number one crop grown by large and small farmers alike (Angeles Hernández et al., 2008; Lillo et al., 1999). In the CCB 65% of cultivated agricultural land is devoted to alfalfa even though it has the highest annual applied water demand compared to any other crop at 4,852,960 m3, over 6 times higher than nut trees which have the next highest demand in the basin (Adolfo et al., 2018).

Water consumption increased in parallel with agricultural development and the CCB saw a surge in water infrastructure projects to accommodate demand. Groundwater pumping increased dramatically with 82.83% of the region's consumption being allocated to agricultural purposes (Ortiz Acosta & Romo Aguilar, 2016). Numerous studies support the likelihood that Ocampo Valley, Hundido Valley, and CCB aquifers are connected, therefore linking increased groundwater extractions in surrounding areas to hydrologic changes in the CCB (Mamer & Newton, 2017; Souza et al., 2006; Wolaver, 2008). Surface water conveyance systems were established to transport and export water from the CCB's pozas. Three main canals, Becerra Canal, Saca Salada Canal, and Santa Tecla Canal (currently closed), along with numerous smaller canals move water to agricultural areas (Figure 1). It's estimated that 82.5% of surface water is either lost in deteriorating infrastructure or exported out of the CCB (Pronatura Noreste, 2018). It is difficult to pinpoint exact causal points since groundwater interactions are complicated and water rights are poorly managed; however, there is consensus hydrologic degradation directly threatens the unique ecosystems that depend on them (Leal Nares et al., 2018; Ortega, 2020).

Figure 1: Map of major hydrologic features in the CCB.

Locals, scientists, and conservationists have called for increases in environmental protection and various CNMPs have been implemented with little success. For example, the Comisión Nacional del Agua (CONAGUA) has worked to modernize water conveyance by converting canals to pipes to reduce evaporation loss, however the conversion has been slow and many canals remain unfinished (Ortiz Acosta & Romo Aguilar, 2016). The Comisión Nacional de Áreas Naturales Protegidas (CONANP) has a local office in town and is invested in managing the ANP, environmental monitoring, and research projects in the basin. Unfortunately, lack of monitoring stations, equipment, and funding limits the scope of projects (Adolfo et al., 2018; Berris personal commentary, 2019). Pronatura Noreste is an environmental group that has approached conservation through means of buying large amounts of land (Pozas Azules Ranch) and filing lawsuits against large farming operations (Berris personal commentary, 2019). However, CNMPs remain underfunded and fragmented.

Social Context

The CCB is composed of private, federal and ejido lands, this study focuses on ejidos and the people who live in and farm ejido lands, called *ejidatarios*. Ejidos are areas of communally managed land where *ejidatarios* do not have ownership over the ejido itself, but rather usufruct rights as communal landowners where the land it's resources are at their disposal (Schumacher et

al., 2019). Legal ownership remains with the government since ejidos are labeled as national goods (Schumacher et al., 2019). *Ejidatarios* can farm together or on individual parcels in the ejido.

Ejido history is critical in understanding their social, political, and environmental position in the CCB. In 1917, Mexico began large scale land reforms called "reparto de tierras" in response to the Mexican Revolution and civil unrest (Wolfe, 2017; World Bank, 2001). The addition of Article 27 to the Mexican Constitution combined with 1915 Agrarian Law allowed for redistribution of large, private land holdings to farmers, workers, and peasants in the form of ejidos, with the hopes that access to lands and resources would uplift low income populations (Wolfe, 2017). Over 1 million ha, or more than half Mexico's arable land, was redistributed (Wolfe, 2017; World Bank, 2001). However, these reforms did not improve livelihoods of rural populations as hoped and ejidos experienced a lack of capital, little technology, unsustainable resource use, and high levels of poverty due to restricted land rights and low levels of investment (Schumacher et al., 2019; World Bank, 2001). In fact, a 1995 study found that the probability of being poor increased by 50% in ejidos (World Bank, 2001)

In response to global neo-liberal trends and in an effort to address the ejido system's shortcomings, 1992 reforms to Article 27 allowed for *ejidatarios* to privatize ejido lands through formal acquisition of a deed (Perramond, 2008). However, while these reforms did lead to a overall decrease in ejidal lands from privatization, most ejidos did not privatize and maintain de-facto internal regulation (Morett-Sánchez & Cosío-Ruiz, 2017; Schumacher et al., 2019). Additionally, many ejidos still experience poor qualities of life with 37.5% finding it difficult to development due to lack of infrastructure and technology and 41.3% experiencing a majority of their young people migrating to areas with greater employment opportunities (Morett-Sánchez & Cosío-Ruiz, 2017).

Ejidos are an important component of Mexico's agriculture at a national and regional scale. Presently, over 42% of Mexican land is incorporated into 29,554 ejidos made up of over 3 million *ejidatarios*, a large part of the rural population (INEGI, 2007; Morett-Sánchez & Cosío-Ruiz, 2017; Schumacher et al., 2019; World Bank, 2001). 90.6% of ejidos have parceled agricultural land and in many regions are the primary place of agriculture (Morett-Sánchez & Cosío-Ruiz, 2017). However, the quality of ejidal land is often lower than in the private sector

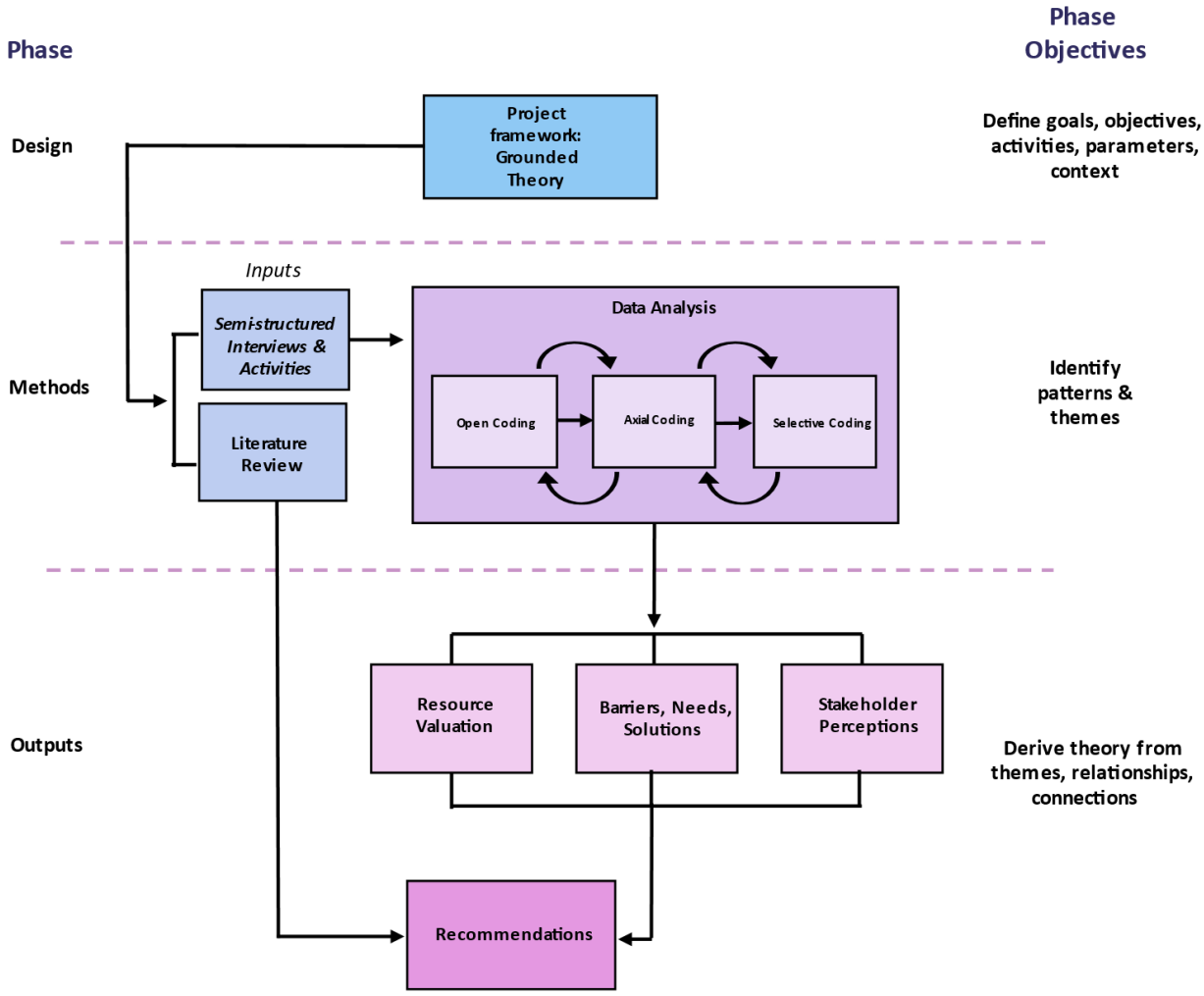
and inefficient agricultural markets make it difficult for ejidos to prosper in some areas (World Bank, 2001).

