DISSERTATION

VULNERABILITY TO DROUGHT IN THE LA PAZ, MEXICO WATERSHED

Submitted by

Melissa Haeffner

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Doctoral Committee:

Advisor: Kathleen Galvin

Michele Betsill
Stephen Leisz
Dennis Ojima

ABSTRACT

VULNERABILITY TO DROUGHT IN THE WATERSHED OF LA PAZ, MEXICO

This study explores the relationship between drought vulnerability and migration in the ranchero community in the Sierras of the La Paz watershed in Baja California Sur, Mexico. Using household survey data, I examine how the various dimensions of vulnerability are related to migration as an adaptation strategy to drought. Contrary to what is predicted by environmental migration and climate vulnerability theory, drought exposed rancheros who had high sensitivity and low adaptive capacity did not use migration as an adaptation strategy in the last severe drought (2006-2012), despite migration being a central part of their traditional culture. This dissertation shows how rural upstream households are constrained in traditional adaptation options (including migration options) while new options have become available (including sedentary options) - because of other social changes in the same watershed, specifically, the expansion of urban services. Taking a closer look at watershed dynamics, I find that urban services have both positive and negative impacts on ranchero drought vulnerability. On the one hand, urban services diversify ranchero water sources in normal seasons; on the other hand, access to urban services does not remain consistent in severe drought. I conclude with a new conceptualization of drought responses with a discussion of the implications of these findings for future research and public policy that includes a need for broader stakeholder inclusion.

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1.0 Introduction

Environmental migration and climate vulnerability literatures predict that vulnerable households will use migration as an adaptation strategy to respond to severe drought. This issue is pertinent in parts of Mexico where extreme drought occurs in areas populated by poor households. This dissertation tests the proposition that households migrate to respond to extreme drought by examining household behavior of poor rural households that self-identify as *rancheros sudcalifornianos* in Baja California Sur, Mexico.

Drought is the most damaging climate event in Mexico (Boyd & Ibarrarán, 2009), and droughts are getting longer and more extreme nation-wide (Alscher, 2010). Trends in Baja California Sur reveal an increase of severity and length of drought events since 1920 (NOAA, 2012), with projections to continue into the future (Cavazos & Arriaga-Ramírez, 2012). Because of low and unpredictable rainfall, La Paz, like many cities in Baja, relies on stressed aquifers to meet growing water demand. Aquifer levels have decreased while population has soared (INEGI, 2012; Organismo Operador Municipal del Sistema de Agua Potable, 2011). Because more rain falls in the rural upstream mountains where more water infiltrates into the aquifer, a great potential exists to incorporate rural stakeholders in Baja California Sur for sustainable water conservation and drought prevention/recovery.

Households who identify as rancheros in Baja California Sur are part of a distinct culture that has ancestral roots in indigenous tribes and Spanish missionaries. Traditionally, rancheros mainly raise cattle as their livelihood. Vulnerability theory suggests that people who are more

dependent on local resources (i.e., the resource dependent) are more likely to be sensitive to hazards like drought because they have a narrower base from which to choose their adjustments (Adger, 2000, p. 351). Environmental migration theory suggests that these groups will migrate to adjust their physical proximity (exposure) to drought. Understanding the lived experience of rancheros and how they cope with drought can inform drought management reform in the area and broader sustainable development initiatives.

1.1 The study region

The La Paz watershed is located on the Sea of Cortez on the Baja peninsula, just north of the Tropic of Cancer (Figure 1.1). It is characterized by a cosmopolitan coastal center surrounded by low density rural mountain communities known as the rancheros sudcalifornianos. The City of La Paz is the capital of the State of Baja California Sur.

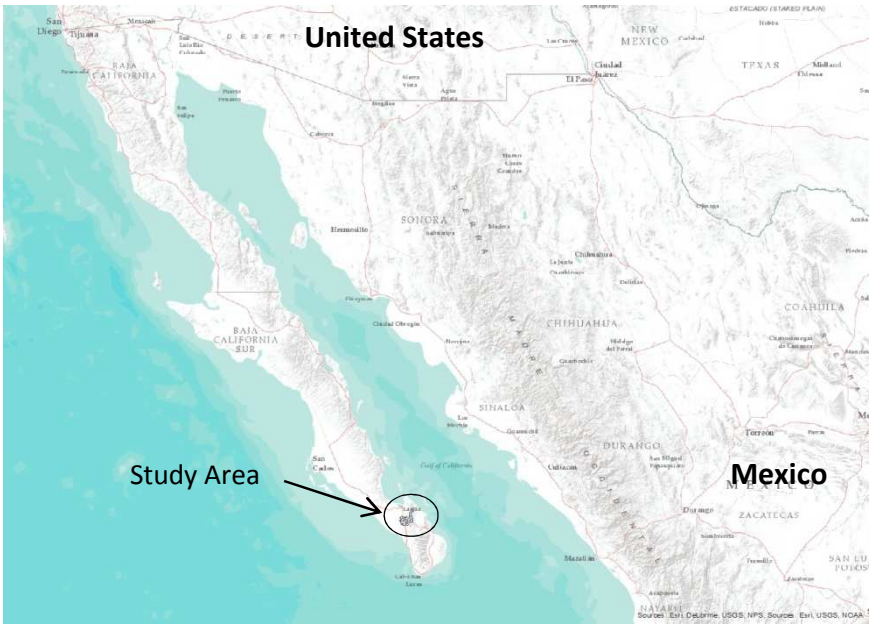

Figure 1.1 Map showing study area. Source: ESRI USOS NOAA

The drought year of 2011 in northern Mexico had wide economic impact and is said to have been the worst in 70 years (CONAGUA, 2013). Baja California Sur registered the most significant drop in the amount of precipitation in the country between the years 2006 and 2012 (CONAGUA, 2013). Whether the drought left visible impacts on household livelihoods in Baja California Sur is central to this study, since drought is a part of the normal climate variability in the semi-arid desert.

1.2 Drought

Drought can lead to an understanding of the diversity of household responses because people identify their exposure to drought in varied ways: as a lack of rainfall (as in *meteorological drought*), lack of drinking water supplies (as could occur with *hydrological drought*), lack of irrigation or crop yield (as could happen in an *agricultural drought*), or increased food prices (as could be in the case of *socioeconomic drought*). Drought is also particularly illustrative of the many household responses because different social groups are exposed differentially to the same drought, and a household can be exposed to the same drought in different ways. Furthermore, because drought is a *gradual* disaster, it provides a context in which household decision making is a contemplative, conscious process, as opposed to *sudden onset* disasters where decisions are immediate and are often made without lengthy deliberation. Because of these human dimensions, drought is studied here as a hazard at the intersection of biophysical nature (the natural system) and social construction (the social system), that is, rooted in biophysical data with social consequences. Baja California Sur is an interesting site to study this phenomenon because, even though aridity is a general characteristic of the region, there is evidence that specific conditions have been causing changes in the hydrological balance resulting

in trends towards increasing drought conditions. Table 1.1 lists terms and definitions of different types of drought used in disaster literature.

Table 1.1 Drought literature terms and definitions

Drought	Lack of access to or absence of one or more of the services that water provides as a natural resource.
Meteorological drought	Abnormally low precipitation (NOAA, 2012).
Hydrological drought	Abnormally low surface and subsurface water storage (e.g., rivers, aquifers).
Agricultural drought	Abnormally high evapotranspiration, that is, dry soil that hinders crop yield (Narasimhan & Srinivasan, 2005; Wang, 2005).
Socioeconomic drought	Loss from expected returns of profit or some other investment (Wilhite & Glantz, 1985) due to water insecurity.
Slow (gradual) onset disaster/emergency	"[An emergency] that does not emerge from a single, distinct event but one that emerges gradually over time, often based on a confluence of different events. Drought is a common example of a slow-onset emergency... When vulnerable populations are exposed to recurring or cyclical hazard events, such as drought, the resultant humanitarian emergencies often a result, not just of the most recent event, but the cumulative impacts of a number of previous events. When livelihoods fail to recover full resilience after a drought or another slow-onset event, a subsequent event, even if less severe, can push them more quickly into a situation of acute humanitarian need. If livelihoods are not restored or strengthened between events through recovery and development activities, then smaller and smaller hazards can push households over the edge, resulting in a vicious cycle" (OCHA, 2011, p. 3).
Sudden (rapid) onset disaster/emergency	"Both 'natural' disasters (e.g., earthquakes, hurricanes, floods) and man-made or 'complex' disasters (e.g., sudden conflict situations arising from varied political factors), for which there is little or no warning" (WHO, 2015).

Meteorological drought is defined as an abnormal deficit of precipitation. Baja California Sur already has the lowest annual precipitation of any Mexican state, an average of 160mm/year

between 1971 and 2000 (CONAGUA, 2010). The City of La Paz records an average of 18 rainy days per year for an average of 169.2mm of rain, most of which occur in the months of July, August, and September (Organismo Operador Municipal del Sistema de Agua Potable, 2011). These rains are associated with the North American monsoon circulation pattern, a combination of a high pressure ridge with a low pressure trough causing pulses of thunderstorms locally known as *chubascos*. A second period of rains can occur in January and February. If hurricanes do form in the Sea of Cortez, they are relatively weak. For example, Hurricane Liza made landfall in La Paz in 1976 only registered a Category 2 on the Saffir-Simpson Hurricane Wind Scale. When Hurricane Odile (Category 3) hit Cabos San Lucas on the southern tip of the peninsula in 2014, La Paz received Category 1 winds.

As the data from a monitoring station in La Paz shows in Figure 1.2, the precipitation trend from 1920 to 2012 is an increase of severity and length of drought events (note specifically the two time periods circled in red).

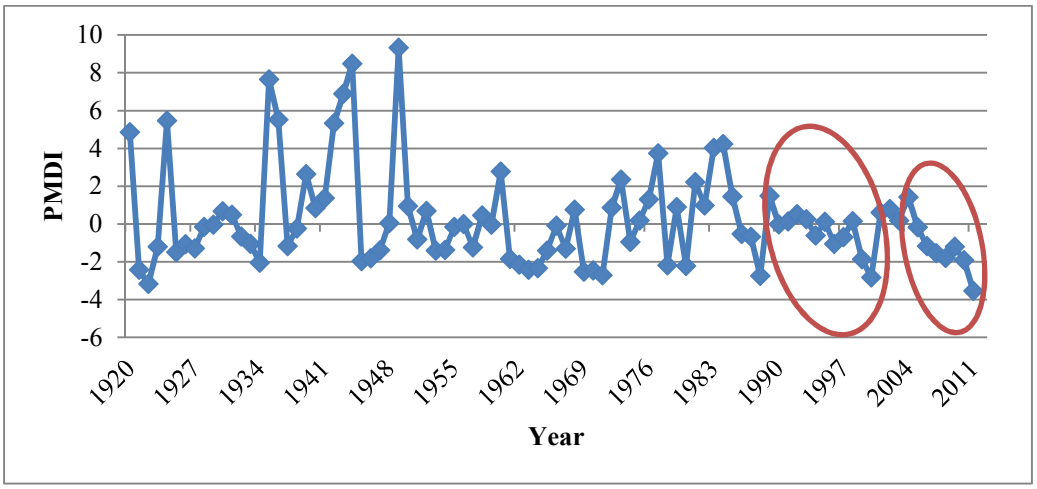

Figure 1.2 Annual time series of the Modified Palmer Drought Severity Index (PMDI) for La Paz, Mexico where the y-axis represents wetness (positive) to dryness (negative). Source: (NOAA, 2012)

Officials began noticing changes in weather patterns long before "climate change" became colloquial:

> "*…se estaba visualizado el problema en los años 80's, y los ciclos hidrológicos se estaban, en aquel entonces no se hablaba del cambio climático, ni el calentamiento global pero ya había señales de que algo iba a pasar en el ambiente. Nosotros lo mirábamos como tres años de sequía y después llovía, dos años de sequía y después llovía pero ya cada vez se fue haciendo más severo*." (SEMARNAT official)

> "*… the problem was already apparent by the 80s in the hydrological cycles. Back then there was not talk of climate change, or global warming, but there were already signs that something was going to happen with the environment. We were seeing three years of drought and then it rained, two years of drought and then it rained, but each time it was more severe*." (SEMARNAT official)

The rural mountainous area studied in this project receives more rain per year than the City of La Paz, with 400-440mm at the highest elevations (Figure 1.3 in red), and 300-350mm at lower altitudes (Figure 1.3 in orange). Because of drought risk in the entire municipality, there is recent interest to capture rainwater and recharge the aquifer in the Sierras (Figure 1.3 in red).

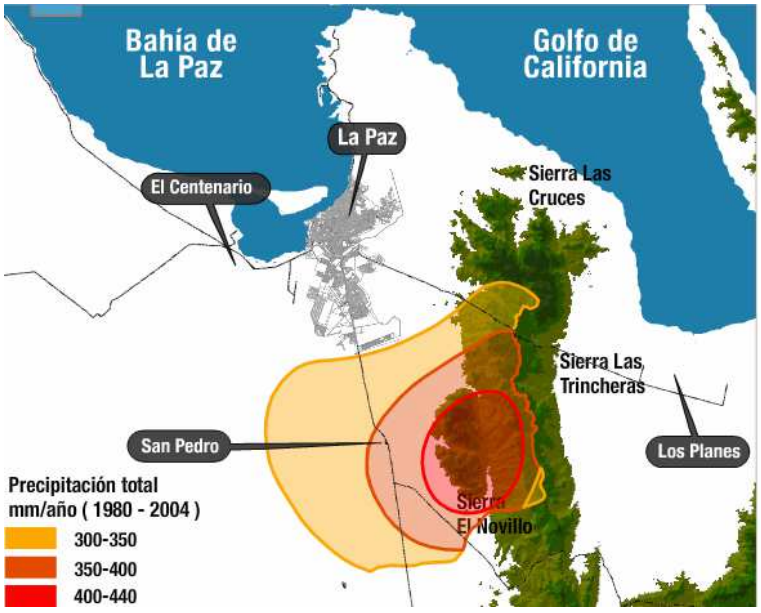

Figure 1.3 Map of study area showing elevation (green), and gradient of annual mean precipitation (red = high, orange = medium, yellow = low). Source: (Niparajá, 2014).

Hydrological drought refers to negative anomalies in streamflow, lake, and/or groundwater levels (Heim, 2002 as quoted in IPCC AR5, 2013). Regionally, there is evidence that the number of hydrological drought days (streamflow below a specific threshold) over North America will increase, and global studies predict a higher likelihood of hydrological drought by the end of this century (IPCC, 2013). Baja California Sur is particularly vulnerable to hydrological drought in terms of groundwater levels. The Baja Peninsula has the highest number of stressed aquifers in Mexico (CONAGUA, 2010). In Baja California Sur, three aquifers are considered "over drafted" and four are affected by salt water intrusion (CONAGUA, 2010). Aquifer imbalance has been monitored since the 1970s and scientists noted a significant decrease in aquifer levels in the 1990s (Organismo Operador Municipal del Sistema de Agua Potable, 2011).

Agricultural drought (also called soil moisture drought by the IPCC (2013)), refers to a deficit of (mostly root zone) soil moisture. In mainland Mexico, this presents a problem because as much as 80% of water is dedicated to agriculture (Wilder, 2006, p. 1982). In the La Paz municipality of Baja California Sur, however, the proportion of water used in the agricultural sector accounts for 35% while the urban sector consumes 63% (the rest is used by industry and other uses) (Organismo Operador Municipal del Sistema de Agua Potable, 2011).

Socioeconomic drought is caused in whole or in part by human activities that change pressure on water resources (IPCC, 2013; Wilhite & Glantz, 1985). In the case of Baja California Sur, urban water demand has the potential to cause socioeconomic drought. Urban residents in La Paz use almost exactly the carrying capacity estimated for the city: 288 L of water/person/day for nearly 250,000 people (Organismo Operador Municipal del Sistema de Agua Potable, 2011). In other words, there is currently no gap between supply and demand – any increase in demand will stress the water system if not managed effectively and efficiently. Population is expected to grow,

putting more pressure on the system: "as water demand increases, the population exposed to different drought conditions (agricultural, climate, urban) is expected to increase as well" (IPCC, 2013, p. 253).

1.3 Population and culture

Climate uncertainty presents a challenge to rural families to manage water resources as they had in the past. Rural inhabitants who occupy areas that serve as critical water recharge zones for larger metropolitan areas. Therefore, rancheros have the potential to alter and increase water capture in the watershed via actions such as controlling upstream sediment, monitoring riparian areas, and increasing soil productivity. Governments at the federal, state, and municipality levels seek stakeholders such as rancheros for involvement in water management activities. Yet, more data is needed to understand the true needs, capabilities, and adaptation strategies of the rural population. In order to structure water conservation efforts that resonate with the rural population, it is vital to understand their traditional and current practices with regards to water use.

Little information has been documented about the lives of indigenous peoples on the peninsula. Archeological work is slim compared to, for example, excavations of the Hohokum canals in what is now Arizona in the United States (Fagan, 2011). The first inhabitants of the peninsula are thought to have arrived 11,000 years ago. In the 17th century, Jesuit Spanish missionaries called *padres* arrived to Baja under the leadership of Juan Maria de Salvaterria (Crosby, 1994). Not surprisingly, water availability was the top priority in siting Spanish occupations in the semi-arid desert. The Jesuits are said to have introduced the first agricultural systems to the Baja peninsula in order to support their missions, and trained some amenable

native groups (mainly those who spoke the native language Monqui, who allied with them) in building irrigation systems (with some resistance from Monqui's traditional enemies who spoke Guaycura and Cochimí). Much of the irrigation construction was made of stone and mortar – remnants of which can be found now throughout the state. Juan Clemente Padilla (1739-1747) is credited with introducing additional masonry skills to irrigation engineering including *acequias* (ditches), *pilas* (reservoirs), retaining walls, and terraces, by using skilled labor from the native tribes (Crosby, 1994, p. 242). In 1768, the Jesuits were ousted by the Franciscans who then ceded control to the Dominicans in 1773. Unlike the Jesuits, the Franciscan and Dominican missionaries accepted newcomers and governance from the mainland. During this part of the colonial period, diseases and violence profoundly impacted the native population. Today, 2% of the Baja population speaks a Mexican indigenous language – Mixteco, Náhuatl, and Zapoteco – but none of these groups are native to the peninsula (INEGI, 2010).

Descendants of the indigenous and missionaries (and pirates from around the world) are now known as rancheros sudcalifornianos who have earned the name "the original cowboys" for their traditional ranching livelihoods. They maintain deep historical knowledge of living off the land in a semi-arid area, but little is known of their water use, conservation methods, and drought responses.[1] For the past 300 years, ranching communities primarily raised livestock (cows, mules, goats, horses, and chickens) and settled near the palm oases (natural springs) that are scattered throughout the state (Santos & Aguado, 2011). Other traditional water sources include

[1] Local UABCS professors Dra. Alba Gámez, Dr. Fermín Reygadas, and Dra. Micheline Cariño, among others, are working locally to collect and preserve data on this social group and have been exceedingly generous in sharing information and resources for this project. One recent publication on *rancheros* living in oases in Baja California Sur is (Santos & Aguado, 2011). Two recent film documentaries are *Los Otros Californianos* (https://vimeo.com/36525315) and *Corazon Vaquero (http://www.corazonvaquero.com/cvj/index.php?option=com_content&task=view&id=20&Itemid=32)*. The rancheros studied in this project are notable for their proximity to the city of La Paz and the changes to traditional livelihoods proximity has made, while *rancheros* captured in the films live far from urban areas and maintain more local traditions.

arroyos (river beds) which flood according to the seasons, post-flooding pools of water called *tajos* used to water animals, and seasonal springs called *ojos de agua*. Human-dug wells (*pozos)* are common but can dry up during droughts. In some parts of the state, families live in the mountains during the wet season and travel to the coast to fish in the dry season. In other areas in Baja California Sur, it has been reported that some households move between two or more areas by settling in one until the fresh water source is exhausted. Then, they move to another location within the state (for example, one site in the mountains and one site on the coast). The ranchero culture in the La Paz watershed is said to be in decline (*personal communication*, Fermín Reygadas), and abandoned ranches with empty water storage tanks can be found throughout the state (Appendix C, Figure C.11).

Baja California Sur is changing climatologically as drought increases, culturally as groups evolve, and socially as the state becomes a more active member of the Mexican government. Geographic, political, and social isolation from mainland Mexico has given way to global influences. Within the past 50 years, the federal government has injected funds into projects, which have created jobs for migrants from rural Baja, mainland Mexico, and international areas while creating a water strain on the aquifers to meet growing water demand. Population has grown exponentially in the 21st century, mostly due to in-migration from mainland Mexico and other countries (Figure 1.4). Baja municipalities now struggle to keep up with water demand for this growing population and growing economy.

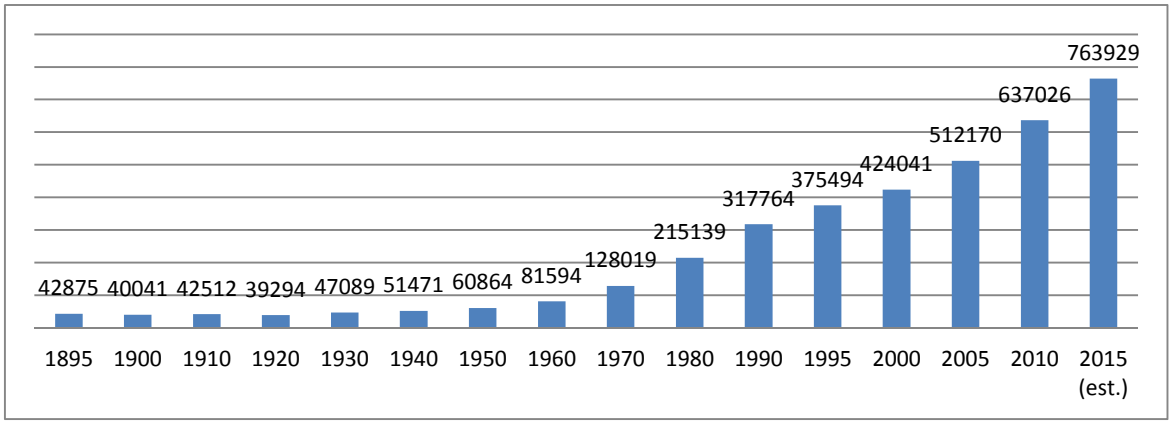

Figure 1.4 Population growth in Baja California Sur, Mexico 1895-2015 Source: INEGI, 2012

1.4 Approach

The more severe and frequent droughts predicted for the semi-arid desert of Baja California Sur places rancheros at risk of loss of livelihoods, crop failure for animal fodder, and reduction of general well-being. An inventory of capacities of rancheros in this area through a social vulnerability assessment can help water managers prepare mitigation and drought recovery strategies that reduce vulnerability, especially for areas where little to no data has been collected such as the site studied in this dissertation.

Top-down approaches to drought relief in Baja California Sur have failed in the past because the specific environmental and cultural context of Baja California Sur, both urban and rural, are sometimes vastly different than that of mainland Mexico where decisions are made. For example, one federal government intervention resulted in the distribution of cattle that could not bend their necks low enough to graze the area's short vegetation and had to be hand-fed, adding another layer of livestock management to an already stressed situation (*personal communication*, CONAZA Commission on Arid Zones official, 2013). New solutions are forthcoming; the 2006-2012 drought prompted President Peña Nieto to declare federal drought policy reform, including

establishing a rural support fund, supporting catastrophic insurance agencies, and creating a National Early Action Program for Drought (CONAGUA, 2013).

This dissertation uses a vulnerability assessment to collect migration data and measure exposure, sensitivity and adaptive capacity (components of vulnerability) among the rancheros in the Sierras of the La Paz, Mexico. This watershed is a system in which rural land users occupy the primary water recharge zone that supplies the aquifer upon which both the rural communities and urban center depends. Household surveys were collected in July 2013, the summer after a severe drought ended, to assess rancheros' perceptions of sensitivity to drought. The same survey collected migration data for each household member, other adaptation strategies used in the last drought, as well as planned adaptation strategies for future droughts, to assess correlations between drought and migration. Household surveys were also conducted in a different, less connected rural location in the state to compare differential social resources of households with different adaptive capacities to cope with drought. Interviews in 2013 with municipal (La Paz), state (Baja California Sur), and federal (Mexico) water service professionals informed an analysis of water availability throughout the watershed. It has been found that sustainable development projects can result in low success rates when development projects are created, funded, and managed by outside sources without consideration of the culture of the local people (Nyong, Adesina, & Elasha, 2007, p. 794). Thus, gathering rural information introduces the potential to incorporate local knowledge and traditions into drought mitigation and recovery projects. Information about how rancheros have coped with previous droughts has the potential of providing important guidelines for addressing current and future climate events, since this traditional knowledge has supported the population in surviving in this region and under climatic variability over the last 300 years.

This dissertation also introduces an alternative approach to address selection bias in environmental migration case studies by first locating an extreme event before identifying the migration patterns of those exposed. Many studies have examined migration as a household response to drought (see Chapter 2). However, environmental migration research often selects cases on the dependent variable (out-migration), which presents a selection bias. In other words, households are often studied after they have already migrated as an explicit response to drought. This rich body of work has revealed much in terms of which conditions cause households to migrate (e.g., coerced or voluntary), how far (e.g., internally or internationally), and for how long (e.g., permanently, temporarily, circularly). More importantly, perhaps, this literature has informed and instigated human rights debates on the rights of migrants in these circumstances. Still, studying environmental migration by selecting cases that have already environmentally migrated leaves open questions of the role that the environment plays in human decision-making, especially when some populations do *not* migrate as might be expected. To address this gap in the literature, this research project selects a case study on the independent variable (drought). I observe both migration and sedentary behavior in order to illuminate variables that may intervene between the external driving forces of a severe drought and the ability/desire of the household to respond by migrating.

Post-disaster and climate-related migration research gained traction in the late 1990s and early 2000s, especially following Norman Myers' famous claim that 150 million people would become new climate refugees by the end of the 21st century (Myers, 2002). Human mobility due to extreme events has been a topic of scholarly inquiry, particularly in the environmental migration and vulnerability literatures. Environmental migration literature has generally been concerned with defining migrants according to how and why they migrate. These studies argue

that while political (e.g., war and conflict) and economic (e.g., labor) drivers of migration have been studied at length, there are also cases in which the environment plays a key role in the household's decision to migrate, in other words, under certain conditions, drought causes migration. The environmental migration literature has been successful at demonstrating many cases in which households have migrated because of environmental factors, and have revealed the conditions of their migration (e.g., forced versus voluntarily, permanently versus temporarily). Despite a growing number of studies of the environmental, socioeconomic and cultural conditions of migration, little attention has been paid to deconstructing *how* the environmental changes figure into the overall decision making processes of the household.

The vulnerability literature, on the other hand, provides valuable complexity to a set of interacting components of the socio-ecological system in which the household responds and acts to external forces. From this perspective, vulnerability is defined as a relative property of exposure, sensitivity, and adaptive capacity where exposure is the *potential* for harm from an outside source, sensitivity is the *degree* to which that subsystem (in this case, the household) can be harmed, and adaptive capacity is the *ability* of the subsystem (e.g., household) to act and respond (Figure 1.5). Vulnerability literature also seeks to show how different social groups can be exposed to the same hazard but react differently based on how strongly they sense the impacts (sensitivity) and what capacities they have at their disposal (adaptive capacity). The literature generally shows that poor households often live in closer proximity to hazards, are more sensitive to those hazards, and have lower overall adaptive capacity. The literature further suggests that households with this combination are relatively more vulnerable than the general population, whether because they are impacted more or are inherently more vulnerable (Romero Lankao & Qin, 2011).

