ACCESS REGIMES AND IRRIGATION TECHNOLOGY: WHERE DOES THE WATER SOFT PATH FOR AGRICULTURE LEAD?

A Dissertation

by

HEATHER NICOLE LEE

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Chair of Committee,	Wendy Jepson
Committee Members,	Kathleen O'Reilly
	Christian Brannstrom
	Nancy Plankey-Videla
Head of Department,	David Cairns

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ABSTRACT

In the twentieth century, central governments managed water supply through large-scale infrastructure, known as the water hard path. Water experts advocate for an alternative paradigm for the twenty-first century, or the water soft path, to encourage demand management through conservation technologies. Geographers and other social scientists have examined the water soft path as a policy prescription by evaluating its water conservation effectiveness. Yet, only a few scholars address how the water soft path intersects with existing socio-economic or political processes, and how these interactions alter social relations for those enrolled in the water regime. These studies tend to focus on the integration of water soft path technologies in urban and peri-urban areas for social reproduction. The major research question therefore becomes: How does the water soft path create new pathways of accessing and using water resources that contribute to larger processes of social and political change in the countryside? This project uses a mixed methods case study approach to examine the implementation of the WSP for groundwater irrigation in the central Mexican state of Guanajuato. Research involved long-term fieldwork, including interviews and surveys with farmers, as well as participation observation.

Results show that the water soft path emerged in response to water scarcity, but also as part of a broader package of political economic reform that entailed the re-scripting of state-led environmental governance. The emergence of the water soft path, however, did not signify a complete displacement of the water hard path, rather a coexistence of the two. This coexistence enabled state power to work through the instruments of the water soft path to enforce principles of demand management without devolving control over natural resources to water users. The contradictions produced by this coexistence exacerbated biophysical, economic, and political uncertainties of groundwater irrigators. The ability to mitigate these uncertainties is tied to access to irrigation efficiency devices of the water soft path. Accessing these devices, however, is not equally available to all irrigators. Thus the water soft path, through its coexistence with the water hard path, reproduces patterns and processes of power asymmetries and uneven development.

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NOMENCLATURE

ASERCA	*Apoyos y Servicios a la Comercialización Agropecuaria* (Support and Services for the Commercialization of Agriculture)
CEAG	*Comisión Estatal del Agua de Guanajuato* (Guanajuato State Water Comission)
CEH	*Consejo Estatal Hidráulico* (State Hydraulic Advisory)
CONAFOR	*Comisión Nacional Forestal* (National Forestry Ministry)
CONASUP	*Compañia Nacional de Subsistencias Populares* (National Company for Popular Subsistence)
COTAS	*Consejos Técnicos de Aguas Subterráneas* (Technical Groundwater Councils)
CNI	*Comisión Nacional de Irrigación* (National Irrigation Ministry)
FIRA	*Fideicomisos Instituidos en Relación con la Agricultura en el Banco de México* (Investments Related to Agriculture in the Bank of Mexico)
IE	Irrigation efficiency
IEF	Irrigation efficiency factor
IEI	Irrigation efficiency index
INIFAP	*Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias* (National Research Institute on Forestry, Agriculture, and Fisheries)

IWRM	Integrated Water Resources Management
LAN	*Ley de Aguas Nacionales* (National Water Law)
MX$	Mexican pesos
NAFTA	North American Free Trade Agreement
NRDC	Natural Resources Defense Council
OECD	Organization for Economic Cooperation and Development
PAN	*Partido Acción Nacional* (National Action Party)
PEMEX	Petroleos Mexicanos (Mexican Petroleum)
PMIR	*Proyecto para la Modernización Integral del Riego* (Project for the Integrated Modernization of Irrigation)
PRI	*Partido Revolucionario Institutional* (Institutional Revolutionary Party)
PROCAMPO	*Programa de Apoyos Directos al Campo* (Program for Direct Support of the Countryside)
PROCEDE	*Programa de Certificación de Derechos Ejidales y Titulación de Solares Urbanos* (Program for the Certification of Ejidal Rights and Household Titling)
REPDA	*Registro Público de Derechos de Agua* (Public Registry of Water Rights)
SAGARPA	*Secretaría de Agricultura, Ganadería, Desarollo Rural, Pesca y Alimentación* (Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food)

SARH	*Secretaría de Agricultura y Recursos Hidráulicos* (Secretariat of Agriculture and Hydraulic Resources)
SRH	*Secretaría de Recursos Hidráulicos* (Secretariat of Hydraulic Resources)
USD$	United States dollar
USDA	United States Department of Agriculture
WHP	Water hard path
WSP	Water soft path

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CHAPTER I

INTRODUCTION

1.1 Buying land

We are going to start at the end—the end of fieldwork, that is. Like a Tarantino movie, I want you to read this story much like I was in the beginning of this project—unaware of its significance to the bigger picture. It is one of those ordinary moments where, once you have more context and background, it later becomes extraordinary. This story will be revisited in the conclusion.

It was late in the afternoon in February 2015 and my last day of data collection before heading back the Texas. I travelled out to a fallowed field available for sale in Dolores Hidalgo with four farmers divided into two trucks. I rode with Jorge[1], a civil society organizer who also a farmed about 20 hectares of corn on the side. Driving the other truck was Martin, a farmer who owned several hundred hectares and a packing plant from which he shipped mostly broccoli and a few other horticultural crops for export to China and the United States. With him were Enrique, who assisted Martin with farm management, and Daniel who worked with Martin on commercialization and marketing. Daniel also operated a small farm himself, though most of his income came from his commercialization consultations with other ranchers in the region. In fact,

[1] All names are pseudonyms to protect the identity of participants in this study.

[2] Coexistence is detailed further in Chapters V and VI of the dissertation.

[3] The term *municipio* (municipality) in Mexico refers to the urban center as well as surrounding rural areas, and operates much like the county system in the United States.

Daniel and I had already met a few months prior in a separate business dinner with another client.

Jorge and I were in the lead because Jorge had a farm nearby and knew that his neighbor was selling this piece of land, and had offered to show it to Martin and his associates. We wound down several dirt roads surrounded by farmlands and through a couple rural communities until the trucks stopped at a field on the edge of a small escarpment in eastern Dolores Hidalgo. The winter sun was hanging low in the sky, slightly dimmed by a few hazy clouds but still lighting up the valley below us. As we hopped out of the truck the dry grass and hard soil crunched beneath my boots—we were well into the dry season. The farmers in the other truck hopped out of the truck as well and got straight down to business. Martin kicked at the dirt with the heel of his cowboy boots and smirked, as if trying to evaluate the soil quality. Daniel walked straight to the well house, jostled the lock on the small building, and turned to Jorge, "Does it have water?" he asked, meaning was it still possible to draw groundwater? Jorge replied with a nod, and we all walked over to inspect the pump, which was old and rusted, and seemed to have been installed sometime in the 1960s or 70s. Daniel tapped the pressure gauge as if that would give some indication that the pump was still useable. The men then chatted about the types of crops they might grow, to whom they might market them, and wondered aloud how much it would cost to get the pump and well functioning again and registered with the National Water Commission. The conversation weaved between threads of business and personal chatter for about a half an hour and we eventually said our goodbyes and went our separate ways. No deals were made that evening.

1.2 Situating the dissertation

This dissertation investigates how shifting dynamics of water governance aimed to promote water conservation and sustainability for agricultural production rework social relations as well as access to land and water resources. I take an explicit focus on technology—defined as a socially and materially constructed system of knowledge and skill, technical practices, and devices (Barry 2001; Suchman et al. 1999; Star 1999)—as a key point of entry for analyses of water governance and resource access. Specifically, I examine the transition of two sociotechnical regimes for water, the water hard path and the water soft path, within the context of agrarian change. This section contextualizes the research question, explains how the research objectives were designed to respond to the research question, and outlines the organization of the chapters.

1.2.1 Research problem

In the twentieth century, governments followed the "hard path" to water management by building large infrastructure projects such as dams, irrigation systems, piping, and water treatment plants to mitigate water scarcity by increasing supply (Moore 2011; Bakker 2010a; Swyngedouw 2007; Gleick 2003; Swyngedouw 1999). Driven by modernization and nationalism (Linton 2010; Mitchell 2002; Swyngedouw 1999; Worster 1992), such projects produced uneven, contradictory, and deleterious outcomes for communities and ecological systems (Christian-Smith, Gleick, and Cooley 2012; Bakker 2010a; Gleick and Palannapian 2010; Giordano 2009; Mehta 2007; Swyngedouw 1999). The water management community responded to these challenges following an alternative water policy regime, the so-called "soft path" solutions to water management (Gleick 2003). The water soft-path (WSP) targets improved water efficiency through the use of water demand management strategies, such as user participation, decentralization, efficient technical devices, training exercises, water sequencing, and re-use of grey water (Brooks and Brandes 2011; Qadir et al. 2003; Mazahreh, Shatanawi, and Ghezawi 2000; Barnes 2013). The term water soft-path also accounts for social and ecological considerations beyond the narrow scope of efficiency by including concerns over water quality, reforestation, and aquifer recharge projects (Brooks and Brandes 2011).

Geographers and other social scientists have examined the WSP as a policy prescription by evaluating its water conservation effectiveness (Zeitoun et al. 2011; Mukherji and Shah 2005; Mazahreh, Shatanawi, and Ghezawi 2000). Yet, only a few scholars address how WSP intersects with existing socio-economic or political processes, how these interactions alter social relations for those enrolled in the water regime, and the broader social and political outcomes for the society as a whole. The critical literature on WSP is thin and fragmented with an urban bias. With the exception of a recent publication on grey-water in Egyptian agriculture (Barnes 2013; 2012), scholars examine domestic water provision in the urban or peri-urban environments (Jepson and Brown 2014; von Schnitzler 2008; Loftus 2006; Meehan 2011). Therefore, this project seeks to describe and explain the processes through which WSP strategies and techniques contribute to or redirect agrarian transformation. The major research question therefore becomes: How does the water soft path create new pathways of accessing and using water resources that contribute to larger processes of social and political change in the countryside?

My approach to the question of WSP in production processes draws on recent work in political ecology that aims to integrate critical human-environment research with materially grounded technology studies (Lave 2012a; Furlong 2011; Goldman, Nadasdy, and Turner 2011). An integrative political ecology and science and technology studies (STS) framework is the best approach for two reasons. First, I draw on work in STS to frame the water soft-path is a sociotechnical regime, or a political-complex system of institutional, knowledge-based, and material practices (Geels & Kemp 2007). Second, political ecology attends to the ways actors and organizations advocate for and enroll certain technological choices to sustain strategies of capital accumulation and resource appropriation (Robertson 2011; Birkenholtz 2009b). In combining these two theoretical approaches, I am able to reconceptualize the role of technology within access theory as both a relational *and* structural mechanism for furthering capitalist production and contributing to processes of social differentiation (Jepson, Brannstrom, and Filippi 2010; Ribot and Peluso 2002).

The attention to social differentiation and technological change is key because it brings into question existing proposals for ”transitions towards more environmentally and socially benign societal systems” (Kemp and Loorbach 2006, p. 15 in Shove and

Walker 2007, p. 766). Shove and Walker (2007) theoretically challenge the notion of sustainable transitions management, specifically targeting the political complexities of how sustainable transitions are crafted and practiced as systems of reflexive governance, and how those politics obscure what is considered benign in the process of implementation. In the empirical chapters that follow, I demonstrate that the water soft path—as one such attempt at sustainable transitions management—fails fulfill these socially benign objectives of sustainable water governance because of the appropriation of political and economic benefits of the water soft path by the state and economic elite. In doing so, I argue that a neglect of sociopolitical considerations further undermines the biophysical component of sustainability interventions.

This project addresses the major research question through an empirical case study of water-soft path in the central Mexican state of Guanajuato, with a specific focus on the technologies of demand management—namely groundwater titles, meters, and irrigation efficiency (IE) devices. Irrigated agriculture is an important part of the Mexican economy and culture in the semi-arid northern states and central highlands, yet farmers in these areas are particularly reliant on overexploited groundwater resources for agricultural production (Aboites Aguilar 2012; Scott et al. 2010; Ortega-Guerrero 2009). This project uses Mexico as a case study because the Mexican government has been applying principles of WSP over a period of two decades through policy mechanisms that include pricing tools, conservation education, and water-user participation. The World Bank cites these water management changes in Mexico as a model for water policy and development throughout Latin America (Ijjasz-Vasquez 2012). This study also builds on previous research on institutional change, the hydraulic legacy, and participatory governance in Guanajuato (Marañon 2010; Scott and Banister 2008; Wester 2008; Buechler 2005; Maganda 2003; Guerrero-Reynoso 2000).

1.2.2 Research objectives and strategies

To respond to the research question, there were three research objectives: (1) Describe how the water soft path emerged in response to scientific and regional discourses of water scarcity; (2) Examine the mechanisms required to gain access to and benefit from irrigation efficiency devices in the countryside; and (3) Explain how irrigation efficiency devices offer farmers opportunities to respond to water scarcity and continue cultivating land under conditions of climate change.

The first objective aims to situate the emergence of WSP historically and geographically, and with a particular focus on its applications in the countryside. It explores the sociopolitical, economic, and biophysical drivers that constituted water scarcity as a problem of governance, which in turn required a revision to legal institutions and everyday practices that constituted the relation between people and water. By extending the focus on water scarcity to include questions of agricultural development, this objective articulates how the introduction of the water soft path emerged as part of broader governance reform within Mexico as well as among international development directives.

Objectives two and three built off of the assumption that the water soft path offers new pathways for some farmers to access water resources for agricultural production. The logic follows that the WSP introduced specific artifacts, such as IE devices, that offer pathways of flexibility for farmers to respond to larger threats of water scarcity while offering continued means to cultivate land. This flexibility, then, offers advantages that are unevenly accrued in the countryside, leaving some farmers more vulnerable to a crisis in production.

Based on these observations, these objectives articulate how specific structural and relational mechanisms lead to particular technology choices and their implications for resource access. Examining access to the WSP in all of its components was beyond the scope of the dissertation, and therefore I focused primarily on IE devices because preliminary findings indicated that both farmers and water policy actors perceived IE devices as the primary pathway through which farmers could display compliance with demand management. Also, IE device access presented an interesting paradox: they were widely accepted as beneficial by farmers and water policy actors alike, yet they were only partially adopted in the countryside.

Objective two specifically aimed to identify the mechanisms of access to IE devices by focusing on the mechanisms of production, namely social and institutional ties, land and capital. In identifying the mechanisms of access it also revealed the challenges and impediments some farmers face in securing IE device access. Objective three then was designed to link access to technology to access to natural resources—specifically land and water—in order to understand how the WSP alters the social relations of production. Specifically, it explores how farmers materially and discursively adopt projections of water scarcity and proposed solutions to advance capital accumulation strategies. Taken together, these three objectives articulate a narrative of how sociotechnical regimes of water originate and are implemented, and in turn how producers are able to respond to sociotechnical regime changes in order to continue agricultural production.

1.2.3 A roadmap for reading

This chapter provides an overview of the research problem and introduces the research question and objectives. In Chapter II, I outline the conceptual frameworks that guided analysis. To emphasize the contribution of this work in water resources and water policy, I elaborate on definitions of the water hard path and the water soft path and defend the use of these terminologies in lieu of the more oft-discussed integrated water resources management. I then situate the water hard path and water soft path as sociotechnical regimes. Lastly, I describe the relevance of work in political ecology related to water, technology, and agrarian change.

Chapter III describes the research design. First, I geographically contextualize Guanajuato with a particular emphasis on water resources. I then describe how my methodology is grounded within a constructionist epistemology and critical theoretical framework, which then informs the mixed method case study approach elaborated in the following section. Lastly I describe some of the challenges of conducting fieldwork and my positionality as a researcher.

Chapter IV situates the emergence of the water soft path as a response to domestic and international pressures, and responds in part to Objective One. I begin by emphasizing the importance of groundwater for agricultural production globally, and frame Mexico within that context. I then describe the history of water and agricultural governance in Mexico following the Mexican Revolution. Institutional histories of water and agriculture were characterized by nationalism and protectionism following the Revolution, however that was swiftly reversed in the 1980s with the gradual implementation of neoliberal economic policies. These policies paved the way for two key legal moments—the National Water Law and the North America Free Trade Agreement—in the beginning of the 1990s that transformed water governance and the agricultural economy in Mexico. The current administration of Enrique Peña Nieto continues to deepen these political and economic commitments. I conclude with an overview of the material implications of these transformations through descriptions of the technologies of the water soft path, and the farms and irrigators who participated in this study.

Chapter V argues that the emergence of the water soft path in practice constitutes a coexistence with the water hard path. I begin by framing coexistence within critical urban geographies of water, and scale up these studies' findings to apply them to the water soft path and hard path as sociotechnical regimes. Following the framework of the sociotechnical regime described above—knowledge, institutions, and devices—I detail how the state has maintained control over water resources through the technologies and instruments of the water soft path. I describe how river basin management and the culture of water campaign circulated ideas and practices of scarcity to legitimize the regulation and enforcement of demand management through groundwater titles and metering.

Chapter VI demonstrates how coexistence produces sociotechnical malfunction and exacerbates conditions of uncertainty for farmers. I contend that irrigation efficiency devices are a key site of inquiry into farmers' ability to mitigate uncertainty and continue production. I detail three key sources of uncertainty—biophysical, economic, and political—and the ways in which some farmers are able to mitigate these uncertainties with IE devices. The uncertainties do not operate in isolation from one another; rather can exacerbate the effects of other uncertainties when combined. Throughout, I show how the various forms of uncertainty produce social differentiation among farmers, enabling some farmers to benefit from the implementation of the water soft path while others are forced out of production.

The concluding chapter (Chapter VII) summarizes the findings of the preceding chapters. I then revisit the story about buying land described above and relate this empirical moment to the broader findings of the dissertation.

CHAPTER II

CONCEPTUAL FRAMEWORK

This chapter provides an overview of the conceptual frameworks that guided the processes of data collection and analysis. The first section defines the water hard path and water soft path, and describes the origins of these concepts and their applications for water governance. It briefly explains why the water soft path diverges conceptually from integrated water resources management. The second section defines the water hard path and soft path as sociotechnical regimes, as described within the Multi-Level Perspective (MLP) from theories of sustainability transitions. The final section situates this study within the framework of political ecology. Following Bridge and colleagues (2015, p. 7), it defines political ecology as guided by a set of theoretical, methodological, and normative commitments. I then outline political ecological perspectives on water, technology, and agrarian change.

2.1 From the hard path to the soft path of water governance

Under the hard path, water scarcity was largely addressed as a spatial deficit, or a problem of supply (Table 1). The objective was to identify sources of freshwater and build infrastructure systems to deliver water to areas where water supply was limited. The problematic of water scarcity therefore was resolved through the installation of large scale infrastructural devices, such as dams, irrigation canals, water treatment plans, and domestic water supply networks. The spatial scale and massive financial resources needed for the implementation of such projects made the involvement and leadership of the central government essential. Furthermore, these infrastructures were symbolic of progress and modernity in terms of the health and wealth of the nation, and therefore essential to stabilizing power for central governments (Wester 2009a; Mitchell 2002; Swyngedouw 1999).

Water Hard Path (WHP)	**Water Soft Path (WSP)**
Water supply management	Water demand management
20^{th} century	21^{st} century
Central government led	Decentralized, participatory
Dams, irrigation canals, piping infrastructure, water treatment plants, etc.	Grey water re-use, water capture, irrigation efficiency devices, soil moisture management
Hydrology, engineering, agronomy	Eco-hydrology, climatology, engineering, socioeconomics
Water as a resource	Water as a service

Table 2.1 Comparison of the water hard path and water soft path.