In the CCB 11 ejidos exist within the ANP boundaries occupying 41% of its total area (Lillo et al., 1999). There are 5 ejidos that are major agricultural water user in the CCB (Adolfo et al., 2018). Most grow alfalfa along with other small food crops for market sale and sustenance. Implementation of various CNMPs in the CCB has segregated *ejidatarios* into two camps: a small portion in support of conservation efforts because they are a part of the process, and a larger group who feel they are victims of it (Berris personal commentary, 2019; Valeria, 1997). Many have complained that while most surface water is exported out of the CCB, *ejidatarios* in the basin have experienced significantly reduced water supply and lack of transparency from other stakeholders (Berris personal commentary, 2019; Ortiz Acosta & Romo Aguilar, 2016). Some *ejidatarios* feel that that CNMPs directly harm their farms and not larger operations or users in neighboring valleys who consume more water (Ortiz Acosta & Romo Aguilar, 2016).

Methodology & Methods

The purpose of this study was to provide a description of *ejidatarios* challenges and perspectives in agriculture to inform CNMPs. Research design was adapted from grounded theory methodology with the intention of *ejidatarios* having greater agency over defining their narrative. Participatory, semi-structured interviews were used to collect data. Interviews combined open-ended questions and participatory activities to allow flexibility in interview topics and encourage *ejidatario* control over conversations. Data analysis was done using grounded theory coding techniques to develop patterns and themes from data. By combining the literature review presented above and interview findings, scientific and *ejidatario* knowledge were integrated to form recommendations for future CNMPs. The research design is presented in Figure 2 and further detailed below.

Figure 2: Project workflow.



Grounded Theory

Grounded theory is an inductive methodology which allows for the discovery of theories from open data analysis making conclusions rooted, or grounded, in the data itself (Glaser & Strauss, 1967; Saldaña, 2013). Many quantitative methods focus on proving/disproving a prior hypothesis, but grounded theory allows for patterns and themes to evolve during the analysis process (Glaser & Strauss, 1967). These tools provided a mechanism for describing and understanding the complicated social landscape, unique challenges, and socio-environmental relationships from the eyes of *ejidatarios* themselves.

The grounded theory tools employed in this study were multiple levels of data analysis, where the researcher is constantly comparing data units in an iterative process. Constant comparison allows for initial generalizations and relationships to be validated by later data

analysis (Boeije, 2002). Patterns, categories, and themes emerge and manifest themselves in broad theories attempting to explain a phenomenon. The phenomenon addressed in this study was the lack of *ejidatario* description, documentation, and participation in CNMPs. Theories revealed during data analysis will contribute to future CNMP formation that is more representative of *ejidatarios*.

Interview Design

With grounded theory in mind, an interview framework was designed to promote participation, open discussion, and a comfortable atmosphere. Semi-structured interviews are somewhere between structured interviewing, such as a formal questionnaire, and unstructured interviewing, such as an open conversation. In this study, semi-structured interviews were driven by guiding activities adapted from the Catholic Relief Services (CRS) "Manual for CRS Field Workers and Partners" for participatory activities. Open-ended interview questions (Appendix A) accompanied each guiding activity (Appendix B). Activities help to lead the conversation while encouraging personal stories, examples, and tangential topics to arise (Freudenberger, 2008; World Health Organization, 2020). This ensures that key topics are touched upon while allowing the participant to shape the direction of the interview by revealing relevant issues (O'Keeffe et al., 2015). When participants are able to speak openly, there is a greater chance of learning drivers behind decisions, actions, and opinions rooted in participant experiences (Merriam & Tisdell, 2016; O'Keeffe et al., 2015).

To initiate the interview, participants were asked to draw maps of their farm parcels and locate important resources. The main goal of participatory mapping is not to obtain exact accuracy of a space, but to learn about important landmarks, infrastructure, and spatial relationships (Freudenberger, 2008). Participants were asked to sketch their farm including crop land, living spaces, farming infrastructure, wells, and irrigation systems.

Seasonal calendars were used to annual temporal changes. This activity aimed to know how seasonal shifts may affect agricultural livelihoods (Freudenberger, 2008). Data from this activity indicated timing of planting, harvest, and farm management (Appendix B).

Next, a resource ranking activity was used to guide discussion towards participant valuation of CCB natural resources. Pozas, the aquifer, air, soil, trees, plants, and animals were listed on the x-axis and ranked from not valuable to most valuable on the y-axis. The goal of this activity was to see how *ejidatarios* connect natural resource degradation to personal livelihoods.

Finally, venn diagrams were used to see how participants relate individual challenges to more broad, regional issues. *Ejidatarios* were asked to discuss the barriers that exist for them individually and communally, what they need to overcome those barriers, and potential solutions to address these issues. All prompts were open-ended with no indication by interviewers of specific topics to be addressed.

There are several limitations to semi-structured interviews. First, they require time consuming preparation and research beforehand. It's important that researchers develop questions that target specific themes but allow for responses to be more free flowing than strict question and answer interviews. We created guiding activites and semi-stuctered interview questions in the months leading up to the interviews and made adjustments as we communicated with our collaborators. Our interview design purposefully touched on specific topics but left ample room for discussion and elaboration. Secondly, researchers must be knowledgeable in targeted topics and know when to probe further on issues that arise during discussion (Freudenberger, 2008). Extensive research was done on the region before arriving to the CCB. Also, communication with our collaborators (both before and during our visit) gave us insight into topics to avoid and focus on. Furthermore, data obtained from semi-structured interviewing is messier and more difficult to analyze (World Health Organization, 2020). Numerous qualitative data analysis methodologies were researched before appropriate techniques were chosen. Qualatative analysis is unique in that each project may require a suite or combination of tools from various methodologies. We chose methodologies based on our project's circumstance and characteristics.