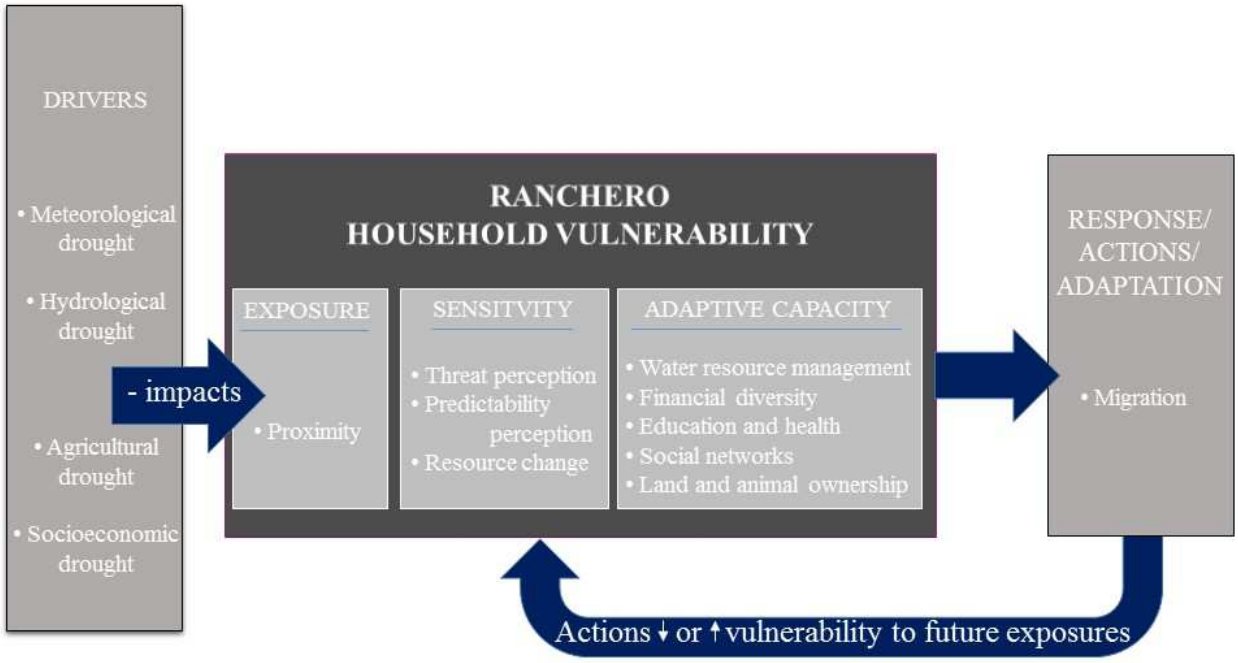

Figure 1.5 Conceptual model of household migration as a drought response, integrating environmental migration and vulnerability literatures.

Figure 1.5 shows a conceptual model of ranchero household vulnerability to drought. The figure shows the relationship between the components of *vulnerability* and the option of using *migration* as an adaptation strategy (as a response) to severe *drought*. Households are exposed to *drivers*. This study is concerned with drought drivers specifically, which can be *meteorological drought*, *hydrological drought*, *agricultural drought*, and *socio-economic drought* as defined and discussed in section 1.2. **The main research hypothesis is that drought causes migration, but that households will be differently impacted by different types of drought depending on their vulnerability context**. The environmental migration literature, as discussed in more length

in Chapter 2, has shown that meteorological drought (low rainfall) has been directly correlated with out-migration, in some cases, including in Mexico. Meanwhile, the climate vulnerability literature suggests that this and the other types of drought (hydrological, agricultural, and socioeconomic) negatively impact *exposure* (degree of contact). Exposure in this study is defined by *proximity* to the drivers, and is held as a constant since all respondents were exposed to the 2006-2012 drought (i.e., lived within the drought affected area). Drivers also have negative *impacts* on the sensitivity and adaptive capacity of the household, which in turn defines overall household vulnerability and may lead to migration.

In this study, household sensitivity to drought (degree of impact) is measured by 1) the respondents' perception of the threat of disaster to their livelihood which can impact their perceived risk, 2) their perception of the unpredictability of the weather which can impact their level of uncertainty, and 3) their experience with the reliability of resources, in this case, water resources, which, if it changes, can indicate instability. These three sensitivity indicators can contribute to various states of vulnerability.

Adaptive capacity can be measured by the assets that households can manipulate to respond. For rural populations, these can be categorized as: 1) the ability to manage (water) resources, 2) diverse financial streams, 3) education attainment and health maintenance, 4) social networks, and 5) land/animal ownership. The adaptive capacity (ability to adjust) of the household also contributes to vulnerability in that households with more adaptive capacity can manipulate their assets to cope with drought while those with less adaptive capacity have less opportunity to do so. As discussed in more length in Chapter 3, this study combines the five variables above which have been noted in the environmental migration and climate vulnerability literatures as important measures of adaptive capacity. The vulnerability literature suggests that

rural households choose from multiple options to respond to drought (categorized in the literature as migration, communal pooling, diversification, exchange, and storage), as discussed in more length in Chapter 3. The present study focuses on migration in particular. Previous studies have shown that places characterized by greater proportions of more vulnerable populations are significantly more likely to experience out-migration, as will be discussed in greater detail in Chapter 2.

Given a household's specific combination of exposure, sensitivity, and adaptive capacity (their vulnerability context), a household can choose to respond using migration as an adaptation to drought. Actions may either increase or decrease household vulnerability to future exposures (the feedback loop from response to exposure in Figure 1.5).

1.5 Organization of the dissertation

Chapter 2 describes the theoretical foundations found in the environmental migration and climate vulnerability literatures to identify the research question, hypotheses, and variables. Chapter 3 describes how these literatures were used to design the methods used in this study to test the hypotheses and measure variables. Chapter 4 on results finds that rancheros livelihoods are evolving. These changes in livelihoods subsequently changes their drought sensitivity and adaptive capacity, giving them new options to choose from to adapt to drought and resulting in new drought responses. A major finding in this study shows that urban expansion of services allows rancheros to stay in place to adapt to drought instead of migrating as the literature suggests. Chapter 5 analyzes one of these urban services – water infrastructure – and how new developments have changed how water flows in the watershed and the larger socioeconomic and

political structure under which rancheros live. Findings extend what was found in Chapter 4 in that urban services tend to enhance ranchero adaptive capacity during normal seasons, but reduces adaptive capacity during severe drought – impacting overall ranchero vulnerability. Chapter 6 introduces an alternative conceptual model to describe the interactions between drought and rancheros households to capture the complexity of both natural and built environment impacts. I conclude by discussing implications for policy initiatives in the watershed, limitations of the research, and recommendations to extend future research.

CHAPTER 2: Literature Review

2.0 Introduction

This study is focused on the social consequences of drought on the ranchero community in the Sierras of the La Paz, especially, whether or not rancheros migrate to adapt to drought. Two main literatures - environmental migration and climate vulnerability - informed the development of hypotheses, methods, and measurement. Environmental migration studies illuminate the role of the environment in migration patterns while climate vulnerability studies emphasize the internal characteristics of society, particularly the household as it interacts with external changes. Combining these two literatures allow a deeper understanding of the lived experience of the rancheros to explain why and when rancheros migrate (or not) under extreme environmental conditions.

2.1 Environmental migration literature

Migration research studies patterns in the geographic movements of people. The social sciences have historically emphasized shifts in labor markets as a primary driver of mass migration, especially from the Global South to the Global North and from rural to urban centers. More recently, scholars have turned their attention to the environment as a driver, for example, as people move to evacuate from a natural disaster or avoid the adverse impacts of environmental degradation. This group is termed *environmental migrants.* Climate change adaptation evidence shows that households and household members sometimes use migration as

a response to drought (e.g., Afifi, Liwenga, & Kwezi, 2013; C. Gray & Mueller, 2012; Leighton, 2011; R. A. McLeman & Ploeger, 2012).

Environmental migrants tend to migrate *internally* (within national boundaries) rather than *internationally* (crossing national boundaries) (Boano, Zetter, & Morris, 2008; Jäger, Frühmann, Grünberger, & Vag, 2009). This is an important distinction to make because if migrants cross a border as *environmental refugees*, sovereign states can be held responsible and international law invoked. Because migrants often do not cross borders but might require human rights protection, the United Nations created the term *internally displaced persons (IDPs)* which can include environmental migrants in some cases (Kälin, 2005) (Table 2.1). For the purposes of the present study, the least political and sensitive term 'environmental migrant' is used because it was initially unknown whether rancheros migrated internally or internationally, or what human rights claims, if any, could be called into question.

Another point to take into consideration when measuring migration is that many migrants do not travel between Point A and Point B and settle as *permanent migrants*. Indeed, environmental migration studies show that environmental migrants are more likely to be *circular migrants* (those who move back and forth between multiple places) as seasons and environmental conditions change (de Sherbinin et al., 2011; Feng, Krueger, & Oppenheimer, 2010; Gray, 2009; Henry, Schoumaker, & Beauchemin, 2004; Joarder & Miller, 2013; Qin, 2010). Table 2.1 shows the important terms in vulnerability studies and those listed are the focus of this literature review.

Table 2.1 Environmental migration terms and definitions	
Migration	"The geographic movement of people across a specified boundary for the purpose of establishing a new permanent or semi-permanent residence" (Haupt & Kane, 1998, p. 35). In this project, migration is operationalized as head of household relocation from their birthplace, permanently or for longer than three months at a time.
Environmental migrants	People who voluntarily move because of something in their environment, but before an environmental threshold has been reached (modified from Bates, 2002, p. 468).
Internal migration	Migration that does not cross a political border such as a nation-state (see, for example, Hugo, 1996).
International migration	Migration that crosses a political border, usually a nation-state (see, for example, Hugo, 1996; Massey et al., 1993).
Environmental refugee	"Those people who have been forced to leave their traditional habitat, temporarily or permanently, because of a marked environmental disruption (natural and/or triggered by people) that jeopardized their existence and/or seriously affected the quality of their life" (El-Hinnawi, 1985, p. 4).
Internally displaced persons (IDPs)	"Persons or groups of persons who have been forced or obliged to flee or to leave their homes or places of habitual residence," and includes people displaced as a result of or in order to avoid the effects of "natural or human-made disasters, and who have not crossed an internationally recognized state border" (Deng, 1999).
Permanent migrant	"…permanent migrants stay away more than six months, do not return to participate as regular members in the life of the household, and do not plan to return. The migrant has shifted his or her work and residence completely to the new location" (Findley, 1992, p. 540).
Circular migrant	"A circular migrant stays away between one and six months and upon return participates in the economic and social life of the household. He or she retains an economic and social role within the original household unit" (Findley, 1994, p. 540).

Another common theme in environmental migration literature is to distinguish between the types of disaster. These are generally divided into sudden onset (e.g., hurricanes, floods), and slow (or gradual) onset (e.g., drought, desertification), defined in Chapter 1 (Laczko & Aghazarm, 2009). Migration studies relating specifically to drought and rainfall deficits have increased over the years. Table 2.2 shows a selective review of migration studies from the 1970s to the present by continent. By far, most drought migration studies have been conducted in Africa. Studies often collect data from recent migrants, although some analyze historical data for past droughts (Benson, Petersen, & Stein, 2007; R. McLeman, Mayo, Strebeck, & Smit, 2008; R. A. McLeman & Ploeger, 2012).

Table 2.2 Sample of drought migration case studies by publication date and region

	Africa	South America	North America	Asia	Australia
1970-1979	(Caldwell, 1975; Forde & Amin, 1978; Webster, 1979)	(Brooks, 1971, 1975)			
1980-1989	(Bein, 1980; Cutler, 1986; Fleurett, 1986; Merryman, 1982; Smale, 1980; Turton & Turton, 1984)		(McGregor, 1985)		
1990-1999	(Findley, 1992, 1994; Juul, 1996; Lindtjørn, Alemu, & Bjorvatn, 1993; Pedersen, 1995; Vogel & Binns, 1995)				
2000-2009	(Barrios, Bertinelli, & Strobl, 2006; Belay & Manig, 2005; Bovin, 2000; Ezra & Kiros, 2001; Hampshire, 2002; Henry et al., 2004; Juul, 2002, 2005)	(Finan & Nelson, 2001)	(Benson et al., 2007)	(Sternberg, Middleton, & Thomas, 2009)	
2010-present	(C. Gray & Mueller, 2012; Rain, Engstrom, Ludlow, & Antos, 2011)		(Feng et al., 2010; Gilbert & McLeman, 2010; R. McLeman, Herold, Reljic, Sawada, & McKenney, 2010; R. A. McLeman & Ploeger, 2012; Nawrotzki, Riosmena, & Hunter, 2013; Pugatch & Yang, 2011; Riosmena, Nawrotzki, & Hunter, 2013)	(Jülich, 2011)	(B. Hunter & Biddle, 2011; Hurlimann & Dolnicar, 2011)

Several studies focus on exposure to drought in Mexico and whether people migrate to modify that exposure – in other words, change their proximity to the drought risk (Feng et al., 2010; L. M. Hunter, Murray, & Riosmena, 2011, 2013; Nawrotzki et al., 2013; Riosmena et al., 2013). There have also been conflicting findings on whether drought leads to more migration or less. Using census and precipitation data, Riosmena et al (2013) found that migration was correlated with drought shocks in the dry, northern states of Mexico but no correlation in the wet, southern states. One study found that for two states in Mexico, migration actually decreased as rainfall decreased (Kniveton, 2008). Using data sources of male Mexican migrants in the US labor force, Pugatch and Yang (2011) find a negative correlation between rainfall in Mexico and Mexican out-migration. To explain the association, they offer two explanations: 1) larger emigration flows from drought in Mexico, and/or 2) lower return flows of Mexicans in the United States. Using the same methodology but data from the country of origin, Chort (2014) offers a third interpretation – that rainfall is only correlated with migration for those who already had the intention to move, explaining that low rainfall pushes migration decisions earlier for those who have a propensity to do so. Meanwhile, other disasters like hurricanes reduce the likelihood of migration as a response to drought because it lowers the households' financial capacity (Chort, 2014). Jülich (2011) also finds that adaptive capacity mitigates environmental drivers that affect migration in India. However, there are a few studies focusing on the ability of households to migrate and what constrains those abilities.

Economics is discussed substantially in migration literature, especially as a function of relative poverty (Laczko & Aghazarm, 2009; Todaro, 1969). Saldaña-Zorrilla and Sandberg (2009), for example, found that those in the poorest municipalities of Mexico were least likely to migrate while those in the richest were migrant-prone. In this case, those who had more lost

more - those who saw their income substantially decrease over the last ten years were more likely to migrate. Meanwhile, Laczko and Aghazarm (2009) found that access to credit was not a statistically significant factor that predicts migration. Other studies have found that home ownership tends to decrease mobility (Gray, 2009). A large body of environmental migration research has focused on the effects of land resources on the decision to migrate, although findings are contradictory. For instance, Zhao (1997) found a negative linear relationship between larger landholding size and a lower tendency to migrate. Meanwhile, others found a U-shaped relationship to migration between households with below or above average landholding size having a higher tendency to migrate (Vanwey, 2003). Still others found an *inverted* U-shaped relationship with intermediate land assets correlated to migration (Bilsborrow, 1987; Yao, 2001). The discrepancies between the results of different studies suggest that the relationship between land assets and migration is context specific and complex. Saldaña-Zorrilla and Sandberg (2009) find a positive and statistically significant correlation between education and out-migration among marginalized municipalities in Mexico. Migrants in their study came from municipalities that reported a higher mean level of education relative to other marginalized regions. Drawing upon the studies listed above, it is clear that certain household characteristics are indicators of migration in extreme events. These include the: 1) ability to manage resources (water), 2) access to social networks, 3) ability to diversify finances, 4) ability to acquire education and maintain health, and 5) land and animal ownership.

Migration has sometimes been interpreted as a sign of "a failure to adapt" (Brown, 2008, p. 36; Kates, 2000). On the other hand, it has also been portrayed as an empowering strategy that provides more income to the home as migrants send back remittances (Barbieri & Carr, 2005; Gray, 2010; Warner, 2009). More likely, migration decisions include trade-offs that will have

both positive and negative effects (e.g., Black, Arnell, Adger, Thomas, & Geddes, 2013; Gemenne, Brücker, & Ionesco, 2012; Piguet, 2010; Warner, Hamza, Oliver-Smith, Renaud, & Julca, 2010). Migration is one of the many adaptation options a household can invoke, but that does not mean that all households will respond to drought in this way. Not all households have equal financial ability, occupational skills, education, or access to the social networks that ease migration. Some households are comfortable with staying in place due to land holdings or infrastructure that modify exposure to drought risks. Even within households, access to assets and desire to migrate varies.

2.2 Climate vulnerability literature

While the environmental migration literature provides a breadth of knowledge about how and why households have migrated in response to different extreme events, the climate vulnerability literature adds depth by identifying the components within the household that impacts decision-making. The concept of vulnerability is particularly suited to the task of understanding how individuals and social groups can choose among options and overcome drought impacts. People must be able to access water resources in order for them to contribute to security. Drought interferes with water resource availability. The social organization of water interferes with water resource access.

Household vulnerability defines which response (adaptation) options households have to choose from, whereas *resilience* is the ability to reduce exposure and sensitivity while enhancing adaptive capacity (Eakin, 2005). Resilience is a concept that links social and ecological processes (Berkes, Colding, & Folke, 2003; Folke et al., 2002; Gunderson & Holling, 2002;

Holling, 2001). Because of this, resilience is popular among policy makers for its applicability in disaster situations to identify both environmental and social causes. Planners also use resilence theory as a framework to envision what sustainability might look like and how to make a transition towards it (Henly-Shepard et al., 2015). However, the social dimensions of resilience remain underdeveloped compared to ecological components (Henly-Shepard et al., 2015). Yet, there is a growing need to establish a database of vulnerable groups for future sustainable development initiatives (Hughes, 2013) and to continue striving for metrics that adequately assess vulnerable groups.

Table 2.3 lists terms and definitions found in climate vulnerability literature. I describe each of the terms in the table as they are integral to addressing vulnerability and migration for my sample population.

Table 2.3 Climate vulnerability terms and definitions	
Vulnerability	"The state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt" (N. Adger, 2006, p. 268). Often notated as Vulnerability = f(exposure, sensitivity, adaptive capacity).
Resilience	The ability and flexibility to engage in livelihood activities that reduce exposure and sensitivity to a hazard while enhancing adaptive capacity.
Exposure	The extent to which populations come in contact with or are subject to hazards (Romero-Lankao et al., 2013, p. 31), often thought of in terms of proximity to a hazard. Measured by the magnitude, frequency, duration, and coverage of a stressor such as drought on a system or subsystem.
Hazard	In general, a source with the potential for damage. In referring to hazards that can become environmental disasters, it is the product of a social system interacting with natural extremes that has the potential to inflict harm (Cutter, Emrich, Webb, & Morath, 2009; Kates, 1971; Mustafa, 1998).
Risk	The probability that a hazard will occur.
Disaster	A hazard that overwhelms local capacity to respond and recover (modified from Cutter et al., 2009).
Impacts	Used in this project to refer to observed or hypothesized effects on components in the system.
Drivers	External forces that trigger change within a system.
Sensitivity	The degree to which people within a system are impacted, a characteristic that may be disproportionately spread throughout a given area (Romero Lankao & Qin, 2011).
Adaptive capacity	The assets used "to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC, 2013, p. 2 Glossary)
Adaptation	The actual adjustments actors make to modify their exposure and sensitivity to a hazard given their adaptive capacity.
Response	Used in this project to refer to household actions to cope with drought stress - inaction is also coded as a response.

Exposure

The conceptual model of the study (Figure 1.5) shows that a household may be adversely impacted by drought depending on its exposure to it. The potential for any component of a social system to experience harm is called *exposure*. Drought is studied here as a *hazard* (see Table 2.3) at the intersection of biophysical nature (the natural system) and social construction (the social system). It is a natural phenomenon exacerbated by anthropomorphic activity with social consequences. When drought is studied as a hazard, it is seen as a phenomenon with the potential for damage or harm to human populations (Cutter et al., 2009; Kates, 1971; Mustafa, 1998). *Risk* is often used interchangeably with hazard, but in the literature, risk refers specifically to the statistical probability that damage will occur while hazard refers to the source of damage. A hazard only becomes a *disaster* when it overwhelms the local capacity to respond and recover.

There is a robust literature that examines hazards of natural disasters and their social *impacts*, or effects. The primary goals of such studies of the early contributions to the studies of hazards were to determine the number of people living in hazardous zones and what losses they might incur (White, 1973). Later, a political ecology approach evolved to recognize the social *drivers* of vulnerability. In other words, which types of people live in hazardous areas, and if certain people were more likely to live there based on class, race, or another social factor (O'Keefe, Westgate, & Wisner, 1976). Scholars articulating this view highlighted the role of human agency in response to hazards, focusing on what constrains people's response, and how people cope. Another human-centric approach, the "pressure and release" model (Blaikie, Cannon, & Davis, 1994), was proposed to understand the root causes of insecurity and risk. In an effort to combine the risk and hazard approaches with political ecology paradigms, the "hazard-of-place" model was developed by Cutter (1996). This theoretical framework introduced

empirical hypotheses to test biophysical and social vulnerabilities over time and space. Maps visually showed how proximity to hazard played a significant role in determining the level of exposure. This approach has since been critiqued for an inability to address the larger social-ecological system. In response, Turner et al. (2003) introduced the vulnerability/sustainability framework to locate local vulnerabilities to hazards within a larger social and political context.

Sensitivity

Second, a household's sensitivity to drought (Figure 1.5) helps to determine a household's response to it. Current articulations of vulnerability frameworks around hazards, especially climate change hazards, tend to conceptualize vulnerability as not just a function of exposure but also sensitivity and adaptive capacity. Sensitivity is the degree to which the system is affected by stress (IPCC, 2013; Kates, 1971; Perch-Nielsen, Bättig, & Imboden, 2008; Smit & Wandel, 2006). Cinner (2012) developed a metric of sensitivity based on the level of occupation dependency on a resource, in his case, fisheries. Perceptions and awareness have also been measured to understand the degree to which famers are adversely affected by drought, for example, by linking drought to a sense of hopelessness or suicide (Udmale, Ichikawa, Manandhar, Ishidaira, & Kiem, 2014). This study uses a combination of these measures and are discussed in Chapter 3. The literature on vulnerability and adaptation literature suggests that people who are more dependent on local resources (i.e., the resource dependent) are more likely to be sensitive to hazards like drought because they have a narrower base from which to choose their adjustments (Adger, 2000, p. 351).

Adaptive capacity

Third, adaptive capacity is integral to vulnerability (Figure 1.5). Social vulnerability assessments and indices focus on measuring adaptive capacity – assets which households use to respond to disaster (for a review of risk and vulnerability indices across scales, see Birkmann, 2007). Household scale assessments have been particularly useful for thinking about vulnerability to short-term hazards like drought because it is at this scale in which people first react. Scholars infer that results from such studies can inform predictions about how the same populations might react to long-term climate hazards.

Household adaptive capacity is defined for the purposes of this study as the assets that help households "to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC, 2013, p. 2 Glossary). Meanwhile, coping capacity allows people to "address, manage, and overcome adverse conditions in the short to medium term." Attempts to identify adaptive capacity variables that are relevant to household vulnerability have been diverse. For example, studies have investigated the role of finances and financial diversity (Anand & Sen, 2000; Bhanojirao, 1991; Joshua E Cinner & Bodin, 2010; Easterlin, 1995), land ownership (Babigumira et al., 2014; Ntshona, Kraai, Kepe, & Saliwa, 2010), social capital (Grootaert, 2004; Jones, Clark, Panteli, Proikaki, & Dimitrakopoulos, 2012; Narayan & Pritchett, 1999; Pelling & High, 2005; Putnam, 2001), and education (Becker, 2009; Cundill, Shackleton, & Larsen, 2011). In the risk and disaster literature, adaptive capacity has been measured at the community level - categorized as physical and demographic variables (e.g., density, demographic pressure, unsafe settlements), social variables (e.g., access to basic services, poverty, literacy rates, attitudes, decentralization), and economic variables (e.g., income diversification, small business, accessibility to financial resources) (Bollin, Hidajat, & Birkmann,

2006). Meanwhile, in the literature on climate adaptation, variables at the household level are often addressed as economic variables (e.g., the ability to use household wealth, broadly defined, external capital such as credit and loans), human capital variables (e.g., knowledge, social memory, education), and physical or institutional variables (e.g., access to technology, which requires a supportive institutional environment in which to access them) (Eakin, Lerner, & Murtinho, 2010; Yohe & Tol, 2002). Studies such as McClanahan (2008) have combined some of the above variables to create an adaptive capacity index. Other factors have also been measured - social capital and material assets, access to technology and infrastructure, occupational mobility, and occupational multiplicity (McClanahan, 2008). However, a consensus on how to measure the adaptive and coping capacity of social resilience at the household scale has not been reached (Henly-Shepard et al., 2015). Chapter 3 discusses how adaptive capacity indicators were measured in this study.

The conceptual model of the study (Figure 1.5) shows adaptive capacity as a product of the household which includes, among other things, 1) the ability to manage water resources, 2) diversity of finances, 3) education and health attainment, 4) social networks, and 5) land and animal ownership. Such assets constantly change due to external forces such as drought, as well as internal household forces to invest or disinvest in certain assets. Because external conditions are not static, households must be dynamic and adaptable to changing conditions, and yet people cannot modify their sensitivity unless they have the *capacity* to do so. The different mix of capabilities that households have is referred to in this project collectively as adaptive capacity. Interacting factors both constrain and create opportunities from which to modify drought sensitivity and exposure.

Adaptation/response

Adaptation in emerging economies is important not just because of increasing exposure to hazards, but also because of the compounding factors that climate change will have on intractable social problems such as poverty, vulnerability, and inequality. These problems increase the exposure and sensitivity to risk that threaten the livelihoods of certain populations. The concept of adaptation has gained traction in debates as society grapples with evidence of global environmental change. Adaptation is defined in multiple ways from the physical or biological "response to environmental stress" (Little, 1983), to a social "response to risk" (Smit & Wandel, 2006). It is not a one-time action, but is a "process of change in anticipation of a stress" (Nelson, Adger, & Brown, 2007; Tschakert & Dietrich, 2010). This project defines adaptation as the actual adjustments actors make to modify their exposure and sensitivity to a hazard given their adaptive capacity. Adaptations are operationalized as the strategies households use to respond to drought. Illustrated in the conceptual model of the study (Figure 1.5), households determine the strategies they take based on how they can use the assets that make up their adaptive capacity given their exposure and sensitivity to a driver or stress such as drought.

Adaptation practices are sometimes categorized as: storage, diversification, communal pooling, exchange, and mobility (at the institutional level, see Agrawal, 2010; at the household level, see Liverman, 1999). Adaptation strategies can modify exposure or modify sensitivity in order to reduce overall vulnerability (Perch-Nielsen et al., 2008). The back arrow in Figure 1.5 shows that actions may increase or decrease household vulnerability to future exposures. In general, households have greater control over modifying their sensitivity to drought by internally building up reserves, diversifying, and investing in their assets. Modifying drought exposure often requires physically moving away from risk areas. It also requires household integration

within a larger social system, that is, using social networks in order to move, for example, or building large infrastructure to move water to and from areas as necessary (e.g., pipes, sewers, retention basins, deep wells, desalination, etc.).

Migration as adaptation to drought

There are many ways in which households respond to drought as a result of the interacting factors of drought exposure, sensitivity, and adaptive capacity. This study is focused on just one strategy - migration- as shown in Figure 1.5. Migration is a household strategy that can modify exposure or sensitivity to drought. Permanent evacuation can be an exposure modification (to change proximity, or, degree of contact), while circular, temporary migration to diversify household income can be a sensitivity modification (to change degree of impact). Responses are notoriously difficult to link directly to climate and weather variability because adaptations are often autonomous and spontaneous rather than conscious and planned (Fankhauser, 1999, p. 69). Further, responses are rarely directly linked to a single variable, such as weather, alone. The ranchero community is poor, and not unlike other populations in rural communities; they have limited economic opportunities, lack assets, and are subject to social and political inequities. Because the capacity to cope with future hazards is largely determined by current states of poverty and vulnerability (O'Brien & Leichenko, 2000), studies on the role of human agency in determining how people learn to adapt adds an important dimension to resilience discourse.

2.3 Resilience

A goal of a study like this is to understand how *resilience* can be enhanced among the rancheros who inhabit the La Paz watershed. Resilience is referred to as household activities that

reduce exposure and sensitivity to hazard while enhancing adaptive capacity (Table 2.3). Greater attention has been paid to rural development in recent decades to alleviate poverty and build capacities among rural populations (Bebbington, 1999; Chambers & Conway, 1992). Vulnerability assessments provide urban planners with end user data, however, they do not by themselves empower those assessed. This is because access to the "table" of decision making on water conservation and drought management represents a potential new gateway for rancheros (Graham & Marvin, 2001) which requires new skills and networks. Optimistically, gateways can and do change to fit in new actors. Evidence has also shown how new infrastructure can reproduce existing biases (Silva, 2000), or legitimize territory (Offner, 2000). Including the rural space presents an opportunity to become more than just a physical extension of the urban through negotiation of access and activity in the watershed. For this to happen, rural water users must 1) choose to engage and 2) be able to overcome disempowering institutional forces. In the La Paz watershed context, this study shows both of these conditions are still being determined with the results for enhanced household resilience unknown.