The water hard path is critiqued as a governance paradigm that produces uneven development and ecological destruction (Bakker 2010a; Mehta 2007; Swyngedouw 1999). For example, the politics behind these water projects led to fragmented urban water supply networks (Kooy and Bakker 2008a), outright exclusion of politically disempowered groups from water supply access (Jepson 2012), and collusion between elites and the state bureaucrats to appropriate rural water resources (Jepson and Brannstrom 2014; Birkenholtz 2009b). In addition, hard path projects led to the overexploitation of water resources (Gleick and Palaniappan 2010; Giordano 2009), and a deterioration of freshwater habitats and processes (Christian-Smith, Gleick, and Cooley 2012; Brooks et al. 2009).

Conversely, the water soft path is grounded in principles of water demand management (Barnes 2013; Gleick 2003; Qadir et al. 2003; Mazahreh, Shatanawi, and Ghezawi 2000); however, it also accounts for the freshwater needs of ecological processes (Brooks and Bandes 2011). Therefore the water soft path regime envisions water as a service to be sustained rather than a resource to be consumed (Christian-Smith, Gleick, and Cooley 2012). In other words, water services are designed for their intended destinations and objectives rather than simply using treated potable water for all uses as with the water hard path. It conceptualizes an interdisciplinary approach to knowledge production for water management, extending the dialogue beyond the realm of hydraulic engineers, agronomists, and economists that governed the water hard path. For the water soft path, then, this participation in water management must be accompanied by a restructuring of the geographies of water management decision-making. This demands decentralized and community based institutions and infrastructure to guide both the water delivery process as well as the rules to manage it. Given its particular emphasis on ecological services, biophysical boundaries such as river basins and aquifers become the ideal configuration of these new participatory forms of governance. While these are a few examples, the soft path is often distinguished in the literature for its differences to the water hard path but it will not replace the hard path entirely. While the emphasis is on decentralization of institutions and infrastructures combined with demand management, the central government plays a central role in the creation, management, and enforcement of existing institutions and infrastructures.

The term and conceptual foundations for the “soft path” comes from physicist Amory Lovins’ 1976 article in *Foreign Affairs* “Energy Strategy: The Road Not Taken?” and shortly after a 1977 publication entitled *Soft Energy Paths*. Lovins criticized the unsustainable nature of centralized “hard path” energy infrastructures that concentrated energy production into a limited number of fuel sources (fossil fuels) and controlled by a small population. In its place, he said that U.S. Energy policy should follow a soft energy path that encouraged energy efficiency and decentralized energy production into a broader array of small-scale, renewable energy supply systems such as solar and wind power.

Peter Gleick popularized the term for water management in a short 2002 commentary in *Nature* entitled “Soft water paths” followed by further elaboration in a 2003 publication in *Science*. Much like Lovins’ concept of soft energy paths, Gleick envisioned an approach to water management that would reimagine water services and promote efficient use through changes in water governance and infrastructure. Peter Gleick’s initial and continuing support for the water soft path as the direction for sustainable water governance in the twenty first century is significant due to his influence on water policy in Washington as well as within academia. Gleick is the founder and director of the Pacific Institute for which he serves as the editor of a biennial publication entitled *The World's Water*—a divest of freshwater resources data and key source of government decision-making on water related issues. The Pacific Institute recently published a book entitled *A 21st Century U.S. Water Policy* that outlines the trajectory for following the water soft path (Christian-Smith, Gleick, and Cooley 2012).

This book, along with another edited volume by David Brooks and colleagues (2009), advocate for the WSP as the future of sustainable water management. They highlight its holistic and flexible approach to the complex challenges faced by water managers in many different social and ecological contexts. Critical research on the social and political implications of the water soft path are nascent and focus on individual devices and techniques used to manage domestic water demand (Jepson and Lee 2013; von Schnitzler 2008; Loftus 2006) or grassroots resistance to the hard path (Meehan 2011). These studies are diverse in terms of empirical cases (e.g. water vending machines, water meters, and rooftop harvesting), but they all address a common theme: domestic provision of water for urban or peri-urban dwellers.

This project fills a gap in critical studies of the water soft path because of its attention to technologies of demand management for agricultural production. I focus on the soft path for irrigated agriculture because it largely depends on water pumped from aquifers, and accounts for over 70% of global water withdrawals (Black & King 2009, p. 62), making it a target for improved efficiency initiatives. Moreover, irrigated area is expected to increase 45% by 2080, with a significant portion of the projected increase likely to occur in developing countries, such as Mexico (Fischer et al. 2007).

This project therefore investigates how the implementation of water soft path technologies cascades into larger processes of agrarian change and uneven capitalist development. Jessica Barnes' research on irrigation canals, grey-water reuse, and the Egyptian state (2013, 2012) is an example of this approach. Barnes critiques the water soft path as a reach of the state into reclaimed areas of agricultural expansion and the everyday lives of farmers. Barnes makes two points. First, processes of uneven development characterize WSP through similar social and political mechanisms found for the water hard path. Second, concurrent with studies of WSP for reproduction, unequal power relations are also found in implementation of WSP for agricultural production. This project evaluates Barnes' observations in the context of demand management technologies for agriculture—such as titles, meters, and irrigation efficiency devices—and their implications of water resource access.

2.1.1 A short note on IWRM

The term the "water soft path" has thus far not had not shared the wild popularity in the public policy discourse as integrated water resources management (IWRM). Given this popularity, it is important that I clarify why the water soft path is the best choice of terminology for this project. The Global Water Partnership (GWP) defines IWRM as "a process which promotes the coordinated development and management of water, land and related resources in order to maximise economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP 2010). At the 1992 World Water Forum, IWRM was codified into a set of rules with the creation of the Dublin Principles (Giordano and Shah 2014). In spite of the loose definition provided by the GWP, IWRM represents a prescriptive formula for integrating different sectors into cooperative agreements about water management.

Within Mexico, much of the academic and political discourse surrounding the institutional shifts in water governance in the 1990s has latched on to this terminology of IWRM (referred to in Mexico as the *Gestión Integrada de Recursos Hídricos* or GIRH). I eschew this terminology in this project because of its prescriptive origins as a set of rigid guidelines. The WSP captures what is happening both within and outside of the rules of IWRM. The WSP represents a way of seeing water and materializing water governance that emerges alongside and extends beyond IWRM's set of management guidelines. In its terminology, the WSP entails a subtle (or soft) alternative (or path) to the current trajectory of water governance; unlike IWRM, which maintains its focus on high modernist objectives of "management."

Additionally, the soft path, by re-defining water as a service, aims to reformulate how policy makers, scientists, and citizens come to know water and in turn themselves as water users, water managers, and water producers. I therefore choose to analyze this case from the perspective of the WSP because it enables the analysis to evade the trap of prescriptive suggestions, and evaluations of policy effectiveness. Instead, it allows the analysis to engage how the WSP is being formulated beyond its initial blueprint, as it is worked out, worked in, and reworked through the everyday relations of human and nonhuman actors who are forging identities in relation to the water soft path. In other words, a focus on the water soft path enables an examination of which paths suggested by the WSP approach are taken, by whom, and for what purposes.

2.2 The soft path and hard path as sociotechnical regimes

Over the past decade, critical human environment geographers have increasingly utilized insights from science and technology studies (STS) in their empirical and theoretical frameworks. This technological turn in political ecology is tied to a broader shift in human geography toward a deeper theoretical engagement with the materiality of resources (Meehan 2014; Bridge 2010; Kooy & Bakker 2008; Bakker & Bridge 2006; Swyngedouw 2004; Mitchell 2002). This has brought increasing attention to the role of technology as a core component of human-environment relations.

The focus on technology in political ecological studies of water has been used to examine a variety of technologies including: urban water supply networks (Kooy & Bakker 2008; Gandy, 2008; Swyngedouw 2004), rural water supply networks (Birkenholtz 2012; O'Reilly & Dhanju 2012), dams (Moore 2011; Mehta 2007), groundwater wells (Sultana 2013; Birkenholtz 2009), water meters (Von Schnitzler, 2008; Loftus 2006), and stream restoration projects (Lave 2012b). However, Kathryn Furlong's (2011) article on political ecology and STS in *Progress in Human Geography* critiques how work on water infrastructure in geography has focused on large supply-driven systems, to the effect that many smaller-scale complementary technologies are left out of empirical analyses. Furlong (2011, p. 460) has identified these as "mediating technologies," or the "devices that can be added to an infrastructural network with the intention of modifying its performance (e.g., efficiency technologies)." In addition to efficiency technologies, mediating technologies is a useful term to refer to devices that modify water quantity and/or water quality (e.g., point-of-use water filtration systems). Furlong argues that the opportunities for integrative research in political ecology and STS emerges over the issue of scale. This collaboration involves opening geography scholars' pessimism to possible contingencies and opportunities technology can afford, while helping STS ground their narrow focus on technological innovation in broader political and economic processes. In this discussion, she points to the multi-level perspective (MLP) approach in STS as a potential opportunity for research.

The multi-level perspective (MLP) investigates trajectories of technical transitions through a nested hierarchical approach (Geels 2010; Geels & Schot 2007; Geels 2002) (Figure 2.1). MLP is grounded in a relational ontology by privileging the co-constitution of humans and non-humans; however MLP is unique from actor network theory (ANT) in that by definition it rejects ANT's flat ontology and emphasizes multiple scales of interaction. Scholars familiar with the history of political ecology may notice similarities between this work and Blaikie and Brookfield's (1987) notion of nested hierarchies. Although the concept of nested scales has been critiqued for its failure to accurately depict reality, the MLP is intended as a heuristic for the purpose of empirical analyses. The MLP represents key contribution to geographic research on technology as a heuristic with which to investigate emergent technologies of sustainability.

The three scales of interaction are the sociotechnical- niche, regime, and landscape. At the niche scale, or micro-level, radical innovations occur which may fail or succeed when the technologies transfer from the incubated niche to the socially embedded regime. The regime scale, or meso-level, is the alignment and coordination of sociotechnical actors through a particular set of knowledges and practices—or the material and discursive “rules” that enable and constrain the processes of alignment among actors. The landscape, or macro-level, is the exogenous structure that provides the context for actor interaction.

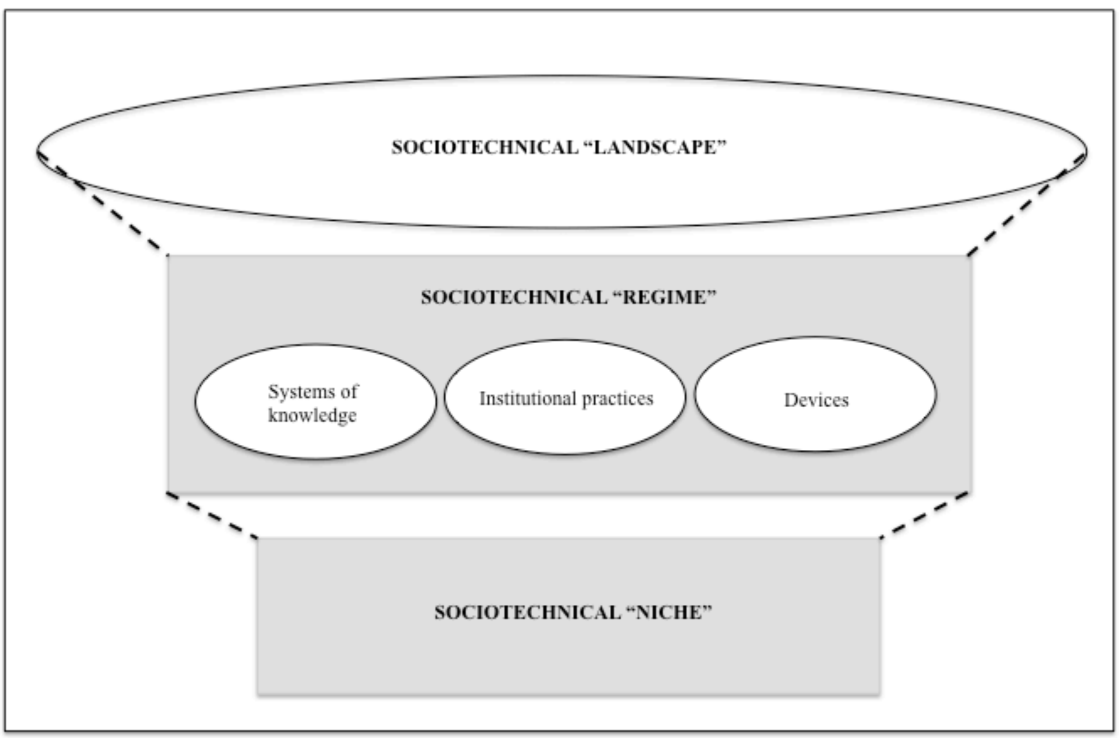

Figure 2.1 The Multi-Level Perspective (MLP). (Based on Geels, 2002).

This project asserts that the water hard path and the water soft path are sociotechnical regimes. Geels (2002) uses the sociotechnical regime to "refer to the semi-coherent set of rules…[which] provide orientation and coordination to the activities of relevant actor groups" (Geels 2002, p. 1260). Geels breaks down the sociotechnical regime into seven dimensions: technology, user practices and application domains (markets), symbolic meaning of technology, infrastructure, industry structure, policy, and techno-scientific knowledge (Geels 2002, p. 1262). While I appreciate the rigor of Geels' categories, I find they can be best represented by a tripartite set: systems of knowledge, institutional practices, and technology. By systems of knowledge, I refer to the way technologies are grounded in epistemological assumptions and institutional practices that guide the symbolic meaning of technology. Therefore, "knowledge is not something an individual has 'more' or 'less' of, but rather reflects the specific forms of practice undertaken in daily life; thick in some areas, thin in others, knowledge is embedded in daily political and environmental activity" (Robbins 2006, p. 191). Institutions are the formal and informal "rules-in-use" (Tucker & Ostrom 2005), including policy, industry structures, application domains, and user practices. Notably, institutions are practices because they must be continuously acted out to become recognized as legitimate and maintain their authority. Lastly, technology refers to the actual material non-human objects in the landscape. These are the artifacts or material transformations of the landscape. While these categories are elaborated on in context below, these are not individually operating categories; rather they are overlapping and relational.

I situate the water hard path and water soft path as sociotechnical regimes and focus primarily on that level. I focus on the regime because studies of the multi-level perspective have tended to privilege examinations of innovation, and therefore focus on the niche as the scale of analysis. As such, scholars have critiques the MLP for obscuring politics and power dynamics (Furlong 2011; Shove & Walker 2007; Geels 2010). This dissertation demonstrates that analyses of transition at the level of the sociotechnical regime can counter this deficit, because of the way it investigates why certain technologies are promoted and how those technologies are then integrated into the sociopolitical landscape.

This project directs its attention toward the transition of two sociotechnical regimes for water. Responding to Shove and Walker's (2007) cautionary critique of transitions management, this project offers insight into the incoherencies and inconsistencies that characterize transition. Indeed, "illusions are productive because they motivate action and repair work, and thus something (whatever) is achieved" (Rip 2006, cited in Shove & Walker 2007). While sociotechnical regimes of sustainability like the water soft path are often promoted for the potential they can achieve (or "illusions"), this project captures "whatever" else is produced in the process. By employing a critical perspective—described in more detail below—this project attends to "trajectories of fossilisation and decay" and the "fundamental transformation in the ordinary routines of daily life" that complicate regime transitions (Shove & Walker 2007, p. 768). By focusing on "fossilisation," I take an explicit look at how legacies of the water hard path are not easily displaced, rather constitute a coexisting and coproducing relation to the integration of the water soft path. Furthermore, the focus on the structural and relational mechanisms of access gets at transformations in social relations and everyday life. To better elaborate on the foundations of this critical approach I turn to work within the subfield of political ecology and its insights on water, technology, and agrarian change.

2.3 Political ecology

Political ecology is a diverse field, but broadly addresses control over and access to resources and the contested relationship between nature and society (Robbins 2011; Peet and Watts 2004; Blaikie and Brookfield 1987). Political ecology emerged around the 1980s with seminal work that questioned the apolitical analyses of environmental degradation (Blaikie and Brookfield 1987), natural hazards (Watts 1983), the binary framing of nature and society (Fitzsimmons 1989; Smith, 1984 [2008]), and positivistic assessments nature, society and economy (Harvey 1974). Political ecology therefore was part of a broader shift within the academy toward Marxist scholarship, post-postivisim, feminist theory, and post-colonial scholarship, however with a specific attention to nature and society (Bridge, McCarthy, and Perreault 2015).

In the decades that followed these origins developed into a wide range of research topics and foci, resulting in a questioning of what truly constitutes a political ecological analysis given its diversity. In a recent compendium of research in political ecology (Perrault, Bridge, and McCarthy 2015), Gavin Bridge and his co-editors (2015, p. 7-8) argue that work within political ecology is made coherent by a set of commitments: (1) a theoretical commitment to critical social theory, (2) a methodological commitment to in-depth, direct observation grounded in qualitative inquiry, and (3) a political commitment to social justice and structural change. To this I would add a commitment to a relational ontology, and constructionist epistemology. Furthermore, I argue that implied within this each of commitments is also a resolution to understand how power works and what power does in the context of social and natural relations. With these set of commitments in mind, the following subsections outline how a political ecology framework is applied to this study, drawing on case studies and frameworks for analyses of water, technology, and agrarian change.

2.3.1 Political ecology and water

Water is a means with which to harness power, an exploration to which geographers have dedicated much attention. States have used water resources as a proxy with which to transform territory and populations, through the assertion of control over landscapes and to revive a spirit of nationalism among the people (Swyngedouw 2004). States have consolidated central power through magnificent feats of water engineering, propelling not only the dispersion of water across the land but also the power of those who capture the waters (Wester 2008). Water conflicts have provided the means with marginalized peasantries reconfigure inner power relations and reassert their cultural customs in the national and international political arenas (Perrault 2008). Water institutions employ a means of fixing scales and privileging a technocratic definition of water in ways that exclude many of those who use the water (Budds 2009). The restructuring of water institutions has also been seen as a way of transferring responsibility of water scarcity problems to other actors, and the overall abandonment of the state (Harris 2009). Some have also suggested that throughout history water has only been what we, as humans, have made it—both discursively and practically (Linton 2010). There are three interdependent threads that permeate this literature.

First, that water is inherently political but has been discursively framed apolitically, by dividing social and hydrological processes into antagonistic binaries. Political ecologists have attempted to rewrite this apolitical history of water through critical analyses of state formation and scientific practice. Indeed it was Erik Swyngedouw's (1999, 445) description of the production of the Spanish waterscape at the turn of the twentieth century that entangled dualistic conceptions of nature and society as socionatures:

> The myriad processes that support and maintain social life, such as, for example, water, energy, food, or computers, always combine society and nature in infinite ways; yet simultaneously, these hybrid socionatural "things" are full of contradictions, tensions, and conflicts.

Furthermore, he asserted that the Spanish state played an active role in the production of particular socionatures as spaces of rule by reorganizing the geographies of water availability as an attempt to rectify social, political, and economic challenges for the state. Building on the work of Swyngedouw (2004; 1999), Jamie Linton (2010) historically traced the rise of "modern water," or the scientific abstraction of water as distinct from social relations through processes of quantification and positivistic science.