Sampling

A combination of purposive and snowball sampling was used to identify participants. Purposive sampling uses specific criteria to select participants representative of the target population (Battaglia, 2008; Freudenberger, 2008). One limitation of purposive sampling is potential sample bias based on researcher developed criteria and selection (Kolb, 2012). Therefore, this sampling method is more applicable when targeting a smaller sample size, limited geographic area, or isolated population as opposed to studies aimed at drawing broad conclusions from larger populations (Battaglia, 2008). For this study, the target population was *ejidatarios* in the CCB; therefore, participants were chosen based on inclusion criteria of 1) the participant

must farm within designated CCB ejidos and 2) the participant contributes to an accurate representation of geographic and economic variability within the whole sample.

Snowball sampling identifies participants based on local recommendations (Donaldson & Franck, 2016). While this type of sampling can lead to recommender bias, it also allows for local expertise to play a larger role in identifying participants that meet the research criteria. We worked closely with our primary *ejidatario* contact and collaborator who gauged participation interest through direct communication with ejidos as well as recommendations from CONANP and Pronatura.

Nineteen *ejidatarios* were identified across 4 ejidos: Cuatro Ciénegas, La Vega, El Venado, and Antiguos Mineros. Participating ejidos are described in Table 1. Interviews were conducted on site in ejidos over a 4-week period during June 2019.

Table 1: (Adolfo et al., 2018; SEDESOL, 2015)

	# Interviews	Total Pop	Geographic location in CCB	Available Agricultural Land (ha)	Degree of marginalization
Cuatro Ciénegas	10	10309	North	600	low
El Venado	3	208	Southwest	85	medium
La Vega	3	154	West central	219	low
Antiguos Mineros	3	76	South central	13	high

Conducting the Interviews

This project was done in parallel with the execution of a Sustainable Agricultural Water Management short course in conjunction with Universidad Tec de Monterrey. See Appendix C for a description of course details and alignment with this project. Interview data were collected by groups of 4 interviewers consisting of Mexican, Universidad Tec de Monterrey students and UC Davis researchers to one participant. All interviewers spoke Spanish. The purpose of creating interview teams of primarily Mexican students was twofold: (1) student's eagerness to learn and converse promoted a more comfortable atmosphere where *ejidatarios* felt encouraged to share their stories (2) interdisciplinary, field-based learning experiences equip younger generations of decision makers with necessary skills to develop holistic environmental solutions

in their countries of origin. Interviewers were trained by UC Davis researchers on guiding activities, semi-structured interviewing, and probing before interviews took place.

For transparency, participants were introduced to the study and presented consent forms indicating the intent of the research before interviews began. It was made clear that participants were not obligated to answer all questions. This was especially important given the existing tension over resources in the CCB. Guiding activites were performed in the order in which they are described in the interview design section above. Semi structured interview questions were asked along with each guiding activity and interviewers probed for more information where needed. Interviews lasted between 45 min and 1.5 hours, and participants were encouraged to elaborate on whatever topics they like.

Data Analysis

Data were recorded on paper and electronically transcribed during the weeks of the interviews. The diversity of our team aided in reducing bias since at least 6 people (4 students and two researchers) reviewed the data before digitizing, in hopes of decreasing bias from one team member. Data were then transferred to Microsoft Excel where all coding was done.

Data analysis can be separated into 3 phases: open coding, axial coding, and selective coding. These phases equate to constant comparison within a single interview, between individual interviews of the same ejido, and all collected interviews. Coding is a way of methodically sorting and labelling data to see a complete picture of the collected information (Glaser & Strauss, 1967; Saldaña, 2013). To do this, interview passages were broken into phrases or comments representing data units that have distinctive meaning. Open coding was used to assign labels to data units that represent the overall significance of the data unit. Open coding allowed for the development preliminary categories within a singular interview (Boeije, 2002). Next, axial coding was used to make comparisons between interviews. This helped reinforce codes, identify common indicators of particular codes, and refine categories in the data (Boeije, 2002; Kolb, 2012). Lastly, selective coding took established categories and related them to each other to form themes. These themes are reflective of larger theories and conclusions that can be drawn from the analysis.

Findings

The primary intent of this research is to provide a qualitative description of the thoughts and perspectives of *ejidatario* participants with the objectives of (1) understand how *ejidatarios* value the CCB's natural resources in relation to their personal wellbeing (2) identify barriers, needs, and prospective solutions to improving *ejidatario* livelihoods (3) describe *ejidatario* perceptions of other CCB stakeholders. Additionally, we report quantitative results in the form of comment frequency counts on specific themes, it should be noted that this is not representative of all opinions in CCB, but only participating *ejidatarios*.

Farm descriptions

Participants were men, aside from one couple interviewed, between the ages of 18-60 whose primary occupation was farming. Farm sized varied considerably from 2-50 ha. All participants grew alfalfa as a primary crop and 79% grew additional crops such as maize, beans, or nopales. Water sources varied and were either wells, canals, piped or a combination of the three (Table 2).

Table 2: General farm description of *ejidatario* participants.

Ejidatario	Ejido	Sex	Land (ha)	Primary crop	Water source	Irrigation
1	Cuatro Cienegas	M	16	alfalfa	well	flood, drip
2	Cuatro Cienegas	M	17	alfalfa	canal	flood
3	Cuatro Cienegas	M	7	alfalfa	canal	flood
4	Cuatro Cienegas	M	10	alfalfa	well, canal, piped	flood
5	Cuatro Cienegas	M	35	alfalfa	piped, canal	flood
6	Cuatro Cienegas	M	37	alfalfa	canal	flood
7	Cuatro Cienegas	M	10	pomegranate	well, canal	sprinkler
8	Cuatro Cienegas	M	12.5	alfalfa	well, canal	flood
9	Cuatro Cienegas	M	50	alfalfa	well, canal	flood, drip
10	Cuatro Cienegas	M	9	alfalfa	well, canal	flood
11	La Vega	M	5	alfalfa	piped	sprinkler
12	La Vega	M	2	alfalfa	piped	flood
13	La Vega	M	13	alfalfa	piped, well, canal	sprinkler
14	El Venado	M	12	alfalfa	piped	flood
15	El Venado	M	6	alfalfa	canal	drip, flood
16	El Venado	M	18	alfalfa	canal	flood
17	Antiguos Mineros	F & M	7	alfalfa	well	sprinkler
18	Antiguos Mineros	M	3	alfalfa	well	sprinkler
19	Antiguos Mineros	M	3	alfalfa	well, piped	flood, drip

Valuation of Natural Resource

Identifying how *ejidatarios* relate to the CCB's natural resources is important in understanding the drivers behind certain decisions and actions. The ranking activity showed that across ejidos, *ejidatarios* recognize the value of natural resources to their personal livelihoods and the wellbeing of the basin. This is expected since many have been working the land for generations. Connections between specific resources and economic activities were commonly discussed. For example, trees are important for mesquite cultivation and wind protection, while pozas and the aquifer are important for irrigation. Many *ejidatarios* acknowledged the ways in which water resources have changed, often referring to a decline in quantity and availability. An *ejidatario* from El Venado states "*mucho consumo de agua...y dependencia total del agua de su region*," meaning that there is a lot of water consumption and he is totally dependent on the region's water resources. Many in Cuatro Ciénegas spoke of failed water infrastructure in relation to decrease in water supply to their ejidos.