CHAPTER 3: Methods

3.0 Introduction

The overarching research question for the project is "did rancheros in the Sierras migrate in response to the last extreme drought?" The hypothesis that rancheros migrated in the last drought was generated from the environmental migration and climate vulnerability literatures described in Chapter 2, where vulnerable populations have been observed to migrate from extreme events as an adaptation strategy. Drought was held as a constant, as all respondents throughout the study were exposed to the 2006-2012 drought. The project consisted of household surveys, key informant interviews, participant observation, and review of official records to test the hypothesis that a migration signal would be visible after severe drought.

I collaborated with two community non-profits and the local university, Universidad Autónoma de Baja California Sur (UABCS), in designing the household surveys and key informant interview guides. The methods, tools, processes, and results were vetted through these local experts who had previous experience working with these populations. Specific methods were chosen for time, cost, and appropriateness for data collection on each research question. Household surveys were designed and conducted to capture household migration data, demographics, sensitivity, adaptive capacity, and adaptation strategies among rural water users. Between the adaptation and environmental migration literatures discussed previously, there is some overlap in the variables that are important to predict household outcomes. These are: 1) the capacity to manage resources (in case of drought, water resources), 2) access and willingness to use social networks, 3) land and animal ownership, 4) financial diversity, and 5) the ability to

acquire education and maintain health. From these, I constructed the metrics to measure the adaptive capacity of rancheros. Key informant interviews and a review of official documents were used to design a timeline of recent urban water infrastructure developments in the watershed. Participant observation allowed for the integration of the findings. Field work was conducted over two years (2012-2014) including three visits - the first to pilot the survey, the second for data collection and participant observation, and the third to present and give results to the local collaborators as well as survey respondents. The project timeline was as follows:

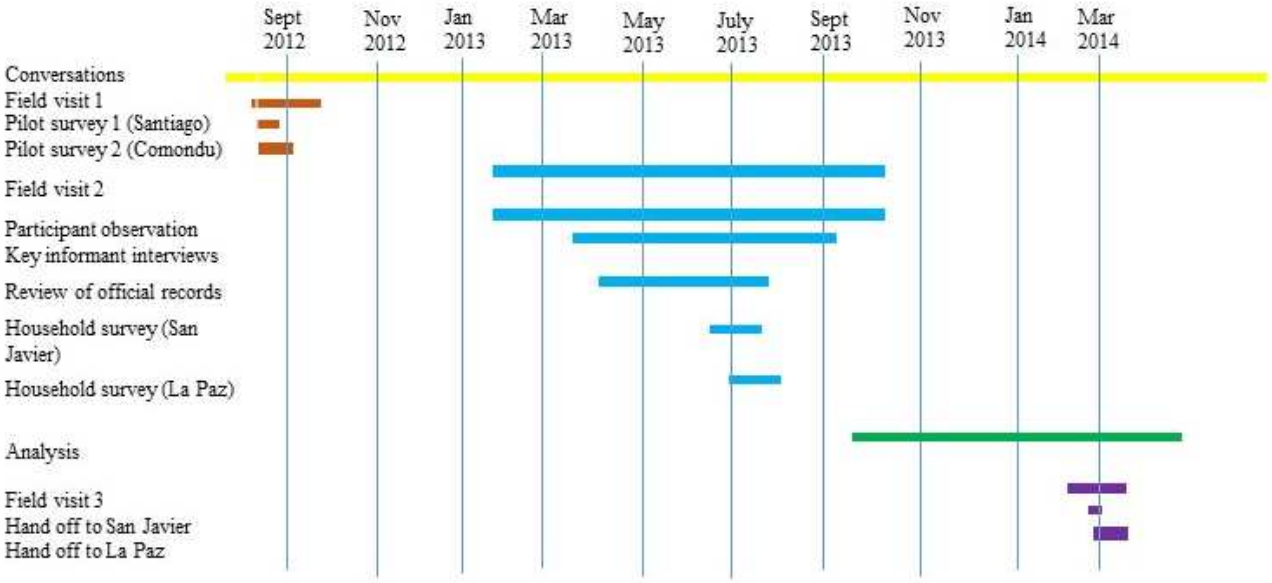

Figure 3.1 Project timeline 2012-2014

3.1 Household surveys

Methods used to test the hypothesis that drought caused migration focused on establishing baseline data on the rural watershed communities in order to assess their vulnerability to the impacts of drought. As explained below, the surveys were designed specifically for use in the ranchero communities, with the intention to test variables in a way that

could be modified for non-ranchero populations. The surveys were also intended to collect baseline data, essential for determining current conditions to compare to future performance (Kusek & Rist, 2004, p. 89). Although field work is time consuming and expensive, I decided on door-to-door household surveys because the federal census does not report on locality-level migration. Likewise, there is a lack of scholarship on historical migration or standard measures for adaptive capacity (e.g., strength of social networks) among this population. Household surveys were established as the most appropriate data collection method to answer the questions of the project because face-to-face data collection was assumed to elicit trust with the population. The questions were grouped into the following categories: 1) sensitivity, 2) adaptive capacity, and 3) adaptation strategies. These questions were asked to understand if rancheros were sensitive to which types of drought – meteorological, hydrological, agricultural, or socioeconomic, and in which ways.

Site and sample selection

In 2006, the northern states of Mexico registered significant drops in precipitation that peaked in 2012, the worst drought to hit Mexico in 70 years. During this drought, Baja California Sur recorded the largest decrease in rainfall, 70% (CONAGUA, 2013). Vulnerable households were identified in an area known as the Sierras in the La Paz watershed surveys. Data were collected in the dry season (July and August 2013) to be more representative of water stress. The surveyed area is also important because it ensures water quality and quantity of the entire watershed, as rancheros live in the main water recharge zone for the aquifer upon which the City of La Paz depends. Figure 3.2 shows where household surveys were collected in the "Very Good" recharge zone (yellow, labeled in Spanish as "Muy Buena," in the "Good" recharge zone

(dark blue labeled in Spanish as “Buena”), and the “Moderate” recharge zone (light blue, labeled in Spanish as “Moderada”). The boundaries were defined by the watershed as outlined by the federal water agency CONAGUA (Figure 3.2).

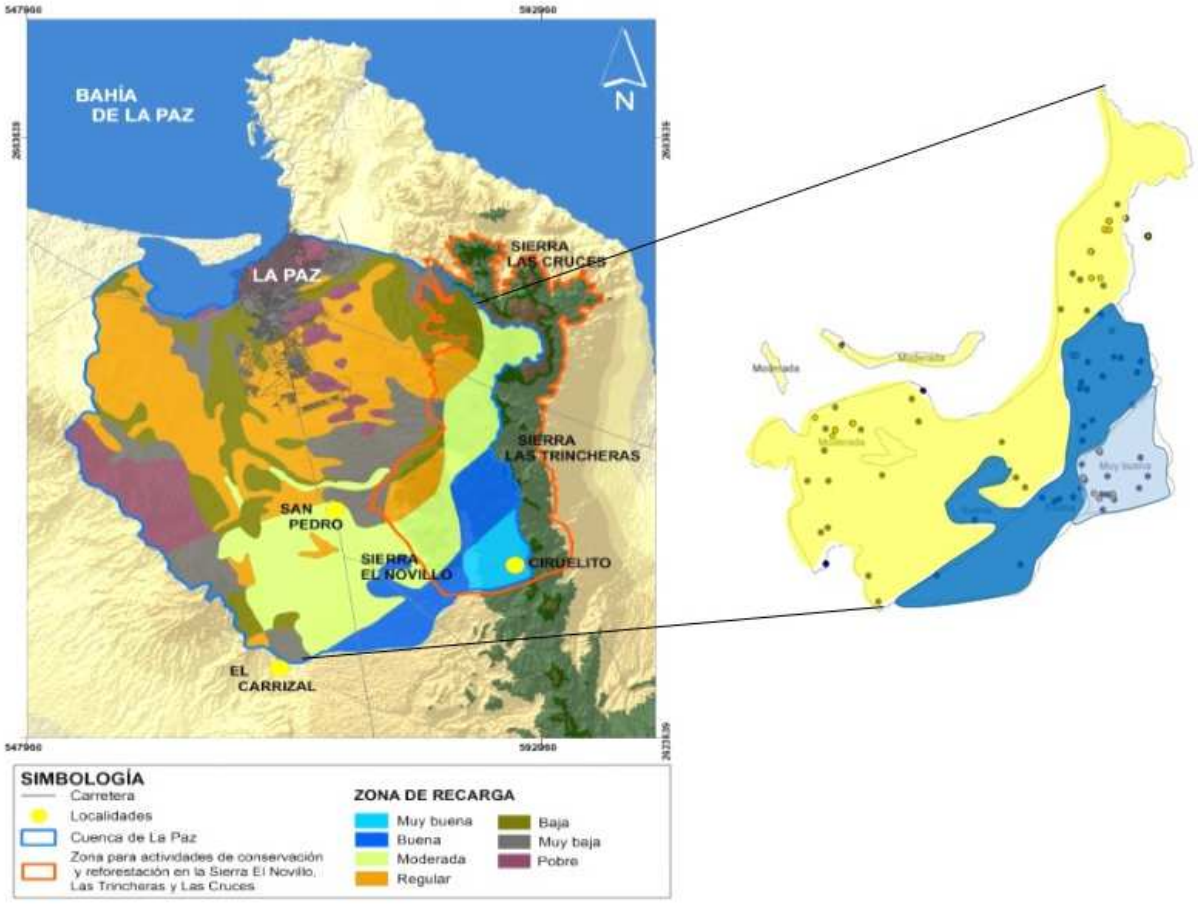

Figure 3.2 Left: Map of the La Paz watershed and detail of water recharge zones: light blue = “Muy Buena” (very good recharge), dark blue = “Buena” (good recharge), yellow = “Moderada” (moderate recharge). Right: surveyed households shown as dots. Efforts were made to survey households in these three recharge zones for the La Paz aquifer. Source: Niparajá 2014.

Through discussions with local practitioners, it was estimated that the total population in the Sierra catchments was approximately 750 individuals. Since the mean household size was estimated to be four persons, it was calculated that 120 household surveys would result in a 95% confidence level with a +/- 5% margin of error. True random sampling was attempted by assigning numbers to localities as reported in the national census (INEGI). However, due to the difficulty of travel on the dirt roads of the Sierras and discrepancies between INEGI data and reality, a dispersed purposeful sample was completed with the assistance of ten local translators. Households in the selected communities where the head was born in Baja California Sur and whose primary income is derived from local resources were included in the study.

Territorial boundaries in Mexican states are called *municipalities* while places such as *urban* cities and *rural* villages are called *localities*. For example, in Baja California Sur, the capital city of La Paz is located in the municipality of La Paz. However, the present study is concerned with water, which does not always follow political boundaries. Instead, I used the outline marking the land that drains precipitation to the aquifer of the La Paz *watershed* to limit the project boundary. The La Paz watershed does not cover the entire La Paz municipality, but it is located solely within the watershed. The households sampled in the survey are part of the ranchero *community*, who occupy the rural, mountainous region of the La Paz watershed known locally as the Sierras. Table 3.1 lists the geographical designations used to inform site selection.

Table 3.1 Geographical designations	
Municipality	A political designation of territorial boundaries within a Mexican state. Baja California Sur has five recognized municipalities: La Paz (1971), Mulegé (1971), Comondú (1971), Los Cabos (1981), and Loreto (1992).
Urban	For the purposes of this study, urban is operationalized as 50,000 inhabitants or more.
Rural	For the purposes of this study, rural is operationalized as fewer than 150 people per sq. km.
Locality	A population identified by the national census INEGI with a name given by law or by custom. According to the 2010 census, Baja California Sur has 2,850 recognized localities with 1,043 in the La Paz municipality.
Watershed	The area of land where all of the water that is under it or drains off of it goes to the same place.
Community	A group of individuals sharing a common geography, interest, experience, network, or other social identification.

A 90% response rate was obtained, representing a total of 120 households and 485 individual family members. The sample is representative of rural households in the La Paz watershed. However, because *rancheros sudcalifornianos* are heterogeneous in the extent to which they rely on ranching as their primary livelihood, this sample should not be used to generalize to all rural households throughout the state.

Comparison site

Household surveys in San Javier in the Loreto municipality served as a pilot for the La Paz watershed. Data were collected in July 2013 using the same purposeful sampling method as in the La Paz watershed, representing 43 households and 211 individuals. Three translators conducted the surveys with me. A local guide recruited from the community who had been actively involved with the non-profit Living Roots introduced us to the first ten households.

Conducting the pilot in San Javier alerted us to some changes in wording of the survey, but the overall content was the same. Therefore, I can make comparisons between the rural San Javier community and the rural La Paz community.

Figure 3.3 Map of Baja California Sur showing San Javier and Sierras (rural watershed of La Paz). Note that San Javier is further from the main highway (in red) than the Sierras.

I conducted the surveys between July and August 2013 with the help of 12 translators paid by the local non-profit collaborators. Together we collected 120 household surveys in the rural mountain ranges of the La Paz watershed and an additional 43 surveys in San Javier. We collected data on the demography and mobility of each household member including age, gender, education level, occupation, dates away from place of birth, and location traveled to (see Appendix A). An additional 40 multiple choice questions were asked in which respondents could

choose more than one response. The questions were grouped into five themes explained in detail below: ability to manage water resources, social network connections, diversity of the financial portfolio, ownership of land and animals, and education and health. The objectives of the surveys were to assess drought sensitivity, adaptive capacity, and adaptation strategies among rancheros. Similar household surveys have been effective in identifying regions where households are likely to be vulnerable to external influences. Further, they help with identifying in what ways households can enhance resilience through participation in the policy process (for example, Nelson, Kokic, Elliston, & King, 2005).

Survey design and cultural sensitivity

Pilot studies are used as a means of learning what works and what does not, to test the quality of data sources, to test collection and analysis strategies, as well as determining necessary data that do not yet exist (Kusek & Rist, 2004). With these goals in mind, the household survey was piloted three times. The first draft of the survey was translated into Spanish by a local in Baja California Sur. To test the first pilot survey in Santiago, Baja California Sur, the translator and I interviewed three ranching heads of household in August 2012. Through these interactions, I determined that the survey was too long and revised it accordingly. I then sought out four local experts to review the questions for clarity and cultural sensitivity. Two of the experts were university professors of sustainable development and anthropology at the Universidad Autónoma de Baja California Sur (UABCS). They provided feedback on the number of questions and structure of the survey, and helped locate students to assist with translation in the field. I then traveled to another area of Baja California Sur (Comondú) in March 2013, and interviewed three ranching heads of households with the aid of a local guide from a ranching family. These

interactions in the field gave me a better understanding of the lived experience of different types of *rancheros* and what they felt were the most important impacts of drought to their livelihoods.

Two other local experts assisted with the development of the survey. They both managed local non-profits concerned with water conservation and sustainable ranching, and asked to include the following questions to aid them with service provision:

1) If you left the town where you were born, do you want to return?
2) Do you conserve water?
3) Do you have a functioning water storage unit that is currently holding water?
4) Have you attended a capacity building workshop in your community?
5) What capacity building workshop topics would you like to see in the future?

The non-profit managers also suggested the following changes to the survey for the sake of cultural sensitivity in the community: data on income, land tenure, and animal ownership were noted as particularly sensitive which the respondents might not answer truthfully. I chose to keep the questions but asked for ranges instead of absolute numbers. Because I was more interested in the diversity of their income rather than absolute numbers, I asked the study respondents to list their income-generating activities, and the proportions that each activity contributed to total income. Respondents could refuse these questions if they did not want to report this information - one household refused.

I tested the finalized survey with 43 households in San Javier, Baja California Sur in the Loreto municipality in July 2013. Two final modifications resulted from this pilot. First, the verb "conservar" in "Conserva el agua?" ("Do you conserve water?") was changed to "Cuida el agua?" when respondents told us that they used the word "cuidar" to connote water management and conservation. Second, the word "migrar" (to migrate) was changed to "salir" (to leave) after respondents told us that they generally use the verb migrar when referring to permanent, usually long-distance moves. I wanted to capture internal and circular migration patterns in the data, so I

changed the wording of the demographic questions to ask if household members have left for any amount of time, and if so, when, where, and why. However, when asking about adaptation strategies for past and future droughts, I kept the word “migrar” to connote a deliberate activity in direct response to drought. Table 3.2 lists water sources available to rancheros with local translations as I understand them.

Table 3.2 Baja terms for water sources	
Acequia	Open ditch.
Acueducto	Aqueduct.
Arroyo	Riverbed.
Bordo	A roughly built dam.
Conservar	To conserve (use less).
Garrafon	Five liter bottle for potable water storage.
Llave	Tap (faucet).
Ojos de agua	Local rural word for seasonal springs.
Pila	Reservoir to collect spring water for irrigation.
Pozo	A well.
Presa	A dam (larger than a *bordo*).
Tajo	Post-flooding pools of water used to water animals.

Sensitivity variables

Environmental migration studies place emphasis on the perception of weather change as a factor in peoples' decisions to respond to environmental change or degradation (Alscher, 2010; Gray, 2009; Laczko & Aghazarm, 2009; Saldaña-Zorrilla, 2008; Vilei & Dabbert, 2007). Climate vulnerability literature places emphasis on sensitivity as an essential component in the overall vulnerability of the unit, in this case, the household. To understand the impacts of drought on households and the degree to which they might be impacted, I asked respondents 1) what they considered to be their main environmental threat, 2) if they thought the weather had become more unpredictable in the last ten years, and 3) if they had to change the way they have

collected water in recent years. These responses were used as indicators to assess sensitivity to drought.

Adaptive capacity variables

The primary interest of this study is to examine the role of drought in the ability of people to perform their livelihoods and adapt to external change, with a particular interest in whether or not people move to respond to drought. Research from the environmental migration and social vulnerability literatures were reviewed to select the questions for the survey. Measures of adaptive capacity which I used are in Table 3.3.

Table 3.3 Measures of adaptive capacity

Access to fresh water source for human consumption[5]
Community network[4,6,7,9]
Source of information[13, 14]
Family financial support (including remittances)[7]
Member of an organization[1,13,14]
Diverse sources of income[1,2,3,10,11]
Access to credit/loans[2,3,7,8]
Property insurance[7,8]
Documentation of land title[4,6,7,12]
Animal ownership[1,6]
Education level[4,6,8,11,14]
Lack of disabled/chronically ill family members[14]
Capacity building workshops attended [3,14]
Sources: [1](Nelson et al., 2005); [2](Ellis, 2000); [3](Vilei & Dabbert, 2007); [4](Gray, 2009); [5](Alscher, 2010); [6](Massey, Axinn, & Ghimire, 2010); [7](Saldaña-Zorrilla, 2008); [8](Laczko & Aghazarm, 2009); [9](Vincent & Cull, 2010); [10](Janvry & Sadoulet, 2001); [11](Eakin, 2005); [12](Liverman, 1999); [13](Narayan & Pritchett, 1999); [14](Romero-Lankao, Qin, & Dickinson, 2012)

The selected questions were then vetted by local experts and piloted in two communities using the process described above. Several questions were removed due to overall length of the

survey or because locals did not think respondents would answer truthfully, as discussed above. Ultimately, the survey questions (Appendix A) were selected for their perceived ability to measure the components that rancheros felt were valuable for their capacity to adapt.

Households without proper documentation can be denied drought relief. Therefore, several questions throughout the survey asked about these holdings, specifically, a water use permit by the government agency CONAGUA, a land title, a contract with the government agency CFE for electricity, and a birth certificate.

Capacity to manage water resources

In effort to consider which of the four types of drought impacted rancheros most, it was necessary to find out which water sources they relied on most. For example, if most rancheros responded with "well," then hydrological drought would probably have a stronger impact. It was assumed that rancheros would use different water sources for human and animal uses, so two separate questions were asked. In both of these questions, a "well" was an option that rancheros could choose, but as mentioned above, the legal access to a well was thought to give a household more adaptive capacity, so a question asked specifically about a CONAGUA permit. Adaptive capacity is required to act. Therefore, if rancheros took adaptation action in the last drought and planned to take action in the next drought, then they must have adaptive capacity. The ability to take adaptive action in times of drought was considered to be one of the proxies for the capacity to manage water resources. Another asset that rancheros can use to manage water resources is to store water. But a broken or abandoned form of storage is not helpful to a family, so I specifically asked if households had storage that was currently functioning and holding water. Lastly, it was assumed that households had a greater capacity to manage their water resources if

they could "read" the weather and climate by observing clues in the environment. It was assumed that doing so would be an indicator of the use of traditional knowledge that helped rancheros take preemptive action when the weather changed. The following questions were categorized as variables that indicate the capacity to manage water resources:

1. What is your principal source of water for human consumption?
2. What is your principal source of water for animal consumption?
3. Do you possess a permit from CONAGUA for water use (e.g., well)?
4. During the last drought (2006-2012), which action(s) did you take to reduce negative effects? (coded if the respondent chose multiple options)
5. During the next severe drought, which action(s) do you plan to take? (coded if the respondent chose multiple options)
6. Do you have some form of water storage for the future (that is functioning and holding water)?
7. How do you obtain drought information? (coded if the respondent chose "signs from the environment, e.g., late rains, animal behavior, etc.")

Education and health

In this study, heads of households who finished at least a primary education were assumed to contribute to greater adaptive capacity of the household, as has been found in previous studies (Eakin, 2005; Gray, 2009; Laczko & Aghazarm, 2009; Massey et al., 2010; Romero Lankao & Qin, 2011). Respondents were asked if household members participated in capacity building workshops offered by local organizations and if they planned on investing in education to respond to the next severe drought in the future. In addition, because healthy household members are better able to work and contribute to overall household capacity, respondents were also asked if any members had a disability or chronic illness, and if the head of household had health insurance. Respondents were also asked if they had birth certificates, and, because migration was a central component of the research question, if they had a passport. Therefore, the following

questions were categorized as variables that indicate households have the capacity to use their education and what their health status was:

1. How many years of education does the head of household have?
2. Do you have a birth certificate?
3. Do you have a passport?
4. Do you have health insurance?
5. Does anyone in your family have a disability or chronic illness?
6. Have you participated in a capacity building workshop?
7. During the next severe drought, which action(s) do you plan to take? (coded if the respondent chose "invest in education")

Social networks

The ability of households to use their social networks to travel or share resources in times of drought adds to their adaptive capacity. Migration was a central concern of the study, so respondents were asked about the social networks that could be useful in times of disaster. Respondents were also asked about specific people they could contact or travel with them to aid in the migration process. Social networks have also been measured in other studies through organizational membership and receipt of remittances (Narayan & Pritchett, 1999; Nelson et al., 2005). Respondents were also asked if they accessed their social networks to obtain information about drought and if they held their community responsible for helping them in times of drought. If respondents took action to adapt to the last drought, then they must have some adaptive capacity. Therefore, respondents were also asked if they worked with other families to share resources to respond to the 2006-2012 drought. The following questions were categorized as variables that indicate the capacity of rancheros to use their social networks:

1. Do you have a telephone number or address of someone in another place that you could contact if it became necessary to migrate?
2. Do you think you could find a travel companion if it were necessary to migrate right now?
3. Are you a member of an organization (for example a Water Users Association, Parent Teacher Association, etc.)?

4. Do you receive money from family members (remittances)?
5. How do you obtain drought information? (coded if the respondent chose "other rancheros")
6. Who do you think has the primary responsibility to help your family in times of drought? (coded if the respondent chose "my community")
7. During the next severe drought, which action(s) do you plan to take? (coded if the respondent chose "work with other families to share resources")

Land and animal ownership

Households with less ties to the land (such as owning land or animals) may be less likely to migrate as a response to disaster (Massey et al., 2010; Nelson et al., 2005). Households who have the option to sell commodities like land and animals can be said to have more assets to draw from to pay for disaster response, and therefore have more adaptive capacity. In Mexico, households who have a land title and own animals can receive federal money to recover from drought. Because of the *ejido* system in Mexico, in which land is collectively owned, it was assumed that some rancheros would report that they would have land but not necessarily a title. Therefore, two separate questions were asked – the first regarding a land title, and the second regarding how many hectares they had access to. Because local experts warned us that rancheros would be hesitant to tell us how many animals they had, data were collected as ranges instead of exact numbers. The following questions were categorized as variables that indicate the capacity of rancheros to use their land and animal holdings as material assets:

1. Do you have a land title?
2. How many hectares do you have access to?
3. How many cows do you have?
4. How many goats do you have?
5. How many mules do you have?
6. How many horses do you have?
7. How many chickens do you have?

Financial diversity

The household's ability to diversify income is said to be an important contributor to adaptive capacity because households then have more flexibility in meeting economic needs. Because local experts warned us that rancheros might not want to tell us their exact income, we asked which types of activities they received income from. The survey asked if they had access to credit, loans, or insurance for land, animals, or disaster. The survey asked if they adapted to the last drought by increasing their income through working more and if they thought they would diversify their income to respond to the next severe drought. The following questions were categorized as variables that indicate the capacity of households to diversify their finances:

1. Two or more sources of income
2. Do you have savings?
3. How do you expect to pay for the damages caused by the next drought? (coded if the respondent chose "savings")
4. Do you have insurance for land, animals or natural disasters?
5. Do you have access to credit or loans?
6. During the next severe drought, which action(s) do you plan to take? (coded if the respondent chose "work more")
7. During the next severe drought, which action(s) do you plan to take? (coded if the respondent chose "diversify income")

Adaptation strategy variables

Adaptation strategies are the actual adjustments actors make to modify their exposure and sensitivity to a hazard given their adaptive capacity. The following adaptation strategies were identified from the literature on sustainable rural livelihoods (Agrawal, 2010; Liverman, 1999): corral animals, plant more animal fodder, store food, plant food for personal use, migrate, work outside the area (defined as the watershed), share resources with other families, and doing nothing (see Appendix A). As described above, local experts were asked to add options, and the following were included: switch from cows to goats, sell more products, and obtain temporary

government work. The survey asked which adaptations they used in the last drought (2006-2012) and which they planned use in the next drought. Respondents were able to choose as many options as applied from a multiple choice list. They were also able to write in answers that were not given or to check "none." In particular, the ability of rancheros to adapt to drought through mobility was a primary interest of the study. Therefore, households were grouped by household heads who no longer lived in their place of birth and those who did.

Analysis structure

SPSS 22.0 was used to run descriptive statistics, chi-square tests, ANOVA, and a Binary Logistic Regression. Because of the use of the term *ranchero*, it might be assumed that the primary income generation among these rural households comes from raising livestock. Although people identified as rancheros only a portion of the households (21%) made their livelihood by ranching alone. Individuals within the households were asked to report their main occupation. The survey asked respondents to list and rank activities in which they received household income including: ranching, temporary government work programs, other regular work, selling market products (e.g., homemade cheese, candies, crafts), family business (e.g., restaurant, etc.), family (e.g., remittances), government aid, pension, savings, or other. Ultimately, livelihoods in this study are categorized by the head of household response into four categories: rancher, unemployed, unskilled and skilled labor.

3.2 Key informant interviews

Interviews were conducted in March-August 2013 with experts working on sustainable development initiatives around water resources in Baja California Sur, with officials in the central government, municipal water utilities, protected areas, universities, and NGOs. The interview guide included questions about how La Paz as a city has responded to drought in the

past, what has enabled those responses, and what have been challenges to adapting to drought (Appendix A). Interviewees were given the option of conducting the interview in English or Spanish. If the interview was conducted wholly or partially in Spanish (9 of 16), a professional translator provided simultaneous translation to ensure that the exact meaning of their responses were captured. Interviewees were given the option to decline audio recording. If recorded (9 of 16), the interview was transcribed by a trained assistant in Spanish and then translated into English (by the author) when necessary.