This dual process of state-making and scientific abstraction has enabled controversial political decisions to be quickly implemented (Kaika 2003). This has resulted in both the production of uneven geographies of water access through the absence of state services for marginalized populations (Jepson 2013; Meehan 2013; Kooy and Bakker 2008), as well as interventions into the everyday lives and practices of citizens (von Schnitzler 2008; Loftus 2006) with a particular emphasis on gendered water practices within the household (O'Reilly 2006). This combination of the contradictions between water as necessary for human life, yet dominated by a history techno-politics, abstraction, and economization has led to an array of inquiries into the neoliberalization of water governance, and the particular implications for water access, human health, environmental degradation, marginalization, and cultural identities (Jepson and Brown 2014; Harris and Roa-García 2013; O'Reilly and Dhanju 2012; Bakker 2010; Harris 2009; Bakker 2007; Hall and Lobina 2007; Page 2005; Perrault 2005; Prudham 2004; Budds and McGranahan 2003).

Second, this focus on techno-politics and the production of space through the abstraction of water, has led to questions of power and in particular of subjectivity and hegemony. Theorizations of power within political ecologies of water primarily stem from work of Michel Foucault and Antonio Gramsci. Their theorizations of power are distinct in important yet nuanced ways, yet can also be read for their complementarities to the complex ways in which power works (Ekers and Loftus 2008; Li 2008). I will only touch on a few key points of their work relevant to this project (although see Ekers and Loftus 2008 for an excellent discussion).

Foucault (1980) understood power as the "infinitesimal mechanisms" that operate between actors, and sees power and knowledge as integrally related. The possession of knowledge—the “right kind of knowledge”—enables one to take the role of what should be done and intervene in particular ways. Because power is embedded in discourse, power is everywhere. Foucault’s (1991) theory of governmentality, or the creation of governable subjects, experienced a resurgence in political ecology with the Arun Agrawal’s (2005) re-framing of his theory as environmentality. This framework has been applied to groundwater conservation initiatives in India (Birkenholtz 2009; 2008), the making of neoliberal subjects in the waterscape of south Texas (Jepson and Brown 2014), and the partial enrollment of Mississippi delta farmers into water conservation efforts (Shoreman and Haenn 2009), among others.

Gramsci theorized power through the concept of hegemony, or the maintenance of one social group’s dominance over a subordinate group through the establishment of consent and coercion with a particular arrangement of social relations (Ekers and Loftus 2008). The state figures prominently in hegemony. Hegemony’s relevance for water governance is a key concept in a recent edited volume on water governance in the Global South (Harris, Goldin, and Sneddon 2013). In this volume, Christopher Sneddon (2013, p.16) writes:

> Hegemonic concepts such as those examined within the contours of water governance – whether linked to markets and privatization, scarcity and crisis, or participation at national or local levels – are tangibly connected to mechanisms of world hegemony such as international organizations, which (among other functions) legitimize certain norms that serve specific interests and co-opt the elites of dependent countries. From our perspective, it is more fruitful to think of multiple hegemonies, or hegemonic projects, that privilege certain ideas about water governance and disseminate those ideas in specific way.

Thus Gramscian hegemony represents descendant and circulating forms of power among elite groups, while Foucauldian power can be thought of as emergent from everyday practices. A combined approach then examines how power is worked out in multiple ways and by various actors (Ekers and Loftus 2008). Both assert that power is more than ideas, because of the ways it takes on material form through artifacts and physical transformations of socionatures.

The third area of focus in political ecologies of water—technology—emerges from these theorizations of power to examine the "materiality of ideology" (Ekers and Loftus 2008, p. 699). It is the topic of the next section.

2.3.2 Technology and critical theory

Several case studies have recently bridged the gap between the fields of political ecology and science and technology studies (STS) (Lave 2012a, 2012b; Goldman, Nadasdy, and Turner 2011; White and Wilbert 2009; Furlong 2011). This scholarship greatly contributes to a better understanding of how non-human natures and objects are fundamental to the relationship between nature and society, asking complex theoretical questions of agency and power dynamics through the lens of actor-network theory (ANT) (Birkenholtz 2013; Meehan 2014; Sultana 2013; Bakker 2010b). This work has been influential in a multitude of ways, but is relevant to this project for its emphasis on exploring how power is emergent from the connections between—or the "network"—rather than something that is possessed within. In order to get at this concept of power as emergent, this research focuses on the objects themselves and traces their connections to people and processes. It draws on both Foucauldian and Gramscian concepts of the materiality of ideology, to explore the ways in which power dynamics condition the technologies in the landscape as well as the ways in which they are emergent from practices and engagements with those technologies.

Technology is not merely an inanimate tool for achieving production, but a window into the very social relations of production and a means through which to materially evaluate our own conceptions of how the world works and how it is actually being worked. In his discussion of the labor and the production of use value, Marx highlights technology, or "the instruments of labor," as a key analytical lens:

> "It is not what is made but how, and by what instruments of labour, that distinguishes different economic epochs. Instruments of labour not only supply a standard of the degree of development which human labour has attained, but they also indicate the social relations within which men work" (Marx 1867[2004], p. 286)

Technology is an indicator of time, political economy, and social relations. Therefore the instruments by which the WSP is achieved provide a lens into the very social relations of production beyond the scope of water conservation. By tending to the materialities of change we can witness less tangible changes as well—or "economic epochs" as Marx refers to above. In this way, technology becomes the palpable material manifestation of social transformation—the artifacts of political economy.

Recounting these transformations through the production of technologies has been the pursuit of historians of science and technology for decades. If this is true, why bring technology into a theorization of nature and society? The answer resides in the oft-cited quotation that presents itself just a few pages prior to Marx's lengthy discussion of the "instruments of labor" in which he directly references the relation between man and nature. Humans acts through labor as a "force of nature" and "through this movement he acts upon external nature and changes it, and in this way he simultaneously changes his own nature" (Marx 1867[2004], p. 285). Humans and nature are one and the same through the forces of their own metabolisms. Thus, if human's interaction with nature—or labor—is the transformation of the self and if the instruments of labor (or technologies) are a lens into social relations, then an explicit look at these tools as a productive force constituted by a sociotechnical regime enables us to see how social relations and socionatural metabolisms are transformed in the process. Technologies, in other words, are artifacts of the constantly evolving dialectical relation of nature and society.

This can be taken one step further to include technology not only as artifact of the socionatural dialectic but as part of the process and product of self-formation and societal reconstruction. The cyborg metaphor first put forth by Donna Haraway (1991) and further elaborated on in the work of Swyngedouw (1996; 2009), provides a space for fertile theoretical engagements that transcend concerns about technological determinisms because of the way it embraces partialities. Much like Marx's reference to labor as a "force of nature," the same can be said for sociotechnical relations because "It is not clear who makes and who is made in the relation between human and machine" (Haraway 1991, P. 177). Although this is in essence a rephrasing of Marx above, the cyborg metaphor offers not merely an heuristic but a path of action.

This path begins with the idea of the cyborg as regenerated rather than reborn, pointing to a temporality and history in the evolution of sociotechnical regimes:

> "There is no drive in cyborgs to produce total theory, but there is an intimate experience of boundaries, their construction and deconstruction. There is a myth

> system waiting to become a political language to ground one way of looking at science and technology and challenging the informatics of domination—in order to act potently." (Haraway 1991, 181)

This dissertation explores the processes of constructing and deconstructing boundaries between two sociotechnical regimes for water. The failure of WSP theorists and its evaluators to recognize it as regeneration rather than rebirth blinds analysis of the WSP as emergent from and still tied to the WHP. The WHP and the WSP therefore represent a coexistence[2] rather than a displacement of one with the other. By reimagining these sociotechnical regimes as co-produced partialities both materially and ideologically, I reveal the ways in which asymmetries of power are bundled, with the intention of unraveling them so as to construct a more progressive politics of water conservation.

2.3.3 Theories of access and uneven development

This study evaluates the application of these theoretical insights from political ecologies of water and technology for agricultural production. It examines how mediating devices shape the access regime for groundwater extraction, and thus, define the means and mechanisms of resource use in agricultural production. This is crucial because it is in production that we understand how processes of uneven development can occur when social, technical, and natural relations are reconfigured (Smith 1984 [2008]; Kirsch and Mitchell 2004).

In their landmark critique of groundwater exploitation and the tragedy of the commons, Rebecca Roberts and Jacque Emel (1992) use the theory of uneven

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[2] Coexistence is detailed further in Chapters V and VI of the dissertation.

development to argue that "capitalist competition generates a landscape of constant change...[T]he resulting problem is political and economic...and reflects the struggles of groups and coalitions to appropriate the benefits of growth and displace the costs of decline" (p. 251). They describe how this process of uneven development is not merely a factor of land tenure, but also spatial distributional inequity, access to credit systems, exogenous economic factors, and socio-institutional alliances.

These findings are elaborated on in Ribot and Peluso's (2003) "theory of access." Access theory argues that in addition to legal institutions several mechanisms enable resource users to benefit from resource access, including technology, capital, labor, markets, knowledge, authority, identities, and social relations. I shift Ribot and Peluso's focus on natural resources to a focus on technology because in areas of agricultural production technology operates as a key interface between the water resources and water users.

Access theory has proven to be an insightful heuristic for examining the relationship between shifts in environmental governance and capital accumulation (Osborne 2011; Corbera and Brown 2010; Jepson, Brannstrom, and Filippi 2010), and therefore, it offers three contributions to critical perspectives on water infrastructure. First, I examine how land and water are linked biophysically and institutionally. Second, case studies of water infrastructures have described how technical objects and the material waterscape become sites of political contestation, enabling citizens to lay claim to resources including capital, water, and land (Bakker 2010a; Birkenholtz 2009b; Harris 2006). Less explored, however, is dialectical relationship between technology access and land access, or how resources such as capital and land enable resource users to lay claim to technical objects in the waterscape, which in turn furthers existing claims on capital, land, and markets. Third, case studies of water infrastructure investments identify a shift in physical labor practices in order to maintain the technical and social infrastructure. People dig ditches for water pipes, attend meetings on how to manage access to taps and collect payments, travel further for better water quality, and have to collect payments from their own community members (Jepson and Lee 2013; Birkenholtz 2013; O'Reilly and Dhanju 2012; Hall and Lobina 2007). This dissertation articulates the labor involved in gaining access to new technologies—such as titles, meters, and IE devices—including the institutional work and specialized knowledge required to engage in labor in the WSP.

Taken together, this project conceptualizes the WSP as a regeneration of the WHP. Consequently, the tools of the WSP provide a means to access water resources and retrench claims to capital, land and markets. This research builds on critical case studies of water, technology, and development by investigating the implementation of the water soft path as a scarcity reducing technology that requires changes in institutions, knowledges, and devices of agricultural production. This empirical shift further contributes to the integration of political ecology and technology studies by focusing on the links between production, resource access, and technology innovation through the optic of political ecology.

CHAPTER III

RESEARCH DESIGN

In this chapter I provide an overview of the research process, including site selection, methodology and methods, and positionality. I first introduce the basic geography of Guanajuato and my specific study site--its geographical location, cultural and economic activities, biogeography, and climate. Then I discuss how my epistemology and theoretical frameworks guide the direction of the research design from research question to data collection and analysis. The third section details my methods of data collection and analysis, including participant observation, interviews, surveys, and secondary documents. The concluding section reflects on my positionality and challenges faced during the course of research.

3.1 Situating Guanajuato geographically

This study investigates water conservation for agricultural production central Mexican state of Guanajuato. Guanajuato is located on the central plateau northwest of Mexico City, the federal district. Guanajuato is bordered by San Luis de la Paz to the north, Michoacán to the south, Jalisco to the west, and Querétaro to the east. The population of Guanajuato is 5.5 million, with a population density of 179 inhabitants per square kilometer. 70% of people in Guanajuato live in urban areas (>2,500 people) (INEGI 2013). Research was conducted in northeastern part of the state, at the foot of the Sierra Madre Oriental Range, known colloquially as the Sierra Gorda.

Municipalities[3] include San Miguel de Allende, Dolores Hidalgo, San Luis de la Paz, San Diego de la Unión, San Jose Iturbide, and Doctor Mora (Figure 3.1). The average elevation of these municipalities is approximately 2000m (6500ft).

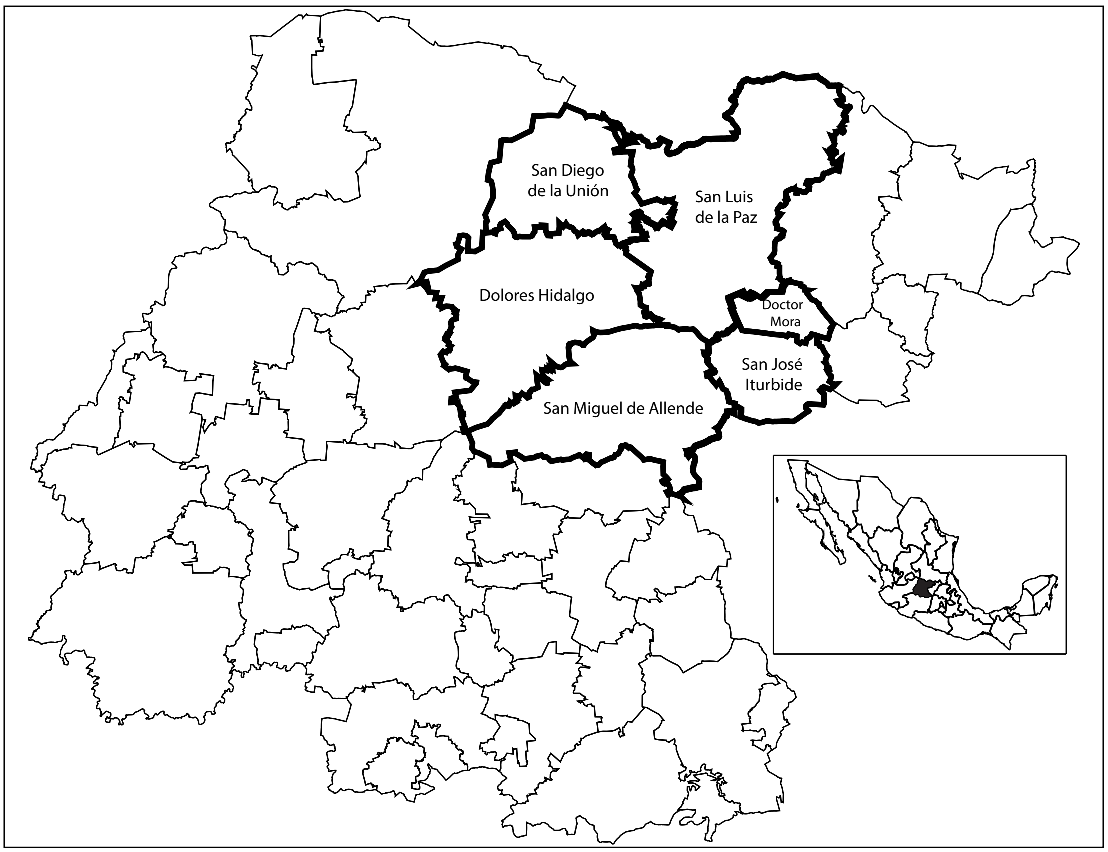

Figure 3.1 Map of municipalities of Guanajuato with study site municipalities highlighted.

[3] The term *municipio* (municipality) in Mexico refers to the urban center as well as surrounding rural areas, and operates much like the county system in the United States.

Guanajuato is located in the heart of colonial Mexico, and historically is known for mining and agricultural production. During the colonial period, the mining of gold and silver in the mountains of northern Guanajuato brought both economic prosperity and environmental destruction to the region. The Spanish are still blamed in many modern discourses of deforestation in northern Guanajuato for the clear cutting of forests. Before the invention of advanced mining techniques, wood was used to fracture rock walls inside the mines. Dry pieces of wood were inserted into holes drilled in the wall, and then wetted to expand and fracture the surrounding rock. Additionally, wood was the primary fuel source for processing and refining gold and silver. Mining still remains in Guanajuato, however tourism has taken its place in the legacy of colonialism.

Guanajuato is home to the town of Dolores Hidalgo, famous for *el Grito de Dolores*, the cry for independence from Spain let out by Father Miguel Hidalgo on the steps of the central cathedral on September 16, 1810. From there, Father Hidalgo led a march for independence south to San Miguel de Allende and westward to the capital city of Guanajuato. For this, Guanajuato is deemed the birthplace of the Mexican independence and attracts Mexican tourists to engage in historical museums, art, and architecture for which Guanajuato is famous. Guanajuato is also popular with international tourists, who come for the charm of the winding underground tunnels and colorful buildings in Guanajuato city, as well as the iconic gothic parish in San Miguel's central square. Many United States expatriates—*los gringos*—have also decided to make San Miguel their home, beginning with artists in the 1970s and 1980s and increasingly retired women and couples from the late 1990s until today.

Guanajuato has also experienced exponential growth in industry in recent years (Cave 2013). Already known for leather processing and shoe manufacturing, it is now rising in prominence as the leading manufacturer of automobiles in Mexico with the presence of GM, Mazda, and Honda (Young 2014). On a direct flight from Dallas, Texas to León, Guanajuato I was sitting in a row with a white middle-aged business man who managed a supply company for clothing manufacturers and a young Mexican-American designer of leather clothing and accessories. Both split their time between the United States and Mexico to varying degrees, overseeing logistics from the United States and production in Mexico. I asked the supply company manager why he thought Guanajuato had seen a surge in manufacturing in recent years, seemingly more so than other states in Mexico. He replied simply, "geography," and went on to explain that all of his clients (clothing manufacturers) were also in Guanajuato, the factories operated at a safe distance from narco-trafficking activity in the North, and it is located right off of highway 57—the main transportation vein that runs through central Mexico from Mexico City to Monterrey, and from there to other highways that connect to border towns in Texas. This same "geography" has also made Guanajuato ripe for agricultural processing and exports, as evidenced by the presence of two major produce freezing facilities and the expansion of U.S.-owned agricultural firms including Mr. Lucky, Monterey Mushrooms, and Taylor Farms. Guanajuato's mild temperatures, and rich volcanic soils in the Bajío region to the south make it an ideal location for agricultural production, and particularly the rising popularity of horticultural products—most notably broccoli, lettuces and spinach.

Northeastern Guanajuato—where this study was conducted—is located on the central plateau, characterized by broad semi-arid grasslands and dispersed mountain ranges. In addition to a variety of grasses, vegetation includes cacti, trees, and shrubs that tolerate dry conditions. Common cacti include various species of *nopales* (*opuntia*), *garambullos* (*cylindropuntia*), and *magueyes* (*agave*). The most common trees include species of oak (*quercus*), mesquite (*prosopis*), and acacia. These species are often cultivated for various reasons—*nopales* and *garambullos* for their fruit, magueys for their nectar, and the trees for their wood. Deforestation and concomitant desertification are of concern due to the high presence of livestock grazing (predominantly goats and cattle), agricultural practices, and climate change. Farmers, scientists, and government officials alike are concerned about the recursive effects of soil infertility, biodiversity loss, and erosion on water availability and water quality in this region.

Mexico is climatically variable, ranging from arid to humid sub-tropical climates. Two-thirds of the Mexico's landscape—in the north and central plateau where Guanajuato is located—is designated as arid or semi-arid with less than 500mm of annual precipitation. This region of Mexico also contains 77% of the population, and generates 79% of GDP (CONAGUA 2013), indicating a geographical mismatch between economic productivity and water availability within the country.