Most significantly, *ejidatarios* expressed a mutual respect for the environment. When shown the resource ranking activity, one *ejidatario* from Antiguos Mineros said, "*todos son indespensables, todos son mucho importante, y todos tienen valor*" (all resources are indispensable, all are very important, and all have value.) While in general pozas and the aquifer were rated the most valuable, all other resources (air, soil, plants, trees, animals) were also recognized as quite important. An *ejidatario* from Cuatro Ciénegas spoke about how he attempted to plant nopales but was unable to cultivate them due to hares eating his crop. However, he decided to continue planting nopales specifically to feed the hares that he displaced with his orchard stating, "we leave something to nature because we have taken something from it." Another *ejidatario* from Cuatro Ciénegas said "we need to achieve physical, chemical and biological balance." However, there were instances of less awareness of local animal species. Knowing the importance *ejidatarios* place on these resources and their desire to seek balance between themselves and the environment is critical in finding common ground among stakeholders.

Barriers

Ejidatarios face a diverse set of barriers hindering them from improving their farming operations (Figure 2A). Thirty-two percent of comments were related to social barriers, 25% were economic related, and 14% were referred to infrastructure and technology. Other barriers

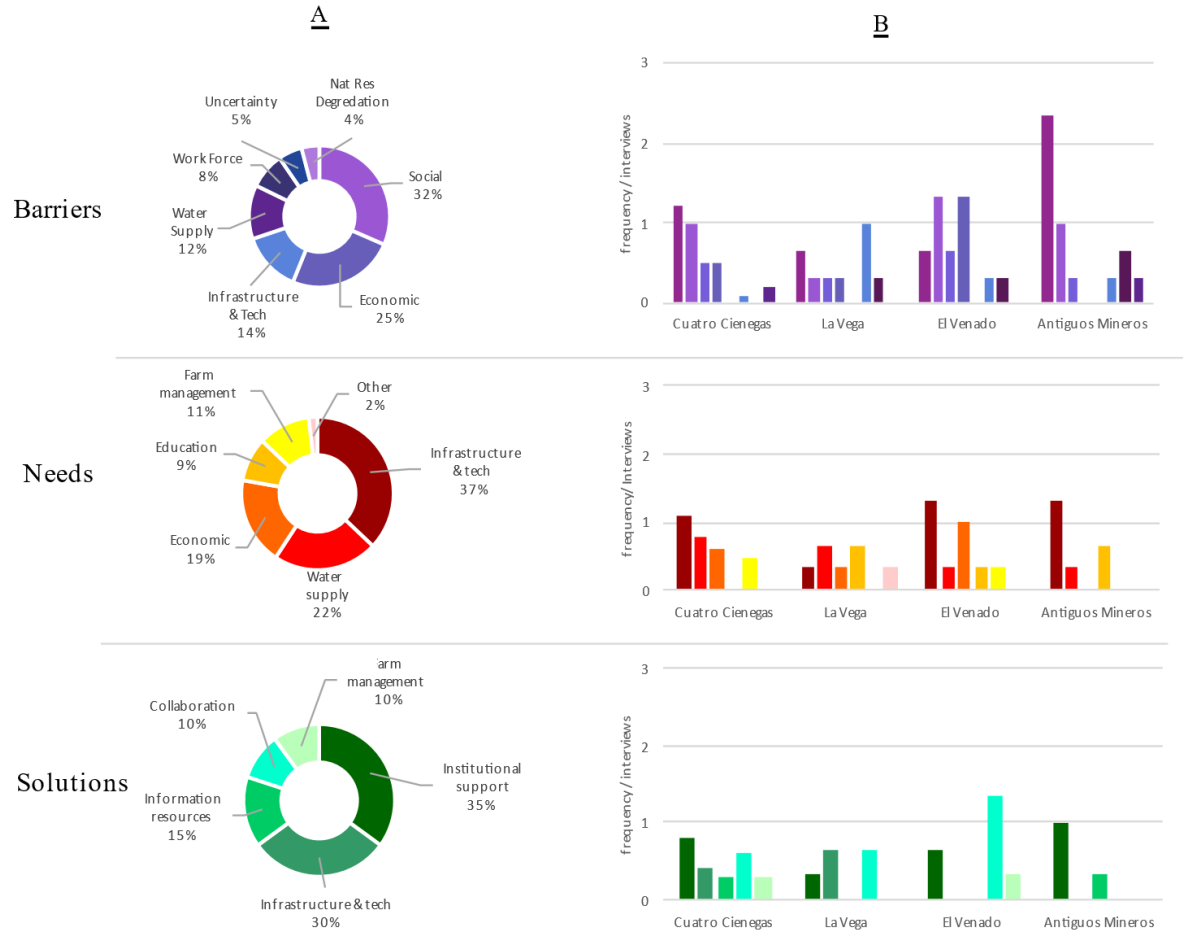
include water supply, workforce, general uncertainty, and natural resource degradation. The barriers are also of different relative magnitueds (Figure 2B). Because ejidos had different numbers of participants, results were normalized as a ratio of number of comments divided by number of participants for each ejido to ease comparison.

Social barriers included a lack of stakeholder communication, collaboration, and trust. These themes arose in the context of internal ejidal disputes, local agencies, NGOs, and government in general. The ejido of Antiguos Mineros commented the most about social barriers. Antiguos Mineros is unique in that some *ejidatarios* help manage Pronatura's Pozas Azules Ranch, while others directly blame Pronatura for not upholding promises of better water infrastructure during the Ranch's establishment. The result is a strict divide in *ejidatario* views on conservation and personal differences which are a core obstacle in ejido growth. "*Hay ejidatarios que quieren conservar el medio ambiente y trabajar mientras que otros no*" (there are *ejidatarios* that want to conserve the environment and work, while there are others that do not) (personal 2019). In general, all ejidos stated that lack of collaboration and trust with other stakeholders was a barrier to their livelihoods, citing specific instances of non-communication about water management, degrading water infrastructure, inorganization among local stakeholders, and unfair treatment compared to larger water users as the root cause for conflict.

Economic related issues are the second largest barrier referring to lack of income and financial support to upgrade their farms and ejido. An *ejidatario* from El Venado stated, "*There is less money flow due to a lack of resources*." Although *ejidatarios* expressed interest in upgrading their farms to more sustainable, efficient practices, most cited high costs of new equipment, insufficient income, and scarcity of support programs as reasons for not doing so. Additionally, *ejidatarios* lack a direct market to sell their crops or are unaware of potential markets.

Thirdly, many comments were directed at degrading infrastructure and technology. On a basin level comments pointed to weirs that reduce flow to ejidos and not enough wells. Individually, most spoke about outdated farm equipment and their desire to implement new irrigation, which goes hand in hand with economic obstacles mentioned above.

Figure 2: Distribution of *ejidatario* barriers, needs, and solutions. Panel A shows results representative of all participants. Panel B shows results per ejido.



Needs

Needs were also discussed by *ejidatarios* (Figure 2). Infrastructure and technology encompass 37% of comments, water supply 22%, and economic support 19%. Other needs were education/technical advice and improved management practices.