Sample selection

Interviewees were first chosen using a strategic sampling method targeting individuals in three water sectors: production, distribution, and water use, and contacted via email. This process resulted in an initial set of only three interviews due to the initial lack of rapport established in the area. The snowball sample method - using past participants to suggest and contact potential interviewees by phone (in Spanish) - was employed to identify and secure the remaining 13 interviews that were thought to be valuable sources of information for the research. Attempts were made to secure interviews across municipal, state, and federal levels of governance. The final set of 16 interviews is provided in the interview participant list (Table 3.4). Interviews were conducted until information began to overlap and no new insights were revealed, for a total of 16 interviews.

Table 3.4 Interview participant list

Level	Department	Title	Language	Recorded
Municipal	OOMSAPAS (Municipal water)	La Paz Technical Secretary	Spanish	Yes
Municipal	OOMSAPAS (Municipal water)	Rural Systems Coordinator	Spanish	Yes
State	Department of Sustainable Development	Sustainable Development Director, Baja California Sur	English	Yes
State	UABCS (University)	Professor, Economics and Sustainability	English	Yes
State	UABCS (University)	Professor, Anthropology and Rural Tourism	English/ Spanish	No
State	UABCS (University)	Professor, Economics, Advisor to State Plan on Climate Change	English	No
State	CONANP (Protected areas)	Ecosystems Manager	Spanish	Yes
State	CONANP (Protected areas)	Director of the Biosphere Reserve	English	Yes
State	CIBNOR (University)	Hydrology and Irrigation	English	Yes
State	CONAZA (Arid Zones)	Biologist	Spanish	No
State	CONAGUA (Water Commission)	Chief of Communication, Baja California Sur	Spanish	No
State	CONAGUA (Water Commission)	Chief of Meteorology, Baja California Sur	English	No
State	CONAGUA (Water Commission)	Subdirector on the Advisory of Watersheds, Social Management, and Emergencies	Spanish	Yes
State	Niparajá (NGO)	Director of Water Conservation	English	No
Federal	SEMARNAT (Secretary of Environment and Natural Resources of Mexico)	Engineer, National Coordinator of the Blue Agenda Advisory Committee	English/ Spanish	Yes
Federal	Enlace Cambio Climatico (Climate Change Network)	General Coordinator of Sustainable Development	Spanish	Yes

The following representatives were interviewed: officials from the State Sustainable Development Program, National Commission on Arid Zones (CONAZA), the National Commission of Natural Protected Areas (CONANP), professors of economics and anthropology at the Universidad Autónoma de Baja California Sur (UABCS), and a professor of hydrology at the Northwestern Center of Biological Research (CIBNOR). To understand how water is distributed throughout the watershed, I interviewed the Coordinator of Rural Systems at the municipal water office (OOMSAPAS), the acting director of the state civil engineering projects, and representatives from different divisions at the state headquarters of CONAGUA, the National Water Commission. To understand how water is used throughout the watershed, I interviewed the director of the water conservation program of a local non-profit. Several sectors are not represented among the interviews, notably commercial water, commercial agriculture, energy, tourism, and real estate - sectors which consume large amounts of municipal water and impact water pricing, regulation, and distribution. Attempts to contact personnel in those sectors and secure interviews within the time constraints of the project were unsuccessful. Future studies incorporating the interactions of these sectors within the water system would be ideal.

Analysis

The online qualitative analysis program Dedoose was used to code events, enablers, and challenges to transition in the history of urban water infrastructure in La Paz. I employed a qualitative content analysis to code main ideas into enablers and challenges of urban water development as respondents saw it. I constructed a timeline using the responses and perceptions of the participants to outline when infrastructure was built. City plans and historical documents were added to the analysis to complete the timeline of urban water infrastructure development. I

then compared the development of La Paz to cities around the world using a literature review and using one summary to code stages (Brown, Keath, & Wong, 2008):

1. Water Supply City (coded by water delivery, city wells, and pipes)
2. Sewered City (coded by sewage and waste infrastructure)
3. Drained City (coded by drainage systems, dams)
4. Waterways City (coded by point source pollution regulations)
5. Water Cycle City (coded by conservation, restoration, and reuse efforts)
6. Water Sensitive City (coded by introduction of multiple purpose planning, interdisciplinary collaboration, stakeholder involvement)

Interview transcripts were coded for traditional views of water infrastructure development: 1) system boundaries set by the built water infrastructure system, 2) a compartmentalized management approach, 3) technical and economic knowledge as the recognized expertise, 4) centralized and linear service delivery, 5) the role of the government as management, and 6) risk seen as something that needs to be regulated. On the other hand, the following were coded as sustainable-leaning: 1) systems defined by multiple purposes, 2) adaptive and integrated management approaches, 3) recognition of interdisciplinary and stakeholder expertise, 4) a flexible service delivery on multiple scales, 5) co-management by government, business, and people, and 6) shared and diversified risk. Respondent comments were further coded according to challenges and enablers to implementation.

Participant observation

Participant observation was essential for understanding water use regimes among different social groups in the watershed. Because water is often taken for granted, asking about water access and allocation sometimes provides little meaning - understanding household systems requires visitations. Participant observation was exceedingly important to corroborate the information from the interviews and surveys and to establish rapport with participants through multiple meetings. I spent five weeks from August – September 2012 in Baja California

Sur doing a pilot study and an additional eight months from February – September 2013 to collect data. From February – May 2013, I rented an apartment in downtown La Paz with a key informant who is a La Paz native and a water conservation professional. I also audited an undergraduate level social science course on Rural Tourism at the local university (UABCS) to learn about rural culture throughout the state. This experience gave me the experience of interacting with local students, who often told stories of their *ranchero* relatives and their experiences visiting the ranches. From June-September 2013, I took advantage of the fact that home owners from Canada and the United States often return north to escape the heat and took up housesitting. This turned out to be an important observation for understanding access to urban water infrastructure for another social group in the area. This situation gave me the opportunity to learn about different home water systems among a different social group, foreign home owners, who use water in the desert.

Deliverables

The survey process was successful in establishing trust among *rancheros*. While conducting the survey, some respondents volunteered to guide us to other households that were difficult to locate. Others, like the Subdelegadora (sub-delegate) of San Blas in the Sierras and Chuy, a respected local in San Javier, provided introductions to respondents that were important in gaining entry to other households in their respective areas. Results of the survey were written in reports in Spanish and distributed to survey respondents (Appendix D).

CHAPTER 4: Drought migration and the rancheros sudcalifornianos in Mexico

4.0 Introduction

Drought management among the rural population of Baja California Sur is a salient issue because climate change is predicted to bring to the area more severe and frequent droughts in the future (Cavazos & Arriaga-Ramírez, 2012). Climate uncertainty presents a challenge to the ability of rural families to manage water resources as they had in the past. Rural inhabitants who occupy areas that serve as critical water recharge zones for larger metropolitan areas have the potential to alter water capture in the watershed via actions such as controlling upstream sediment, monitoring riparian areas, and increasing soil productivity. While governments at the federal, state, and municipality levels seek stakeholder involvement in water management activities, more data is needed to understand the real needs, capabilities, and adaptation strategies of the rural population. In order to structure water conservation efforts that resonate with the rural population, it is vital to understand their traditional and current practices with regards to water use. The narratives of these rancheros have yet to be fully incorporated into risk reduction planning for drought and water management.

The environmental migration and climate vulnerability literatures suggest that vulnerable populations households are likely to use migration as a response to drought. A household survey was conducted to assess vulnerability among drought-exposed rancheros by measuring sensitivity to the last severe drought (2006-2012) and adaptive capacity (water resource management, financial diversity, education and health, and land and animal ownership) which allows rancheros to use drought adaptation strategies, particularly migration. The key findings from the household survey data are that rancheros are sensitive to drought and that migration is

not a primary response to drought even though it is part of the ranchero traditional culture. The data also falsifies the assumption that rancheros are a homogenous group – Sierras rancheros seek diverse types of employment other than ranching, although they still self-identify as a culturally distinct group, called rancheros sudcalifornianos. Results show that migration is not conclusively linked to drought as predicted by the environmental migration and climate vulnerability literatures.

Sensitivity

Because rancheros live in the semi-arid desert in which drought is a frequent occurrence, it has already been determined that they are exposed to drought. However, it is precisely because of this experience of living under these conditions for so long that one might assume that they have adapted and, therefore, are not sensitive, or affected by stress. To test if this was a correct assumption, I asked three open-ended questions: 1) which environmental threat respondents perceived the most (a perception and awareness of stress), 2) if they thought the weather had become more unpredictable in the last 10 years (a perception and awareness of stress), and 3) if they had to change their water source (an active response to stress). Because external conditions are not static, households must be dynamic and adaptable to changing conditions. But people cannot modify their sensitivity unless they have the adaptive capacity to do so. Interacting factors constrain and create opportunities from which to modify drought sensitivity.

Livelihoods

Sensitivity has also been correlated to occupational dependency on resources (Joshua E Cinner & Bodin, 2010). To assess if rancheros' occupations were dependent on water resources, I asked for head of household occupation, occupations of each household member, and a list of

all income streams to the household. This chapter reports household livelihood by head of household occupation for simplicity.

Adaptive capacity

The ability of households to adjust to stress, their adaptive capacity) is based on their cumulative internal assets (e.g., health, geography) as well as assets that they have from being a part of social organizations (e.g., formal education, markets, government, other institutions). In this study, measures of adaptive capacity are categorized into five groups: 1) the ability to manage (water) resources, 2) diverse financial streams, 3) education and health, 4) social networks, and 5) land/animal ownership.

Response, adaptation and migration

Adaptation strategies, or responses, are the actual activities that households make to modify their exposure and sensitivity given their adaptive capacity. I grouped households by heads who no longer lived in their place of birth and those who did to observe differences between migrating and non-migrating households. I also asked participants how they responded (including migration among other adaptations) to the last severe drought (2006-2012) and how they think they would respond to the next one to observe if households with different adaptive capacities participated in different adaptation strategies. Respondents could choose more than one response or add their own.

4.1 Methods

First, I assess the drought sensitivity of rancheros using their perceptions of environmental threats and predictability of weather, as well as if they have had to change their water source due to drought. I then describe the sample as a whole and by type of livelihood using descriptive statistics. A chi-square was used to test if households with different livelihoods

engaged in different adaptation strategies in the last drought or have different plans to adapt to drought in the future. I use a one-way ANOVA to test if households with different livelihoods have different characteristics and to test if heads of households who have migrated have different characteristics. To determine if migration could be predicted based on characteristics of the households, a Binary Logistic Regression is used. The organizational logic of the analysis is as follows:

1) Sensitivity
2) General characteristics of contemporary rancheros in the Sierras
    - Livelihoods
    - Physical conditions
    - Demographics
3) Investigation of the relationship between household characteristics with adaptation strategies
    - Correlation of livelihood with drought adaptation strategies
4) Identification of which heads of households have migrated and which have not
5) Investigation of the relationship between head of household migration with adaptation strategies
    - Correlation of head of household migration with drought adaptation strategies
6) Investigation of the relationship between head of household migration with household characteristics
    - Correlation of head of household migration with characteristics
    - Prediction of head of household migration by characteristics

A comparison is then made between ranchero respondents in the Sierras with respondents from San Javier, another community in the state.

4.2 Results

1) Sensitivity

Most respondents (84%) listed drought and water scarcity as their primary environmental threat – this was true even though the survey was not conducted during a drought. This finding was taken to indicate that rancheros were aware of drought as a constant threat and not just one that was immediately apparent. Further, almost all respondents (93%) said that they had noticed

that the weather had become more unpredictable in the last ten years. In particular, they noticed that the summer monsoon season has been starting later and later. One respondent said: ““I remember when I was young the rains used to begin earlier in the month of June and July but now, no, not anymore.” Again, the fact that respondents were aware of change suggests that they are sensitive to weather and climate conditions. About a quarter (27%) have had to change where they sourced their water from in the last 10 years.

2) General characteristics of contemporary rancheros in the Sierras

Livelihoods

The term ranchero suggests a traditional ranching livelihood involving producing goods made from livestock. Although 77% reported that they raised animals of some sort, only 6% of the respondents said that ranching accounted for their entire household livelihood. Further, less than half (45%) said that ranching accounted for some portion of their income. Sixty-one percent said that they had two or more incomes. Head of household occupation response clustered into livelihoods in the following categories: 1) “rancher” (livestock management and agriculture), 2) “unskilled labor” (*jornaleros*, or day-laborers), 3) “skilled labor” (accountants, social workers, and government workers), and 4) “unemployed” (pensioners, homemakers). Under this scenario, ranching was only the second most common occupation among heads of households in the sample (21%) after unskilled labor (41%).

Physical conditions

Many had a solar panel that powered a radio and other small appliances. Forty-seven percent of households saved water for future droughts in a storage tank called a *tinaco*. Most of the respondents fetched their drinking water from wells (60%) and surface water like arroyos and natural springs (10%). However, many (35%) also accessed water through the municipal pipe network and water trucks. Some (19%) used municipal water for their animals. The survey did not include questions about sanitation (see Chapter 3), but observations revealed that outhouses were the dominant toilets in the rural households, although some houses closest to the road had flush toilets.

Demographics

Household size of the sample ranged from 1 to 14 with a mean of four and a mode of three. The mean age of the heads of households in the sample was 58 with a range of 24 to 92. Of households that lived in the same locality their entire lives, the heads were much older, with an average age of 72. The majority (87%) of heads of household had some form of formal education. Meanwhile, 22% of the heads of households received an education beyond the elementary level (an adaptive capacity measure of education). Less than a third (27%) reported that someone in their household had a chronic illness or disability. Seventy-eight percent of households said that they had health insurance to help if someone in their family fell ill or suffered an injury.

Fifty-nine percent of respondents reported that they owned the title to their land (an adaptive capacity measure of land and ownership). A third said that they owned 20 hectares or less while 28% owned more than twenty hectares. The majority of households (68%) owned cows. Almost half (49%) raised chickens while 40% owned goats, 18% owned horses, and 6%

owned mules. Many respondents said that drought affects their animals first and hardest. Corralling animals was an important coping strategy rancheros used to save their animals. Twelve percent of households reported that they worked with other families to share resources in the last drought while 28% said that they would collaborate to survive future droughts. Eleven percent of respondents said that they were a member of an organization like a parent association or a water committee. Over half (53%) said that they had contact information of someone in another place if they found themselves in a situation where they had to evacuate.

The results of the chi-square test determined if households with different livelihoods exhibited different characteristics (listed in Table 4.1). Again, although all respondents in the sample considered themselves rancheros, not all ranched as a primary mode of income. Because of this, ranchero households were grouped according to the head of household occupation. The only characteristics in which there were statistically significant differences between the livelihoods were water access and access to insurance (Table 4.1). Ranchers were more likely than those in other occupations to draw from wells (80%) while skilled laborers were more likely to access urban water (46%). Households with rancher heads were more likely than the other groups to prepare for drought by keeping a personal water reserve. Ranchers continued learning through capacity building workshops[2] but they were the least likely to hold membership in an organization that could be useful in preparing and responding to droughts. They were also more likely to have a chronically ill or disabled person in their household. Meanwhile, unskilled

[2] For example, economic development programs have been conducted to teach *rancheros* how to tan hides that they would otherwise throw away (*personal communication*, CONAZA official, 2013). However, some projects have been derided as unnecessary, such as those teaching women to make plastic home decorations (*personal communication*, UABCS professor, 2013).

laborers (day laborers) in this study were the most likely occupational group to own the title to their land and to have access to some type of property insurance (Table 4.1).

Table 4.1 Selected characteristics of different livelihoods.

	Unemployed N = 22	Unskilled Labor N= 49	Skilled Labor N = 24	Rancher N = 25	**Total N = 120**	x^2 p-value
Sensitivity						
Perceived change in weather predictability, last ten years	96%	94%	92%	92%	93%	.948
Water resource management						
Urban water access for human use	50%	35%	46%	12%	35%	**.026***
Surface water access for human use	14%	8%	13%	8%	10%	.853
Ground water access for human use	37%	63%	58%	80%	61%	**.023***
Functioning water storage unit	14%	20%	13%	24%	82%	.672
Education and health						
More than primary school education	10%	18%	33%	28%	22%	.202
Access to health insurance	86%	82%	67%	76%	78%	.368
Disability or chronic illness in household	23%	29%	17%	36%	27%	.456
Capacity building workshop	41%	31%	25%	44%	34%	.442
Social networks						
Member of a local organization	23%	8%	13%	4%	11%	.182
Household has network tie	50%	65%	46%	36%	53%	.092
Weather forecasting based on social network	41%	74%	58%	68%	63%	.06
Land and animal ownership						
Own land title	55%	63%	63%	52%	59%	.759
Horses	27%	47%	21%	32%	35%	.118
Cows	77%	63%	58%	76%	68%	.376
Financial diversity						
Diversified income	68%	59%	50%	68%	39%	.517
Savings for the next drought	23%	31%	33%	32%	30%	.864
Property insurance	0%	20%	4%	4%	10%	**.017***
Access to loans or credit	5%	25%	25%	20%	20%	.223
Percentage indicates within livelihood group reporting. * and bold indicates significance at p = <.05						

3) The relationship of household characteristics with adaptation strategies

There were no statistically significant differences between livelihoods and past adaptation strategies (Table 4.2). The most popular choices of adaptation in the previous drought (2006-

2012) were to corral animals and find work in the temporary government program (PET).[3] The least popular choice was to switch from cows to less water-intensive goats. Ranchers were most likely of the livelihood groups to corral animals. Households whose heads were employed in the skilled labor fields were the most likely to migrate in the recent drought and to find work outside of the area. They were also the least likely to have not tried any of the listed strategies to adapt to the last drought. The most popular choice of both the unemployed and unskilled labor households was to take advantage of the government temporary work program (PET). The unemployed were most likely to have done nothing to adapt to the last drought.

Table 4.2 Adaptation strategies to last drought (2006-2012) by livelihood

	Unemployed N =22	Unskilled Labor N= 49	Skilled Labor N = 24	Rancher N = 25	Total N= 120	x^2 p-value
Government temp work (PET)	36%	29%	29%	32%	31%	.930
Corral animals	18%	29%	38%	40%	31%	.587
Work outside the area	14%	18%	29%	12%	18%	.411
Store food	9%	20%	21%	20%	18%	.801
Did nothing	32%	12%	8%	16%	16%	.321
Migrate	5%	14%	21%	4%	12%	.388
Share resources with other families	9%	6%	17%	20%	12%	.276
Sell more products	9%	10%	8%	20%	12%	.728
Plant more animal fodder	14%	4.1%	8%	8%	8%	.752
Plant food for personal use	0%	10%	4%	12%	8%	.552
Buy more	5%	6%	4%	4%	5%	.973
Switch from cows to goats	0%	8%	0%	8%	5%	.487
Dark shading represents popular adaptation strategies per group. Light shading represents least popular adaptation strategies per group. Percentage indicates within livelihood group reporting.						

Only three household respondents anticipated that they would rely on their family for help in a future drought (an adaptive capacity measure of social networks). The most popular plans for adapting to future droughts were to conserve water or to do nothing (Table 4.3). The

[3] Many PET programs involve building roads and installing street infrastructure (benches, lights) for tourism. Another example is a government dam building program which hires rancheros to bring stones to the site while the government pays for cement, hoses, pipes, etc. (personal communication, CONAZA official, 2013.)

least likely plan overall was to migrate. Ranchers were the most likely to have multiple plans for future droughts while the unemployed were the least likely to have any plans. Households whose head is employed in the skilled labor occupations were more likely than any other group to invest in education to adapt to future droughts (Table 4.3). Here too there were no statistically significant differences between livelihoods and predicted adaptation strategies (Table 4.3). However, it is clear that ranchers have the most plans and the unemployed have the least plans. Across the survey, if respondents did not plan on conserving water, they would otherwise not have a plan.

Table 4.3 Planned adaptation strategies for future droughts by livelihood

	Unemployed N = 22	Unskilled Labor N= 49	Skilled Labor N = 24	Rancher N = 25	Total N= 120	x^2 p-value
Migrate	0%	8%	4%	8%	6%	.419
Store water	14%	29%	21%	40%	27%	.234
Conserve water	32%	22%	38%	48%	33%	.222
Diversify income	9%	12%	17%	20%	14%	.697
Invest in education	5%	6%	21%	8%	9%	.204
Work with others	18%	29%	21%	44%	28%	.236
No plans	50%	31%	33%	20%	33%	.220
Multiple responses were recorded. Percentage indicates within occupational group reporting. Dark shading represents the most popular adaptation strategies per group. Light shading represents least popular adaptation strategies per group.						

4) Identification of which heads of households have migrated and which have not

In the sample, no heads of household moved internationally, all but two stayed within the state of Baja California Sur, and the majority stayed within the watershed boundaries. Who migrated and who did not was determined by a 2 samples t-test (chi-square and Fisher's Exact Test with assumed equal variances) where adaptive capacity is the response variable and migration status as the predictor. Three variables showed statistical significance were access to

surface water (p = .035), diversified income streams (p = .049), and access to loans or credit (p = .043) (Table 4.4). More heads of household (5%) who had not migrated reported that they used surface water (e.g., arroyos, oases) for human consumption. Meanwhile 3% of heads who had migrated used surface water. Further, households in which the head has migrated were more likely to access urban and ground water (e.g., wells) (although not statistically significant). Meanwhile, households who had never migrated were more likely to store water on site. Heads with more financial resources (diversified income streams, access to loans or credit) were more likely to have migrated.

Table 4.4 Characteristics of households with and without head of household migration

	Head of household has never migrated N = 47	Head of household has migrated N = 68	Total N = 120	x^2 p-value
Sensitivity				
Perceived change in weather predictability, last 10 years	34%	55%	93%	.096
Water resource management				
Urban water access for human use	11%	23%	35%	.253
Surface water access for human use	5%	3%	10%	**.035***
Ground water access for human use	27%	33%	61%	.318
Functioning water storage unit	31%	25%	58%	.435
Education and health				
Primary school education or less	30%	44%	39%	.470
More than primary school education	8%	13%	57%	.470
Access to health insurance	29%	45%	78%	.398
Capacity building workshop	11%	22%	34%	.482
Disability or chronically ill member	10%	17%	27%	.348
Social networks				
Member of a local organization	9%	2%	11%	.094
Household has network tie	19%	33%	53%	.223
Weather forecasting based on social network	2%	9%	11%	.094
Land and animal ownership				
House plot owned	23%	34%	59%	.671
Cows	29%	35%	68%	.299
Horses	11%	8%	18%	.081
Financial diversity				
Diversified income	27%	30%	61%	**.049***
Savings for the next drought	14%	17%	32%	.633
Property insurance	4%	6%	10%	.747
Access to loans or credit	4%	16%	20%	**.043***
Demographics				
Age	Mean = 55	Mean = 55	Mean = 55	
Household Size	Mean = 4	Mean = 4	Mean = 4	
Five households did not report head of household migration status. * p<.005, **p <.01, *** p<.001				

5) The relationship of head of household migration with adaptation strategies

Twelve percent of total respondents reported that they migrated as a response to the previous drought (Table 4.5). Heads of households who had migrated at some point in their lives were also more likely to have said that they had migrated specifically as a response to the last drought. Households in which the head had not migrated were more likely to plant more animal fodder and food for personal use, sell more products, and make more purchases in times of

drought. Less than half of survey respondents (45%) reported using more than one strategy to respond to drought while it was happening. The two most popular strategies were corralling animals and obtaining work from the government temporary work program PET (Table 4.5). However, no adaptation strategy was correlated, with statistical significance, with head of household migration.

Table 4.5 Adaptation strategies of households with head of household migration

	Head of household has never migrated N = 47	Head of household has migrated N = 68	Total N = 120	x^2 p-value
More than one strategy	18%	25%	45%	.935
Corral animals	13%	17%	31%	.756
Switch from cows to goats	2%	3%	5%	.444
Plant more animal fodder	4%	3%	8%	.359
Store food	8%	8%	18%	.395
Sell more products	8%	4%	12%	.186
Plant food for personal use	5%	3%	8%	.297
Migrate	3%	8%	12%	.521
Government temp work	13%	16%	31%	.670
Work outside the area	4%	14%	18%	.083
Share resources with other families	3%	8%	12%	.621
Buy more	3%	2%	5%	.352
Did nothing	5%	10%	16%	.752
Shaded boxes represent high percentages per category. Five households did not report head of household migration status.				

A one-way ANOVA tested for migration differences among the five characteristic groupings. Migration did not differ significantly across the five capacities, except in education and health, $F(2, 112) = 3.787$, $p = .026$. This suggests that, consistent with the literature, education and health are important for migrating households (Table 4.6).

Table 4.6 One-Way ANOVA migration differences by characteristics

	df	F	Sig.
Water resource management	2 112	.666	.516
Social networks	2 112	1.482	.232
Financial diversity	2 112	1.585	.209
Land and animal ownership	2 112	2.032	.136
Education and health	2 112	3.787	.026

To determine if migration could be predicted based on adaptive capacity based on a clustering of characteristics, a Binary Logistic Regression is used. Migration is the response variable, and each grouping is a predictor variable (Table 4.7). The relationship between migration and the capacity to manage water resources is not significant, but it is negative, suggesting that the more access to freshwater a household has, the less likely they might be to move. Land and animal ownership is significantly correlated with migration status in a negative direction.

Table 4.7 Binary Logistic Regression by head of household migration

		Parameter Estimate	SE	Sig.
	Water resource management	-.175	.156	.261
	Social networks	.290	.196	.140
	Financial diversity	.148	.156	.344
	Land and animal ownership	-2.83	.138	.04
	Education and health	.178	.182	.327
			.182	.464
Pearson goodness of fit statistic	145.027			
Cox & Snell R Square	.088			
Nagelkerke R Square	.118			

4.3 A small comparison study: differences between San Javier and Sierras

Traveling from San Javier to the municipal capital of Loreto is far more difficult than traveling from the Sierras to the municipal capital of La Paz (*personal observation*, 2013). Due to difficulty in transport, San Javier households receive less access to urban services than rural households near La Paz. In fact, only 5% of San Javier households reported using municipal water for human consumption while 35% of Sierra households did. While 19% of Sierra households used municipal water for animals, no San Javier households did (Table 4.8).

The mean household size of the San Javier sample was slightly larger at five persons, compared to four persons in the Sierras. The head of household was slightly younger, at 55 compared to 58 in the Sierras. San Javier respondents were slightly less likely to have a household member that was chronically ill or disabled (70% compared to 73%). Households in San Javier were more likely to gain at least some of their income from traditional ranching, 56% compared to 45% in the Sierras. They were slightly more likely to report holding a land title: 63% compared to 60%. Households in San Javier were equally likely to own chickens and slightly more likely to own cows. They were far more likely to own mules, horses, and goats. Sixty-one percent of households in San Javier reported that they equally grow and buy food to eat. Only 3% in the Sierras reported the same (Table 4.8).

Ninety-five percent of households in San Javier reported that at least one member has migrated in the past (compared to 85% in the Sierras): 65% to an urban area (compared to 43% in the Sierras), 74% to a rural area (compared to 53% in the Sierras), and 30% circularly (compared to 44% in the Sierras). In San Javier, 28% of the sample reported that they migrated in response to the last drought, and 9% said they might migrate in the next drought. In the Sierras, 11% said they migrated in the last drought, and 6% said they might in the next drought.

Households in San Javier were much more likely to report that they would leave their community if there were a natural disaster (21% compared to 4%). Even so, their highest ranked reason for ever leaving was for health issues (49% compared to 10% in the Sierras).

Five percent of San Javier households accessed urban water for human consumption and none for animal consumption, while, in the Sierras, 35% accessed urban water for human consumption and 19% for animals. Respondents in San Javier were more likely than those in the Sierras to hold multiple agents responsible to help their family in times of drought: themselves (72% compared to 15%), the government (70% compared to 48%), and their community (33% compared to 4%). Those in San Javier were more likely than those in the Sierras to be a part of a community association (23% compared to 11%). They were also more likely to obtain information about droughts from other ranchers (42% compared to 28% in the Sierras). They were also slightly more likely to "read" the environment for signals that would indicate drought (47% compared to 43%). Households in San Javier were slightly more likely to report that they had savings to pay for damages in the next drought (35% compared to 30%). They were also more likely to keep a functioning water storage unit on their property (63% compared to 58% in the Sierras). This finding indicates that San Javier households may be more self-reliant in drought scenarios, potentially out of necessity since they have a harder time accessing urban services.