Guanajuato has a temperate and arid climate, with average annual temperatures ranging from 12-30°C (52-86°F). The normal annual precipitation Guanajuato from 1971-2000 was 595 mm (23 in) (CONAGUA 2010b). Precipitation in the state ranges from 300mm to 1000mm annually with an average of 700mm annual precipitation in the south and 500mm annual precipitation in the north. There is consistent rainfall during the summer months (June-September), with the driest months typically occurring between February and April (CONAGUA 2013). In 2011 Mexico experienced on of the worst droughts on record, with an exceptionally dry rainy season. As of November 2011, the entire country was experiencing abnormally dry conditions with Guanajuato classified as in severe and extreme drought conditions (CONAGUA 2013).

Climate change is projected to reduce mean annual precipitation while increasing mean temperatures in Mexico (Christensen et al. 2013). By 2020, precipitation is expected to decrease between 5% and 10%, while temperatures increase between 0.5°C and 1.5°C (Christensen et al. 2013). As a result, half of Guanajuato's land area, is expected to see the effects of desertification, with the northern region where this study was conducted experiencing the bulk of desertification (Christensen et al. 2013). Some models are uncertain whether there will be a long term overall decrease in rainfall, however the increase in temperature is expected to increase overall evaporation and therefore decrease available soil moisture (Liverman and O'Brien 1991).

These shifts in precipitation and temperature pose threats to water availability and therefore water management for farming activities. Climate change has resulted in losses in temporal (rain-fed) agricultural systems, such as the traditional *milpa* system of corn, beans, and squash cultivated by smallholders and communal farmers, which are essential to food security in rural communities. Researchers are now suggesting alternative and more drought-tolerant crops such as amaranth, sorghum, and sunflowers to supplement human and animal diets for these farmers (Granados-Ramirez et al. 2004).

Climate change also has an effect on irrigation farmers, most obviously due to the decreased availability of rainwater but also in its unpredictability. Farmers describe how previously it would rain a small amount each day, whereas now they experience dry spells followed by heavy downpours that carry away the topsoil and sometimes crops. These precipitation patterns are associated with climate change and expected to continue and possibly worsen in the future (Huerta et al. 2013). Precipitation variability leads to further reliance on irrigation to offset drought risk, as evidenced by the 44% increase in land under irrigation in my study site from 1999 to 2009. State officials of Guanajuato have deemed water scarcity a crisis for the state, claiming that supply could be exhausted in only ten years (Romo 2013).

3.1.1 Water resources[4] in Guanajuato

Mexico is currently divided into 13 major administrative hydrologic regions (*regiónes hydrológicos administrativas*), following the 1992 National Water Law that aimed to decentralize water governance around watersheds rather than political boundaries. The majority of Guanajuato, as well as the study site for this project, is located within the Lerma-Santiago-Pácifico region (LSP). The LSP is the most

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[4] Surface water for irrigation refers to the water in rivers, lakes, and reservoirs that is often dammed and diverted in canal systems. Depending on the location, surface water is managed privately through cooperatives or publicly at local and/or federal levels. Groundwater, on the other hand, refers to freshwater resources in underground aquifers that are extracted through individual wells, which are constructed and operated privately by landowners but often subsidized and regulated by the state. Much is still unknown about groundwater hydrogeology, however hydrogeologists are attempting to classify aquifers that by renewable and nonrenewable or "fossil" groundwater resources. Renewable groundwater refers to that which is rechargeable even if the rate recharge is exceeded by overconsumption. Conversely, nonrenewable groundwater refers to resources that are not rechargeable, at least not within the time frame in which humans would be able to access and use it.

populated hydrologic region in Mexico, at 22.3 million inhabitants and includes the major metropolitan areas of Guadalajara in the state of Jalisco and León in the state of Guanajuato. The LSP is further sub-divided into three river basin councils (*consejos de cuenca*), of which Guanajuato is located in the Lerma-Chapala river basin council. There are three main rivers in Guanajuato: the Río Turbio in the west and the Río Laja to the east, which both empty into the Río Lerma in the south. The Río Laja runs from just north of the city of Dolores Hidalgo, including part of the study area of this project, and meets the Río Lerma in Salamanca in southern Guanajuato.

Surface water for agriculture is primarily managed by two irrigation districts, known as 011 and 085, which are both located in the Bajío region of Guanajuato where soil quality is some of the best and agricultural productivity some of the highest in all of Mexico. 011 is located in southwestern Guanajuato and manages 109,893 HA, and 085 is located in eastern Guanajuato and manages 11,363 HA. Irrigation district 011 is supplied by 5 major dams (*presas*) that draw predominantly from the Río Lerma: Solís, Yuriría, Tepuxtepec, and Purísima. Presa Solís, located in the municipality of Abasola, is the largest dam in the state and was built in 1949. It stands at 56.7 meters tall with a maximum capacity of 870,000 cubic meters and a usable volume of 738,640 cubic meters in 2010. Irrigation district 085 is supplied by Presa Ignacio Allende along the Río Laja, which was constructed in 1968 just outside of the city of San Miguel de Allende. Presa Ignacio Allende stands at 43 meters with a maximum capacity of 150,000 cubic meters and a usable volume of 115,650 cubic meters in 2010.

Surface water contamination is one of the greatest threats to surface water availability the Lerma-Santiago-Pacífico region (LSP). The LSP has high concentrations of organic material in 46.7% of the surface waters tested, indicating low levels of oxygen availability, which can threaten biodiversity (CONAGUA 2013). In Guanajuato, researchers have identified traces of rat poison, mercury, nickel, petrochemical solvents, lead, arsenic, and industrial wastes in the Turbio, Laja, and Lerma rivers as well as in other smaller rivers in the state (Garcia 2014). The Lerma watershed is deemed unsuitable for drinking and recreation, and treatment is recommended before agricultural or industrial use (Espinal Carreón, Sedeño Díaz, and López López 2013). The section of the Río Laja where this study was conducted suffers from chemical contamination and nutrient loading from agricultural runoff, as well as sedimentation and erosion due to gravel extraction from the riverbed and livestock grazing along the edges of the river.

Groundwater is also an important source of water in the semi-arid central plateau due to demands of urban residents, agriculture, and industry, coupled with low levels of surface water availability and low, seasonal precipitation. Groundwater exploitation is the most pressing issue for water management in Guanajuato, with 85% of the state water deficit corresponding to groundwater (CEAG 2006). The total aquifer deficit has been increasing every year, reaching a deficiency of 1,126 cubic meters (Hm3) in 2004 (CEAG 2006). Aquifer depth in northeastern Guanajuato ranges from 36 to 175 meters (118 - 574ft), some of the deepest levels in the entire state. The aquifers in my study site are declining at a rate of 2 meters per year on average, with a range of 1.3 to 3.6 meters per year (COTAS de Guanajuato 2013) (see also Figure 3.2).

State and federal water authorities divide Guanajuato into 18 aquifers, which are monitored by 14 technical groundwater councils or COTAS (*consejos técnicos de agues subterráneas*). According to CONAGUA, most of the aquifers (78%) in Guanajuato are considered overexploited, meaning the amount of extraction exceeds recharge (CONAGUA 2013). In fact, 3 of 4 aquifers in my study site are exploited—Laguna Seca, Alto Rio Laja, and Doctor Mora—while the San Miguel de Allende aquifer is the only one classified as stable (CONAGUA 2013).

Geologist Marcos Adrián Ortega Guerrero (2008) disputes the governmental authorities' delineation of aquifer boundaries and argues that many of the aquifers are hydrogeologically connected. He identifies the area of northern Guanajuato to be connected by one aquifer, which he terms the Independence Aquifer. The Independence aquifer is characterized by gravel and sand infiltration that can take hundreds of years of recharge. According to carbon dating of groundwater, the water extracted from the Independence Aquifer is between 5,000 and 35,000 years old, making groundwater in the aquifer a "fossil" or nonrenewable resource (Ortega Guerrero 2008). The groundwater in these aquifers also has high levels of sodium at 15% of test sites, which has implications for soil fertility and plant health in agricultural zones. Fossil water also has implications for human health due to higher concentrations of naturally-derived

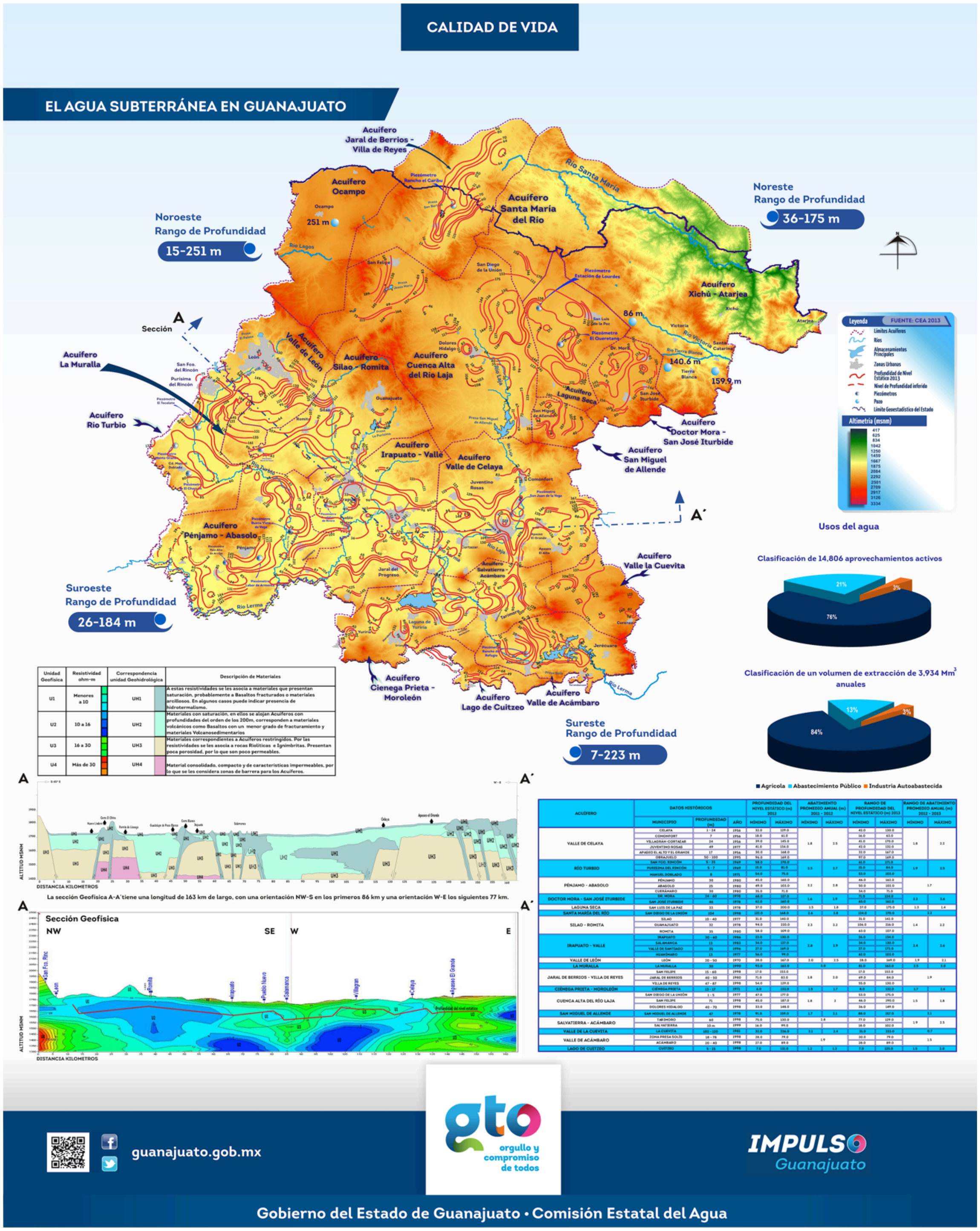

Figure 3.2 Groundwater data poster circulated by the Guanajuato State Water Commission, (CEAG) at the National Meeting of Aquifers Councils in 2011. The poster depicts elevation, hydrogeology, groundwater allocations, and aquifer decline. (COTAS de Guanajuato 2013)

fluoride and arsenic (Ortega Guerrero 2009). The designation of groundwater in northern Guanajuato as nonrenewable is particularly alarming, because groundwater is the only legal source of water for agricultural and domestic consumption in this part of the state. Concessions for surface water resources from the Río Laja are allocated downstream in the Lerma-Chapala watershed.

Groundwater allocation is divided into agricultural, public, industrial, and hydroelectric uses (Figure 3.1). At the national level, 69% of groundwater concessions are designated for agricultural use, or 22.2 billion cubic meters of water annually. Agriculture is an essential part of the economy and culture in Guanajuato, and is consistent with global agricultural freshwater consumption (87%). Irrigation and water capture are important mechanisms used by farmers to provide water for crops and livestock during the dry season. There is a deficit between rainfall and potential evapotranspiration for every month with the exception of July and August (Wester 2008). Although the state of Guanajuato covers only 1.6% of the surface area of Mexico, it accounts for more than 9% of irrigated land and only 3% of land fed by temporal rainfall in Mexico (SIAP 2014). Guanajuato has 478,236 HA (1,181,750 acres) of land under irrigation, representing 15.6% of total land cover and 45.6% of total land under agricultural production (SIAP 2014). The top five irrigation crops in the state of Guanajuato in terms of hectares under production are: sorghum, grain[5] corn,

[5] Mexico's agricultural statistics delineate between cereal crops grown as grain (*grano*) or fodder (*forraje*). Therefore grain cereals typically are reserved for those grown for human consumption, such as grain corn that is ground into cornmeal for tortillas. Nevertheless, in daily practice the line between grains for human and animal consumption are often not entirely clear, because many farmers use some of the plant to supplement livestock food.

alfalfa, grain barley, and grain wheat. In my study site in northeastern Guanajuato the top five crops are: alfalfa, grain corn, broccoli, beans, and fodder oats. Alfalfa is by far the most popular irrigated crop, with more than twice as many hectares under production as the next crop (SIAP 2014).

Alfalfa is a popular crop because it is easy and inexpensive to grow, and is often easy to sell as well. Alfalfa is grown for animal fodder for use in livestock production, primarily dairy and beef cattle. Indeed fodder production constitutes 98% of the water usage of livestock rearing, of which beef cattle, dairy cattle, and pigs are the most water-intensive animals (Mekonnen and Hoekstra 2012). Alfalfa represents a significant burden on water usage because it requires year-round production, and therefore nearly nine months of irrigation depending on precipitation. In other words, farmers continue to irrigate and harvest alfalfa between January and April even while the remainder of the land is left fallow due to low water availability and the risk of frost. Over the past twenty years, farmers in Guanajuato have been gradually shifting toward vegetable production geared toward national as well as export markets. In my study site, farmers are increasingly producing broccoli, cauliflower, lettuce, bell peppers, and dried chiles. The shift toward horticultural crops is being heralded by the state and federal water commissions as a better use of scarce water resources due to higher potential profit margins than fodder crops, as well as more seasonal production patterns that allow the land to lay fallow for a cycle. Some civil society organizers, however, doubt this strategy actually works to reduce water consumption in practice. Although less water is used per peso earned, many farmers in practice cultivate broccoli and other cold-tolerant plants year-round. Furthermore, as more farmers enter the horticultural market there is a risk of plunging profit margins due to the over-saturation of the market, as has already happened in other groundwater-dependent agricultural systems (Birkenholtz 2009).

Like much of Mexico, agriculture has been declining in economic importance and supplemented by the growth of the industrial and service sectors. Agriculture, however, still remains a key employer in rural areas and a cornerstone of the culture and history of Guanajuato. It also remains the largest consumer of both surface and groundwater resources. In response to the high demand for water resources coupled with the increasing threat of climate change to water availability, Guanajuato has been a central focus for water policy reforms which will be discussed in more detail in Section 4.1. Guanajuato is in the process of undergoing interconnected political, economic, and biophysical transformations that directly impact the lives and livelihoods of rural citizens who depend on agricultural production for subsistence and commercial purposes. Though the specificities of this research project pertain directly to the study site, the findings are relevant to other agricultural producers around the world who are also faced with changes in the way waters' flows are restricted by political-economic and biophysical factors.

3.2 On methodology

Research is inherently a political process in which the researcher decides what is considered “data,” how to analyze that data, and how to interpret that data in the communicative process (Denzin and Lincoln 2011). Academic research is therefore almost always informed by theory in an explicit manner, of which the researcher is self-conscious. As such, it is necessary for researchers to reflect upon the assumptions that ground their own research in order to develop an awareness of these prioritizations in data generation and analysis. Denzin and Lincoln (2011) identify various interpretive communities, which clarify the types of knowledge the researcher would consider legitimate. Two research concepts underpin the type of interpretive community with which a researcher might identify: epistemology and theoretical perspective.

A researcher's epistemology is an abstract concept that guides "how we know what we know" (Crotty 1998, p. 8). Epistemology, or a theory of knowledge, helps to identify where meaning is made between the researcher and object of study (or subject and object). Crotty (1998) identifies three epistemological stances that can be thought of as existing along a continuum: objectivism, constructionism, and subjectivism. Depending on the epistemological stance of the researcher, might exist "out there" waiting to be discovered (objectivism), only within the subject that is making meaning of what she is seeing or experiencing (subjectivism), or knowledge could only come to fruition through the relationship between subject and object (constructionism). Our epistemological stances guide the way we develop, analyze, and represent our data in the research process.

As researchers, we then use our epistemological stance to guide how we make sense of the world around us. In other words, our epistemology informs our theoretical perspective. A theoretical perspective is "our view of the human world and social life within that world, wherein assumptions [about our methodological strategies] are grounded" (Crotty 1998, p. 7). While epistemology is our assumptions of knowledge and meaning-making, a theoretical perspective takes us a step further to identify how our understanding of meaning-making informs the way we intend to interpret social life. The theoretical perspective is therefore instrumental in how we plan, conduct, and make meaning out of the social phenomena we observe. It directs the questions we ask in an interview, the answers we are seeking (be they exploratory or limited), the notes we write down as significant in our observations, the themes we pull out in our analytical processing of the data, and the rhetoric we use when we write up our findings. In sum, our theoretical perspective both enables and constrains every step of the research process and will inform the way we as researchers engage with and interpret the social world.

As evident in my research question and objectives as described in Chapter 1, I take an explicit constructionist epistemological stance. This research focuses on the sociotechnical restructuring in Mexico and other countries around that world in response to concerns about water availability, distribution, and quality which together produce geographies of water scarcity. Water experts in government and academic institutions in Mexico conceptualize water scarcity as driven by biophysical--changing microclimate conditions and precipitation patterns--or social (mismanagement of water due to water use practices and state policy). Rarely are the biophysical and social seen as working in conjunction with one another. By taking a constructionist stance, I am not arguing that water scarcity is a fabrication on the part of farmers and water experts; rather, I assert that water scarcity is a relational process that is contingent upon entangled associations of the social and the natural, or "socionatures" (Swyngedouw 1999). In this way my assumptions of knowledge are used to understand the way that *others* make meaning of the world, though with the recognition that I bring my own filter to how that meaning making is translated in the research process.

By using a constructionist perspective, my research reveals the ways in which the dominant narrative about the phenomena of water scarcity in central Mexico is centered on an objectivist stance that then informs particular types of solutions to the problem in ways that are technical and programmatic. Like other social constructionists, I am concerned with how "different discourses construct social phenomena in different ways, and entail different possibilities for human action" (Burr 1995, p. 15). My concern with discourse is grounded in a Foucauldian theory of power and knowledge (Foucault 1990). These prevailing ideologies inform how the strategies of governing—which Foucault refers to as the "technologies of government"—lead to the formation of particular subjectivities that are disciplined by subtle negotiations of power (Foucault 1991). My disposition for a constructionist epistemology has led me to frame my interpretations of research within critical theory.