Infrastructure and technology comments mostly referred to needing new machinery, broken equipment, outdated technology, more efficient irrigation, and better maintained water conveyance infrastructure. An *ejidatario* from Cuatro Ciénegas spoke about his desire to have more productivity and efficiency on his farm, but to do so he needed financial support to install new irrigation systems. Furthermore, an *ejidatario* from La Vega commented on seeing other's

newer irrigation systems stating, “since they installed the new sprinklers, other farmers are producing more and can cultivate more hectares.”

Water supply was the second most mentioned need and included comments about lack of water, clean water, water rights, wells, and access. As expected, Cuatro Ciénegas comparatively spoke about needed water the most because most *ejidatario*’s water supply is from Poza Becerra which has recently begun heavily monitoring its outflow. Complaints that current water rules and regulations are too strict was mentioned often. One Cuatro Ciénegas *ejidatario* said he would like to see “all the water allowed to come” to ejidos, while another spoke directly about how rules and regulations are too strict and need to be relaxed.

Economic-related needs included a large need for financial support, investments, and better market options. Curiously, Antiguos Mineros did not directly mention financial needs even though they are the most marginalized ejido; however, *ejidatarios* here emphasized the need for more technical advice and education programs so workers stop leaving the ejido.

Solutions

The distribution of solutions recommended by *ejidatarios* reflects how they proposed to overcome barriers and obtain the resources they need to prosper (Figure 2). Thirty-five percent of comments referred to solutions in the form of institutional support, 30% in infrastructure and technology, and 15% in improved information resources. Other suggested solutions were better farm management and more collaboration among stakeholders.

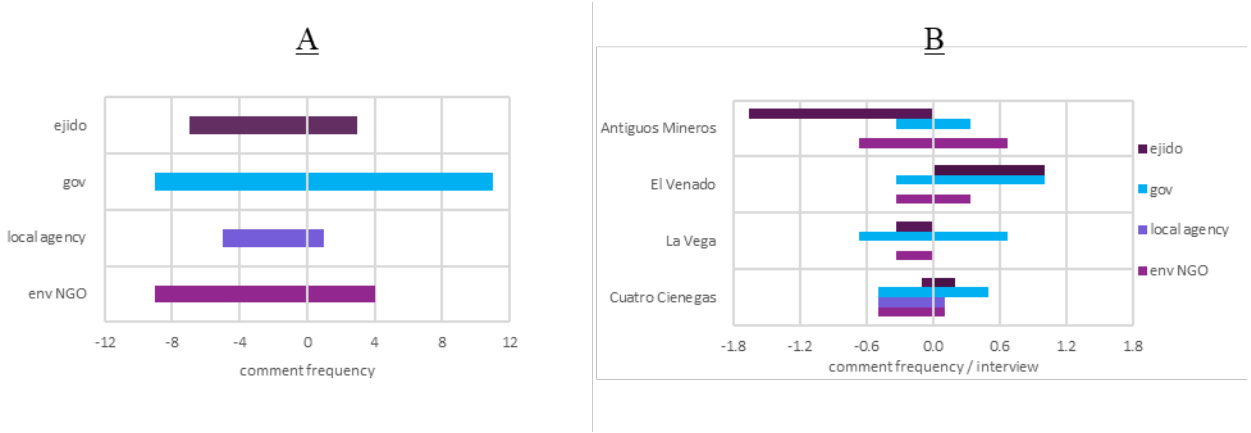
Many solutions were consistent with information discussed in barriers and needs. Institutional support is crucial to improved livelihoods and ejido development. While some comments directly mentioned financial support from institutions, many other forms of support such as rural development projects, water projects, less requirements for grants and water rights were also common. Action for improving infrastructure and technology pointed to installation of new irrigation systems, wells, and better water conveyance infrastructure. These improvements all rely on receiving support. *Ejidatarios* strongly believe that these changes would solve many of their water management problems.

Cuatro Ciénegas and La Vega *ejidatarios* suggested better information resources to better educate worked on new farm management techniques and aide ejidos in regulatory processes. Demonstration fields and training workshops would help older *ejidatarios* become comfortable with new technologies since some are weary of change due to a lack of familiarity and

knowledge with newer agricultural innovations. One *ejidatario* from Cuatro Ciénegas said, "*Lo que más necesito es asesoría*," (what I need most is training).

Stakeholder Perceptions

Figure 3: *Ejidatario* stakeholder perceptions. Negative values indicate negative perceptions while positive values indicate positive perceptions.



Data were also analyzed to gauge *ejidatario*'s perceptions of various CCB stakeholders. Analysis revealed environmental NGOs, local agencies, government, and ejidos themselves were the most mentioned stakeholders. Comment frequency across all ejidos where negative values indicate a perspective of stakeholders as being part of the problem (i.e., preventing CCB and ejido prosperity), and positive values a part of the solution (i.e., potential to aide CCB and ejido prosperity) (Figure 3A). Information for individual ejidos where data are normalized to a ratio of comment frequency divided by number of participants for each ejido (Figure 3B). The absence of stakeholder perception in some ejidos indicates that participating *ejidatarios* did not comment on a particular stakeholder.

As supported by the barriers, needs, and solutions analysis, ejidos in general view other stakeholders as somewhat detrimental to their wellbeing. Most comments indicated views that other stakeholders contribute to ongoing social conflicts by not keeping their word in agreements or simply not taking *ejidatario* needs into consideration. There is a lack of trust due to previous research and studies by NGOs, the government, and universities having "never solved the problems." An *ejidatario* from El Venado stated, "*Ninguna organización ha venido*," (no organization has come) referring to the lack of tangible solutions *ejidatarios* have seen from stakeholders.

Additionally, there is a consensus in ejidos feeling unseen, targeted, or treated unequally. Comments that local natural resource management agencies and environmental NGO's put unfair pressure on CCB *ejidatarios* rather than focusing their attention on larger farming operations outside of the basin. To this, an *ejidatario* from Cuatro Ciénegas said, "*nosotros no somos los malos, y se lo hemos dicho a las organizaciones*," (we are not the bad guys, we have said this to organizations).

Antiguos Mineros has the largest negative opinion of any stakeholder, towards ejidos. This is consistent with findings presenting in the barriers section. There is a high degree of internal ejidal conflict and split perceptions on environmental NGOs. This is a direct connection to social tension over whether Pronatura's reserve is to blame for changes in the ejido's water resources. One *ejidatario* said, "we want to preserve the water, but there are some among us who do not."

While hostility seems overwhelming, there is a silver lining in that *ejidatarios* acknowledge the value of other stakeholders as being part of solutions moving towards a more equitable, sustainable CCB. The calls for financial support and grants, willingness to learn from technical experts, desire to modernize farms for efficiency, readiness to communicate shows that there is room for collaboration. However, this will take compromise from all stakeholders to see change.

Discussion & Recommendations

The complexity of ejido history combined with the CCB's unique environmental challenges has left *ejidatarios* wondering where they fit into future development. Social issues were the most mentioned barrier, however collaboration was one of the lowest mentioned solutions. This indicates an acknowledgement of social tension but an unwillingness to directly engage. Frustrations expressed about other stakeholders included trust, communication, collaboration, coordination, and representation; however, *ejidatarios* also spoke about power dynamics and stakeholder abilities to shape the future of the CCB. There is a dissatisfaction among *ejidatarios* with the level of representation, power, and inclusion they possess in decision making processes; to address this gap agencies with more power must re-evaluate stakeholder engagement strategies.