Table 4.8 Selected differences between sampled San Javier and Sierras rancheros

	San Javier	Sierras
Mean household size	5	4
Mean head of household age	55	58
Chronically ill/disabled member	70%	73%
Ranching livelihood	56%	45%
Own land title	63%	60%
Own cows	75%	68%
Own mules	46%	6%
Own goats	70%	40%
Grow own food	5%	3%
Buy own food	26%	87%
Grow and buy food	61%	3%
At least one member has migrated	95%	85%
At least one member has migrated to an urban area	65%	43%
At least one member has migrated to a rural area	74%	53%
At least one member has migrated circularly	30%	44%
Head of household migrated in response to the last drought	28%	12%
Head of household plans to migrate in response to the next drought	9%	6%
Would leave area if there were a natural disaster	21%	4%
Would leave area due to health concerns	49%	10%
Uses urban water for human consumption	5%	35%
Uses urban water for animal consumption	0%	19%
Self is responsible for drought relief	72%	15%
Government is responsible for drought relief	70%	48%
Community is responsible for drought relief	33%	4%
Member of community association	23%	11%
Obtains drought information from other ranchers	42%	28%
Obtains drought information from environmental signals	47%	43%
Used savings to cope with the last drought	35%	30%
Owns a functioning water storage unit	63%	58%

4.4 Discussion and implications

Livelihoods

Although the term ranchero connotes a livelihood based on raising livestock, the rancheros in this study area were found to rely on several sources of income. Only 25 heads of households receive their sole means of livelihood from ranching, and most households have non-ranching members. Local experts have claimed that the ranchero culture will "die out" in the next two generations because of rancheros evolving to incorporate other livelihoods, and also because generation-to-generation knowledge transfer is hindered by the formal education system

(*personal communication*, Fermín Reygadas, anthropologist, 2013). It is clear from the survey data that rancheros are adapting to larger social organization change through livelihood change.

Sierra ranchero household sensitivity

To answer the question if the sample population was sensitive to drought, the survey respondents answered with a resounding "yes" across all livelihoods. By a substantial majority, respondents perceived drought to be their most prominent environmental threat and responded that the weather has become less predictable in the last ten years. Fewer respondents reported that they had to change their water reservoirs; they added urban services such as water truck delivery and pipes as water sources.

Sierra ranchero household adaptive capacity

The household survey found that rancheros across all livelihoods ranked low in several measures of adaptive capacity. Only 22% of all heads of household had more than primary school education, a measure of education. Only 11% were members of a local organization, a standard measure of social networks. Only 39% were able to diversity their incomes, and only 30% were able to save for the next droughts, measures of financial diversity. However, more than half, 59% owned a land title, and more than half, 68%, owned cows. These are measures of land and animal ownership and assets that can be valuable if they needed to be sold to raise money for disaster relief.

In looking at different livelihoods in terms of adaptive capacity, ranchers were the group to be more likely to have a household member who was chronically ill or disabled. Having immobile household members may hinder their ability to evacuate quickly in a disaster situation

and may reduce overall household ability to recover from disasters in the long-term by decreasing labor productivity.

Skilled laborers were statistically more likely than any other group to use urban water for human use. While it might be assumed that skilled laborers, who have steady jobs, or ranchers who need land for livestock, would be more likely to own property and insure it, it was the unskilled laborers who were most likely to own a title to their land and have insurance. Because disaster funding is typically disbursed to property owners and those with insurance, unskilled laborers may have an advantage.

Sierra ranchero household adaptation

Although anecdotally rancheros have a tradition of moving in times of drought, only 12% of contemporary rancheros the Sierras sample reported that they moved during the previous drought (2006-2012) as a direct response. This population does not show signs of modifying their exposure to drought by moving to more water secure locations. Instead, findings showed that this sample has a small and potentially growing reliance on urban water to reduce exposure to drought and reliance on government services such as the temporary work programs to reduce sensitivity in times of drought. In San Javier, one household was in the process of moving specifically to be near a well holding water. Six additional interviews were conducted with elders in the San Javier site, anecdotally confirming that migration during past droughts was typical in this area. This finding may indicate that households further from an urban center are more likely to migrate to decrease their exposure to drought. In fact, San Javier households reported higher rates of migration than Sierras households on all measures – total migration, urban migration, rural migration, and circular migration. San Javier households were also more likely than Sierras

households to have reported migrating as a response to the last drought and plan to migrate to respond to the next drought (see Table 4.8).

The urban component

Tapping into urban services seems to be growing as informed by informal interviews outside of the structured survey. In the household survey, respondents were asked how they accessed water and were given groundwater and surface water options. It was assumed that most households in this area would draw their water from a well or fetch it from natural springs or arroyos (rivers) when they contained water. Over 60% of total households did indeed report that they obtained water for human use from a well and 10% from surface water. It was assumed at the beginning of the study that rural households were isolated based on information gathered in the city center. Therefore, it was surprising that many of the respondents in the Sierras indicated that they used water from urban sources for human use (35%) as well as for animals (19%). Many reported that they relied on the federal (CONAGUA) or municipal (OOMSAPAS) agencies to supply cisterns and to deliver water by truck twice a week. However, reliance on urban services is uneven – heads of households who ranched were much more likely to rely on wells (80%) as opposed to municipal services (12%). Dependency on wells might indicate that ranchers might be more sensitive to hydrological drought. Meanwhile, skilled laborers were able to access both (46% urban, 58% groundwater). Because many respondents chose multiple answers, municipal services may be acting as a buffer to add another option for rancheros to access. However, urban water delivery is not constant but fluctuates depending on water supply (see Chapter 5). This situation suggests that urban services are influencing overall adaptive capacity among Sierra rancheros, but not their sensitivity. If rancheros come to expect urban

water services, their vulnerability will increase in times of drought when the urban utilities fail to serve them.

4.5 Conclusion

This study concludes that drought does not always cause out-migration due to broader social, political, and economic complexity that is exacerbated in globalized and urbanized water systems. Previous studies have found that drought can lead to out-migration under certain conditions, but this study found that migration is not used as a modification of household exposure to drought among contemporary rancheros in this area. In the case study area of the Sierras, the results do not support that drought is pushing people out of their current homes. Instead, there appears to be a trend towards immobility. On the one hand, survey data along with conversations among the studied population revealed that rancheros preferred this situation. When respondents were asked if they wanted to move away from their current locations, many were emphatic in their preference for rural life especially in comparison to what they felt was a needlessly stressful life of the city. In this way, many rancheros in the study exhibited attachments to their identities as rancheros. They encouraged the idea of separation from urbanity, no matter how closely connected their occupations and daily behaviors were linked to urban services.

Despite an overwhelming response from participants in their desire to stay where they are, it can be speculated whether or not rancheros would be able to move if they wanted to. Coastal tourism developments and the transition from *ejido* (common property) to private property constrain traditional mobility options. In countries around the world, nomadic transition to immobility has been linked to concentrated land use in areas that were once allowed partial or total rest from grazing. This situation may contribute to the complex interactions that lead to land

degradation (Weber & Horst, 2011). Future studies should explore the consequences of immobility among this population – both the negative impacts of who benefits when this population becomes immobile as well as positive potentialities of building on an already existing sense of place - to support water conservation activities through community solidarity. Future research can determine if an anthropological approach to social capital through the measurement of informal connections (e.g., kin, friends) would be a helpful addition to understanding collaboration in this community. Efforts to build social capital might take this into consideration and promote activities as informal gatherings.

It might be assumed that because rancheros have lived in the desert for 300 years, they would be fully adapted, and therefore not sensitive to drought. This study revealed that, on the contrary, contemporary rancheros are sensitive to drought. Changes in drought frequency and severity along with changing social organization that are linking this particular group to municipal services are providing new opportunities and constraints for adapting to new conditions. Rancheros are adapting their livelihoods by incorporating *jornalero* (temporary) work, exploding a stereotype that rancheros are a homogenous group. They are not totally dependent on ranching, in fact, only 6% of all households reported that they ranch as their sole source of income. Contemporary rancheros in the Sierras are also accessing fresh water for both themselves and their animals through the municipal system – either through pipes to their houses or through water truck delivery. It would be misleading, however, to assume that all rancheros throughout the state are universally integrated into urban services. This study shows that households in another municipality are more isolated. The data suggest there are real differences among communities in drought response depending on distance to urban and water infrastructure.

For development practitioners, the implication of this research highlights water security as a development strategy to increase the adaptive capacity of rural households. While migration could not be conclusively linked with drought, this study presents baseline data that can be used in future studies to compare to other communities in Baja California Sur, or to begin longitudinal data to observe temporal patterns. The case study offers a snapshot of how rancheros in this particular watershed adapt to water variability given their access to certain resources. This study encourages understanding and recognition of the human experience of rancheros sudcalifornianos in the Sierras of the La Paz, Mexico watershed toward inclusive, sustainable development.

CHAPTER 5: Urban forces influencing household vulnerability in the La Paz watershed

5.0 Introduction

The previous chapter found that rancheros in the Sierras do not respond to extreme drought in isolation from the City of La Paz. Rather, their level of interaction with nearby urban services allows them to adjust their livelihoods and adaptation strategies during drought. This situation allows rancheros to use different assets that make up adaptive capacity, impacts household drought sensitivity, and ultimately influences the decisions that ranchero households make regarding adapting to drought through migration. Solely looking at the results of the household survey, it is obvious that expanding urban services are impacting rancheros. Indeed, it might be assumed that these services are increasing the overall adaptive capacity of rancheros to respond to drought. However, this chapter provides a larger context of water infrastructure and expansion in the last 40 years. Through this broader lens, it is revealed that, while urban water services increase ranchero adaptive capacity during normal seasons, they actually decrease their adaptive capacity during times of drought since water utility managers serve the urban population first and deliver water to rancheros only when there is surplus. Municipal utilities prioritize urban users because of the financial and political reasons that will be discussed in this chapter. If rancheros come to expect continued municipal water delivery when supplies are low, their adaptive capacity actually decreases and their overall vulnerability increases.

This chapter changes the focus from rural households to urban services to understand expanding services throughout the watershed and its effects on both urban and rural dwellers. Specifically, the intention of this chapter is to understand more deeply how the developing urban

services affect rancheros' exposure to drought (degree of contact), their sensitivity (degree of impact), adaptive capacity (ability to adjust), and their drought decisions.

It is necessary to document a brief history of urban development and water delivery in the city, which has not been done before. This chapter describes the evolution of water production, distribution, and use in recent history and argues that the City of La Paz resembles other globalized, urbanized water systems. Urban water infrastructure tends to cause a shift in water use regimes as the sophistication of the system grows and as the urban population demands more water based on non-climatological factors. Rancheros have become more intimately connected in this this system by changing their behaviors based on urban services and because their water supplies are impacted.

5.1 Water and the urban-rural interface

Urban water infrastructure represents one aspect of urban connectivity that fulfills the societal function of potable water delivery. This movement of water involves adjusting water flows from an ecological context to a social one as expanding cities reach farther into the hinterland to access fresh water sources. At the same time that cities seek to provide basic coverage of water services to both urban and peripheral users, it does so through a means of production and re-production of existing power dynamics. Graham (2000b, p. 115) argues that precisely because infrastructure networks bring together people and the built environment, these systems link practices of production and consumption through a grid that unevenly disburses these services. Institutions that deliver water extend their influence through networks across space and time. The user acts within that network, reinforcing the dynamic. Every new pipe or sewer line that is placed is likely to "negatively affect the control over place of some while

extending the control and power of others" (Swyngedouw, 1993, p. 322). Infrastructure is inherently value-laden.

Access to water under this system is defined by connection points instead of natural supplies, for example, a tap that connects to the main water line. Without a connection point, there might as well be nothing at all. Graham (2000b, p. 116) gives as an example: "consider the poor shanty districts in Mumbai (Bombay) where people use large surface water pipes purely as walking routes, because the potable water flowing in the pipe lies totally beyond reach (destined as it is for elite consumers in gated condominium complexes that are being constructed within the informal settlements)." Social inclusion, then, is more than direct access to a natural resource but also access to the social organization.

In today's networked utility structure, basic access to water and sewage are necessary but not sufficient conditions to overcome poverty – they are now socially linked to markets and governance (Silva, 2000). Global processes such as changes in production and supply chains, climate change, and natural hazards expose the links between resource extraction, use, and disposal across urban-rural gradients. New conceptualizations of urbanity and rurality have emerged to describe hybrid network spaces and flows (for example, on urban land teleconnections, Güneralp, Seto, & Ramachandran, 2013; Seto et al., 2012).

Cities have two primary functions when it comes to potable water – locating freshwater sources, and delivering clean water to the people. In semi-arid deserts in the developing world, both of these tasks pose different challenges. In other words, installing pipes is one challenge in itself; moving the water through the system is another challenge entirely. Infrastructure remains a challenge in Mexico. For example, Mexico as a whole ranked 55 out of 148 countries in the 2013-2014 Global Competitiveness Index with a *downward* trajectory in environmental

sustainability and "insufficient supply of infrastructure" (WEF, 2013-2014). In the La Paz watershed, water quality and quantity are daily concerns. Upper and middle class families do not drink water from the tap; they either install household purification systems or buy *garrafons* (5L bottles) from private companies that drive trucks through the city. Municipal tap water is delivered by pipe by a *tandeo* system – one day on and one day off. Urban households have adapted by collecting water on the "on" days in a cistern to be able to use on the "off" days. Because the growing number of people drawing from this network decreases the pressure in the system, they sometimes have trouble pumping water even on "on" days. Private developers are now required to provide up-to-code infrastructure for new developments to help the city meet demand (*personal communication*, OOMSAPAS, 2013).

Reports claim that nearly 100% of La Paz's greywater is recycled through the sale to private developers to water lawns and golf courses (Organismo Operador Municipal del Sistema de Agua Potable, 2011). Public spending has been invested in pipe and sewer systems, wells and aqueducts, water delivery trucks to the hinterland, and dam construction. Figure 5.1 demonstrates the city's efforts in keeping up with water demand. In 1970, La Paz had approximately 46,000 inhabitants but grew to 215,000 by 2010 (INEGI, 2010). While not all urban households had access to pipes and sewers in the 1970s and 1980s, almost all had coverage by 2010 (Figure 5.1).

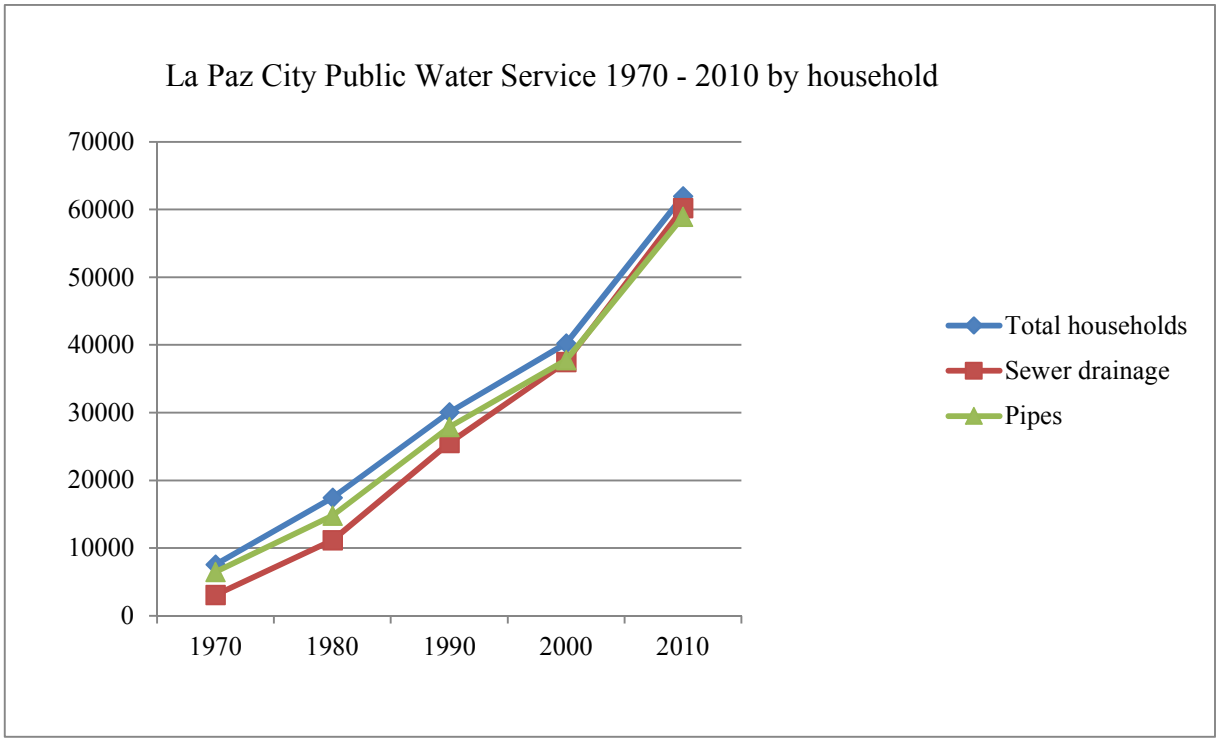

Figure 5.1 La Paz City Public Water Service 1970-2010 by household Source: (INEGI, 2010)

Figure 5.2 shows aqueduct connection in relation to rural households (Sierras, my study site) and the La Paz city center. El Centenario is a growing neighborhood, importantly, populated by foreigner households who were not connected to the public water system at the time of writing (*personal observation*, 2013).

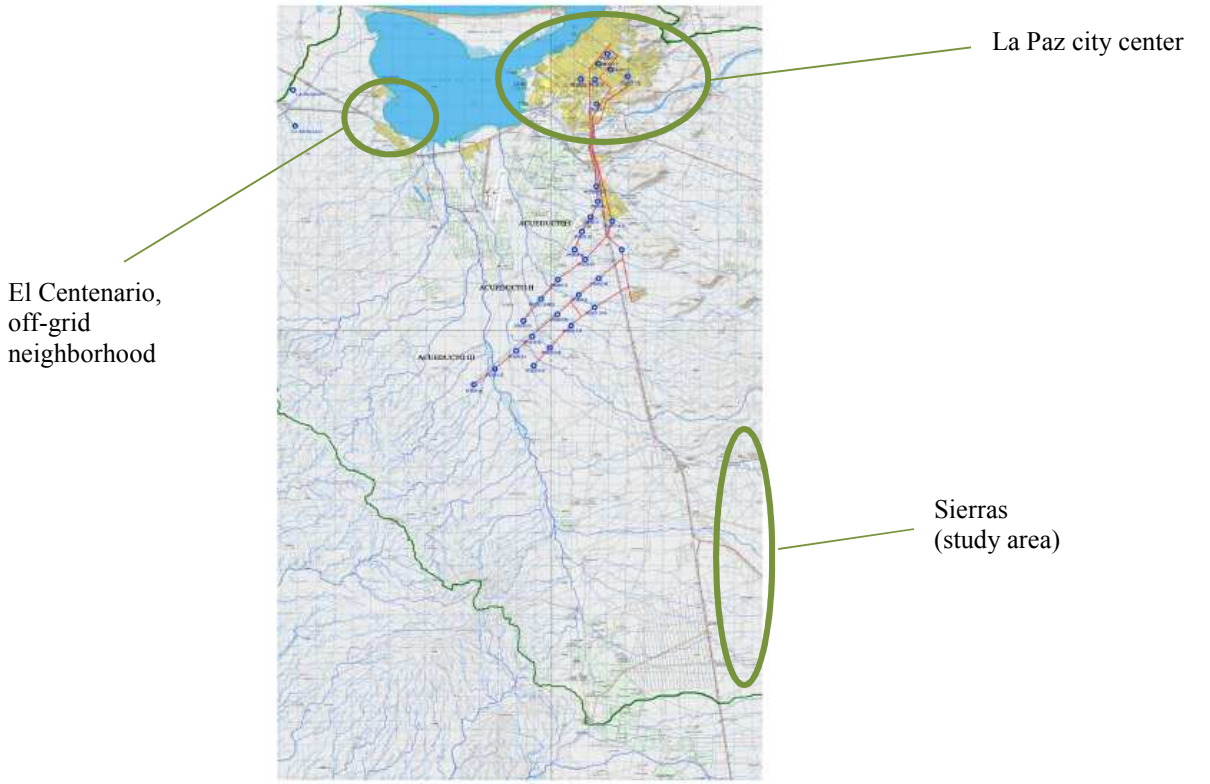

Figure 5.2 Aqueduct (acueducto) map (red lines) Source: (Organismo Operador Municipal del Sistema de Agua Potable, 2011)

La Paz is a rapidly growing city, one of the fastest growing cities in the country. In 1970, La Paz grew from approximately 46,000 inhabitants to 215,000 in 2010 (INEGI, 2012). Figure 5.3 shows population growth and sprawl in the municipality. Tan indicates established population settlement in 1993 (2.3% coverage of the watershed) and red indicates new settlements in 2011-2013 (4.8% coverage of the watershed), representing a 3.7% growth.

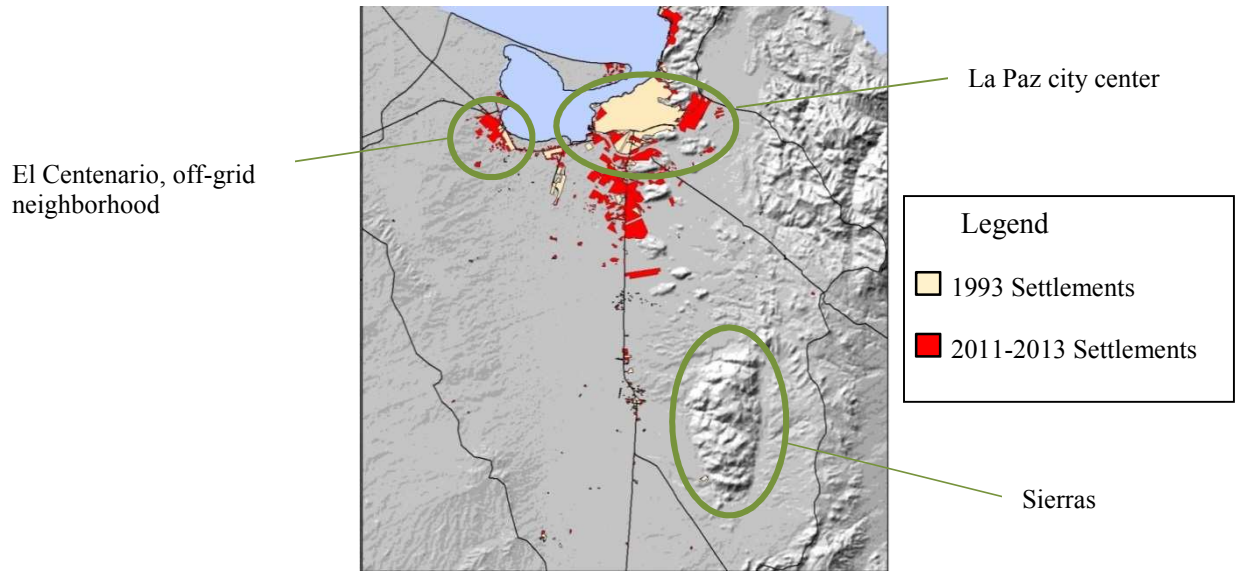

Figure 5.3 Population growth and sprawl 1993-2013. Source: Mabilia Urquidi (Niparajá, 2014)

Today, urban residents use almost exactly the total amount of available water estimated for the city: 288 L of water/person/day for nearly 250,000 people (Organismo Operador Municipal del Sistema de Agua Potable, 2011). In other words, there is currently no gap between supply and demand – any increase in demand will stress the water system if not managed effectively.

5.2 Urban water infrastructure: stages of development

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Finding similarities in the ways that Australian cities developed in parallel with western Europe and eastern United States, Brown et al (2008) simplified the global stories mentioned above into a guiding heuristic to compare water sector transitions in urban history. This heuristic is the following:

1. Water Supply City (defined by introduction of hydraulic infrastructure, focus on social access and security to water)

2. Sewered City (defined by sewage/waste infrastructure, focus on protecting public health)

3. Drained City (defined by drainage systems, focus on flood protection)

4. Waterways City (defined by point source pollution regulations, focus on social amenities and environmental protection)

5. Water Cycle City (defined by conservation efforts, focus on limits to natural resources)

6. Water Sensitive City (not yet accomplished, focus on intergenerational equity, resilience to climate change)

This general outline is helpful in comparing water sector development in La Paz, Mexico, in an effort to increase understanding of how cities in the developing world transition. However, this approach is taken with a few caveats in mind. First, just as no city exactly fits the guide that Brown et al. (2008) developed, La Paz is not representative of all cities in the developing world. Mumbai also shares some of the stages of development described above, with the first municipal water supply scheme in British India in 1860, for example, but in a context embedded in the particular historical colonial relationship (Gandy, 2014).

Second, the presentation of the stages are not meant to claim that once on this path, cities follow the stages in order without disruption, without stagnation, or without retroactive movement. Infrastructure development is "messy" and embedded in complex network architectures that help define and articulate their goals (Graham, 2000a, p. 115). The point is that the present cannot be divorced from the past. The cost and material installation of large-scale water infrastructure made earlier means that future decisions depend on prior decisions (Saleth & Dinar, 2005).

The following is a brief history demonstrating how the stages where determined. Modern cities have tended to meet new demands through large-scale, expensive infrastructure. Often, a

tried-and-true method to lower financial and political risk was to borrow successes from others, despite the ecological and climatological specifics of the environment to which it had been imported. In fact, when the natural contours of the environment did not cooperate, competitive cities took advantage of the opportunity to "booster" their city through imagining feats of engineering, conquering nature to attract growth and investment while offering the same amenities as found in other cities. (For example, the reversal of the Chicago River to prevent raw sewage from entering the city's drinking water source (for an environmental history of Chicago including the impacts of the River reversal, see Cronon, 2009)). The following describes a pattern of knowledge and technology diffusion that highlights some key moments in city development in industrializing cities. I argue that if similar patterns can be found in developing cities, then an outside ecological and social context is being superimposed on the fabric of cultural and economic life of its citizens. A reading of this situation could, on the other hand, further highlight subtle nuances in which developing cities interpret the global in terms of their particular local context, and how various actors within the hydrosocial system transfer power as the system is modified to local conditions.

Prompted by the need for clean water, industrializing cities implemented wood and cast iron pipe-bound systems for water and sanitation (see for example, (Gandy 1997) regarding the history of New York; see for example, the history of Pittsburg, (Tarr 2002)). For instance, the first public system is said to be the mains in London in 1746 (Melosi, 2008, p. 16). The 19th century marked a value shift away from individual responsibility of waste management towards a reliance on local governments (Drangert, Nelson, & Nilsson, 2002). Cities initially relied on private companies to construct systems. However, as companies competed for markets while

neglecting others, the public became cynical about their ability to serve the common good (Melosi, 2008). Eventually, public agencies gained control of water distribution.

Fire protection motivated town councils and property owners to invest in public water systems. However, most of the scholarly attention has been paid to the great successes of municipal water supplies in relieving waterborne epidemics, especially cholera but also typhoid, tuberculosis, and diarrheal disorders. Increasing water supply has been successful worldwide in decreasing disease, total morbidity, infant mortality, and total work lost, at least to certain thresholds (Biswas, 1972; Briscoe, 1984). For example, the years 1920-56 averaged 25 waterborne disease outbreaks in the United States, but in the last six of those years, no deaths were reported (Melosi, 2008, p. 179). Slow sand filters were used to treat water in Europe and Brazil as early as the late 1800s. US cities began treating water in the 1930s with chlorine, later switching to the less pungent chloramine made popular in Britain (Melosi, 2008, pp. 59, 135). Along with piped water service to the household, sewer systems became seen as part of a vital public works system. Many of these designs included combined sewer overflows (CSOs) to handle both wastewater (sewage) and stormwater (flood water). To drain water away from populated sites as well as to store water for future use, an era of dam building commenced in the 1960s in the United States. More were built in the 1960s than in any other decade (Graf, 1999, p. 1309).

Prompted in large part by Rachel Carson's *Silent Spring* in 1962 (Carson, 2002) and the Cuyahoga River fire in 1969, civic engagement increased and eventually swayed federal policies. For example, the Clean Water Act was subsequently passed in the United States in 1977. These environmental movements highlighted the role of public perception and grassroots pressure on urban water management and institutional reform. These initiatives focused on pollution, limits

to natural resources, and conservation. Dams that relieved water storage problems created environmental problems and were publicly criticized by US activists. Dam building slowed after the 1960s heyday, and few were built in the United States after the 1980s (Graf, 1999, p. 1309). Engineering marvels of the past are now being challenged, for example, research to remove dams have been initiated in the late 1990s and early 2000s (e.g., Poff & Hart, 2002). The combined sewer overflows (CSOs) that were installed to relieve waste management have now become overwhelmed in the denser, more impervious cities where contaminated flood water poses problems each time it rains.