Critical inquiry is a multifaceted and complex theoretical perspective that has its roots in Marxian theory and is comprised of various sub-fields. Critical inquiry seeks to identify sources of contradiction, unlock (class) consciousness, and engage the researcher with the object of study by aiming to change unjust or unequal social conditions (Crotty 1998). While my discussion above revealed the ways in which I am concerned about *ideas* of water scarcity, my disposition for critical theory also tends to the material outcomes and conditions that inform and are informed by these ideas.

Indeed, (Marx 1888[1969], p. 15) writes in one of his most (in)famous lines “The philosophers have only *interpreted* the world in different ways, the point is to change it” (Crotty 1998, p. 117). In his *Theses on Feuerbach*, Marx suggested that critiques of ideas alone were insufficient; rather we must pay attention to the ways in which our consciousness is informed by the world around us. Therefore Marx, considered the founder of critical theory, himself was a perhaps a constructionist. A critical perspective therefore leads me to question not only the institutions that govern farmers’ conservation of water resources, but also the technical devices, labor relations, and capital investments involved in this process. Furthermore, I do not seek to understand water conservation ‘in the moment’ but as an historical process that is guided by structural conditions at multiple scales. My research therefore seeks to understand not only the practices of water use and conservation at the level of the individual farmer, but also how those are informed by the farmers’ relationship to formal and informal institutions and capital resources.

As Crotty’s (1998) schema suggests, my constructionist epistemological perspective indeed informs my critical theoretical perspective. As a result, the processes of data generation and analysis are necessarily reflexive and require a mixed method ethnographic approach. Before reflecting on my positionality in the final section of this chapter, I outline the methods of data collection and analysis.

3.3 Methods

3.3.1 Timeline of data collection and analysis

Methods of data collection for this dissertation were primarily fieldwork based, and involved multiple long-term stays in Guanajuato. In 2011 and 2012 I conducted four weeks of preliminary field research in Guanajuato on three separate occasions and began collecting data in March 2013. In May 2011 I attended a workshop "Water, Climate, and Society in Guanajuato," where I met a key informant in the state water commission (CEAG). In September 2011, I attended the 17th Annual Water Expo in Guanajuato and the national meeting of technical groundwater councils (COTAS). In November 2012, I visited nine farms and six COTAS managers in five different COTAS districts in Guanajuato with the assistance of contacts at CEAG and the State Hydraulic Council (CEH).

From February to November of 2013 I returned to Guanajuato to complete a total of 7 months of fieldwork on two separate visits. During this time I developed new research contacts in the agricultural and civil society sectors, leading to several participant observation opportunities. At this time I also conducted in-depth farmer interviews to assist in the development of the survey, which was piloted in November 2013. After revising the survey, I returned to Guanajuato on three separate visits from May 2014 until March 2015 and collected survey data, additional interviews, and attended relevant participant observation opportunities for a total of 7 additional months. In sum, data were collected over a total of 14 months and 5 separate visits. These data were analyzed throughout the process of data collection, but predominantly when I returned to College Station from January to April 2014 and again in January through July 2015.

Fieldwork and data analysis were divided into several short-term visits in order to navigate sources of funding and personal needs. Although this sometimes challenged the ability to maintain a working relationship with participants and key contacts, in the end I found this style of data collection and analysis to be beneficial for the research process. First, it avoided exhaustion on the part of my participants, key informants, and myself as a researcher. Second, it enabled me to witness agricultural production in all seasons in addition to several changes in the institutional, social, and biophysical landscape in ways that can only be afforded by conducting research over the course of several years. Third, the pauses in data collection gave me the time to reflect on my findings, which gave a more organic flow to the types of questions asked and notes taken during observation opportunities. In other words, data collection as well as data analysis followed a grounded approach, allowing the findings to emerge from the research experience as much as from the research questions I sought to answer.

3.3.2 Participant observation

In the beginning stages of fieldwork, participant observation focused on organized events regarding water management, water conservation, and agriculture. I attended several government and civil society sponsored meetings to observe the ways that concerns about water scarcity were framed and what solutions policy makers and civil society advocates proposed. These meetings also served as a venue with which to network with key actors in my study site, including government employees, prominent farmers, scientists, and citizen-activists. The most notable of these meetings included the annual meeting of the COTAS, the annual meeting of the LSP River Basin Council managers, and several presentations headed by a civil organization for water conservation based in San Miguel de Allende. The government sponsored meetings—COTAS and LSP—provided observations about how water scarcity and proposed solutions are framed by policy makers, the governance processes through which the WSP is rolled out, and the institutional tensions and hierarchical structures that enable and restrain decentralized water governance. The civil organization meetings provided opportunities to observe how knowledge of water scarcity is circulated by scientists and policy makers to citizens, and illuminated the processes by which citizens voiced concerns to the state and the concerns they valued most.

These organized meetings and presentations were notably centered on water management and conservation broadly speaking, but led me to several key actors in the agricultural sector who held leadership roles in agricultural or water civil organizations. Several of these individuals became key informants who helped me to contact farmers in my study site for interview and survey data collection, and occasionally invited me to accompany them to their meetings, workshops, and day-to-day work related activities. For example, I accompanied a water civil organization leader to visit several water conservation projects, including a reforestation project, installation of irrigation efficiency devices for a local *ejido*, a greenhouse project for applied learning for local high school students, and to monitor water meters on groundwater wells. I also accompanied an agricultural civil organization leader to a statewide agricultural meeting of ranchers, and went with him on several visits to his own ranch and organizational members' ranches to observe agricultural and water management techniques and infrastructure. In 2014, I attended two agricultural workshops held by INIFAP that instructed farmers on pest control and production techniques for chile and bean crops. From these workshops I developed a working relationship with prominent local rancher who invited me to travel with him on several work related events, including visits to the bank to apply for loans for irrigation infrastructure and greenhouses, meetings with contractors and logistics coordinators for commercial sale of produce, meetings with legal consultants and agricultural researchers, and several visits to produce processing facilities.

Specific observations from these events obviously vary due to differences in the types of experiences, but they provided me with a first-hand observation of the type of work involved as agricultural and water organization leaders and farmers. It enabled opportunities to see how water conservation plays out in practice and how it fits within the broad spectrum of agricultural production activities. Lastly, it underlined the significance of building and maintaining social relationships as a key access mechanism for participating in the WSP.

Throughout these events I took photographs when permitted and jotted down field notes in my notebook, which were later digitized ad then added to for clarification and reflection. Early notes and observations were helpful in guiding the interview process with farmers, and also provided a starting point for the creation of the survey instrument. To analyze participant observation field notes and photographs, I coded key phrases using Atlas.ti software.

3.3.3 Interviews

I conducted semi-structured interviews with farmers that use groundwater to irrigate crops (n = 24). Interviews were audio recorded when permitted by the research participant (n = 17), and for the remaining interviews I took detailed notes during the interview process, and then clarified and elaborated on those notes after the interview was completed. Interview transcripts and detailed notes were entered into Atlas.ti software for coding analysis. Interviews lasted on average an hour and were conducted at local agricultural association offices and on-site at farms. At the agricultural association offices I conducted random sampling with the assistance of the secretary who helped me identify which persons entering the office were farmers. Those farmers who had a groundwater well that they used to irrigate crops were asked if they would like to participate in the interview. For the remaining participants I conducted snowball sampling using key informants from previous interviews and participant observation opportunities to identify interview participants.

Interviews were semi-structured meaning that they were organized around a set of themes, however the conversation was permitted to travel. Themes included knowledges and experiences of groundwater scarcity and climate change as well as strategies to respond to these challenges, agricultural production processes and patterns, water management techniques and infrastructure, benefits and limitations to using IE devices, and experiences with the government and civil society organizations related to water management and conservation on the farm. The purpose of the interviews was to understand the farmers' practices, knowledges, and devices of water use, as well as their engagements with policy makers and civil society organizations involved in water management. The interviews also helped develop the creation of the survey instrument, by indicating which issues were of concern to farmers that need to be further explored and validated by other farmers' experiences.

3.3.4 Survey[6]

3.3.4.1 Survey design and data collection

Building off of data gathered from insights from interviews with farmers, I designed a survey in order to quantitatively assess the mechanisms through which farmers access IE devices. The first draft of the survey was piloted in November 2013 with four farmers and then revised for wording, structure, and some content to help the conduct of the survey flow and make it more understandable to participants. A key informant was very helpful in guiding me through specific translations in order to better communicate the questions.

I conducted face-to-face surveys with 39 farmers in May, June, October and November of 2014 and February of 2015. Surveys lasted 26 minutes on average, but ranged anywhere from 12 minutes to 96 minutes. Four farmer surveys were removed from analysis because they did not fit location-based criteria within the upper Lerma-

[6] Survey instrument is in Appendix A

Chapala river basin, leaving 35 farmer surveys for analysis. Farmers were selected through random and snowball sampling techniques. Randomly selected participants were identified at the local Cattle Association and Agricultural Association offices. I then asked those farmers as well as key contacts made during participant observation and farmer interviews if they had suggestions for other farmers in the area I could contact for the survey. Farmers for the survey were screened on the basis of owning and operating a well for groundwater extraction, and using that water for the irrigation of crops. Once farmers passed the screening process, we reviewed the IRB consent form and I responded to any questions before receiving verbal consent and beginning the survey.

The survey consists of four parts: (1) Ranch description; (2) Farm groundwater management; (3) Irrigation management; and (4) Participant characteristics (see Table 3.1). The content for the survey was derived from interviews with farmers as well as participant observation. I verbally asked the farmer the questions written in the survey, and filled out their answers while the farmer looked on at my notes.

In Section 3 (Irrigation Management) of the survey, I asked farmers to evaluate the significance of statements regarding the benefits and limitations of using or adopting IE devices. From farmer interviews, I developed a list of 7[7] benefits and 8 limitations (Table 3.2).

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[7] There were originally 6 benefits, but after asking several farmers if they had another benefit they would like to add they included "More efficient use of inputs (fertilizers, etc.)" This had not initially been mentioned in any interviews and therefore it was not included in the survey when piloted. After a second farmer also mentioned inputs I added it into the survey as a benefit alongside the other 8. Therefore, there is no information regarding the rating of inputs for 13 of the 39 farmers analyzed.

#	Section	Description
1	Farm characteristics	Municipality; HA owned; HA irrigated; Land tenure; Soil quality; Number of laborers; Crops grown and how they are irrigated and marketed; Animals for consumption/sale
2	Groundwater management	Well depth and flow; Concession amount and type; Meters; Electricity costs
3	Irrigation management	Types of IE devices used and whether they were bought with financial support; Change in irrigation area in past 5 years; Ranking of benefits and limitations to using IE devices
4	Farmer characteristics	Age; Gender; Education; Civil organization membership; Off-farm work

Table 3.1 Survey description

#	Benefit statements	Limitation statements
	With irrigation efficiency devices...	***It is difficult to access irrigation efficiency devices because...***
1	The farm produces higher yields.	There is not enough money for installation.
2	There is a more efficient use of water.	There is not enough money for maintenance.
3	There is less labor demand.	I lack market access.
4	I can produce more profitable crops.	The groundwater title is difficult to obtain or maintain.
5	I can increase the area under irrigation.	There is too much financial risk involved.
6	There is more efficient use of energy.	I don’t know how to use them.
7	There is more efficient use of inputs.	It is difficult to access credit or support for them.
8	-------------------------------	I am worried about insecurity.

Table 3.2 Benefits and limitations statements within survey.

I first asked the farmers about each benefit individually, and asked them to rank it on a scale from 1 to 5 with "1" meaning that they did not perceive it to be a benefit of or limitation to using or owning IE devices, and "5" meaning that they thought that it was the most significant benefit of or limitation to using or owning IE devices (Table 3.3). Farmers were instructed to give only one statement a ranking of "5," however some farmers still chose "5" for more than one statement. For these farmers, I reviewed each statement they designated as a "5" and asked them to pick one statement from these that they thought to be more important than the others. I then kept that statement ranked as a 5 to indicate that it is the "principle benefit/limitation," and changed the other statements to a value of 4, or a "very important benefit/limitation." Other farmers did not give any statement a ranking of "5," however they were still asked to choose one statement as the most important. Their answer was noted as the "principle benefit/limitation" however their response was not changed to a value of "5" because they did not rank the benefit/limitation in that manner. Some farmers—particularly those who did not have experience with using or owning IE devices themselves—did not feel confident in the forced ranking of one benefit or limitation, and therefore were allowed to say "I don't know." In both the benefits and limitations section, farmers were asked if they had any additional suggestions to add to the list which were written down and ranked in the same manner as the other statements.

Rating	Benefits meaning	Limitations meaning
1	It is **not a benefit** of using IE devices.	It is **not a problem** for accessing IE devices.
2	It is a benefit, but it is **not important to me**.	It is a problem, but it is **not important to me**
3	It is a benefit, but it is **somewhat** important to me.	It is a problem, and it is **somewhat** important to me
4	It is a benefit, and it is **very** important to me.	It is a problem, and it is **very** important to me
5	It is the **most significant (principle)** benefit of using IE devices	It is the **most significant (principle)** problem for accessing IE devices.

Table 3.3 Description of ranking system for benefits and limitations.

3.3.4.2 Survey analysis

Data were entered into and analyzed in Excel software. Each survey participant represents a row and the columns represent the questions of the survey. Notes were added in a column at the end for any extraneous information that was provided during the survey but was not a question included in the survey.

In order to understand the number of hectares irrigated by device type over the course of the year, I extracted out the crop data. Once I did this I calculated the total number of hectares irrigated (2,636.5 HA) which exceed the area under irrigation reported in the earlier section (2,118.5 HA) by more than 500 hectares—a 24% increase! The increase can be explained by crop rotation. For example, a farmer reported that he had 100HA under irrigation over the past year, but he irrigated 50HA of that land in alfalfa year-round and rotated the other 50HA between corn in the spring/summer and oats in the fall/winter. When reported by crop type this would calculate as 150HA irrigated. Thus in order to comparatively analyze crops irrigated year-round with crops only irrigated in a single season (such as Spring/Summer or Fall/Winter) I multiplied the hectares for year-round crops by a factor of 2. Using the same example above, that farmer would now be classified as irrigating 200HA ((50HA alfalfa * 2) + (50HA corn) + (50HA oats)).

IE Device	Irrigation	Irrigation Efficiency Range	Irrigation Efficiency Factor
NO	Open furrow	50-70%*	0.55
YES	Gated furrow	50-70%*	0.65
YES	Sprinkler	70-75%	0.725
YES	Drip	>90%	0.95

Table 3.4 Calculating the irrigation efficiency factor (IEF). (irrigation efficiency range based on Enciso et al. 2004)

40% of the farmers who participated in the survey used more than one type of irrigation system. In order to calculate and compare the water efficiency of farmers' irrigation management, I created an irrigation efficiency index (IEI). First, I identified the irrigation efficiency factor (IEF) of each device based on estimations from previous studies (Table 3.4) (Enciso et al. 2004). For gated pipe irrigation there was not an estimate provided, rather it was lumped into the same category as overall furrow irrigation. Gated pipe is seen as an improvement upon traditional open-canal furrow irrigation because the water is encapsulated in a pipe as it travels to the field, thus eliminating losses due to evaporation or percolation. As indicated in the table below, I therefore took the median of the lower half of the range (0.55) as the IEF for open furrow irrigation, and the median of the upper half of the range (0.65) as the multiplier for gated pipe irrigation. For portable sprinkler users, I took an average of the range (0.725), and for drip irrigation, I attributed the IEF as slightly higher than the minimum efficiency (0.95).

I then multiplied the IEF by the percentage of hectares irrigated by its respective irrigation method, and the sum total of those calculations provided the IEI. For example, a farmer who irrigated his fields entirely with drip irrigation, regardless of farm size has an irrigation efficiency score of 0.95, or 95% water efficiency; whereas a farmer who irrigates with half drip irrigation (0.475) and half open furrow irrigation (0.275) would receive a score of 0.75, or 75% water efficiency.

The farmers who participated in this study were normally distributed across the spectrum (Figure 3.3). High efficiency users (23%) are those who used only drip irrigation, while low efficiency users (20%) are those who used only open furrow irrigation. Those in the moderately low (26%) and moderately high (31%) groups used either entirely gated pipe irrigation, or a combination of irrigation methods. Sprinkler systems represented the lowest use of any irrigation type among participants. None of my participants relied entirely on sprinklers, and in fact the percentage of area irrigated by portable sprinklers among all participants was a mere 5%.

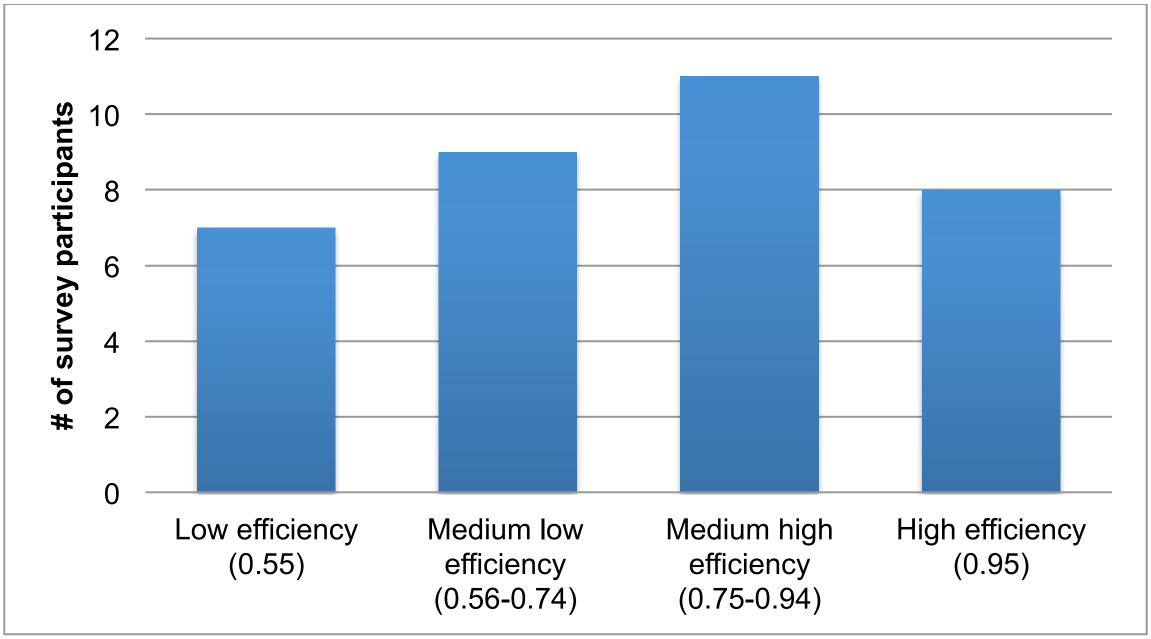

Figure 3.3 Distribution of irrigation efficiency index of farmers (*n* = 35).

3.3.5 Secondary documents

I collected many secondary documents from participant observation opportunities, including PowerPoint presentations, handouts, pamphlets, posters, and newsletters. Some civil organizations made recordings of meetings and presentations, as well as some transcripts of those meetings, available online. I also collected local, national, and international newspaper articles and a few social media publications that pertained to agricultural water use, water policy, and water scarcity. These documents were essential to constructing a narrative about how different groups and actors conceptualized water conservation and water management policy, and how those conceptualizations were communicated to the general public. They helped to frame the type of knowledge government and civil society organizers prioritized, and the actions they desired on the part of citizens.