Historically, stakeholder engagement shows that low income rural populations have been frequently under represented or excluded from water governance (OECD, 2015). Policy choices are often made in silos by the deemed experts in fields, but voices of traditionally unheard populations can provide information rooted in real time realities that can help make processes more successful (OECD, 2015). Engagement also leads to empowerment by allowing participants to impact future outcomes of policy. This is an important step in shifting the power structure of current water governance towards more stakeholder balance and equity.

While stakeholder engagement efforts will depend on a specific location and complexity of its water, social, and political landscape, literature points to the importance of ongoing communication, coordination, and continuity from governing organizations (Lacroix & Megdal, 2016; Megdal et al., 2017; OECD, 2015). In "Explore, Synthesize, and Repeat: Unraveling Complex Water Management Issues through the Stakeholder Engagement Wheel," Mott Lacroix and Megdal describe a deliberative, iterative, and flexible approach to water management resulting in effective, continuous stakeholder engagement. The cyclical nature of this approach results in constant re-evaluation and consultation of stakeholders which helps shape processes that are more reflective of all stakeholder needs.

Successful stakeholder engagement must include willingness to compromise. If current agricultural practices in the CCB are proven unsustainable, then resources, information, and support must be provided to aide transition for historically marginalized *ejidatarios* into other avenues of income or farm management. Inversely, *ejidatarios* should try to be open to shifting towards less water intensive activities. To achieve this, local water management and conservation agencies must create frameworks that refocuses attention towards consistent *ejidatario* input and involvement. CNMPs should include obtainable, concrete action items focused on human preservation in addition to environmental preservation. Identification of next steps after implementation of action items will keep processes going, clarify agency objectives, and provide insight to how rules and regulations will function.

One *ejidatario* said, "*Si no tenemos agricultura sustentable, no tenemos una sociedad saludable*" (If we don't have sustainable agriculture, we don't have a healthy society). *Ejidatarios* spoke about their appreciation of the CCB's natural resources, desire to modernize farm management, and lack of financial capital. This shows *ejidatario* willingness to change and

highlights how economic status is inhibiting their management choices. Confusion surrounding how to obtain support and general lack of funds must be addressed at local, state, and municipal levels to create equitable opportunities of prosperity as water resources in the CCB continue to change. This study shows that *ejidatarios* have the motivation to participate in conversations about sustainability and many want to transition towards new practices, but systems of support and stakeholder engagement efforts must be developed to ensure ejido are not left out of key decision-making processes that impact their livelihoods.

Limitations to this study leave room for future efforts to build on our findings. Our sample size was small due to restricted time and accessibility to study sites. A larger sample size that includes all 5 ejidos of significant agricultural water use would be more representative. A more detailed investigation on individual *ejidatario* parcel management (individual or communal) would add to the overall understanding of *ejidatario* land management and how it varies between ejidos in the CCB. There is potential bias since all data analysis took place at UC Davis which reduced local stakeholder participation. Results would be most valuable if used to inform CNMP development with additional qualitative studies and follow up monitoring and evaluation of *ejidatario* challenges and perspectives. Ideally, local managing agencies can have the resources to design and implement interview campaigns and data analysis independently and on a larger scale.

Conclusion

Findings from this study reveal *ejidatario* challenges and perspectives that should be considered in future policy making processes to ensure livelihoods. Interview activities and discussion were open ended and not guided towards specific water related issues, however the analysis shows it to be a pervasively contentious topic among *ejidatarios*. Lack of financial, technological, natural, and informational resources hinders *ejidatario* development capabilities and limits adaptive capacity as water resources shift. Negative perspectives of conservation and water management agencies show how fragmented efforts to manage the CCB's water has left *ejidatarios* confused and divided. Future initiatives must be holistic and include effective, multilevel stakeholder engagement processes that use an iterative approach to ensure *ejidatario* inclusivity in CNMPs.

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Appendix A

Semi-structured interview questions.

Entrevistas

Van a participar en grupos de enfoque con ejidatarios del área Natural Protegida de Cuatro Ciénegas. Por favor, miren las preguntas siguientes y completen con tanto detalle como sea posible durante las entrevistas. Si no escuchan repuestas para todas las preguntas, pueden dejarlas en blanco. Además, si escuchas algún dato interesante y no encuentras la pregunta específica anótalo en el área de Notas, toda la información recabada es muy valiosa!

Información demográfica:

1. Nombre:
2. Sexo (hombre, mujer)

Hombre	
Mujer	

3. ¿Cuántos años tiene?
4. ¿Cuántos personas viven en el hogar?

Mapa Individual:

5. Tomaño de tierra:
6. ¿Que es su fuente de agua (pozo, río, canal, etc.), como es su recursos de agua?
7. ¿Cuáles son los cultivos principales de su tierra?

Cultivo	Tipo de cultivo	Area
Principal		
Secundario		
Otros		

8. ¿Dónde está las infraestructuras importante (casa, bombas, riego, etc.)

9. ¿Cómo es su tierra, Cuáles el área total de tu tierra?

Total	
Granja	
Cultivos	
Pasto	
Sin cultivar	
Conservación	
Otro	

10. Notas:

Línea de Tiempo:

11. ¿Qué tanto ha cambiado el clima, hacía más o menos calor, inundaciones, sequías y cambios en precipitación, temperatura?

12. ¿Qué tanto han cambiado tu cultivos (que sembrabas antes y ahora que siembras)?

13. ¿Has tenido otros trabajos diferentes a la agricultura?

14. ¿Qué tanto han cambiado la dinámica social (cuál es la presencia (CONANP, CONAFOR, SEMARNAT, CONAGUA, PRONATURA, etc. más significativa)?

15. Notas

Ranking: Objetivo: Entender cuánto valor los agricultores tienen por las pozas, la fauna y flora, árboles, el suelo, y el aire