Meanwhile, cities contend with ever greater water demand. Cities have begun to engage in vision planning towards sustainability and resilience (e.g., Coffee, Parzen, Wagstaff, & Lewis, 2010). While urban development ideas have been exported to middle and lower income countries through neoliberal reform (for an explanation of water impacts in Mexico, see Wilder & Romero Lankao, 2006), contemporary sustainable development acknowledges a two-way learning street. Participatory budgeting developed in Cochabamba, Bolivia and the "Rights to the City" argument of South Africa, and public transit in Mexico City, are just a few of the examples of urban management innovations that blossomed out of emerging economies.

5.3 The making of La Paz's water system

The City of La Paz is called the "City of Windmills," and to commemorate this legacy, the city erected a model, non-functioning windmill on the main coastline boardwalk. Before extensive public infrastructure was installed, families would pump water using small private windmills for domestic use. As the city began to grow, the number of wells increased until too much freshwater withdrawal near the coast pulled salt water into their private wells. At the same

time, the city installed sewer lines to serve the downtown hospital, as most of the urban buildings relied on septic tanks. Eventually, residents were connected to the public water service.

In the 1970s, La Paz enjoyed duty-free status as a port town that added to the attraction of this popular destination. The main highway connecting the United States to the end of the peninsula was completed in 1973. The following year, the territory of Baja California Sur became a state of Mexico. The population doubled from about 46,000 in 1970 to about 91,500 in 1980 (INEGI, 2012). Scientific studies were commissioned to identify potential groundwater sources, finding overexploited aquifers and confirming saltwater intrusion in several public wells (Organismo Operador Municipal del Sistema de Agua Potable, 2011).

Summer storms are normal in Baja, and the rain is usually a welcome relief after a long dry season. But in 1976, Hurricane Liza hit La Paz. The hurricane is said to have only brought light-to-moderate rains, but it was enough to break a 30-foot dike. People living in cardboard shacks were swept away in a mudslide in what is regarded as one of the worst disasters in Mexican history (*personal communication* CONANP, 2013).

> *En alguna ocasión aquí en La Paz, en 1976 con [Hurcan] Liza, las cifras oficiales mencionaban 3,000 muertos pero las extraoficiales eran arriba de 12,000... Entonces fue cuando llovió y se reventó y agarro la mitad de La Paz. Por ahí hay un libro que dice que al día siguiente estaba lleno de tiburones en la Bahía, hubo cuerpos, familias completas.* (Sustainable Development Office official)

> *In 1976 official figures counted 3,000 dead in [Hurricane] Liza, but unofficially we counted more than 12,000 When it rained, [the dike] burst, and destroyed half of La Paz.* (Sustainable Development Office official)

The dam called Presa Buena Mujer was built to replace the broken dike. Before the hurricane, there was no drainage plan and, no treatment for sewage that routinely headed downstream to the bay.

In 1980, the Secretary of Agricultural and Natural Resources initiated the State Water Plan to address the imbalance of the aquifers through treatment, reuse, and improved agricultural technology.

> *El otro punto del cual hablaba el plan de los 80's, era cambiar los usos agrícolas de los pozos. Hubo un programa federal para cambiar el tipo de cultivo que se estaba usando y cambiar los métodos de riego; se empezó a dar apoyo para revindicar todos los pozos que se estaban usando en la franja de la costa. Y otra de las cosas es que ya para esas fechas ya se trataba el agua, de una manera incipiente las aguas negras ya se trataban, entonces se cambiaba el uso de las aguas tratadas a aguas negras tratadas para regar para que dejaran de extraer agua del subsuelo. Y eso equilibra el balance de la extracción con la recarga. Eso fue más o menos lo que en ese plan estatal se dio.* (SEMARNAT official)

> *The [State Plan] of the 1980's was to change the agricultural uses of wells. There was a federal program to change crop type and irrigation methods… They also began to reuse greywater, to treat wastewater so they could stop drawing water from the aquifer, and to balance extraction with recharge.* (SEMARNAT official)

As the quote above describes, the objective of the State Plan of the 1980s was to optimize agricultural water use by incentivizing less water-intensive crops, federally subsidize irrigation technology (e.g., center pivot sprinklers), and to encourage greywater reuse. The State Plan is generally regarded as successful and primarily responsible for the municipal shift in water use from agricultural dominant to urban (personal communication, SEMARNAT official, 2013, Cariño & Monteforte, 2008).

The National Water Law passed in 1992 and was followed by several regulations concerning water quality of potable water and wastewater. By the end of the nineties, La Paz was selling greywater to private entities, mainly hotels and developers to water lawns and golf courses. Environmental activism gained traction as a series of campaigns succeeded in implementing beach protection regulations, notably, the Balandra beach in 2008 (Figure 5.4).

Figure 5.4 Protected Balandra beach in La Paz, Mexico. Source: Haeffner, 2013.

Despite local successes, public water infrastructure in this era lagged in keeping up with the expanding population. This government official explains the difficulty the city had in accessing federal funds when the Mayor represented a different party than the national administration:

> *Del año 1998 al 2010, las administraciones del municipio fueron diferentes colores, no fueron las del PRI entonces eso contrajo la inversión, o sea, los programas federales no llegaban como antes entonces eso reflejo una mala infraestructura urbana, porque no había dinero, eran PAN después PRD, entonces los recursos simplemente no llegaban por eso es que hay un pico en la infraestructura, por eso no hubo crecimiento en sistema hidráulico, agua potable, drenaje, etc.* (SEMARNAT oficial)

> *From 1998 to 2010, the administrations of the municipality were different [political] parties [than the federal government], so federal programs failed… we now have a poor urban infrastructure because there was no [federal] money. [La Paz elected] PAN and then PRD, so resources simply did not arrive…for this reason there was no growth in hydraulic system, drinking water, drainage, etc.* (SEMARNAT official)

Government corruption is also a real threat to delivering goods and services to the public. One government official relates a story about how nearly half a million US dollars that were supposed to be dedicated to water infrastructure was never accounted for:

> *Se pidió un préstamo en el año 2000 de $56,000,000 [pesos] para invertirlos en la planta y la infraestructura como comentaba Víctor Castro que era el presidente municipal y ese dinero no se vio registrado en obras. Después en el tercer periodo, hace dos administraciones, la CONAGUA subsidio en un programa donde el Gobierno Federal le da a los ayuntamientos dinero a cambio del número de m^3 que ellos reciben de agua en la planta y la procesan, o sea, subsidiaron para fortalecer la estructura siempre y cuando haya mejoras, … pero ese dinero nunca se vio reflejado entonces desde hace 5 años que el ayuntamiento no es sujeto de los programas federales porque le debe ese dinero que las administraciones federales pasadas no aplicaron, deben casi $52,000,000 que no se invirtieron.* (SEMARNAT official)

> *In 2000, we borrowed 56,000,000 pesos to invest in plant and infrastructure under Víctor Castro who was the Mayor and that money was not registered in projects. Then in the third period, we had two administrations in which the federal CONAGUA subsidy…i.e., subsidized to strengthen the structure provided there is improvements, …but that money never was reflected in the 5 years that the City Council was not subject to federal programs the federal authorities did not send the money. They were not implemented. There must have been almost 52,000,000 pesos which were not invested.* (SEMARNAT official)

Today, La Paz is serviced by 33 deep wells, delivered by three aqueducts, connected by 367 km of pipes, and stored in 37 tanks (Organismo Operador Municipal del Sistema de Agua Potable, 2011). Besides the Presa Buena Mujer dam, little drainage has been built such as street side ditches. Instead, gravity is considered a "free amenity." Run-off is left to flood coastal roads for a few days during the monsoon season, a newsworthy but otherwise normal event that often cuts off road access to the El Centenario neighborhood (e.g., Figure 5.5) (Redacción in BCS, 2014).

Figure 5.5 September 8, 2013 Flooded roads on the way to El Centenario. Source: Haeffner, 2013.

Potable water is treated by chlorine gas injection in the city's one treatment plant (Organismo Operador Municipal del Sistema de Agua Potable, 2011). Sewer pipes are narrow, a common problem throughout Mexico and toilet paper waste cannot be flushed. Municipal officials express frustration that consumers complain about paying for a basic necessity like water even though it is sold at a much lower price (about mid-range compared to the rest of the country, *personal communication*, OOMSAPAS official, 2013). The municipal water management agency, OOMSAPA has begun to install water meters, with 29% household coverage by 2011(Organismo Operador Municipal del Sistema de Agua Potable, 2011). However, transitioning to payment for what was once a free utility has not been easy, and officials report instances of bribery and refusal to pay, especially among commercial entities (*personal communication* Enlace official, 2013).

> *El espíritu de diseñar ese esquema es para promover el uso racional y eficiente de agua, es una manera de estimular que al que cuida el agua paga menos. Y el que la desperdicia, tira dinero, es un castigo. ….Hay una dotación en función de la tarifa del mínimo son 177 litros. Es la dotación que se tiene del rango del costo mínimo por persona. Es el universo en todo lo que es aquí, esto es lo que se tiene en función de la tarifa.* (OOMSAPA official)

> *The spirit of the [metering] scheme is to promote the rational and efficient use of water; it is a way to encourage that if they conserve water, they pay less. If they waste it, it costs money, it is a punishment. …The amount granted depends on the minimum rate of 177 liters. The amount granted is a range of the minimum cost per person.* (OOMSAPA official)

While La Paz boasts a strong civil society with activists camping out to protect beaches from development, environmental awareness has not translated to behavior change in the home.

> *La verdad es que en algunos de los casos donde se tiene servicio más continuo en la ciudad rebasan los 250 litros. Hasta 300 litros llegan algunos, y esto es un abuso…Pues ese es el problema de la conciencia que no se tiene. Es una situación que falta mucha cultura del uso racional del agua.* (OOMSAPA oficial)
>
> *The truth is that in some cases where you have more continuous service in the city they exceed 250 liters. Some use up to 300 liters, and this is an abuse… Maybe the problem is that we don't have consciousness. We lack a culture of rational use of water.* (OOMSAPA official)

A feasibility study by the UNAM Institute of Engineering proposed a future desalination plant to meet future water demand (Castro, 2014). Desalination is the conversion of seawater or brackish groundwater to fresh water, globally touted as a "drought-proof" solution to water insecurity (McEvoy & Wilder, 2012, p. 354). Some environmental concerns are that the process is energy intensive and that disposal of the residual brine into the sea may harm marine life. The national university UNAM has addressed the issue of brine disposal and has recommended a high turbulence site for waste water. A social concern of desalination is that the high price of converting seawater renders it cost-prohibitive to offer it to the public. La Paz's southern neighbor Los Cabos installed Mexico's first municipal desalination plant. However, reports claim that even with subsidies and a public-private partnership to keep prices affordable, the municipality is losing money (selling at 8 pesos/m^3 compared to 16 pesos/m^3 to produce, *personal communication*, OOMSAPAS official, 2013). Instead, desalinated water in La Paz will likely be offered for sale to private entities such as those in the tourism industry. In addition, if

desalinated water were publicly available, delivery would be problematic. The proposed plant site is on the northeast side of the city, but population density is growing to the south and west (see Figure 5.3). Either new pipe infrastructure must be built to deliver desalinated water to households or zoning laws need to be installed in order to encourage denser development in the city center (*personal communication*, SEMARNAT official, 2013).

Like many cities around the world, La Paz officials also desire to move towards being a more Water Sensitive City. Vision 2030, for example, is currently being negotiated to plan for digging a new well for public use, concretizing arroyo channels to prevent flooding, and constructing two new dams for water storage. A desalination plant is in the works, deliberately learning from the negative experiences of the municipal desalination in Cabo San Lucas. Most importantly, perhaps, is not what the municipality plans on doing, but how they are doing it. Officials recognize that they have to coordinate much more between departments and with other stakeholders:

> *I only know that coordination in [the last] two years have advanced much more…in environmental issues. [The Office of Sustainable Development] coordinated the State Climate Change Plan with the University, we did the Oasis Sudcalifornianos program, Solid and Urban Waste also was a very large step forward, the State Solid Waste Management Plan was made and municipal plans are underway, proposals for environmental legislation by our Office are being made, I presented a proposal of Decree for the Integration of the Inter-Ministerial Committee on Climate Change.* (Office of Sustainable Development official, original in English)

La Paz used federal disaster relief funds from the 2012 floods to repair streets, and replace water and sanitation pipes (*personal observation*, 2013). Although these new roads used high albedo reflection to reduce urban heat island effect, the opportunity to install other low-cost sustainable infrastructure was not taken – for example, shade trees, permaculture, street narrowing, bike lanes, etc. Meanwhile, on the other side of town, a local NGO obtained permits to install many of these features, mostly in effort to cool down streets in the summer (and reduce

the need for residents to cool down the streets themselves by using water to wet the sidewalks). The disconnect between top-down government and civil society demonstrates how innovations get caught up in a struggle over power in the constant re-making of the city.

A primary challenge to transition has been maintaining the infrastructure that is already in place. For example, although the World Bank had funded dams throughout the state in the 1970s, sediment build-up due to disuse has rendered many useless with permanent scars on the landscape. Figure 5.6 shows an abandoned dam.

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Figure 5.6 Abandoned dam, Baja California Sur, April 2013. Source: Haeffner, 2013.

Likewise, pipes are rarely repaired, and 40% of municipal drinking water is lost through leakage (Organismo Operador Municipal del Sistema de Agua Potable, 2011). The 2012 federal disaster relief funds financed street and underground pipe repair for the first time since their initial installation (*personal communication*, OOMSAPAS official, 2013).

> *El problema es más bien de que es infraestructura que en gran parte ya cumplió con su vida útil. Derivado de que no son suficientes en el pago de los servicios, entonces no hay recursos económicos que alcancen para atender el reemplazo de su mayoría. (OOMSAPAS official)*

> *The problem is that infrastructure in large part has already served its useful life. It is not sufficient for services, so there are no economic resources to replace most of it. (OOMSAPAS official)*

Transitions require human capacity at different levels to implement change. In this regard, La Paz has an advantage. La Paz has a highly educated population with a high literacy rate (INEGI, 2010). Local higher education institutions rank among Mexico's best in marine biology, and an integrated program in water was offered at the undergraduate level in the 2013 academic year (Universidad Autónoma de Baja California Sur, 2013). Both local and international environmental groups are active in the area around a variety of water issues including pilot programs to distribute low flow toilets to urban residents and educational campaigns to reduce household water usage (Niparajá, 2013).

> *I think BCS is a very peculiar state in that has an enormous amount of civil society working here, not just local, but international. This has meant to have a lot of debates about what is happening in the state. I think that this is a positive force. Because it pinpoints a lot of issues that would go unseen or not discussed… Maybe you cannot tackle every problem, but at least you are building a more conscious society.* (UABCS professor, original in English)

5.4 Results

Table 5.1 organizes the references to urban water infrastructure developments I identified in the interviews and historical documents by transition stage in the framework proposed by Brown et al. (2008).

Table 5.1 Urban water infrastructure timeline of La Paz, Mexico

	Water Supply City	Sewered City	Drained City	Waterway City	Water Cycle	Water Sensitive City
1960s	Saltwater intrusion becomes noticeable in private household wells, switch to public services	1st sewer pipes installed to service hospital				
1970s	Scientific studies commissioned to identify potential groundwater sources		World Bank builds dams in rural mountains, defunct within 30 years			
1980s	State-level Water Plan passed; wells moved out of saline zone	Sanitation decentralized to municipalities Urban sewer expansion to 86%	Large dam project for flood control in response to 1976 Hurricane damage		La Paz begins to reuse greywater	
1990s				Water quality regulations passed at national level	1st greywater treatment plant in the city	
2000s	Federal funds allotted to respond to 2011 drought		Municipality elects different political party than federal 3 terms in a row-increases difficulty to attain federal funding for projects	Environmental activists succeed in protecting local beach		Small rural stabilization projects to reduce runoff Federal policy response to drought
Present	33 wells (6-8 with salt), 37 storage tanks, 92% pipe coverage, 3 aqueducts	Federal disaster relief is spent on street repair, included sewer pipes	Federal disaster relief is spent on street repair, no ditches or channels included	9 point chlorination dosing 1 water treatment plant	Private entities purchase municipal greywater, reported 100% reclaimed	Water meters installed with 30% coverage Water User Associations established
Future proposals	New well to meet urban demand 2 new dams		2-3 proposals to channel water, but street drainage is low priority		Education efforts	Desalination plants Collaborative initiatives

The red line in Table 5.1 shows that it is possible to fit La Paz's infrastructural developments into a truncated version of the Brown et al. (2008) model. As mentioned, the model is based on the experience of Australian city development beginning in the 1800s. Table 5.1 begins in the 1970s. Globalization has significantly altered La Paz's transitions by changing the speed and timing of events, financing, and interests.

Beginning in the 1960s and 70s, securing fresh water supplies for urban dwellers was the city's priority as saltwater intrusion threatened small household wells. Next, the sewer network eventually increased to near-universal coverage. A hurricane in 1976 commanded attention to flood risk and focused recovery on drainage, but this priority appears to have been short-lived, and subsequent storms have not challenged any new focus on infrastructure. The Waterways City era appears to have gained traction in the 1990s with top-down regulations of water quality and treatment standards. The 2000s saw an engaged civil society winning campaigns to save beaches, although this had as much to do with anti-development sentiment as it did water quality. The Water Cycle City has been an important stage for La Paz, generating income from the sale of wastewater. As Brown et al. (2008) suggest, no city in the world has fully transitioned to a Water Sensitive City, and La Paz has not either. This study has shown that "water sensitive" efforts such as metering has been met with everyday resistance in the form of bribes and stealing while other efforts are blocked when finances for large projects "disappear." Meanwhile, new impervious road developments are installed by the government even as local grassroots associations are literally tearing up old ones. Conservation techniques are nascent, runoff capture is non-existent, leaks in pipes undermine water delivery, public water is valued at a cheaper price than cell phones or cable, and water metering to determine actual urban use stands at just 29% of household coverage. But necessity is a strong motivator. La Paz is weighing the option to "take

or make" water – that is, to dig wells or desalinate. The latter is an effort that, if successful, could delay conversations of water conservation until later.

This study has shown the trajectory of urban water infrastructure in La Paz can fit the general path followed by cities in industrialized countries. However, the case study illuminates a number of drawbacks in the proposed stages. First, the model does not take into account varying temporal scales. While the pattern of following the stages is similar to other cities throughout the world, the particular historical context and multiple layers of colonialization has shaped the timing of infrastructure implementation in La Paz. Second, the model does not adequately take into account economic drivers of infrastructure development. In presenting the stages as transitions, it does not fully acknowledge the impact of maintenance of previous infrastructure on the subsequent stages. Cities with tight budgets must choose between installing new infrastructure and maintaining current services. As seen in the La Paz case, public infrastructure followed an economic boon in the 1970s. Then, it lagged in the early 2000s when the city elected a political party that conflicted with the political party of the federal government, curtailing finances. Third, while the model addresses cultural drivers as positive instigators for restoration and conservation, it is insufficient in explaining how cultural drivers inhibit and subvert change. For example, in the La Paz case, water metering is met with disdain, with individuals and businesses actively undermining the system by bribing officials to look the other way. The subtle ways in which end users modify top-down approaches to water management to meet their self-interest can explain the success or failure of a transition and expose everyday resistance to superimposed infrastructures. Finally, it does not apply a holistic framework – neither taking into account where the regional aquifer is and its condition, nor the rural inhabitants in the aquifer zone.

Water behavior across a spatial urban-rural gradient

Collective mind change and individual habits form feedback loops and learning experiences that shape ongoing institutional changes (Saleth & Dinar, 2005, p. 6). Evidence from participant observation reveals how urban development technology transforms daily life at the urban and rural household scale. Social groups manage water differently depending on access to urban water infrastructure. The following illustrates behavior changes based on access to free flowing water. It is a continuum, as best expressed by rural residents – the closer they are to the city center, the more likely they are to access urban water (discussed in more detail in Chapter 4).

Even though rapid urban growth has occurred in the last 40 years, many native urban residents have not entirely converted to modern water use practices but continue traditional practices. For example, I observed that *paceña* (City of La Paz residents) households tend to keep a bucket in the shower to collect greywater for plants - although I did not find the same for households who have recently migrated from mainland Mexico. Walking down the street on a hot day, one may come across locals wetting down the sidewalks, a practice the rural households also use. It is effective; it does indeed cool off the area, but it is wasteful in terms of water use.

For urban residents, water availability is impacted not just by lack of water, but by lack of water pressure in the pipe system, so they receive water every other day. Households often store water for bathing and cleaning in personal cisterns and can cope for a few days without public service. For potable water, they purchase water from commercial vendors or have an in-house filtration system. It is common to be woken up in the early morning by a truck broadcasting the jingle of their water company, reminding consumers to fill up their *garrafon*. Residents can also

take their reusable bottle to any of the many water factories to fill up for ten pesos per five liter cans.

When asking urban residents about the last drought, they remember hearing about it on the news. Behavior changes were imperceptible among urban dwellers. In contrast, rural households can often articulate which adaptations they adopted, specifically, in response to past droughts. Likewise, many urban residents are reactive to drought while rural residents plan in advance (see Chapter 4).

In addition to long-term residents, another increasingly common social group settling in the municipality is the foreign community, often retirees who live in Baja seasonally. The growing population inhabits a neighborhood on the outskirts of La Paz that is not currently served by public water infrastructure. Instead, households install two or three underground holding tanks connected to the house through PVC pipe and an aboveground valve system. The situation leaves an open market for commercial water; El Centenario residents contract with local delivery truck owners and call them days in advance to re-fill the tanks. If the roads are blocked due to monsoons, the wait might be longer. The purchased water is not used for drinking or cooking (potable water is purchased in *garrafons*), but for washing, irrigation, and sometimes swimming pools. For households that irrigate small gardens and keep on-site washing machines, the water lasts for 10-12 days (*personal observation*, 2013). Water use comes to consciousness in daily activity with real costs associated with each action. North Americans might be used to turning on the tap in the United States or Canada and trusting the water to be of potable quality. In Mexico, they must change their relationship to water in regard to time and space. Many households in this social group report a heightened conscious about daily water use. Of those who keep gardens, most use xeriscaped landscapes of indigenous plant species instead of water-

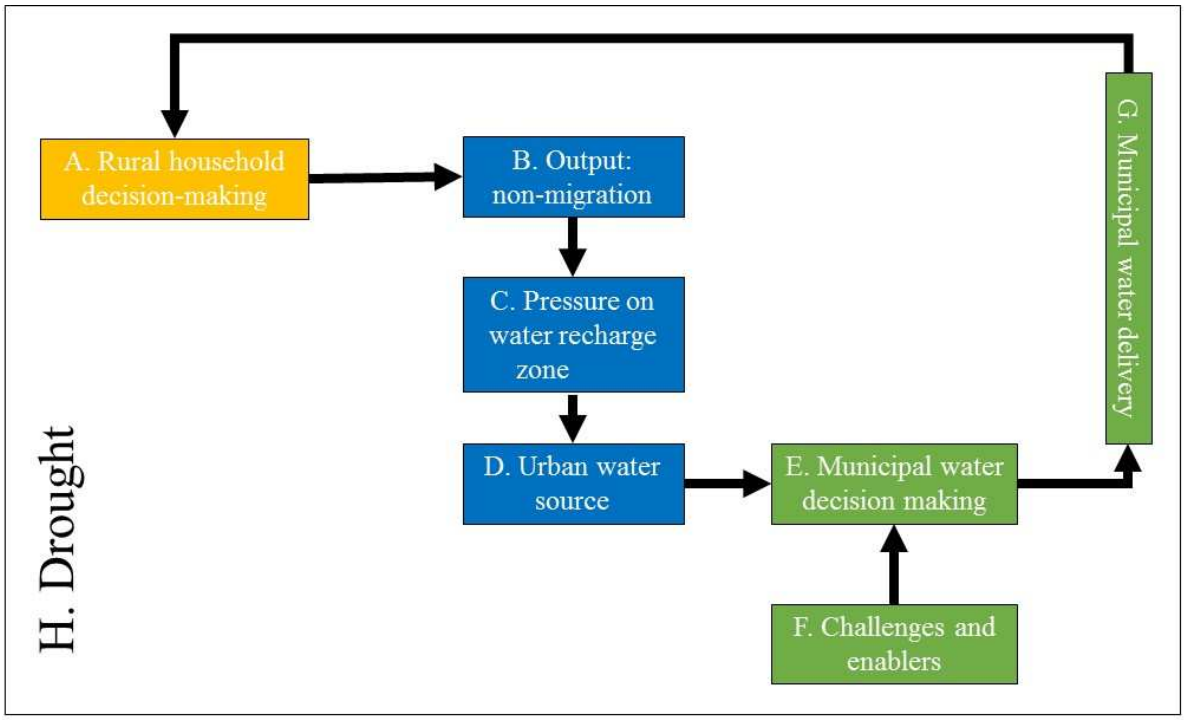
intensive grass around their homes (*personal communication*, 2013). But use is relative. In the United States, average water use per person is 575 L/day (Watkins, 2006, p. 34). Compared to their home practices, foreigners might use less, but compared to locals who use 255 L/day, they might be using far more. Because water demand amid low water supply can lead to hydrological drought, it is necessary to understand how different social groups impact the ability of other social groups to manage their water supply.

5.5 Discussion: Links between urban and rural water

Location within the watershed significantly impacts how households manage their water supply. The ability of households to manage their own water supply affects their sensitivity (degree of impact) to drought, their adaptive capacity to respond to drought, and their exposure (degree of contact) to drought. This situation is as true for different social groups in the city as well as rancheros in the rural areas. Although urban dwellers and government officials view rancheros as separate from them, and indeed rancheros see themselves as separate from city folk, this chapter has shown the multiple ways in which they are intimately linked by water. Figure 5.7 visualizes this process, where rural households decide to migrate or not to respond to drought (Box A). The figure shows that if fewer ranchero households decide not to migrate (Box B), increased permanent settlement could lead to increased pressure on the main water recharge zone of the aquifer in terms of extraction through deeper and more wells (Box C). If some households maintain some form of ranching, there is also the potential for an increase in grazing and soil impaction that can lead to soil degradation and reduced permeability. If the Sierras can no longer recharge the aquifer, the city, which nearly exclusively depends on the aquifer for drinking water (Box D), will experience a further decline in available water resources, contributing to a hydrological drought. Municipal water operators will be forced to make decisions (Box E) to

respond to increased water demand and lowered water supply. These decisions are limited by political and financial challenges but also enabled by emerging sustainability awareness among citizens and leaders in the area (Box F). Ultimately, the municipal government must follow federal mandates, including providing water for all households in the municipality, both rural and urban. The La Paz municipality chooses to deliver water via truck to rural areas (Box G), which Chapter 4 has shown to have a significant impact on rural household decision-making (Box A). All of this occurs in a context of droughts that are predicted to become more frequent and severe under climate change scenarios (Box H).

Figure 5.7 Water management in the La Paz, Mexico watershed



5.6 Conclusion

Water availability and access was once constrained by season in the La Paz watershed, falling at particular times (mostly in the monsoon season) and stored in particular places (such as

arroyos and springs). Now social, economic, and political factors are responsible for change in water availability and access to the rancheros. Today's pipe and sewer system transform space and time through the massive human activity of extraction and transportation. With climate change producing more frequent and severe droughts and demographic shifts that drive growth, investments in water infrastructure is not responsive to biophysical change, but socioeconomic demands. The urban process has followed a historical trajectory that has been transplanted from more water-rich regions to promote economic growth, divorced, in part, from place and the specific watershed context that La Paz inhabits. At the same time, La Paz seeks to become a global leader in advanced water technologies such as desalination.

In this chapter, I make two separate but intertwined points, one about time, and the other about space. First, it was found that the City of La Paz has recently followed a time trajectory of modern water infrastructure development closely resembling its global contemporaries. The city has constraints and capabilities in managing exposure to drought today. As desalination projects are being discussed to increase further supply, the primary intent is to serve the tourism industry. If the system currently operating in Cabo San Lucas is any indicator, providing citizens with desalinated water at a fair price cannot justify the cost of installing a municipal system (*personal communication*, Enlace officer, 2013). A second desalination system is already underway in Cabo because the first cannot meet public demand. Reports say that the first is operating at a loss (*personal communication*, Enlace officer, 2013). This process has had consequences for households in different social groups as they adjust their behavior and attitudes to comply with more or less water availability.