I also accessed secondary documents and statistical information from online databases provided by the Mexican government, the World Bank, and the FAO. The primary repositories used were the Information Service for Agriculture and Fisheries (SIAP; *Servicio de Información Agroalimentera y Pesquera*) and the National Institute of Statistics and Geography (INEGI; *Instituto Nacional de Estadísticas y Geografía).* These sites provided basic statistical information regarding population, economy, and agricultural production. To supplement these sources, I used scientific journal articles articles that pertained to water governance, hydrogeology, and agricultural production in Guanajuato and Mexico. These provided much of the historical context and legal analysis, and provided an alternative perspective to government findings on issues of groundwater hydrogeology and water quality.

3.4 Positionality and challenges of research

Over the course of research two challenges were influential to how the research design played out in practice. First, insecurity and uncertainties perpetuated by narco-trafficking and associated government corruption altered plans for collecting interview and survey data with farmers. Second, there were difficulties of conducting research in a male-dominated society and political-economic sector. In this section, I detail each of these challenges, their impacts on the research process, and how I navigated them in order to complete data collection.

3.4.1 On violence, research, and snowball sampling

It is nearly impossible to discuss governance, resource access, and power in Mexico without mention of the sway of narco-trafficking and associated insecurities experienced in the everyday lives of Mexican citizens. In 2007, President Felipe Calderón led a sweeping intervention into the long-standing collusion between Mexican government officials and the drug-trafficking cartels in Mexico. His move coincided with the fracturing of some prominent cartels into smaller factions—namely the splitting off of the Zetas from the Gulf Cartel—that no longer abided by the traditional "rule of law" that previously existed among the cartels and Mexican government. Territorial battles ensued, particularly in Northern states for access to border-crossing routes as well as along the east and west coast Sierra Madre mountain ranges, such as the states of Veracruz in the east and Michoacán and Guerrero in the west.

Guanajuato, along with its neighboring central states, has been largely isolated from the persistent and sometimes large-scale violence associated with battles among the cartels and between the cartels and federal police or military. Although the violence along the border seems to have slightly subsided after the election of President Peña Nieto in 2013, violence in Michoacan and Guerrero continues and there is speculation that cartels are expanding into new territories. Furthermore, Guanajuato and the municipality of San Miguel de Allende, from which this study was conducted, experienced a surge in petty crimes in 2014 that exploited the general sense of insecurity and mistrust built by the persistent violence on the part of the state and the cartels.

There was a rise in robbery, assault, and kidnapping within the city of San Miguel de Allende and in the surrounding countryside.

In October 2014 Hector Beltrán Leyva, head of the Beltrán Leyva cartel, was arrested by the Mexican military at a small seafood restaurant in San Miguel de Allende. Local newspapers later reported that he had been arrested while meeting with a developer of upscale neighborhoods in San Miguel, and talk around the town speculated that Leyva had ties to the mayor of San Miguel, who residents thought was affiliated with the *La Familia Michoacana* cartel. The speculation and lack of confirmation regarding the collusion between corrupt businessmen, politicians, and cartel members is a common theme in Mexico, because it is one of the most dangerous places in the world to be a journalist and in particular for investigations of government corruption and narco-trafficking (Navarro 2015).

I am not describing this to add further sensationalization to the story of Mexico's narco-violence, but to relay how this violence works its way into the everyday lives of Mexican citizens in complex and often indirect ways. The impacts of persistent insecurity on research are numerous. Most obvious, there were research opportunities that were foregone in order to ensure my own safety. Furthermore, some ranchers were initially hesitant to share information regarding their operations in spite of assurances of confidentiality and credibility with the university. One farmer went so far as to call me the day after our survey to redact his entire survey, explaining to me that it just was not smart to be speaking of the things one owned and the businesses one conducted in a "situation like we find ourselves in."

I had initially planned to use a survey conducted by CEAG to randomly select farmers for the interview and survey processes, but I decided that this was unsafe for myself once I began fieldwork. To offset the dual challenges of my own insecurity and the uncertainty of the farmers I worked with, I often met research participants through existing organizations or with other farmers to protect myself as well as the confidence of research participants. The consequence of this method of selecting research participants is that it compromised my ability to conduct random sampling. From a positivistic standpoint, this may be seen as a drawback; however, as a constructionist, the process of data collection became a finding in and of itself.

Troubled by my own inability to transcend networks of politics and power in order to conduct more equitable research, I realized that the whole process affirmed what I had already learned through constructionist readings of how science is conducted—that it is within the relationships and the networks that we formulate the world as we know it, and not within the knowledge itself or the world "out there." Power—deeply interconnected with knowledge—is made manifest through this process of coupling between humans and non-humans. Here I am referring to the power to be known and the power to be heard through research projects like my own.
This "coupling" for the purposes of data collection has come to be innocuously termed "snowball sampling."

While the positivistic scientific voice in my head would like to say that "snowball sampling" is an appropriate term for the type of sampling I conducted (and technically it is that word), I find it insufficient. A snowball sample does not necessarily grow from randomly rolling down a hill as much as it is directed through a series of choice, chance, and channels (or networks). The participants in this study became participants because of who I knew, what their previous relationship with that individual was, and an active persistence on both my part and that of my key informants to make data collection possible in spite of security challenges. By relying on key informants who also had work of their own to attend to, I was limited as to which days I could go out to solicit research participants which resulted in relatively low enrollment than initially planned for farmer survey and interviews.

3.4.2 Positionality: Foreigner, scientist, American, woman

In the process of studying politics one becomes acutely aware of the micro-politics around her. Being not only a foreigner, but an absolute stranger in my study site, the early months were about meeting anyone that had anything to do with water and farming. The project was initially going to focus on participation and decentralized water governance through the COTAS, and I was happy to have met an individual who worked with the state water agency (CEAG) in the COTAS division during my first round of preliminary fieldwork. This relationship enabled me to attend COTAS meetings and travel the state to meet with COTAS managers and technical assistants. A couple of months into the project I realized that there were tensions between COTAS leaders and CEAG that were not initially visible to me because of my prior associations with CEAG. These tensions discouraged me from conducting the questionnaire of COTAS managers that I had planned in my proposal, because I was going to use my contacts in CEAG to execute the questionnaire. Instead of relying on the questionnaire I dug deeper into working relationships with COTAS managers, which led to several of the participant observation opportunities described above. The tensions also encouraged me to diversify my alliances with as many different organizations and individuals as possible that in order to avoid being associated with any one group—be it any level of government or civil society organization. Though this enabled me to escape some of the politics of being associated with a particular group, it was impossible to escape the politics of simply being myself—as a white, female, foreign scientist.

As an "American scientist" I was met with both reverence and skepticism. Some saw me as a way of "scaling up" their pleas for help, with the idea being that a scientist from a prestigious university in the United States clearly had a more powerful voice than a farmer or even a civil society leader in Mexico. In fact, one farmer asked me during an interview to tell Peña Nieto, the president of Mexico, to ask CONAGUA to stop extorting money out of farmers for groundwater titles. Taken aback by the request, I fumbled my words a bit and then kindly explained to him that I could not speak to the president directly, but would do my best to make my findings available to the public. On the other end of the spectrum, I was often asked in a sometimes curious and sometimes accusatory tone: "Why Mexico and not the United States?" When asked by Mexicans, the sentiment stemmed from sensitivites about a long history of U.S. intervention in Mexico and the associated power inequalities that come with quasi-imperialist relations. I attempted to alleviate their skepticism, by explaining that Mexico's water policy is said to be one of the most progressive in all of Latin America, and with Guanajuato's reliance on groundwater for irrigation understanding the effects of this policy constituted important research.

Lastly, Mexico is notorious for its *machismo* culture, and particularly so in rural areas and regions such as Guanajuato where the culture tends to be more socially and politically conservative than other parts of the country. As a woman, this led to many complicated conversations in order to maintain IRB compliance—as it is seen to be unlady-like and also potentially dangerous for a woman to be alone with a man. This *machismo* culture also led men to underestimate my intelligence at times in spite of my credentials as a doctoral student. This led to open conversations to which I perhaps would not have been privy had I not been female. This gendered dynamic was complicated, and resulted in the severing of some ties and consequently the forfeiture of potential data collection opportunities because of my discomfort with a man's rapport in my presence. Overall, being female in a macho land resulted in both research opportunities and pitfalls.

In spite of the complications inherent in the research process, I am confident in the quality of the data presented in the sections that follow. My intention in this section was not to obscure the complicated and very messy world of research, but to make it more visible so as to better reveal how data was translated in the processes of project development.

CHAPTER IV

FROM THE WATER HARD PATH TO THE WATER SOFT PATH IN GUANAJUATO, MEXICO (1917-2015)

In this chapter, I provide an overview of the historical politics of water and agriculture that facilitated the transition from the water hard path to the water soft path in Mexico. The first section situates the use of groundwater for irrigation in Mexico within the broader global context of water for agriculture. The following two sections highlight key actors and moments in the governance of water and agriculture over the course of the twentieth century until the present, beginning after the Mexican Revolution of 1910 and tracing the rise and decline of the *Partido Revolucionario Institucional* (PRI; Institutional Revolutionary Party). The twentieth century saw the consolidation of state power in the middle part of the century, followed by a severe economic crisis in the 1980s, and the subsequent roll out of neoliberal policies from the late 1980s to the present, which decentralized water management and pushed Mexican farmers into the global market. The final section examines the material manifestations of these institutional shifts toward decentralization and globalization by describing the infrastructure and devices that constitute the WSP in Guanajuato.

4.1 Groundwater for agriculture

Agriculture is the leading consumer of water resources globally and consumes 85% of the volume of water extracted from freshwater resources (rivers, lakes, and aquifers) (Shiklomanov 2000). Irrigated agriculture, which occupies nearly 301 million hectares worldwide and consumes almost 1.3 billion cubic meters of water annually (Siebert et al. 2010), is a vital element of global food security and the global economy because it represents nearly half of the value of world crop production (Shiklomanov 2000). Irrigated agriculture draws from both surface water and groundwater resources; however, these waters are often differentiated in research and management due to complex regional hydrogeologies that are not yet fully understood (Foster and Perry 2010).

Groundwater consumption exploded globally in the second half of the twentieth century due to the introduction of advanced groundwater lifting technologies, the incentivization of these technologies by the state, the subsidization of rural electricity, and the lack of regulation or enforcement of groundwater pumping (Birkenholtz 2015; Garduño and Foster 2010; Scott 2013). Globally, irrigated agriculture is the leading consumer of groundwater resources. Groundwater draws 545,359 cubic meters of groundwater annually, or 43% of total annual global water consumption, to irrigate 113 million hectares, or 38% of total irrigated area (Siebert et al. 2010). In some arid and semi-arid regions around the world, groundwater represents the sole source of irrigation supply, as surface water resources are not available due to political, economic, or physical constraints. In areas where surface water is accessible, groundwater may even be the preferred source of irrigation water. Groundwater is close to point-of-use, making the construction of costly canal systems unnecessary, it may be of better quality than the surface water resources, and it is better for pressurized irrigation systems (Garduño and Foster 2010).

Nevertheless, many agroeconomies reliant on groundwater for irrigation are facing declining quantities and qualities of groundwater supply due to unrestricted use or noncompliance with existing regulations. This is further complicated by climate change, which is expected to heighten drought risk, increase evaporation, and/or alter normal precipitation patterns in many of these areas (Appendini and Liverman 1994). Unlike surface water resources, the dispersed nature of groundwater extraction has led to a lack of institutional arrangements in place to administer groundwater resources and avoid overexploitation. Over the last twenty years, states, with the assistance and encouragement of international organizations, led the organization and financing of decentralized groundwater management institutions to try to curb aquifer over-exploitation. Institutional measures oriented toward agricultural production facilitate awareness and outreach measures to educate farmers on issues of water quality and quantity, as well as build capacity to adapt to declining groundwater availability through water catchment programs, irrigation efficiency technologies, and alternative sources of water.

In the Global South, Mexico is leading initiatives to adapt to threats of groundwater scarcity in drought-prone areas where irrigation is crucial for economic productivity and community livelihoods. Concurrent with global groundwater irrigation patterns, groundwater is used to irrigate 39% (2.49 million HA) of Mexican lands under irrigation (Siebert et al. 2010). Each year Mexican farmers use 11,386 million cubic meters of groundwater for irrigation (Siebert et al. 2010), or enough water to fill more than 4.5 million Olympic sized swimming pools. The semi-arid highlands in central Mexico have some of the richest volcanic soils, where groundwater is a key source of irrigation water for many farmers. Restrictions on new groundwater wells have been in place for over 50 years in much of this region, but aquifer depletion has continued unabated.

The combined pressures of groundwater overdraft, climate change, international and domestic political pressure, and economic crisis forced the Mexican state to restructure institutions of water and agriculture governance in the early 1990s. Guanajuato is a central state with a history of agricultural and industrial development dependent on scarce water resources and also contains the headwaters for the most populated watershed in Mexico. Consequently, it became a major focus of decentralization initiatives centered on groundwater and surface water alike. In spite of institutional and financial investments in awareness, capacity building, and technical infrastructure for just over 20 years, most aquifers in Guanajuato are overexploited and continue declining between 1 and 3 meters per year. As a consequence, groundwater quality is declining and dangerous for human health in some parts of the state due to high levels of naturally derived fluoride and arsenic as fossil waters are tapped. State officials and water conservation experts have declared between 10 and 16 years of water left in the state (Romo 2013; Huerta 2013). To understand the production of water scarcity in Guanajuato, I turn to making of the "hydraulic state" and the Mexican Constitution of 1917.

4.2 Brief history of twentieth century water politics in Mexico

The history of Mexican water governance after the 1910 Revolution is wrought with tensions among hydraulic engineers and agronomists with strong interests in controlling the development and control of the flow of water. What began as a largely agricultural institution following the Revolution with a focus on irrigation development ended in the (re-)consolidation of water rights as the property of a single, autonomous water agency in 1989 (CONAGUA, *Comisión Nacional del Agua*). While the formation of CONAGUA led to the subsequent decentralization of irrigation districts and groundwater management, CONAGUA has not devolved power over the allocation of water rights to state or local levels.

4.2.1 Following the hard path through the "hydraulic mission"

Following the Mexican Revolution of 1910-1920, water management was controlled and propelled by the federal government of Mexico through the "hydraulic mission," or the centralized effort to capture every last drop of water for human use. Central state control over water resources was secured in Article 27 of the 1917 Constitution and had twofold implications for irrigated agriculture. First, Article 27 created the Mexican ejido system, or the redistribution of *latifundias* (large estates) and the creation of common property land tenure. Second, it declared oil, land, and water the property of the nation.

Less than a decade later in 1926, President Calles led the development of irrigation districts and the constructions of large-scale state led irrigation and water storage projects. From 1926 and 1976 between 61% and 100% of the federal water budget for agriculture went toward the construction of irrigation districts (Rap, Wester, and Pérez-Prado 2004, p. 63). These projects were administrated by the newly minted National Irrigation Commission (CNI; *Comisión Nacional de Irrigación*). Both the Calles administration in the 1920s and the Cardénas administration in the 1930s used the CNI as a mechanism for following through on the promises of land distribution that stemmed from the revolution, however their tactics had varying outcomes for the types of farmers produced. Calles strategies for land redistribution centered around independent farmers and thus his policies created a new class of mid-sized commercial farmers. Cardénas, on the other hand, focused on the development of the *ejido* system which gave the peasantry infrastructural ties to the central state. The federal government therefore used the flow and distribution of water to direct the (re)development of land and citizens with varying tactics that resulted in a mix of *ejidatarios* and ranchers within the irrigation districts.

In 1946 the state reformulated the CNI as the Secretariat of Hydraulic Resources (SRH; *Secretaria de Recursos Hidráulicos*), the first time water administration had been elevated to the federal level in any country of the Western hemisphere (Rap, Wester, and Pérez-Prado 2004). The SRH accelerated federal control of water resources, manipulating waterways through the construction of vast dam and irrigation infrastructures in order to create a national identity under the auspices of modernization (Aboites-Aguilar 2012; Tortolero-Villaseñor 2000). During the reign of the SRH, hydraulic engineers were given full financial and bureaucratic autonomy to achieve the hydraulic mission in whatever way possible. Irrigation districts, however, were managed by the Agricultural Secretary, not the SRH, until 1951. Furthermore, it was not until the 1972 Federal Water Law that irrigation districts were completely centralized from construction to management.

In 1976 President Lopez Pontillos created the Secretariat of Agriculture and Hydraulic Resources (SARH; *Secretaria de Agricultura y Recursos Hidráulicos*). The merging of the agricultural and water sectors dealt a blow to the power and authority of hydraulic engineers, heightening the influence of agronomists and political experts with administrative backgrounds. This shift was partly in response to the chronically low water fees for farmers and irrigation districts, and the previous inability of the government to raise these fees due to political backlash. The low water fees resulted in a lack of investment in repair and maintenance of existing hydraulic infrastructure, particularly among less wealthy farmers who did not have the profit margins to pay for the repairs themselves (Rap, Wester, and Pérez-Prado 2004, p. 64). Eventually the failure of centralized water management to self-finance and maintain its infrastructure would lead to the decentralization of political authority and financial responsibility to the irrigation districts themselves (Wilder 2010).

Alongside the proliferation of expansive surface water infrastructure in the twentieth century, people outside these networks began drilling wells to access groundwater. Wells were particularly important in the central highlands where rain and surface water are comparatively scarce, agricultural production abundant, and groundwater the most reliable source of water for production in the dry season. As an "invisible resource," the control of groundwater extraction has proven difficult and the social and political consequences of reducing groundwater extraction could prove costly for government officials (Wester 2008; Shah et al. 2004). Beginning in early 1948, the state of Guanajuato began issuing *vedas*—legal mechanisms that prohibit the sinking of new wells—because overexploitation of groundwater is illegal under the federal constitution. *Vedas* were placed in the area of this study between 1949 and 1958 and over the entire state of Guanajuato by 1983 (Scott and Shah 2004). Nevertheless, *vedas* have been virtually unsuccessful as indicated by a rise in the number of tubewells in Guanajuato from 2,000 in 1958 to 16,500 in 1997 (Guerrero-Reynoso 2000).

4.2.2 Integrated Water Resource Management heralds in the fading of the hard path

In the 1980s Mexico faced a devastating fiscal crisis and severe devaluation of the peso. As a result, in 1982 Mexican citizens elected President de la Madrid, their first economist as head of state and an advocate for neoliberal economic reform. It is in this period that Mexico slowly began to move the focus of water governance away from supply driven approaches and restructured their institutions toward decentralization and demand management. In the 1980s decentralization was justified as a means for achieving efficiency and equity in developing countries struggling financially due to an overburdened and bureaucratic centralized government. While decentralization is often seen as going hand-in-hand with neoliberalism and structural adjustment policies, the implementation of one does not necessarily denote the other. To clarify, "decentralization has been defined as any act in which a central government formally cedes power to actors and institutions at lower levels in a political-administrative and territorial hierarchy" (Agrawal and Ribot 1999). The ability of decentralization to achieve goals of equity and efficiency, however, is dependent upon the power of actors to make decisions, implement compliance, and adjudicate disputes in the context of a governance system that makes those actors accountable to those responsibilities and other actors in the system (Agrawal and Ribot 1999). Demand management—or treating water provision as a problem of control of water use—therefore complements institutional practices of decentralization by re-inscribing citizen participation in water management through outreach and training campaigns as well as the introduction of mediating devices that monitor and regulate how water is used at the point of distribution (Walsh 2011).