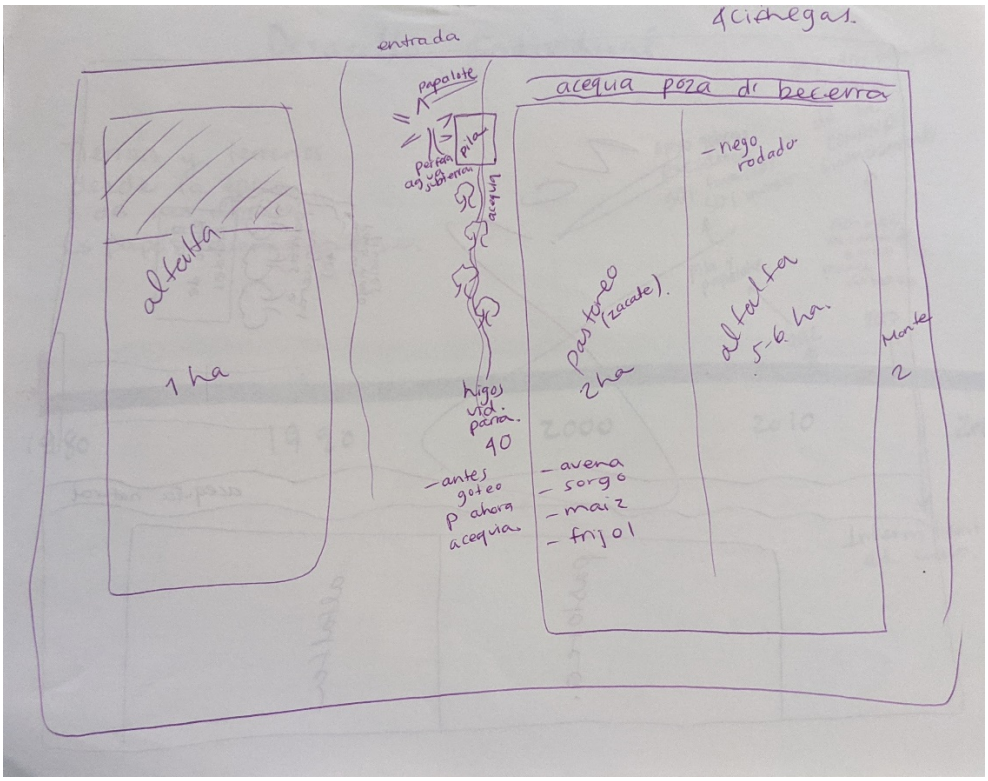
16. Notas

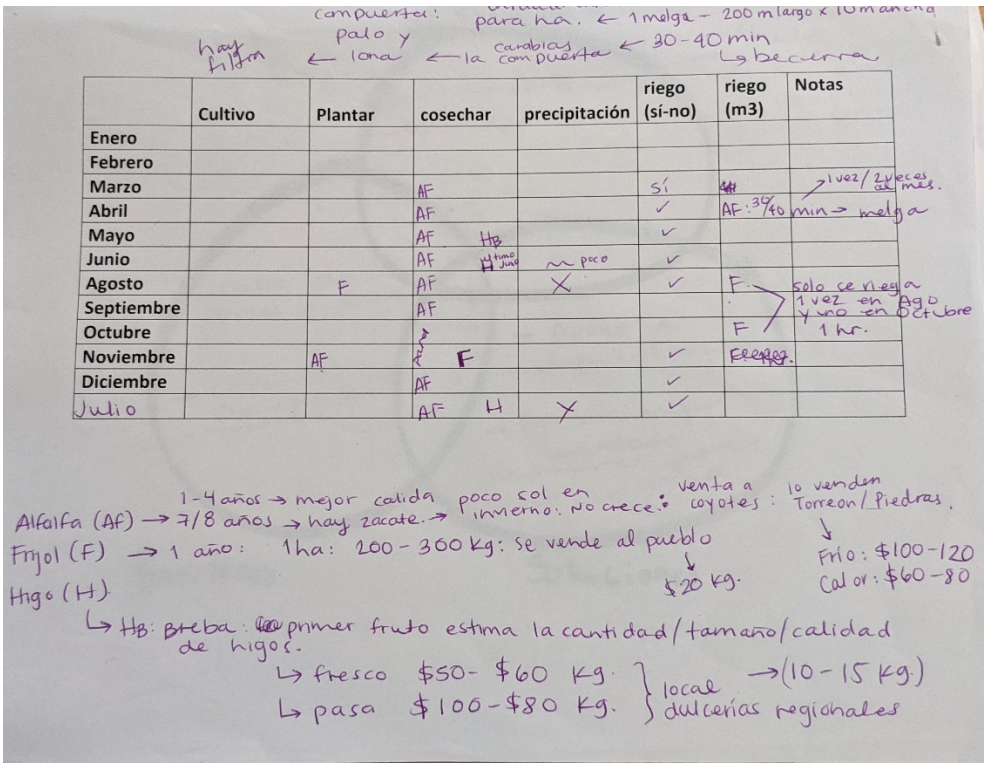
Diagrama de Venn: Objetivos: Identificar los retos, soluciones, y necesidades de los agricultores en la cuenca de Cuatro Ciénegas.