Second, for the purposes of understanding how superimposed infrastructure developments impact households, results of Chapters 4 and 5 show that spatial differences in

water uses are correlated with water availability. The current network of standard-sized pipes is not a given or an accident, rather, an outcome of specific human actions embedded in social groups. This could not be made clearer than in Baja, where the action of accessing drinking water takes multiple forms. Availability depends on the day, and requires different equipment based on where in the watershed one is located. For example, one family may drink water directly from an indoor tap connected to a personal treatment system, another family buys water from the market, and yet another family keeps a ceramic pot to collect rainwater. As more and more people depend on indoor systems and expect water to appear when they turn a knob, the less likely they are to connect their personal water use with the overall supply. Hence, a local water conservation NGO finds it necessary to remind urban residents that "water does not come from the tap, it comes from the mountains."

Likewise, the rancheros who live in the mountains are greatly impacted by urban behavior even though they prefer to see themselves as separate. Chapter 4 showed how expanding urban services impact ranchero adaptive capacity. This chapter delved deeper into these urban services, focusing on water infrastructure, to find that the impact on Sierra rancheros is not straightforward. While a diversity of water access (through pipes and water delivery) might increase ranchero adaptive capacity during normal seasons, these services dwindle during severe drought as municipal water utilities serve the urban population first. This more nuanced perspective shows that ranchero drought vulnerability might actually decrease, especially if they dismiss or forget their traditional drought adaptations and expect urban services to be consistent. Viewing the watershed as a whole, this project finds a deeper interconnection between urban and rural users.

CHAPTER 6: Conclusion

This dissertation is concerned with the spatial and socioeconomic conditions of the rancheros sudcalifornianos in the Sierras of the La Paz watershed and asks whether or not they migrated due to the severe drought of 2006-2012. The environmental migration and vulnerability literatures predict that because they are a vulnerable population, they would have been expected to migrate as a response to the drought. However, this study found that they did not. Thus the hypothesis has been rejected.

Household surveys were conducted to understand internal household factors that drive decision making. The surveys incorporated decision-making variables from the environmental migration and climate vulnerability literatures. The vulnerability literature defined the parameters of household decision making. To take any adaptive action there must be proximity to an external change (exposure), awareness of the change (sensitivity), and the ability to change internally (adaptive capacity). Results from this research showed that rancheros are adapting (responding to external changes) not by migrating as the literature suggests, but by changing their livelihoods to benefit from the external conditions of an urbanizing environment. In other words, they are trending away from ranching as their sole source of income, reducing their dependency on immediately available resources, and becoming connected to urban services. Further investigation into nearby urban development revealed that the land on which rancheros reside is of great importance to watershed health. However, mechanisms are not in place for rancheros to be involved in decision making. Research results suggest that because rancheros occupy a critical space in the watershed and are significantly impacted by what happens in the city, ranchero involvement in water conservation practice is necessary for the sustainability of

the ecological services of the watershed and the ability for both rural and urban users to adapt to future drought risk. Although urban and rural populations view each other as separate, the inclusive watershed perspective posed in this dissertation demonstrates the ways in which these two social groups are interconnected. Figure 6.1 offers an alternative conceptual model to explain why rancheros in the Sierras did not migrate despite being a vulnerable population exposed to drought. The diagram introduces urban water services as a variable that discourages household migration. The diagram is explained in the next sections.

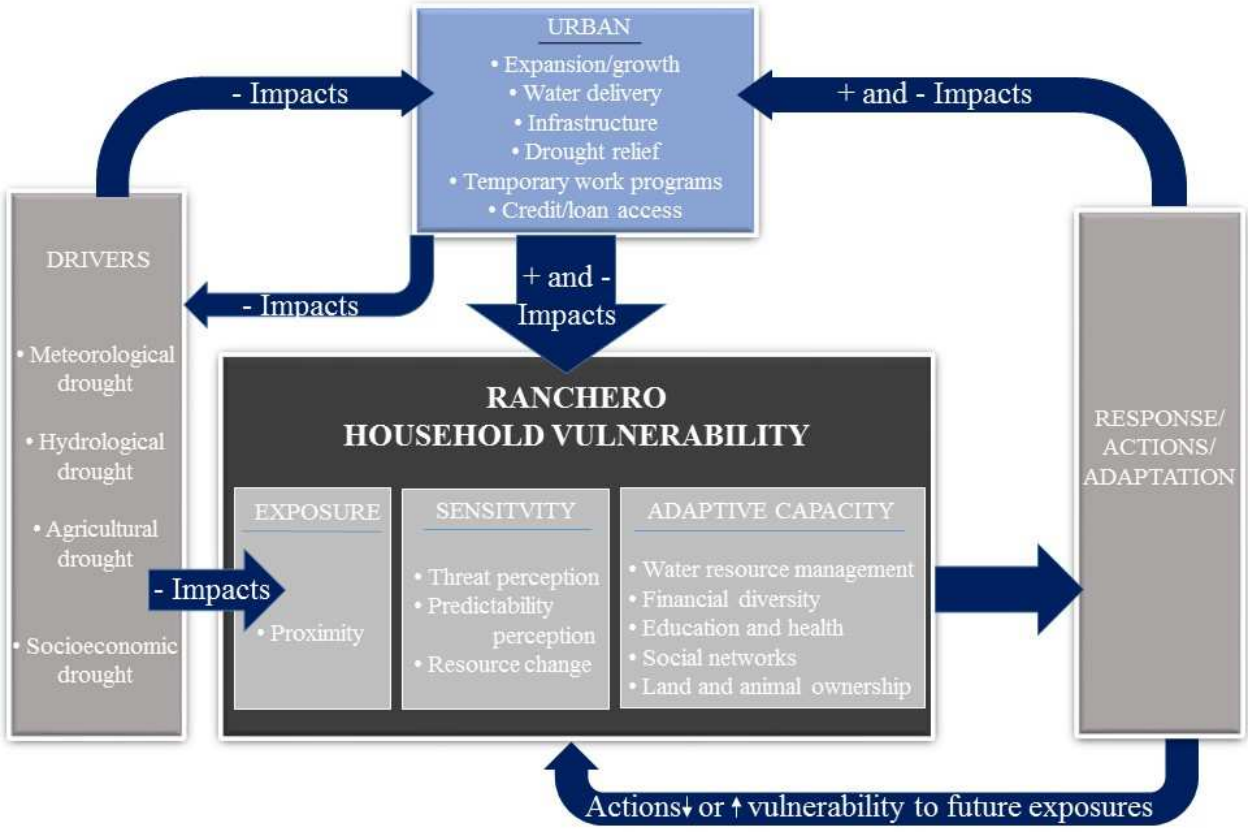


Figure 6.1 Alternative conceptual model depicting the urban role in ranchero exposure, sensitivity, and adaptive capacity incentivizing immobility over migration

6.1 Ranchero household vulnerability

At the center of Figure 6.1 is the *Ranchero Household Vulnerability* box and the main components of the main question of this dissertation, if drought caused migration. This project found that rancheros in the Sierras of the La Paz watershed of Baja California Sur, Mexico, face environmental risks to their livelihoods from drought and changing seasons, and are therefore vulnerable. The rancheros listed drought as the primary source of weather-related vulnerability and reported that the monsoon season arrives as much as a month later than in years past, with February rains all but disappearing. Given these findings, I conclude that rancheros were *exposed* to the 2006-2012 drought and that they were *sensitive* in that they perceived threats and experienced changes due to the drought (*drivers*). Figure 6.1 shows that rancheros experience drought negatively (by the "- Impacts" arrow linking "Drivers" and "Ranchero Household Vulnerability"). Further, ranchero *adaptive capacity* to drought has changed in recent years. The ranchero households in the Sierras scored low in several measures of adaptive capacity: formal education of head of household, formal associations, and financial diversification. Figure 6.1 links Ranchero Household Vulnerability to migration, but only in that if rancheros do not migrate, this can have impacts on the watershed, which in turn, impacts the urban water supply, discussed in more detail below. The Sierra ranchero population did not show signs of modifying their *exposure* to the last severe drought by moving to more water secure locations. Instead, household survey findings suggest that rancheros in the Sierras used adaptation strategies that modified their *sensitivity* to drought. In other words, Sierra rancheros changed the way they accessed resources instead of changing their physical proximity to drought conditions (by migrating).

Rural household vulnerability to drought was found to be mediated by *urban* services. This is not what I expected when I started this research, since experts had told me that rancheros were isolated from the city. But in reality, the urban sector turned out to be very important to the overall adaptive capacity of the ranchero community – increasing it during normal seasons but decreasing it during severe drought. (Figure 6.1 shows this relationship in the "+ and – impacts" arrow linking "Urban" to the "Ranchero Household Vulnerability" box). Changes in urban dynamics have negative impacts on the drought as water demand reduces water supply (and increased carbon emissions which has been linked to more frequent and severe droughts). Drought, overall, has been shown to have negative impacts on both urban and ranchero populations.

Urban

Introducing urban water services helps to explain why rancheros did not migrate due to the last severe drought as the literature would suggest. Figure 6.1 shows that urban services intervene in the resource dependency of rancheros in the Sierras, allowing them to modify their drought sensitivity through livelihood changes and taking different adaptation strategies. This project revealed some important ways in which expanding urban services impact ranchero livelihoods positively and negatively (as shown in the "Urban" box in Figure 6.1). *Population growth*, with its subsequent growing water demand, affects rancheros because all residents in the region rely on one aquifer with its limited water supply. Urban *expansion* further impacts the amount of land available both in the periphery and along the coast as developers buy real estate that rancheros might otherwise migrate to in times of drought. The municipality does alleviate some drought impacts to the rancheros through *delivering water* under the federal mandate. Some ranchero households have access to water tanks which the government agency

CONAGUA fills twice per week. However, while this new agency is providing a buffer in times of drought through wider water distribution it may also increase the overall vulnerability of the watershed by depleting the water supply. Other *infrastructure*, such as pipes, extend into the rural periphery to connect wells to the urban center, and some ranchero households are benefiting from this new source of semi-reliable water. Some ranchero households also reported that they receive *drought relief* that is ultimately distributed at the municipal level. However, drought relief and recovery programs are mandated at the national scale. Programs designed to aid farmers in mainland Mexico may be inappropriate on the Baja peninsula because of different ecological and cultural conditions. There are also real political challenges that impact the institutional capacity of governmental agencies to offer practical help to rancheros. Of the programs offered, rancheros relied most heavily on *temporary work* programs in times of drought. They reported that they expect that these will be available in the future – so much so, that many respondents did not have any other plan but to work to pay for drought damages. A small but statistically significant number of rancheros in the Sierras also benefited from being close to the city to access credit and loans. Meanwhile, those in another more remote part of the state reported that they would be eligible for credit and loans, but the difficulty in traveling to the city kept them from obtaining them. Thus, the growing capital city offers both a threat and an opportunity for the rancheros in their ability to adapt to drought, since the city depletes the main aquifer but also delivers water to rancheros that they otherwise would not have, at least in the short run. The movement of water involves adjusting water flows from its ecological context to a social one as expanding cities reach farther into the hinterland to access fresh water sources.

Drought

One reason drought and migration were not clearly linked in the Sierras is because the focus on meteorological drought is too narrow a definition to include all forms of low water availability. This dissertation instead investigated three additional drivers of decreased water availability: hydrological drought (low ground and surface water), agricultural drought (low soil moisture), and socioeconomic drought (negative economic impacts), defined in Chapter 2. In the Sierras, rancheros were certainly sensitive to meteorological drought, but hydrological drought arguably plays a larger role in overall watershed health. Meanwhile, drought impacts the urban center that responds by developing infrastructure to move water to different places at different times.

Although the municipality can manipulate access and allocation of water across the watershed, they are ultimately constrained by a finite supply. In this way, drought is also a part of the municipality's vulnerability (negative impacts arrow from "Drought" component to "Urban" component Figure 6.1). Meanwhile, changes in the urban structure impact drought (arrow from "Urban" component to "Drought" component). As the sophistication of the urban system grows, water use regimes shift, as discussed in Chapter 5. As the urban population demands more water based on non-climatological factors, this affects drought conditions in terms of water withdrawals (negative impacts arrow from "Urban" component to "Drought" component). Water was transferred from agricultural uses to urban ones in the 1980s which may have impacted *agricultural drought* in terms of water that once was used for irrigation was transferred to the urban center. This dissertation shows that the urban center influences vulnerability to drought by having very real *socioeconomic* consequences for rancheros. On a much larger scale, urban areas, in general, may affect *meteorological* drought in terms of

increased carbon emissions causing global warming leading to more severe and frequent droughts. Drought links rural and urban users together as they share and compete for water sources, as well as land to access freshwater sources.

Response

Water use regimes in the entire watershed have very real livelihood consequences for rural upstream watershed households who must adapt (or not) to compensate for increased stress and variation in water availability. In turn, rural upstream households are constrained in traditional adaptation options (including migration options) while new adaptation options become available (including sedentary options), because of other social-cultural changes in the same landscape. If fewer households migrate, increased permanent settlement could lead to increased pressure on the main water recharge zone of the aquifer in terms of extraction through deeper and more wells. Likewise, if some households maintain some form of ranching, a potential increase of grazing and soil impaction can lead to soil degradation and reduced permeability. If this zone can no longer recharge the aquifer, the city that nearly exclusively depends on the aquifer for drinking water, will experience a further decline in available water resources, contributing to a hydrological drought for the entire watershed, including the ranchero population.

Interconnectedness

The rancheros' lives cannot be divorced from external institutions that define the availability and allocation of resources. Any attempt to understand the adaptive capacity of rancheros must include an analysis of the changing social organization of water in a water-limited environment. The rancheros are not separate from the city - if rural users permanently settle in the main water recharge zone for the region, then their activities affect overall watershed

health. Likewise, if rural users increasingly use urban services for access to clean water, then they might become dependent on a system that was not built to serve them.

Municipal decision makers tend to not take into account the conservation opportunities in the main recharge zone of the Sierras, yet view rancheros primarily as end users of urban water. Where rancheros are "first in line" if they use water from the ground or surface sources, in the urban system they are last. Municipal services extract water primarily from one aquifer, deliver it to the city to be treated, and then use trucks or pipes to deliver it to communities in the mountains. As a municipal water manager reported in an interview, less and less water was delivered to the rancheros as the drought of 2006-2012 wore on. Meanwhile, urban users saw little change in their water availability. Yet, urban and rural water users in the Sierras are interdependent. The actions of rancheros in the main water recharge zone have implications for the urban water supply system, just as the water demand of the city has implications for the rural water supply system.

At the time of writing, the federal government is pursuing drought reform (*personal communication*, UNAM faculty), and the State of Baja California Sur and the City of La Paz are pursuing sustainable development initiatives (*personal communication*, UABCS faculty, and the Sustainable Development Manager of the State of Baja California Sur). This situation opens up the potential for new forms of citizenship around water issues. The use of participation and collaboration processes in sustainable development may increase people's access to decision making so that they may receive benefits from the system. Reducing sources of social and economic vulnerability can help rancheros adapt to drought, for example, through government work programs or subsidy programs. However, the specific social and environmental context must be incorporated into drought recovery more than it has in the past. The Baja Peninsula

differs considerably in ecology and culture than the rest of Mexico, and many adaptive strategies that work on the mainland fail here. Practitioners with Niparajá, the local NGO, are well-positioned to address this issue, as they have already accomplished significant achievements in water conservation in other parts of the state.

This research has shown that access to urban water increases the adaptive capacity of rural Sierra households in normal seasons. However, the municipal water providers have said that they cannot deliver the same amount of water to rancheros during severe drought. This situation suggests that ranchero adaptive capacity is negatively impacted during drought, although urban services may delay the rancheros' response. Modern urban water management in the La Paz watershed is an outcome of historical change developed alongside a ranchero culture. This study encourages understanding and recognition of the human experience of rancheros sudcalifornianos in the La Paz, Mexico watershed as a needed component in an inclusive, regional, and sustainable development plan. It is important that future sustainable development initiatives recognize both the impact of urban growth on rancheros and the impact that rancheros have on the urban water supply. Public participation initiatives in the state meant to incorporate the needs of the rural communities into policy making have seen some success, particularly in recruiting rancheros to participate in Water User Associations in Guerrero Negro to the north (*personal communication*, CONAGUA, 2013). Also, the local non-profit Niparaja has been successful in the ranchero communities of the Sierra la Giganta y Guadalupe in organizing to purchase land for conservation.

Even if the role of local knowledge is recognized as important in such sustainable development decision making, there may be uncertainties about what to do with that knowledge. This is because the governing bodies of the La Paz watershed lack institutional capacity, contend

with internal corruption and interagency politics and struggle for compliance with water use regulations. Rural communities tend to exhibit distrust of external institutions and lack experience in the democratic process. At the same time, stories of success spread as rancheros travel and present their ideas about drought mitigation and alternative tourism to other ranchero communities. Rancheros have demonstrated a willingness to be open to new ideas and practices. Implications for practitioners would be to promote word-of-mouth and rural-to-rural engagement, perhaps by employing young rancheros to travel to other communities and share knowledge.

This study also presents baseline data that can be used in future studies to compare to other communities in Baja California Sur, or to begin longitudinal data collection. Although many of the specific sources of vulnerability experienced by rancheros in the study area are unique to the La Paz watershed, the results of the case study provide relevant findings. Drought interacts with social risks and opportunities that shape both the adaptive capacity of households as well as the adaptation strategy options from which they can choose. Future studies should also account for extreme events that do not lead to migration, and the negative or positive consequences that result from immobile rural populations in a critical recharge zone for an aquifer.

Because it has been shown that the Sierra rancheros are a vulnerable population, and that their drought context in terms of both social and climatic changes are in flux, consistent monitoring of ranchero adaptive capacity to drought is warranted to promote water justice.

6.2 Future research

Since demographic and migration information was collected on each family member, further analysis of the household survey data could reveal gender and age differences in mobility/immobility between family members. Opportuntiies exist to triangulate these findings with the geospatial data collected in the La Paz municipality. These could collectively be used to incorporate more variables that can further explore proximity determinants on mobility/immobility such as household distance to roads, wells, pipes, and city center, among other variables. Remotely sensed vegetation data was collected that could also be used as a proxy to study soil degradation over time, an idicator that is commonly used to measure natural capital at the household scale. For example, (Nelson et al., 2005) measured natural capital focusing on land use, using proportion of farm area significantly degraded (%) and the average proportion of days that the pasture growth index was less than 0.05 over a ten year period. Another study operationalized natural capital in terms of soluable C, microbial biomass N, Olsen P, soil Ph, and number of earthworms, for a very specific measurement of New Zealand kiwifruit orchards (Saunders, Kaye-Blake, & Campbell, 2010). Soil science could be added to the current research results to understand the social impacts of soil degradation in the area, since agricultural drought was under-studied in this project. Additionally, geographers in La Paz and in Colorado were interested in ground-truthing remotely sensed data with transect surveys that could contribute to understanding of agricultural drought and potential for soil degradation. Such an analysis can be further correlated with survey questions that ask about travel times to market and the ability of rancheros to grow food.

Raw historical rainfall data was obtained for the past 40 years throughout the La Paz municipality. Scientists at the University of California, Irvine were designing a model to

calculatepredicted migration based on rainfall data and were interested in modelling La Paz migration against drought over time. With financial support, these linkages could contribute to the connection between environmental change and human behavior, and could differentiate between rural and urban impacts. For this study, I collected data on the spatial differentiation of water access and allocation in the Sierras. Municipal services are not distributed evenly in the city center either, and further study in this area could survey urban residents to understand urban and peri-urban spatial and water inequality. In addition, because this study was focused on access to freshwater resources in terms of quantity, water quality issues were eliminated to shorten the length of the survey. Future research on water quality is warranted to understand the full extent of water insecurity in this region. If households do have access to water, but that water is contaminated, then water security is negatively impacted.

Beyond the present study, several research opportunities around extreme weather, water supply, and mobility emerged as I began to learn about the area and establish rapport with communities in different parts of the state. Driving back and forth down the Baja Peninsula, I stopped in Mulegé on the coast of the Sea of Cortez. An American, who graciously offered her guest house for a night, told me that the municipal government was actively re-locating locals out of the floodplain after several consecutive floods. Meanwhile, foreigners living in the floodplain hired locals to maintain their homes during the monsoons instead of buying insurance. This situation could possibly be a symbiotic relationship that is a cheaper alternative for foreigners living in Mexico while helping the local economy. This situation provides a textbook case of environmental migration with clear roles of the environment, culture, economy, and politics interacting in a socio-ecological system.

I also met a family in San Javier, who was in the middle of moving their ranch to another location with a more reliable water source. They expressed willingness to host an ethnographer to study their move through participant observation. With my work with UABCS and the local non-profit Living Roots, I learned about households who are isolated who could provide interesting comparative insights about the constraints and opportunities that city services offer. They introduced me to a *ranchero* whose family continues the tradition of moving to and from the mountains and coastal areas to follow water sources. This family was willing to host an ethnographer for long-term study, and there is interest in the local university UABCS for this type of study.

Another study site for research on the ability and willingness of new actors to join the dialogue on climate action and environmental conservation is in the rural area surrounding Guererro Negro on the northern border of the state. This area is home to one of the success stories in stakeholder involvement and water conservation (through the water users associations (WUAs) program through CONAGUA) (*personal communication*, CONAGUA and the Office of Sustainable Development, 2013). Research in this area was inaccessible to me at the beginning of the study due to mistrust of outsiders after international NGOs won regulations against over-fishing that ultimately effected the self-sufficiency of local fishers. However, participants in this study offered to introduce me to people in this community. Opportunities now exist for comparitive household surveys, ethnography, and participant rural appraisals on the social impacts of drought on ranchero communities throughout Baja California Sur.

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APPENDIX A - Household survey materials

Consent to Participate in a Research Study, Colorado State University

TITLE OF STUDY: *Drought-induced human migration in Mexico*

PRINCIPAL INVESTIGATOR: *Kathleen Galvin, Ph.D., Professor, Department of Anthropology,*

CO-PRINCIPAL INVESTIGATOR: *Melissa Haeffner, Graduate Degree Program in Ecology, Doctoral student,* melissahaeffner@gmail.com

You have been selected to participate in this research because there are high levels of dryness and also high levels of migration in your area. Households in this community have been selected at random to discuss whether or not these two things are related. Ideally, the head of household will fill out the survey. If the head is not available, the spouse or other adult is asked to fill out the survey. *This study is being conducted by Colorado State University. The purpose of this study is to understand how drought conditions have affected you, and to study how people decide to migrate based on these conditions.*The survey will be conducted at your home, and is expected to last less than 1 hour. You will be asked to fill out a questionnaire in Spanish or English. If you cannot read and write in either of these languages, the researcher will ask you the questions in one of these languages and record your answers. It is requested that only persons 18 years or older fill out this survey. It is best if the head of household, or an adult family member, complete the survey.

- *There are no known risks to filling out this survey. If at any time you feel uncomfortable, you can skip any question or stop completely.*
- *It is not possible to identify all potential risks in research procedures, but the researchers have taken reasonable safeguards to minimize any known and potential, but unknown, risks.*
- *There are no direct benefits to you as a result of completing this survey. However, it is anticipated that the knowledge generated from this study may benefit all of those suffering from drought. Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.*
- *We will keep private all research records that identify you, to the extent allowed by law. Your information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. You will not be identified in these written materials. We may publish the results of this study; however, we will keep your name and other identifying information private. We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be replaced by a numerical code, for example, 0001, and this will be stored electronically in a password-protected file. After seven years, all data records will be destroyed.*

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions about the study, you can contact the investigator, Melissa Haeffner at melissahaeffner@gmail.com.or Andrew Jones, Baja Bioregional: ajventure@gmail.com. *If you have any questions about your rights as a volunteer in this research, contact Janell Barker, Human Research Administrator at 970-491-1655. We will give you a copy of this consent form to take with you. This consent form was approved by the CSU Institutional Review Board for the protection of human subjects in research on August 8, 2012.*Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing 2 pages.

Signature of participant	Printed name	Date
Signature of research staff	Printed name	Date

Small landholder Questionnaire

Date: _____

Ranch Community: _____ Larger Region: _____ Municipality: _____

GPS: UTM Zone Easting _____ Northing _____

Interview # _____

	Relationship	Gender (m/f)	Age	Education level	Occupation	Birthplace	Current residence	If not living in birthplace, is there a desire to return?	If migrated, dates	If migrated, place(s)	If migrated, motivation(s)
Person 1	Head of household										
Person 2											
Person 3											
Person 4											
Person 5											
Person 6											

Natural Capital

1. What is your main water source for human consumption?
   a. □ surface water (e.g., arroyo)
   b. □ well
   c. □ spring
   d. □ other _____
2. What is your main water source for animals?
   a. □ surface water (e.g., arroyo)
   b. □ well
   c. □ spring
   d. □ other _____
3. Do you conserve water? □ Yes, how? _____ □No
4. Do you hold a concession with CONAGUA for any water use (e.g., tubewell)? □ Yes □No
5. Have you had to change where you get your water from in the last 10 years? □ Yes why? _____□No
6. Do you think the weather has gotten more unpredictable over the last 10 years? □ Yes why? _____ □No
7. What would you say is the main **environmental** threat to your life? _____
8. During the last drought, did you take any of the following actions to mitigate the negative effects?
   a. □ Switched from free-range to corralled animals
   b. □ Switched from cows to goats
   c. □ Planted more feed for animals
   d. □ Stored feed
   e. □ Planted more produce to sell
   f. □ Planted food for personal use
   g. □ Migrate
   h. □ Obtained PET work
   i. □ Obtained other work outside of the ranch
   j. □ Worked with other families to share resources
   k. □ Other _____
9. Are you currently doing any of the following activities to plan for a severe drought in the future?
   a. □ Plan to migrate
   b. □ Store water
   c. □ Conserve water
   d. □ Diversify income sources
   e. □ Invest in education
   f. □ Work more closely with people in the community
   g. □ Other _____

Social Capital

1. Do you have an address or phone number of someone in another place who you could contact right now if you needed to migrate?
   □ Yes □No

2. Do you think you would be able to find a travel companion if you needed to migrate right now? □ Yes □No

3. Are you a member of any organizations (e.g., COTAS Comité Técnico de Aguas Subterráneas, school board, other)?
   □ Yes, which? _____ □No

4. How do you obtain information about droughts?
   a. □ Environment signals (e.g., previous rains, animal behavior, change in vegetation, etc.) _____please explain
   b. □ Family
   c. □ Other ranchers
   d. □ Radio
   e. □ TV
   f. □ Other _____

5. Who do you feel is the most responsible for helping your household in times of drought?
   a. □ Myself
   b. □ My community
   c. □ Government, which agency? _____
   d. □ NGOs, which? _____
   e. □ Other _____

Financial Capital

1. Please indicate the percentage of your income adding up to 100%.

A	Ranching	
B	PET	
C	Other job	
D	Sale of produce	
E	Family business (restaurant, handicrafts, etc.)	
F	Remittances	
G	Government aid	
H	Pension	
I	Savings	
J	Loans	
K	Other	
	TOTAL	100%

2. How do you expect to finance recovery from the next drought?
   a. □ Personal savings
   b. □ Government help, which agency? _____
   c. □ Other _____

3. Do you have insurance for your land? □ Yes, with whom? _____ □ No, why not? _____

4. Do you have insurance for your animals? □ Yes, with whom? _____ □ No, why not? _____

5. Do you have disaster insurance? □ Yes, with whom? _____ □ No, why not? _____

6. If you do not have insurance, what would make you more likely to get insurance in the future?
   _____

7. Do you have access to credit or loans? □ Yes, with whom? _____ □ No

8. Do you have any concessions/contracts with CFE? □ Yes □ No

Physical Capital

1. Do you have a land title to your property?
   □ Yes □ No

2. How many hectares do you have access to?
   a. □ 0
   b. □ 1-5
   c. □ 6-10
   d. □ more than 20 _____

3. How many cows do you own?
   a. □ 0
   b. □ 1-10
   c. □ 11-20
   d. □ more than 20 _____

4. How many goats do you own?
   a. □ 0
   b. □ 1-10
   c. □ 11-20
   d. □ more than 20 _____

5. How many mules do you own?
   a. □ 0
   b. □ 1-10
   c. □ 11-20
   d. □ more than 20 _____

6. How many horses do you own?
   a. □ 0
   b. □ 1-10
   c. □ 11-20
   d. □ more than 20 _____

7. How many chickens do you own?
   a. □ 0
   b. □ 1-10
   c. □ 11-20
   d. □ more than 20 _____

8. Do you mainly grow your own food to eat, or do you mainly buy food?
   a. □ Grow food
   b. □ Buy food

9. Do you have **stored** water for the future? (functions and holds water)
   a. □ Bordo
   b. □ Presa
   c. □ Other _____

10. How far, **in hours**, do you have to travel to the nearest market? _____to sell _____ to buy

Human Capital

1. Do you have a birth certificate? □ Yes □ No
2. Do you have a passport? □ Yes □ No
3. Do you have health insurance? □ Yes □ No
4. Does anyone in your family have a disability or chronic illness? □ Yes □ No

5. If you thought you had to leave your community, what would drive you to do so?
    a. □ Natural disaster
    b. □ Job
    c. □ School
    d. □ Lifestyle
    e. □ Health reasons
    f. □ Other _____
    g. □ Would never leave, under any circumstance

6. Have you received training from outside experts?
    a. □ Water conservation, who? _____
    b. □ Economic development, who? _____
    c. □ Weather forecasting, who? _____
    d. □ Other, who? _____
    e. □ None

7. In which areas would you like to receive services? _____

Thank you for your participation!