This ideological shift away from centralized bureaucratic water supply management and toward decentralization and demand management was influenced by domestic and international factors (Wilder 2010; Wester 2009). De la Madrid's election in 1982 coincided with the increasing solicitation of World Bank loans, particularly for the water sector (Wilder 2010). A 1983 World Bank review of the water sector had infrastructural and socio-economic implications. First, the World Bank assessed that infrastructure investments should shift their focus toward management and efficiency of existing infrastructure, rather than construct new systems. Second, they asserted that water users should be increasingly involved in administrative decision making and financing of existing infrastructure. Instead of "development" and "control," the water managers were now accountable for the "management" and "efficiency" of existing water infrastructure and technologies. In 1989, shortly after Carlos Salinas became president, international pressure coupled with domestic economic strife culminated in the dissolution of the marriage between water and agriculture and a rebranding of federal water management as the Comisión Nacional del Agua (CNA: National Water Commission; later named CONAGUA). CONAGUA is responsible for the administration and conservation of water resources, and manages individual rights through the allocation of concessions.

President Salinas' goal during his term was to modernize Mexico, and continue the neoliberal agenda initiated by de la Madrid. In particular, his focus was on the modernization of the countryside by reducing dependency on the central government (Rap, Wester, and Pérez-Prado 2004). Three years later, CONAGUA had developed a new National Water Law (LAN: *Ley de Aguas Nacionales*) in December 1992. LAN did several important things for water management.

First, LAN made it legal for *ejidatarios* to title and sell *ejido* land for the first time since 1927. Therefore, land that was previously collectivized could now be privatized. Nevertheless, groundwater remained the property of the federal government and a concessions system was regularized through the creation of the registry of public water rights (REPDA), which requires that water users renew their concession with CONAGUA every ten years.

Second, LAN paved the way for a renegotiation of centralized water management away from control by the agricultural sector. With the commitment of a $400 million USD loan from the World Bank, Mexico underwent the process of

Irrigation Management Transfer (IMT) with the objective of modernizing administration and infrastructure within irrigation districts. IMT helped to shift financial and administrative sovereignty over to the hydraulic bureaucracy and away from the agricultural sector (Rap, Wester, and Pérez-Prado 2004). Shortly after the passage of LAN, CONAGUA was also moved out of control of the Agricultural Ministry (SAGARPA) to the Ministry of Natural Resources (SEMARNAT) in order to foster a sustainability ethic (Wilder 2010).

Third, LAN modeled decentralization on the principles of integrated water resources management (IWRM) to create *Consejos de Cuencas* (River Basin Councils) whose purpose was to create a forum for stakeholder participation in decision-making and conflict resolution (Wester, Rap, and Vargas-Velázquez 2009). The study site for this project is located in the Lerma Chapala River Basin Council, which was founded in 1993 (Figure 4.1). The council is comprised of the director of CONAGUA, five state governors and six representatives for the water-use sectors (agriculture, fisheries, services, industry, livestock, urban) (Wester, Rap, and Vargas-Velázquez 2009). The river basin model has been critiqued as superficial decentralization because CONAGUA still retains most of the power and authority in processes of decision-making and accountability (Scott and Banister 2008). This has made the enforcement of existing regulations difficult, leading international agencies such as the World Bank and Global Water Programme to encourage the allocation of concessions move to the state level (Garduño and Foster 2010). The implications of LAN are particularly important in the upper part of the basin where this study was conducted. LAN prohibits the extraction and use of surface water in the Upper Rio Laja, one of the headwaters for the LCRB and the study site for this project, forcing a reliance on groundwater. There is a large dam in the municipality of San Miguel de Allende, however that water is promised for the lower part of the basin where the soils are richer for agricultural production and farmers are better organized. In other words, anywhere in the upper part of the basin above Irrigation District 85 in Celaya, farmers are only legally permitted to use groundwater.

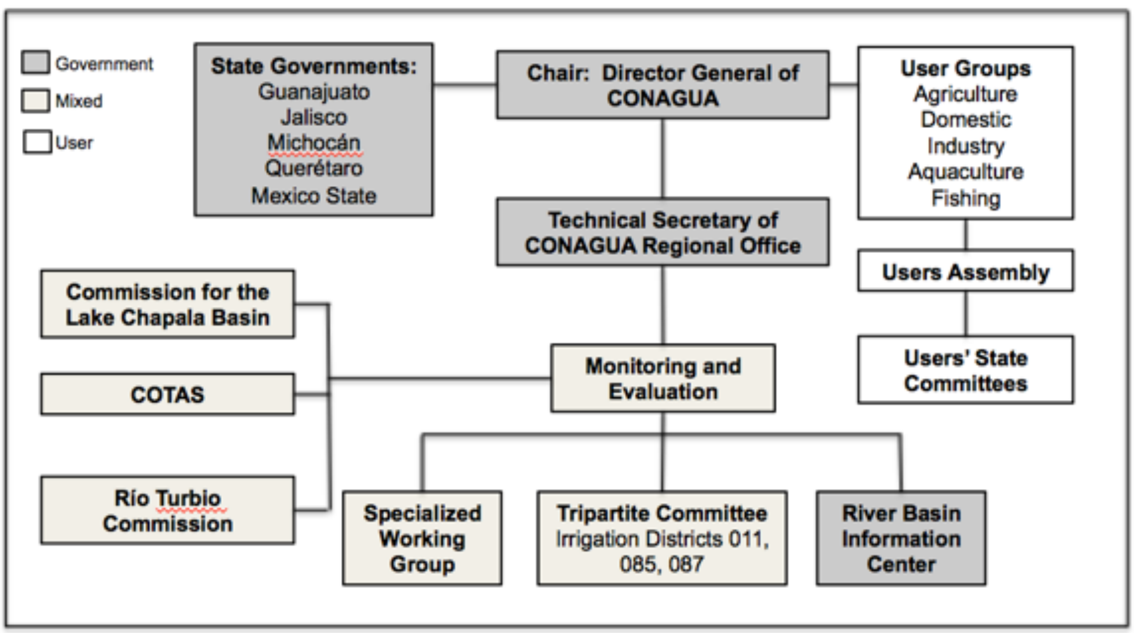

Figure 4.1 Organization of the Lerma-Chapala River Basin Council. (Based on Wester 2008; Millington et al 2006)

Propelled by the concept of river basin councils, around the mid 1990s the focus on decentralization shifted toward groundwater management with the creation of

Technical Groundwater Councils (COTAS: *Consejos Técnicos de Aguas Subterráneas*). The COTAS are a civil organization (*asociación civil*) designed to promote the stabilization, recovery and preservation of depleted groundwater resources. COTAS were formed in the state of Guanajuato between 1998 and 2000 (Wester, Hoogesteger, and Vincent 2009; Shah et al 2004). The World Bank played a key role in advising the funding, organization, and assessment of COTAS by working closely with the state water commission (CEAG) who oversees the COTAS (Foster 2004). The COTAS were part of a broader global initiative led and monitored by the World Bank to promote water conservation in areas of heavy groundwater extraction in Latin America and Asia (Garduño and Foster 2010). The principal activities of the COTAS are monitoring of groundwater consumption, registration of existing wells, and outreach activities to encourage water conservation through management techniques and the introduction more efficient irrigation systems. COTAS are designed as consensual and cooperative platforms for water users, with the membership constituting all water users of an aquifer.

The presence of multiple stakeholders at COTAS meetings, however, has only been minimally achieved (Wester 2008). Representatives at COTAS meetings are predominantly the agricultural elites—commercial farmers or agro-industrialists (Wester, Sandoval Minero, and Hoogesteger 2011). Although the state water commission (CEAG) led the formation of the COTAS and continues to be their primary source of funding, finances are often short and unstable due to the classification of the COTAS as a civil organization. For most managers, the COTAS constitute a secondary source of income and many in rural areas are farmers themselves. Therefore, many

COTAS managers seek additional funding for administration and project supplies from other governmental agencies at the state and federal level, and occasionally other non-governmental organizations.

In addition to issues with finances and equitable representation, scholars argue that the COTAS inability to enact change in groundwater overexploitation stems from a lack of devolution of powers to COTAS managers from CONAGUA . In spite of their shortcomings, the COTAS are essential to groundwater management in Guanajuato because they are seen by water managers at all levels of governance as the link between the government and the farmers. In other words, the COTAS are the institutional space through which decentralized aquifer management is played out—facilitating a space for groundwater farmers to make organized claims on the state while the state simultaneously increases surveillance through monitoring and outreach for those farmers.

Over the course of the 1990s, the creation of decentralized institutions for surface and groundwater administration was successful, however scholars argue that Mexico continues to suffer from overexploitation of water resources in part because CONAGUA has failed to devolve powers of enforcement and accountability to River Basin Councils and the COTAS (Scott 2011; Scott and Banister 2010; Wester 2008). In 2004, the LAN was revised to incorporate the introduction of 13 regional branches of CONAGUA known as *Organismos de Cuenca*, yet these offices do not have financial or legal independence from the central office in Mexico City (Wilder 2010, 22). In spite of having the legal and structural mechanisms in place for decentralization, water governance in Mexico still operates firmly within the powers of the central government, demonstrating a hidden institutional obduracy of the water hard path.

In May 2013 current President Enrique Peña Nieto presented his water plan for Mexico for the duration of his six-year term as president. The plan includes four lines of action: [1] Adequate and accessible water services; [2] Water for food security, by modernizing infrastructure to increase food production; [3] Responsible and sustainable water management through the rational use and consumption of water; [4] Water security in the face of climate change and environmental contingency. A CONAGUA representative who outlined this plan to a room of more than two hundred River Basin Council managers in August 2013 declared that continuing decentralization and organizational strengthening was essential to ensuring the President's lines of action are advanced. Furthermore, he declared "social participation" to be key to this process, however the terms of participation remain unclear. Despite party differences, Peña Nieto's (PRI, 2012-2018) strategies for water governance do not diverge dramatically from Felipe Calderón's (PAN, 2006-2012) emphasis on modernizing infrastructure and Vicente Fox's (PAN, 2000-2006) support for sustainability and infrastructure investments through public-private partnerships (Wilder 2010). Therefore, the pillars of decentralization and demand management of the WSP remain core elements of Mexican water policy for the foreseeable future, while CONAGUA's central power over water governance remains unchallenged.

4.2.3 The water-energy nexus in Mexico

The centralized control over water in the 20th century is mirrored by a centralization of the development and distribution of energy resources. In 1938 President Cardénas nationalized the energy industry and created *Petróleos Mexicanos* (PEMEX), which controlled the production and distribution of oil resources, and the Federal Electricity Commission (CFE; *Comisión Federal de Electricidad*) which controlled the generation, transmission and distribution of electricity or *luz*, as it is commonly referred to. PEMEX and CFE remained under federal control until the current administration of Peña Nieto who has effectively passed legislation that went into effect December 2014 and will open the energy industry to private competition for the first time in 77 years.

Energy regulations are tied to agricultural water supply because of the energy requirements to pump water from reservoirs for surface water and to pump water out of the ground—referred to as the water-energy nexus (Scott 2011). In northeastern Guanajuato the water-energy nexus is particularly important because of high energy costs for lifting water an average of 132 meters to the surface for irrigation—the distance of nearly one and half American football fields. Water pumped from underground is typically stored in small reservoirs in order to pressurize the water for use in irrigation systems (Figure 4.2).

Figure 4.2 Reservoir storage of groundwater with pump. (Photo by the author)

In 2002, President Vicente Fox—former governor of Guanajuato—successfully passed the Rural Energy Law (*Ley de Energía para el Campo*) through the Chamber of Deputies as a mechanism for reducing the burden of energy costs for farmers while simultaneously creating a means for the federal government to monitor and regulate groundwater over-extraction (Scott and Shah 2004). The Rural Energy Law revised the pricing structure for agricultural producers using electricity to pump groundwater for irrigation and created two fixed subsidized prices, known as 9-CU for daytime use and 9N for nighttime use. In 2015, the cost of electricity for agricultural producers who qualify for the subsidy is MX$0.54 per kWh for daytime use (9-CU) and MX$0.54 per kWh for nighttime use (9N), while the cost of electricity for the average domestic consumer is MX$0.976—35% higher than the cost charged to farmers (CFE 2015). In order to qualify for the subsidized tariffs, farmers are required to have a title registering their groundwater well with CONAGUA, and also must comply with an Annual Energy Limit (AEL). The AEL compels farmers to pay regular agricultural 9 tariffs if they exceed the AEL, which costs farmers more than ten times per kilowatt hour than the subsidized 9-CU tariff (Scott and Shah 2004).

Although the Rural Energy Law was designed to link kilowatt-hours of electricity to cubic meters of groundwater, enforcement of the regulation has proven more challenging than anticipated and has not resulted in a reduction in groundwater extraction. Even worse, there is speculation that the subsidies—in particular the nighttime tariff—have actually escalated groundwater overdraft (Scott 2011). Furthermore, the subsidies are very expensive for the state. In 2013 the subsidy cost the federal government MX$13.5 billion (US$275 million)—equal to 18% of SAGARPA's total annual budget—with 54% of that subsidy going to the top 10% wealthiest producers (Ruiz Funes 2014). As a result, critics have called for revisions to the Rural Energy Law to restructure the subsidy program by increasing the cost of electricity for farmers and redirecting federal money toward programs for water efficiency and infrastructure investments (Scott 2013; Ruiz Funes 2014; Scott 2011).

The problem of enforcement and the revision to the law, however, is that it tends to overlook the political power of rural producers. Over the course of fieldwork I was repeatedly reminded by civil organization leaders and policy makers that many of the farmers in my study site had developed a "culture of non-payment" (*cultura del no pago*) for electricity tariffs. They were correct. 1 in 3 farmers I surveyed for this project reported that they had not paid their electricity bill for at least one month over the past year. However, farmers would phrase it as "we are in a union against CFE" rather than referring to their lack of payment as a "cultural" phenomenon. Ironically, they cited high energy costs and unfair—or "corrupt"—charges on the part of CFE.

Even those who had paid all of their bills and were not part of the union reported similar experiences CFE in which they had to renegotiate an electricity bill due to false charges. Many of those who did not pay told me they simply did not have the money, and that the charges for not paying had far surpassed anything they ever would be able to pay if the charges were not pardoned. For farmers, nonpayment was not something they simply were used to getting away with, as the term "culture" indicates; rather it represented political action against the federal government as a way to voice concerns over the economic challenges of agricultural production. As of February 2015, the union had dissolved in an agreement with CFE, and farmers reported that they were back to paying their bills so long as CFE complied with the agreement. The water-energy nexus therefore operates as political space on both ends—providing a mechanism for state regulation, but also an opportunity for political action on the part of producers.

4.3 Brief history of 20th century agricultural politics in Mexico

Agricultural politics are central to the culture and history of Mexico in the twentieth century. Although agriculture's significance to the Mexican economy has declined over the course of the twentieth century and currently represents 3.6% of the GDP, it employs a significant portion of the population (13.6%). Beginning with the Revolution of 1910, the government initiated a series of agrarian reforms that redistributed land at an unprecedented scale into ejidos or communal lands. Throughout the twentieth century agricultural productivity grew through the expansion of land under cultivation aided by the state's massive investment in irrigation canals and dams, with limited investment in intensification technologies. The combined pressures of economic crisis and declining agricultural productivity due to inefficient production methods led to a re-articulation of agricultural policy during the reforms of the Salinas de Gortari administration, paving the way for the North American Free Trade Agreement (NAFTA) in 1994. During this time the state opened agricultural prices to the international market and enabled the privatization of state-held communal lands established during the agrarian reforms of the Revolution. Surprisingly, these policies did not result in a complete dismantling of the ejido system, however they did stimulate massive migration to the United States, an increase in fruit and horticultural exports, and an increase in rural employment; however there was a simultaneous growth of socioeconomic inequality within the agricultural sector (Puyana and Romero 2009; C. De Grammont 2003).

4.3.1 Post-revolution agricultural nationalism

Much like water policy, the Revolution spurred a nationalistic ideology for agricultural development, resistant of foreign intellectual or financial resources and in particular those from the United States. In the period after the war and up until 1940, research and outreach in agronomy predominantly focused on rural development and assistance and pushed forward the investments in social programs (Cotter 1994).

Furthermore, this nationalistic ideology was institutionalized in the declaration of water and land as the "property of the nation" in the 1917 Constitution. The decades after the Revolution also saw the formation of the *ejido*, or common property system, which redistributed large estates and gave usufruct rights to those who worked the land. The *ejido* system was at first slow to gain traction, however in the late 1930s President Lázaro Cardénas further propelled the nationalistic agenda set forth by the Revolution. He helped to stimulate agrarian reform unlike any of his predecessors or successors, by formally creating more *ejidos* than any other Mexican president before or after him. These land reforms coincided with the centralization of energy resources discussed above and helped to consolidate the power of the Institutional Revolutionary Party (PRI), which ruled Mexico for the duration of the twentieth century, and brought agricultural development under federal power and control.

The surge of agrarian reform and social programs, however, was short-lived. The 1930s brought the the economic pressure of the depression and a corn crisis, lending to a shift in agricultural policy away from small-holder investments and toward the development of large-scale irrigation networks, particularly in the northern states. The state and agricultural researchers supported irrigation-intensive wheat production through subsidized credit and input systems, known as the Mexican Green Revolution, moving the political and economic focus away from rain-fed corn systems. (Cotter 1994; Hewitt de Alcántara 1976). Both large-scale producers and *ejidatarios* alike benefited from subsidies offered by the National Company for Popular Subsistence (CONASUP), which provided price supports for staple crops, such as corn and beans, as both a food security program and buffer against competition with global imports. Thus alongside the expansion of surface water irrigation canals, Mexico also saw an explosion in the proliferation of groundwater wells and an increase in the allocation of the federal budget toward subsidies for electricity for pumping and irrigation that largely benefitted the agricultural elite (Fox and Haight 2011). However, the inequalities in state investments were offset by the simultaneous growth in the industrial sector which helped provide supplemental employment for the large rural labor force through the middle part of the century.

Up until the 1970s, Mexico experienced a steady growth of agricultural productivity due to extensive growth of agriculture onto new lands. The "Mexican miracle," however, was short lived as inefficiencies in bureaucratic management and agricultural production techniques became very apparent during the 1980s economic crisis. Alongside stagnation in the overall Mexican economy, agricultural expansion seemed to reach the limits of expansion and experienced slowed growth in productivity. Concerns over productivity declines and inefficiencies in the countryside, coupled with economic crisis and pressure from international donors for economic reform, led to both internal and external pressure to re-articulate the century long experiment with agrarian forms and push Mexican agriculture into the global market.

4.3.2 Globalization of the agricultural sector

The 1980s economic crisis resulted in a sweeping deregulation of the agricultural sector, and opening of Mexican agriculture to the global market through the North

American Free Trade Agreement (NAFTA) in 1994. In order to pave the way for NAFTA the state made two significant institutional changes in the agricultural sector: marketization and privatization.