17. Notas

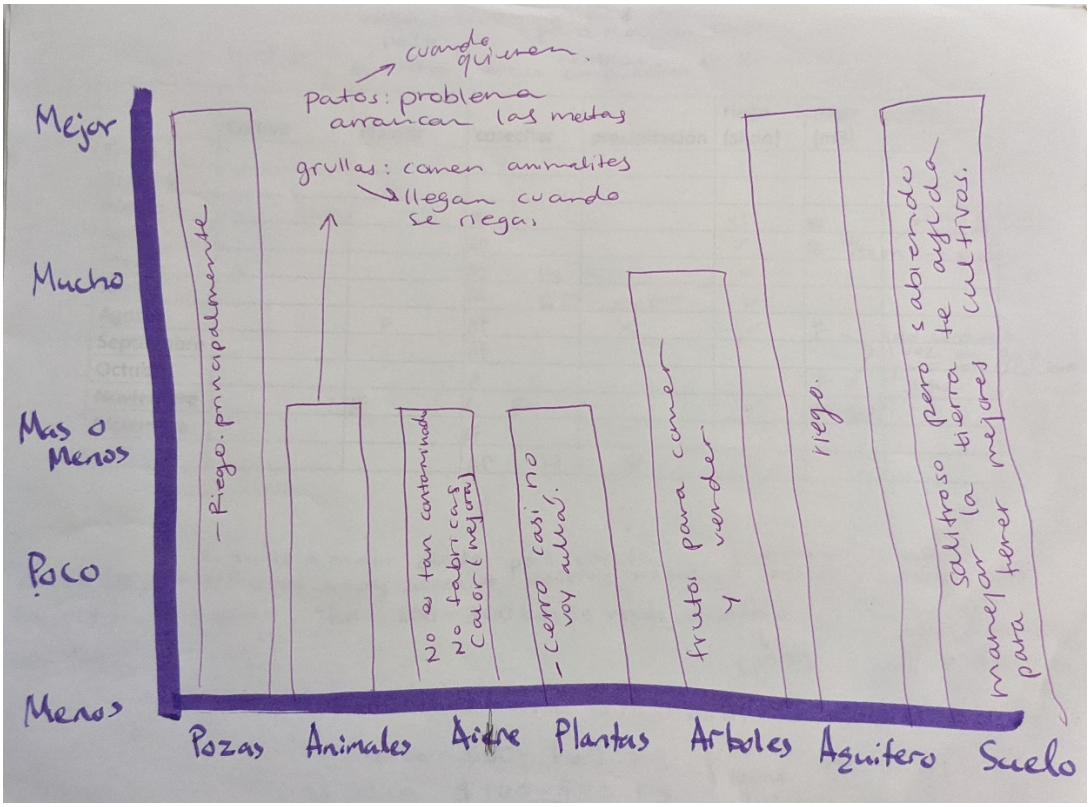
Appendix B

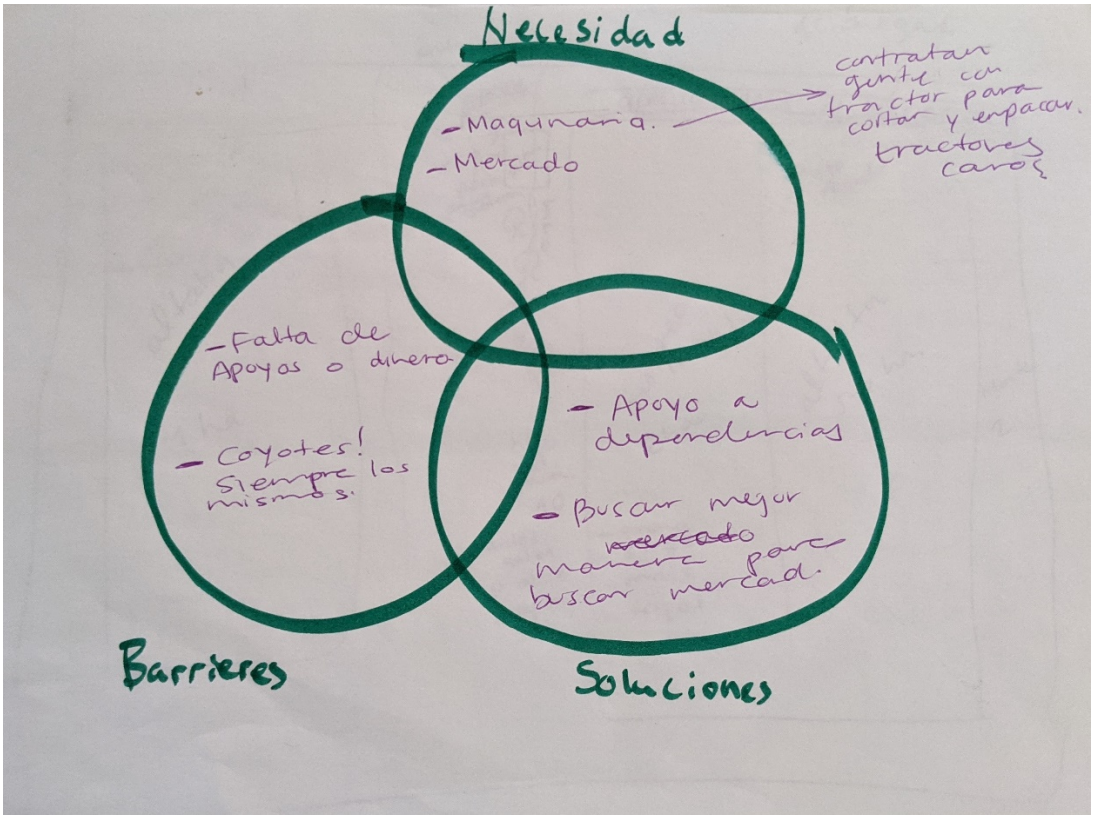
Guiding activity examples.





	Cultivo	Plantar	cosechar	precipitación	riego (sí-no)	riego (m3)	Notas
Enero							
Febrero							
Marzo			AF		sí		1 vez / 2 veces al mes.
Abril			AF		✓	AF: 30/40	min → melga
Mayo			AF Hb		✓		
Junio			AF H último Junio	poco	✓		
Agosto		F	AF	X	✓	F	solo se riega 1 vez en Ago y no en Octubre
Septiembre			AF				
Octubre						F	1 hr.
Noviembre		AF	F		✓		
Diciembre			AF		✓		
Julio			AF H	X	✓		


Mejor
Mucho
Mas o Menos
Poco
Menos
Patos: problema arrancan las matas
cuando quieren.
grullas: comen animalitos
llegan cuando se riega.
- Riego: principalmente
No es tan contaminado
No fabrica gas
Calor (mejora)
- Cerro casi no voy allá.
frutos para comer y vender
riego.
Saliitroso pero sabiendo te ayuda manejar la tierra para tener mejores cultivos.
Pozas
Animales
Aire
Plantas
Arboles
Aguifero
Suelo


Necesidad
- Maquinaria.
- Mercado
contratar gente con tractor para cortar y empacar.
tractores caros
- Falta de Apoyos o dinero
- Coyotes! Siempre los mismos.
- Apoyo a dependencias
- Buscar mejor manera para buscar mercado.
Barrieres
Soluciones

Appendix C

Two UC Davis student researchers (myself included) and one faculty member collaborated with Universidad Tec de Monterrey faculty and Pronatura Noreste to create and disseminate a four week (June 3 – June 28; 6 hrs per day) undergraduate short course entitled Sustainable Agricultural Water Management. Twenty-one students from majors including economics, business, environmental engineering, industrial engineering, and ecosystem conservation. The goal of the course was to use multidisciplinary collaboration to create holistic solutions to real world agricultural water management issues; the water resources issues in the CCB described in this paper served as our case study.

The first week of the course took pace on the Universidad Tec de Monterrey campus and focused on background information to ensure all sudents had an equal understanding of major course topics and planning for the following weeks. Lectures included: course introduction, water management 101, background of water and agriculture in the CCB, conservation efforts in the CCB, basics of hyrologic monitoring and modelling. Activities included: basics of hydrologic modelling in WEAP, poster presentation of the CCB, construction of surface and groundwater model, a tour of Universidad Tec de Monterrey greenhouse and irrigation system, water level logger testing, student group formation and assignments.

The following three weeks of the course took place on site in the CCB where students and professors stayed in the town of Cuatro Ciénegas. The second week focused on hydrologic assessment of the CCB. During this time, students were trained in the basics of hydrologic field methods including how to measure river width, reach, thalweg, and slope to calculate flow. Then, we conducted a field campaign of Río Mezquite where students determined these components for three segments of the river, where ten reaches per segment were measured. The same procedure was done on canal Becerra for two segments. Students visited major hydrologic features in the CCB including poza Becerra, poza Churince, poza Azul, Canal Becerra, and Río Mezquite. UC Davis faculty and reserachers specializing in water management gave on site lectures describing the connections between hydrology, agriculture, and ecology and pointed out hydrologic characteristics such as floodplains, stream classification, and groundwater and surface water dynamics. Students deployed two new water level loggers in poza Becerra and poza Azul to monitor water depth.

The third week focused on agriculture in the CCB from a social science perspective. Students were trained on all guiding activities, semi-structured interview questions, and probing techniques. Then, students were divided into groups of four. As a group, students decided how to assign the roles of notetaker (1), organizer (1), and facilitator (2). Notetakers were responsible for writing down all information from the interviews. Organizers were in charge of materials, photos, and compensation packages. Facilitators encouraged discussion, lead the activites, and wrapped up the interviews. Students prepared their own guiding activity templates for each of their interviews before they took place and practiced each of the interview components in small groups so they were able to ask professors clarifying questions. One practice interview was perfomed as a class with a volunteer *ejidatario* where each group was responsible for one activity. This was done so that professors could monitor and give feedback on interviewing skills. Over a four day period, professors and students visited the ejidos of Cuatro Ciénegas, El Venado, La Vega, and Antiguos Mineros conducting interviews. Data was recorded with pencil and paper during the interviews and input electronically after.

The fourth and final week students wrote final reports and created presentations of their findings. One report and presentation was required for each group. The report and presentation were designed for students to reflect on their experiences and analyse what they had seen. Professors prompted them to imagine that they were to present a diagnostic report to Pronatura Noreste explaining their findings over the past to weeks. Two main questions guided this assignment (1) how are hydrology, agriculture, ecosystems, and human interactions important to the CCB? (2) how have the characteristics mentioned in (1) changed in the past and how do you think they will develop in the future? Reports were required to have an executive summary, introduction, methods, results, discussion, conclusion, and recommendations and limitations section. Finally, students presented to professors and were awarded a diploma of completion of the course.