Consentimiento para participar en una investigación de la Universidad Estatal de Colorado

Investigador PRINCIPAL: Kathleen Galvin, Ph.D., profesor, departamento de Antropología, kathy@nrel.colostate.edu CO-PRINCIPAL investigadora: Melissa Haeffner, programa graduado de licenciatura en ecología, estudiante de doctorado, melissahaeffner@gmail.com.

La encuesta se llevará a cabo en su casa y se espera que dure menos de 1 hora.

Se solicita que sólo las personas de 18 años o mayores llenen esta encuesta. Es mejor si la cabeza del hogar, o un miembro adulto de la familia, completa la encuesta.

- **No hay riesgos** conocidos por llenar esta encuesta. Si en cualquier momento se siente incómodo, puede omitir cualquier pregunta o detener completamente la encuesta. No es posible identificar todos los riesgos potenciales en los procedimientos de investigación, pero los investigadores han tomado precauciones razonables para minimizar los riesgos conocidos y los riesgos potenciales pero desconocidos.

- Por completar esta encuesta usted no tendra ningun beneficio directo. Sin embargo, **se prevé que el conocimiento generado en este estudio puede beneficiar a todos los que sufren de sequía.** Su participación en esta investigación es voluntaria. Si decide participar en el estudio, puede retirar su consentimiento y dejar de participar en cualquier momento sin penalización o pérdida los beneficios que le corresponden

- **Todos los registros de la investigación que lo identifican a usted los mantendremos confidenciales**, hasta lo permitido por la ley. Su información se combinará con información de otras personas que participan en el estudio. Cuando escribamos el estudio para compartirlo con otros investigadores, vamos a escribir acerca de la información combinada que hemos reunido. Usted no será identificado en estos materiales escritos. Quiza publiquemos los resultados de este estudio; Sin embargo, mantendremos su nombre y otra información de identificación confidencial. Haremos todo lo posible para evitar que cualquier persona que no está en el equipo de investigación sepa que usted nos dio información, o lo que es esa información. Por ejemplo, su nombre será sustituido por un código numérico, por ejemplo, 0001, y esto se almacenará electrónicamente en un archivo protegido con contraseña. Después de siete años, se destruirán todos los registros de datos.

Antes de decidir si desea aceptar esta invitación a participar en el estudio, por favor preguntar cualquier duda que pudiera venirle a la mente ahora. Más tarde, si usted tiene preguntas acerca del estudio, puede contactarse con el investigador, Melissa Haeffner en **melissahaeffner@gmail.com**. Si tiene alguna pregunta acerca de sus derechos como voluntario en esta investigación, póngase en contacto con Janell Barker, administrador de investigación humana en 970 491 1655. Le daremos una copia de este formulario de consentimiento para tenerlo con usted. Este formulario de consentimiento fue aprobado por la Junta de revisión institucional de CSU para la protección de sujetos humanos en investigación el 08 de agosto de 2012.

Su firma indica que ha leído y entiende esta información y que voluntariamente firmar este documento de consentimiento. Su firma también indica que ha recibido, en la fecha de firma, una copia de este documento que contiene 2 páginas.

_____ ___ _____

Firma del participante nombre impreso Fecha

_____ ___ _____

Firma del personal de investigación nombre impreso Fecha

Cuestionario para los rancheros

Fecha: _____

Comunidad del Rancho: _____ Región: _____ Municipio: _____

GPS: UTM zona Este_____ Norte_____

Entrevista # _____

Miembros del hogar

	Relación	Género (m/f)	Edad	Nivel de educación	Ocupación	Lugar de nacimiento	Residencia actual	¿Si no viven en el lugar de nacimiento, existe un deseo de volver?	Si ha migrado, fechas	Si ha migrado, lugar(es)	Si ha migrado, motivo (s)
Persona 1	Cabeza de la familia										
Persona 2											
Persona 3											
Persona 4											
Persona 5											
Persona 6											

1. ¿Cuál es su principal fuente de agua para el consumo humano?
   a. □ Aguas superficiales (p. ej., arroyo)
   b. □ Pozo
   c. □ Poza
   d. □ Otro _____
2. ¿Cuál es la principal fuente de agua para sus animales?
   a. □ Aguas superficiales (p. ej., arroyo)
   b. □ Pozo
   c. □ Poza
   d. □ Tajo
   e. □ Otro _____

3. ¿Conserva el agua? □ Sí, ¿cómo? _____ □No

4. ¿Posee una concesión de CONAGUA para cualquier uso del agua (p. ej., pozo)? □ Sí □ No

5. ¿Ha tenido que cambiar la fuente de dónde saca el agua en los últimos 10 años porque no tiene agua? □ Sí □No

6. ¿Cree que el tiempo se ha vuelto más impredecible en los últimos 10 años? □ Sí ¿por qué? _____ □No

7. ¿Cuál diría que es la principal amenaza ambiental a la que se enfrenta? (p. ej., escasez de agua, inundaciones) _____

8. ¿Durante la última sequía, cuáles de las siguientes acciones hizo para disminuir los efectos negativos?
   a. □ Encerró a sus animales en un corral
   b. □ Cambió de vacas a cabras
   c. □ Plantó más alimento para sus animales
   d. □ Almacenó alimentación
   e. □ Produjo más para vender
   f. □ Plantó alimentos para uso personal
   g. □ Migro
   h. □ Obtuvo trabajos PET
   i. □ Obtuvo otro trabajar fuera del campo
   j. □ Trabajó con otras familias para compartir recursos
   k. □ Nada
   l. □ Otro_____

9. ¿Están actualmente haciendo cualquiera de las siguientes actividades para planear una severa sequía en el futuro?
   a. □ Plan para migrar
   b. □ Reservas de agua
   c. □ Conservar el agua
   d. □ Variar – diversificar sus ingresos
   e. □ Invertir en educación
   f. □ Colaborar más estrechamente con personas de la comunidad
   g. □ Nada
   h. □ Otro _____

1. ¿Usted tiene un número de teléfono o dirección de alguien en otro lugar que podría contactar ahora mismo si necesitará migrar?
□ Sí □No

2. ¿Cree que podría encontrar un compañero de viaje si usted necesitará migrar ahora? □ Sí □ No

3. ¿Es miembro de alguna organización (por ejemplo, COTAS Comité Técnico de Aguas Subterráneas, Consejo escolar, otros)?
□ Sí, ¿de cuál? _____ □No

4. ¿Obtiene información sobre las sequías?
   a.□ Sí Señales del medio ambiente (p. ej., lluvias anteriores, comportamiento de los animales) por favor explique_____
   b.□ Sí Familia
   c.□ Sí Otros rancheros
   d.□ Sí Radio
   e.□ Sí TV
   f.□ Sí Otra _____
   g. □ No

5. ¿Quién piensa que tiene la mayor responsabilidad de ayudar a su familia en tiempos de sequía?
   a. □ Yo
   b. □ Mi comunidad
   c. □ El gobierno ¿quién exactamente? _____
   d. □ ONG, ¿cuál? _____
   e. □ Otros _____

Por favor, indique su ingreso u otros recursos usados cada mes para vivir poniendo monedas en los vasos para representar la cantidad. Me doy cuenta de que esto puede ser una pregunta personal, pero no estoy interesado en la cantidad de dinero que usted gana, sólo el grado de importancia que estas actividades representan para usted.

Por ejemplo, si la mayoría de su sus ingresos los obtiene con la cría de ganado y su cónyuge vende productos en el mercado, y su hija que vive en el extranjero y le envía un poco de dinero cada mes, tal vez le pondría 6 monedas en la taza que dice "ganadería," 3 monedas en la taza que dice "venta de productos" y 1 moneda en la taza para "Mi familia me manda dinero."

A	Ganadería	
B	PET	
C	Otro trabajo	
D	Venta de productos	
E	Empresa familiar (restaurante, artesanías, etc.).	
F	Mi familia me manda dinero	
G	Ayuda del gobierno	
H	Pensión	
I	Ahorro	
J	Otros	
	TOTAL	10 monedas

2. ¿Cómo espera pagar los daños que ocasionará la próxima sequía?
   a. □ Ahorros
   b. □ Ayuda del gobierno ¿Qué organismo? _____
   c. □ Otro_____

3. ¿Tiene seguro para su tierra? □ Sí, ¿con quién? _____ □ No, ¿por qué no? _____

4. ¿Tiene seguro para sus animales? □ Sí, ¿con quién? _____ □ No, ¿por qué no? _____

5. ¿Tiene seguro de desastres naturales? □ Sí, ¿con quién? _____ □ No, ¿por qué no? _____

6. Si no tiene seguro, ¿qué le haría tener ganas o necesidad de un seguro en el futuro?

_____

7. ¿Tiene acceso a créditos o préstamos? □ Sí, ¿con quién? _____ □ No

8. ¿Tiene cualquier concesión o contrato con la CFE? □ Sí □ No

1. ¿Tiene título de tierra de su propiedad? □ Sí □ No

2. ¿Cuántas hectáreas tiene?
   a.□ 0
   b.□ 1-10
   c.□ 11-20
   d.□ más de 20 ____

3. ¿Cuántas vacas tiene?
   a.□ 0
   b.□ 1-5
   c.□ 6-10
   d.□ más de 10 ____

4. ¿Cuántas cabras tiene?
   a.□ 0
   b.□ 1-5
   c.□ 6-10
   d.□ más de 10 ____

5. ¿Cuántas mulas tiene?
   a.□ 0
   b.□ 1-5
   c.□ 6-10
   d.□ más de 10 ____

6. ¿Cuántos caballos tiene?
   a.□ 0
   b.□ 1-5
   c.□ 6-10
   d.□ más de 10 ____

7. ¿Cuántos pollos tiene?
   a.□ 0
   b.□ 1-5
   c.□ 6-10
   d.□ más de 10 ____

8. ¿Normalmente cultiva su propia comida para comer, o compra su comida?
   a. □ Cultivo mis alimentos
   b. □ Compro mis alimentos

9. ¿Tiene alguna forma de almacenar agua para el futuro? (¿funciona? y ¿tiene agua?)
   a. □ Bordo
   b. □ Presa
   c. □ Otra _____
   d. □ No

10. ¿Qué tan lejos, **en horas**, tiene que viajar al mercado más cercano? _____para vender _____ para comprar

Capital humano

1. ¿Tiene un certificado de nacimiento? □ Sí □ No

2. ¿Tiene un pasaporte? □ Sí □ No

3. ¿Tiene seguro de salud? □ Sí □ No

4. ¿Alguien en su familia tiene una discapacidad o enfermedad crónica? □ Sí □ No

5. ¿Por qué razón dejaría usted su comunidad?
   a. □ Desastres naturales
   b. □ Trabajo
   c. □ Escuela
   d. □ Calidad de vida
   e. □ Razones de salud
   f. □ Otro _____
   g. □ No la dejaría nunca, bajo ninguna circunstancia

6. ¿Ha recibido capacitaciones de profesionales?
   a.□ Conservación de agua, ¿de quién? _____
   b.□ Desarrollo económico, ¿de quién?_____
   c.□ Meteorología, ¿de quién? _____
   d.□ Otro, ¿quién? _____
   e.□ Ninguna

7. ¿En qué áreas desearía recibir capacitaciones? _____

¡Gracias por su participación!

APPENDIX B – Interview materials

Consent to Participate in an Interview for a Research Study
Colorado State University

TITLE OF STUDY: Drought-induced human migration

PRINCIPAL INVESTIGATOR: Dr. Kathleen Galvin, Department of Anthropology, PhD, kathy@nrel.colostate.edu

CO-PRINCIPAL INVESTIGATOR: Melissa Haeffner, Graduate Degree Program in Ecology, PhD student, melissahaeffner@gmail.com

WHY AM I BEING INVITED TO TAKE PART IN THIS RESEARCH? You are invited to take part in this study because you are an official in public services relating to water, land use, natural resource management, agriculture, economic development or migration.

WHO IS DOING THE STUDY? This study is being conducted by Colorado State University.

WHAT IS THE PURPOSE OF THIS STUDY? The purpose of this study is to understand how people respond to drought conditions, and when people decide to migrate based on these conditions.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST? The survey will be conducted at the participants' office, and is expected to last less than 1 hour.

WHAT WILL I BE ASKED TO DO? You will be asked some questions about your expertise. You may choose to skip any question at any time and would not affect your participation.

ARE THERE REASONS WHY I SHOULD NOT TAKE PART IN THIS STUDY? All measures will be taken to keep your name confidential unless you prefer that your name is used in the study.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?
> There are no known risks to participating in this interview. If at any time you feel uncomfortable, you can skip any question or stop completely.
> It is not possible to identify all potential risks in research procedures, but the researchers have taken reasonable safeguards to minimize any known and potential, but unknown, risks.

ARE THERE ANY BENEFITS FROM TAKING PART IN THIS STUDY? There are no direct benefits to the participant. However, it is anticipated that the knowledge generated from this study can be a benefit to all of those suffering from drought.

DO I HAVE TO TAKE PART IN THE STUDY? Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

WHO WILL SEE THE INFORMATION THAT I GIVE? We will keep private all research records that identify you, to the extent allowed by law.

Your information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. You will not be identified in these written materials. We may publish the results of this study; however, we will keep your name and other identifying information private.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be replaced by a numerical code, for example, 0001, and this will be stored electronically in a password-protected file. After seven years, all data records will be destroyed.

WILL I RECEIVE ANY COMPENSATION FOR TAKING PART IN THIS STUDY? No, there is no compensation available at this time.

WHAT IF I HAVE QUESTIONS?
Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions about the study, you can contact the investigator, Melissa Haeffner at melissahaeffner@gmail.com. If you have any questions about your rights as a volunteer in this research, contact Janell Barker, Human Research Administrator at 970-491-1655. We will give you a copy of this consent form to take with you.

[This consent form was approved by the CSU Institutional Review Board for the protection of human subjects in research on (Approval Date).

Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing 2 pages.

_____ _____

Signature of person agreeing to take part in the study Date

_____

Printed name of person agreeing to take part in the study

_____ _____

Name of person providing information to participant Date

_____

Signature of Research Staff

Public Official Interview Guide

Role of Organization
What is the role of your agency in water management?
What is your role in the organization?
What do you or your organization think is the major concern about water management in your jurisdiction?
Do you think that environmental conditions are changing in your jurisdiction? If so, how?

Water policy and drought
Which droughts has your organization responded to?
How has your organization responded to drought?
Has your organization learned from past drought and changed its operations accordingly?
Is your policy around water management influenced by other actors (e.g., federal government, state government, lobbyists, civil protests, scientists, etc.)? If so, how?
What do you see are the institutional challenges around drought?
Who do you think should be responsible for responding to drought?

Water infrastructure and drought
What technology, physical or human capital, has your organization pursued to alleviate water scarcity issues? (e.g., dams, irrigation, desalinization, storage, conservation, economic development/alternative livelihoods)

Vulnerability and drought
Who is the target population for your services?
What kinds of community relief has your organization devised to respond to drought? What were some the major successes? Were there any failures, if so, have they been addressed?
To what extent do you think government funds influence people's relationship with the environment at the local level? (What influence does it have on people's behavior?)
Migration and drought
Do you think that households in Baja California Sur have changed how they use water recently? If so, which households? When? Why? How?
Do you think that households in Baja Califoria Sur move when there is a drought?
Do you feel the water infrastructure is adequate to serve the needs of in-migration in the towns/cities?
Do you feel that water infrastructure is adequate in the rancheros?

Suggestions
If you could suggest a policy to better manage water in your jurisdiction, what would it be?
Which agencies or groups in your area are involved in water management (broadly defined) in Baja California Sur?
Whom should I talk to next?

Consentimiento de participación en una entrevista para un studio de investigación de la Universidad del Estado de Colorado.

TITULO DEL ESTUDIO: Impactos del manejo del agua en el estilo de vida de los rancheros
PRINCIPAL INVESTIGADOR: Kathleen Galvin, Ph.D., Professor, Department of Anthropology, kathy@nrel.colostate.edu
Co-INVESTIGADOR PRINCIPAL: Melissa Haeffner, Graduate Degree Program in Ecology, PhD student, melissahaeffner@gmail.com

POR QUE SE LE ESTA INVITANDO A PARTICIPAR EN ESTA INVESTIGACIÓN: Usted esta siendo invitado a participar en este estudio porque es un oficial a cargo de servicios públicos relacionados con el agua, uso de la tierra, manejo de recursos naturales, agricultura, desarrollo economico o departamento de migración.

QUIEN ESTA REALIZANDO ESTE ESTUDIO? Este studio es realizado por la Universidad Estatal de Colorado.

CUAL ES EL PROPOSITO DE ESTE ESTUDIO? El propósito de este studio es entender como la gente responde a las condiciones de sequía, y en que momento desiden migrar debido a estas condiciones.

EN DONDE SE REALIZARA LA ENTREVISTA PARA ESTE ESTUDIO Y CUANDO TIEMPO DURA? La entrevista sera realizada en su oficina en el horario más conveniente para usted, y se espera que dure una hora.

¿QUE ES LO QUE SE LE PIDE QUE HAGA EN ESTA ESTREVISTA? Re realizaran algunas preguntas relacionadas con su esperiencia. Usted puede elegir saltar cualquier pregunta en cualquier momento. El entrevistador grabara la entrevista únicamente si usted consiente a ello.

¿EXISTEN RAZONES POR QUE NO DEBERIA TOMAR PARTE EN ESTE ESTUDIO? Se tomaran medidad para mantener los datos del entrevistado en estricta confidencialidad, a menos que desee que su nombre sea usado en este studio.

¿CUALES SON LOS PRINCIPALES RIESGOS E INCONVENIENTES?
> No existen riesgos relacionados con la participacion en esta entrevista. Si en cualquier momento usted se siente incomodo, puede saltar cualquier pregunta o detenerse en cualquier momento.
> No es posible identificar todos los riesgos potenciales en los procedimientos de esta investigación. Pero los investigadores han tomado medidas de seguridad razonables para minimizar cualquier riesgo potencial conocido o desconocido.

¿EXISTEN BENEFICIOS RELACIONADOS CON LA PARTICIPACION DE ESTE ESTUDIO?
No existen beneficios directos asociados con esta investigación. De cualquier manera se anticipa que el conocimiento generados en este studio beneciaran a aquellas personas que son afectadas por la sequía.

¿ESTOY OBLIGADO A TOMAR PARTE EN ESTE ESTUDIO? Su participación en este studio es voluntaria. Si usted decide participar en este studio podra retirar su consentimiento y detener su participación en cualquier momento sin que sea usted penalizado por ello o pierda beneficios a los que tiene derecho.

¿QUIEN TENDRA ACCESO A LA INFORMACION QUE USTED POROPORCIONE? Mantendremos la confidencialidad de todos los registros e informacion que pueda ser utilizada para identificarlo, en la medida que la ley lo permita. A Menos que usted otrogue su consentimiento para hacer uso de su nombre, su informacion sera utlizada en conjunto con la informacion proporcionada por otras personas que participant en este studio. Cuando realicemos escritos y documentos para compartir con otros investigadores, utilizaremos la informacion combinada con la de otras personas que participaron en este studio. Usted no sera identificado en el material escrito. Es posible que se realice la publocacion de los resultados de este studio; de cualquier manera mantendremos la confidencialidad de su nombre y otra informacion que pueda identificarlo.

¿QUE PASA SI TENGO ALGUNA DUDA? Antes de que usted decida aceptar esta invitación a tomar parte de este studio, sientase libre de preguntar cualquier duda que pueda surgir. Si posteriormente surgen dudas, usted puede contactar al investigador Melissa Haeffner at melissahaeffner@gmail.com. Si usted tiene alguna duda hacerca de sus derechos como voluntario en eesta investigación, contacte a Janell Barker, Administrador de Investigacion en el area de humanidades al teléfono (1) 970-941-1655.Le entregaremos una copia del consentimiento de participacion para que usted lo conserve.

Da usted consentimiento al investigador para grabar su entrevista en format de audio, y/ o usar su nombre? Usted tiene el derecho de rechazar cualquiera de estas opciones y cambiar de opinion en cualquier momento durante la entrevista.

____ Sí, otorgo mi consentimiento para grabar el audio de esta entrevista.
____ No, no otorgo mi consentimiento para grabar el audio de esta entrevista.
____ Sí, doy mi consentimiento para utilizar mi nombre completo, cargo y departamento.
____ No, no otorgo mi consentimiento para utilizar mi nombre completo, cargo y departamento.

Esta forma fue aprobada por el CSU Revision institucional para la protección de personas que participan en studios de investigación expedida en enero del 2013.

Al firmar este documento, usted reconoce que ha leído la informacion contenida en el mismo y firma de manera voluntaria la carta de consentimiento. Al firmar tambien reconoce que usted ha recivido en la fecha señalada una copia de este documento.

_____ _____
Firma de quien acepta tomar parte en este estudio Fecha

_____
Nombre de quien acepta tomar parte en este estudio

_____ _____
Nombre de quien entrega la información al participante Fecha

_____
Firma del equipo de investigación

Entrevista Guiada a Oficiales de Servicio Público

Función de la Organización
¿Qué papel desempeña su organización en lo referente al manejo del agua?
¿Qué papel desempeña usted- cuál es su función- dentro de la organización?
¿Bajo el cargo que usted desempeña, qué es lo que usted o su organización consideran que es la mayor preocupación en lo referente a gestión del agua?
¿Piensa usted que las condiciones ambientales están cambiando en el área geográfica que está bajo la jurisdicción de su cargo? Si es así, ¿Como?

Política del Agua y Sequía
¿A qué periodos de sequía ha tenido su organización que actuar-hacer frente?
¿Cómo actuó-respondió su organización ante esta sequía?
¿Ha aprendido su organización de la última sequía realizando cambios en sus operaciones como consecuencia?
¿Está su política en torno a la gestión del agua influenciada por otros actores (por ejemplo, el gobierno federal, gobierno estatal, grupos de presión, las protestas civiles, científicos, etc.)? Si es así, ¿cómo?
¿En su opinión profesional ¿Cuáles son los retos institucionales que se presentan en su organización en lo que se refiere al tema de sequía?
¿Quién crees que debería ser responsable de responder a los problemas relacionados con la sequía?

Infraestructura Hídrica y sequía
¿Qué tecnología, recursos-capital físico o humano a desarrollado o implementado su organización para aliviar los problemas de escases de agua? (por ejemplo, presas, sistemas de riego, desalinización, el almacenamiento, la conservación, el desarrollo económico / medios de vida alternativos)

Vulnerabilidad y sequía
¿Quién es la población objetivo de sus servicios?
¿Qué tipo de soluciones a dado su organización a la comunidad para responder ante los periodos de sequía? ¿Cuáles fueron algunos de los principales logros? ¿Hubo algún error, si es así, como se soluciono el problema?
¿Hasta qué punto cree usted que los fondos gubernamentales influyen en las relaciones del hombre con el medio ambiente a nivel local? (¿Qué influencia tiene sobre el comportamiento de la gente?)

Migración y sequía
Crees que en los últimos años ha cambiado la forma en que los pobladores o familias de Baja California utilizan el agua? Si es así que hogares? Cuando? Por qué? De qué manera se ha visto este cambio?
¿Cree usted que la escasez de agua a llevado a los rancheros a abandonar el estado?
¿Cree que los hogares- familias en Baja California Sur se mueven o migran cuando hay una sequía?

¿Considera que la infraestructura de agua es suficiente para atender las necesidades de la inmigración en los localidades urbanas y rurales de Baja California Sur.?
¿Considera que la infraestructura del agua es adecuada para los rancheros?

Sugerencias
¿Bajo la jurisdicción de su área de trabajo, si usted pudiera sugerir un cambio en material política para hacer un mejor manejo del agua, cual sería este cambio?
¿De manera general mencione que agencias o grupos están relacionados con el manejo del agua en Baja California Sur?
¿A quién más me recomienda usted que entreviste?

APPENDIX C – Photos from the field

Figure C.1 Outdoor patio of rural La Paz watershed home. Source: Haeffner, 2013.

Figure C.2 Inside a typical rural home. Source: Haeffner, 2013.

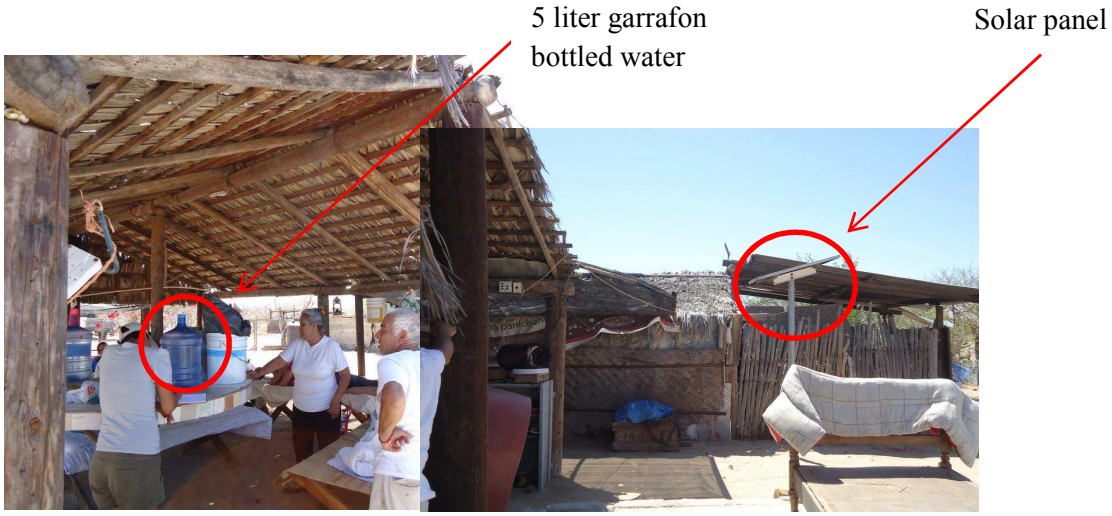

Figure C.3 Rural household in the La Paz watershed. Source: Haeffner, 2013.

Figure C.4 Arroyo flowing through the Sierras, September 2013. Source: Haeffner, 2013

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Figure C.5 Hand-dug storage (*tajo*) to capture natural spring water for animals. Source: Haeffner, 2013.

Figure C.6 Different types of water containers: cistern on top of a *tinaco* (top right), open rainwater harvesting container (top left), commercial water truck (bottom). Source: Haeffner, 2013.

Figure C.7 Washed out road on the way to San Javier from Loreto, July 2013. Source: Haeffner, 2013.

Figure C.8 Sign announcing investments in potable water infrastructure. Source: Haeffner, 2013.

Figure C.9 Water resource for the San Javier communities (right), gravity irrigated to households (left). Source: Haeffner, 2013.

Figure C.10 Local ranchero couple in outdoor patio (right), typical farm plot, San Javier, 2013. Source: Haeffner, 2013.

Figure C.11 Abandoned ranch, Baja California Sur, August 2012.

APPENDIX D –Supplemental Materials

See supplemental materials.