First, price supports were abandoned in favor of market prices, though in a piece-meal manner. The government dismantled the CONASUP program, however to avoid popular unrest during the drafting of NAFTA, the state rolled out other support programs in their place: ASERCA and PROCAMPO. ASERCA helps to provide farmers assistance with the commercialization of their products. PROCAMPO was initiated in 1992 and 1993 and provides direct payments to farmers who were producing grains before the initiation of NAFTA, as a mechanism to buffer farmers against competition with United States corn farmers. Studies have shown that although PROCAMPO has not reached every farmer evenly, it has provided benefits across the socioeconomic spectrum (Fox and Haight 2011). Additionally, it has helped maintain food security among subsistence farmers by helping keep corn imports low (García-Salazar et al. 2011).

Second, the state reformed Article 27 of the constitution and opened *ejido* land to the market through the initiation of PROCEDE (*Programa de Certificación de Derechos Ejidales and Titulación de Solares;* Program for the Certification of Ejidal Rights and Urban Sites). PROCEDE led the registration, titling, and mapping of ejido lands. Under the new regulation, however, *ejidatarios* were allowed to privatize some, all, or even none of the land under their control by registering parcels to the individual. Although the intention was to marketize the *ejido* system and abandon state led agrarian reform

(Assies 2008), the result has been a piece-meal and incomplete privatization of *ejido* land in which the state remains accountable to the agrarian responsibilities they created in the twentieth century (Perramond 2008). Therefore the proposed deregulation of the agricultural sector is better termed a re-articulation, in which the relationship between the agricultural sector and the state remains intact yet tenuous.

The continuing presence of the state, however, has not left the countryside unchanged in the wake of NAFTA. Mexico is currently the second largest source of food imports for the United States. U.S. imports of Mexican food products have increased from USD$5 billion in 1999 to USD$22 billion in 2014, or an increase of about $1.5 to $2 billion per year (Jerardo 2016). Furthermore, the U.S. imports more fruits and vegetables from Mexico than any other country in the world. NAFTA stimulated growth the production of fresh fruits and vegetables for export, referred to by farmers as *hortalizas* or horticultural crops.

In Guanajuato, there has been explosive growth in vegetable production in a region previously reliant on the production of livestock, dairy cattle, fodder crops, and dried chiles. For example, in the state of Guanajuato traditional vegetables such as the tomatillo (husk tomato) and tomato have seen a slight decline since 1994, while there has been an increase in the production of vegetables such as broccoli, lettuce, and spinach which tend to be produced for export as either fresh or frozen vegetables (Figure 4.3). Many fruits and vegetables for export are produced by Mexican farmers, and some contract with packing companies operating within the state such VegPacker and Birds Eye. Of farmers surveyed for this project, 43% (*n* = 15) cultivated at least some of their land for export production. Other horticultural exports from Guanajuato, however, originate from U.S. own agroindustrial farms, such as Monterey Mushrooms and Taylor Farms.

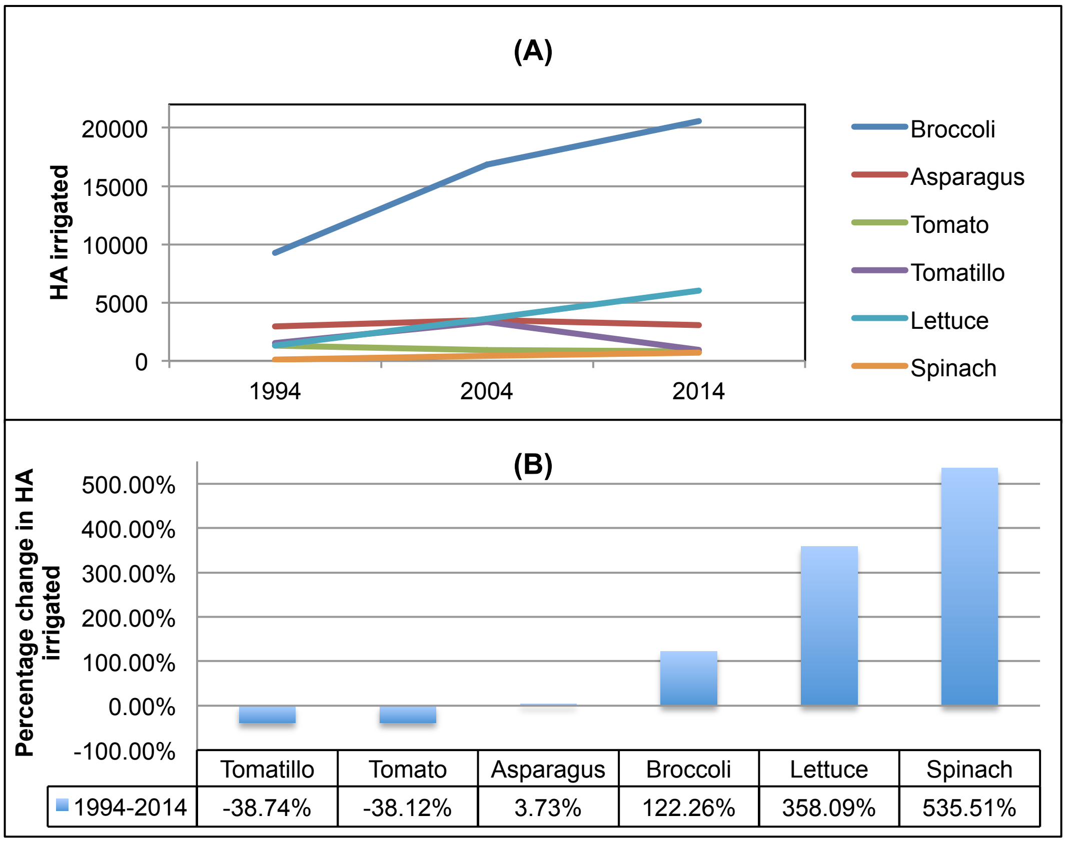

Figure 4.3 Growth in horticultural crop production. (A) The change in irrigated area (HA) of vegetables from 1994 to 2014 in the state of Guanajuato. (B) Percentage of change in irrigated area (HA) for the same vegetables. (Data derived from SIAP 2014)

The shift to horticultural products has been made possible in part by crediting and technology transfer programs carried out by FIRA (Trust Funds for Agriculture) and

SAGARPA (Federal Agricultural Secretariat), who have encouraged the construction of greenhouses and installation of drip irrigation technology typically associated with horticultural crop production. For example, according to farmers surveyed for this project, 79% received support for the installation of IE devices from SAGARPA and 17% received support from FIRA (Table 4.1). Financing programs are supplemented by agricultural research and extension agencies, such as state-sponsored INIFAP (National Forest, Agriculture and Fisheries Research Institute) and Produce Guanajuato, a civil organization. These agencies lead question and answer forums and research projects in the field related to common diseases and best management practices for particular crops.

Irrigation device	**Gated Furrow**		**Sprinkler**		**Drip**		**All IE devices**	
	n =	***%***	***n =***	***%***	***n =***	***%***	***n =***	***%***
Total number of farmers	13		6		22		41*	
Received support for installation	8	62%	1	17%	15	68%	24	59%
Support from SAGARPA	5	63%	1	100%	13	87%	19	79%
Support from FIRA	2	25%	0	0%	2	13%	4	17%
Support from CONAGUA	1	13%	0	0%	0	0%	1	4%

Table 4.1 Source of financing for irrigation efficiency (IE) devices among survey participants. *The number of farmers using all IE devices exceeds the total number of farmers surveyed because some farmers used more than one type of IE device.

There are implications for resource use and quality as producers aim to increase productivity through the intensification of production methods in order to offset the decline in profits and market uncertainty (Puyana and Romero 2009). This shift in production led to a growth in employment, but a decline in overall wages, with the benefits of international market competition being accrued by a small number of producers in the agricultural sector (Puyana and Romero 2009). *Ejidatarios* are not the only producers that feel the squeeze of globalization and declining state support, but also a significant number of midsize producers or ranchers (C. De Grammont 2003). One livelihood strategy in the wake of NAFTA has been the rise in contract farming despite the disadvantages for producers, because otherwise the risks of production are too high (Echánove Huacuja and Steffen 2005). A second livelihood strategy for many peasant producers has been migration to the US to provide remittances to family members back home (Eakin 2006). Indeed, Guanajuato had one of the highest out-migration rates of any state. Most migrants are men, and as a result, women are left behind to tend to the land without formal rights to engage in collective decision-making councils (Buechler 2005). In sum, the agricultural sector has been greatly transformed by both domestic policy and international markets with the benefits largely accruing among agro-industrialists while midsize and subsistence farmers pursue alternative livelihood strategies to offset the risks associated with globalization.

4.3.3 Peña Nieto's *Pacto por México*

The day after President Peña Nieto of the PRI party was signed into office, the Mexican government passed a consensus based reform package, known as the *Pacto por México* (Pact for Mexico), that would be carried out in parts throughout Peña Nieto's six year term. The *Pacto* includes reforms of several sectors including: education, social security, telecommunication, energy, security, and government transparency. The *Pacto* has been heralded by international development agencies and the media as a monumental step in structural reform, which will help propel the Mexican economy on a path toward growth and prosperity (OECD 2015; Crowley 2014). In Mexico, however, the public has decried the reforms as "selling Mexico" to foreign interests and "slaying Mexico" in parodies on a *Time* magazine cover that claimed Peña Nieto was "saving Mexico" with the *Pacto* reforms (Figure 4.4). Mexican citizens do not have faith that the PRI party will carry out a reform of government corruption after nearly a century-long reign of power grabs and suspected election fraud.

Although the *Pacto* does not explicitly tackle the agriculture sector, the fiscal reform and the privatization of the energy sector (PEMEX and CFE) have important implications for agriculture. As I accompanied a farmer to the local municipal building to file paperwork, he explained to me that the reforms made things more complicated for farmers. He said that his family, who own several ranches greater than 50 HA, was accustomed to the tax paperwork and therefore the fiscal reform did not make a significant impact on them. He noted, however that other farmers who had informally sold small quantities of produce and grains to local vendors for their entire lives were now being forced to file formal paperwork for their sales or risk being penalized for their failure to comply.

Figure 4.4 *Time Magazine* cover parody of Peña Nieto. (Source: Fox News Latino 2014)

Additionally, after the energy reform was implemented in late 2014, farmers have noticed spikes in the price of fuel and electricity. Due to the depth of groundwater wells in Guanajuato, electricity represents a substantial burden on agricultural finances. Consequently, the spikes in price resulted in farmer protests that blocked a section of Interstate 57 near the major metropolitan city of Querétaro in July 2014 (Medina et al. 2015). The implementation of the energy reforms also coincided with a devaluation of the peso in relation to the U.S. Dollar over 2014 and 2015 at rates not seen since the devaluation of the early 1990s (Figure 4.5). The *Pacto* therefore represents the most dramatic political economic reforms since the early 1990s policies that were implemented to pave the way for NAFTA, and further advance neoliberal ideologies and the globalization of natural resource management in Mexico. While the outcomes of the *Pacto* remain uncertain, the tensions of structural reform are very apparent and mark a further shift away from the nationalistic agenda set forth by the Revolution.

Figure 4.5 Devaluation of the Mexican peso in relation to the U.S. dollar from 1 Sep 2014 to 1 Sep 2015. (Source: Trading View 2015)

4.4 Technologies of the water soft path in Guanajuato

Technologies of the hard path—such as dams, water treatment plants, wells, and irrigation canals—still remain an important part of water infrastructure. However, with shift in policies geared toward water conservation and agricultural intensification, there is likewise increase in WSP technology investment. WSP technologies for agricultural production in Guanajuato have taken four forms: water retention projects, grey water re-use, metering, and irrigation efficiency.

4.4.1 Water retention projects

Water retention projects typically include capturing water or slowing runoff in order to encourage the regrowth of vegetation and improve the infiltration of water into the aquifer. Water retention projects are useful for farmers because they help to prevent soil erosion, and to capture water for use on the farm—typically for livestock. There are multiple methods for achieving these outcomes: *gaviones* (gabions), terracing, reforestation, *bordos* (water retention ponds), and soil leveling (Figure 4.6). *Gaviones* are modular shaped metal cages filled with rocks that are typically put on steep inclines or stream beds in areas of high runoff as a way to prevent soil erosion and encourage vegetation re-growth. Terracing usually involves the construction of a long wall of rocks along an area of steep incline, or flatter areas holes are dug and the excavated dirt is built up around the hole in the shape of a parenthesis. Reforestation refers to planting of trees, predominantly mesquite and *nopales* (prickly pears), but also oak, pine, and acacia varieties in some areas. *Bordos* are water retention ponds, or where soil has been removed from an area of low elevation in order to capture precipitation in order to provide drinking water and cooling place for livestock. Broadly speaking, water retention projects can be subdivided into re-vegetation projects (*gaviones*, terracing, and reforestation), and agricultural water capture (*bordos* and soil leveling).

(A) (B)

Figure 4.6 Water retention projects. (A) Looking down on a 10-year-old gabion installation constructed of chain link fencing and rocks. (B) water catchment pond surrounded by a reforested protected area. (Photos by the author)

Revegetation projects are carried out by non-governmental organizations with an interest in long-term water conservation and sustainability. Revegetation projects are often conducted on ejido lands with the assistance of volunteer labor by local urban residents as well as *ejidatarios*. Volunteers dig trenches, carry rocks, and plant trees. NGOs provide leadership and financing of materials for this project, and also follow up on the projects to assess their success. In the case of one NGO, funding for the project came from the National Forestry Commission of Mexico (CONAFOR) but also from the Natural Resources Defense Council (NRDC) in the U.S. and the United States Department of Agriculture (USDA), due to the importance of migratory bird habitat in this region of Mexico. In recent years, the U.S. has scaled back investments, and CONAFOR has taken a leadership role in reforestation projects in Guanajuato. Although CONAFOR has provided a lot of resources, NGO workers complain that assistance often falls short. In May 2013 at the end of a long dry season, I visited one such project with an NGO leader and a volunteer. The leader poked at a roasted mesquite sapling and said, “See these? They aren’t big enough. CONAFOR keeps giving us these trees, which is great, but they don’t last out here” (personal communication, April 2013). A leader from a separate NGO echoed the same sentiment with a project of pine reforestation in the Sierra Gorda. Although revegetation projects are most commonly led by NGOs, many ranchers were aware of the importance of perennial vegetation and especially trees to the maintenance of farm resources and would draw my attention to the trees they had planted on their own property to help with soil erosion, shade, and water retention.

Farmers attempt to capture water during the rainy season and prevent runoff through *bordos* and soil leveling. *Bordos* are a common practice that has been utilized for most of the twentieth century, with all farmers I interviewed citing they have always relied on them as a key source of water for livestock during the dry season. The construction of new *bordos*, however, is now prohibited in my study site under the LAN agreement because it is seen as a capture of surface water resources destined downstream. Many farmers suggested that geological studies combined with the construction of new *bordos* would be an effective strategy for aquifer recharge, however this is impossible until the government makes the construction of new *bordos* legal once again. Lastly, many farmers are investing in land leveling in order to make the processes of flood irrigation more efficient. This is done through traditional methods that involve heavy manual labor, and increasingly farmers in my study site are investing in laser-leveling technologies. Laser leveling is an expensive technology, and often farmers who have implemented this technology have sought financial support from the National Agricultural Secretariat (SAGARPA) or other rural support programs. In some cases, farmers are able to borrow the device through the assistance of government agencies and regional civil organizations.

4.4.2 Grey water re-use

The re-use of grey water (*aguas residuales*) for agriculture is thus far not used directly in my study site, but is employed in another region of Guanajuato. This project began implementation in the early 1990s as a mechanism for re-using wastewater to grow fodder for livestock, predominantly cattle and goats. The use of grey water for horticultural production is prohibited due to health concerns. Part of the process of making the grey water work was to build a treatment plant so that the water met health standards for fodder application. Furthermore, previously exposed sewage canals are now being enclosed in piped systems to prevent trash from getting into the canal systems, improve soil quality due to decrease chemical contamination, and prevent evaporation. According to local non-governmental organizers and farmers, the project has been successful for participating communities, but required a lot of "institutional effort" on the part of communities and local technocrats in order for the project to be successful. COTAS managers worked with community members to solicit government funding for the water treatment plant and distribution piping in order for the project to be feasible.

4.4.3 Irrigation conservation technologies

Lastly, and the most widespread WSP approach among farmers, is the adoption irrigation conservation technologies. The traditional method of irrigation in Guanajuato is known locally as *rodado* in which farmers irrigate their land using a system of earthen canals to bring water from the well or dam to the fields, and then flood the fields between the rows of crops. *Rodado* is condemned by water policy makers as an inefficient use of scarce groundwater resources, due to losses from evaporation and soil infiltration as the water travels to the field. Farmers also prefer to use more advanced methods of irrigation, because *rodado* results in lower yield and requires more labor to maintain the furrows to ensure the water flows appropriately. As of 2010, an estimated 67% of farmers who use groundwater still irrigate their crops with *rodado*. Nevertheless, over the past decade there has been an increase in irrigation conservation technologies irrigation conservation technologies in the past decade with many farmers using more than one type of irrigation system.

The proliferation of irrigation conservation technologies can be linked to the revision of the National Water Law and the influences of the World Bank in financing both the restructuring of water governance administration and the modernization of irrigation infrastructure. Specifically, the Groundwater Management Advisory Team (GW-MATE) of the World Bank has been globally influential in leading, evaluating and providing suggestions for irrigation conservation programs worldwide, and cite irrigation technology as one key part of achieving these goals (Garduño and Foster 2010). Since 1991 the World Bank has committed over $900 million USD toward these goals, including decentralization efforts, irrigation canal infrastructure, and on-farm investments to improve irrigation efficiency and productivity. The most recent commitment was made in 2003 in the amount of $303 million USD and known as the Integrated Irrigation Modernization Project (PMIR; *Proyecto de Modernización Integral del Riego*). Specifically related to groundwater management, the World Bank has played an active advising role to CEAG in the organization of the COTAS, who provide key assistance to groundwater farmers in terms of titling wells and accessing government supports for technology installation (Foster et al. 2004). These funding sources have enabled the diffusion of two forms of irrigation conservation technologies: (1) soil moisture management, and (2) irrigation efficiency (IE) devices.

(A) (B)

Figure 4.7 Technologies for soil moisture management. (A) Greenhouses for cucumber and tomato production. (B) High tunnels for tomatillo production.

Technologies for soil moisture management include greenhouses and *macrotúneles* (high tunnels or hoop houses). Greenhouses are the most expensive and sophisticated of irrigation conservation technologies, costing between $70,000 and $100,000 USD per hectare to build according to farmers (Figure 4.7). They are often built in very dry areas or areas of limited arable land, because fertilizer and water inputs can be computationally controlled. Greenhouses are only used for the production of horticultural crops and enable an extended growing season. Tomatoes are by the far the most common crop, but farmers in my study site produce specialty hot chiles, bell peppers, and cucumbers in greenhouses as well. *Macrotúneles* or hoop houses refer to a metal frame similar to greenhouses, however the sides are open and exposed to the elements (Figure 4.7). Therefore, they are a much more affordable option to install and maintain than greenhouses. They help prevent rapid evaporation caused by direct sunlight and are often used in conjunction with traditional gravity irrigation systems, though some strawberry farmers in southern Guanajuato use them with drip irrigation. Hoop houses also require much less expertise and training to operate and therefore represent lower risk of use and installation.

Irrigation efficiency (IE) devices include *compuerta* (piped furrow irrigation), sprinklers, and drip irrigation systems (Figure 4.8). These systems represent increasing degrees of water efficiency beyond traditional *rodado* systems—or open furrow irrigation. The cost of these devices varies with lower prices per hectare of installation the more devices that are purchased at a time.

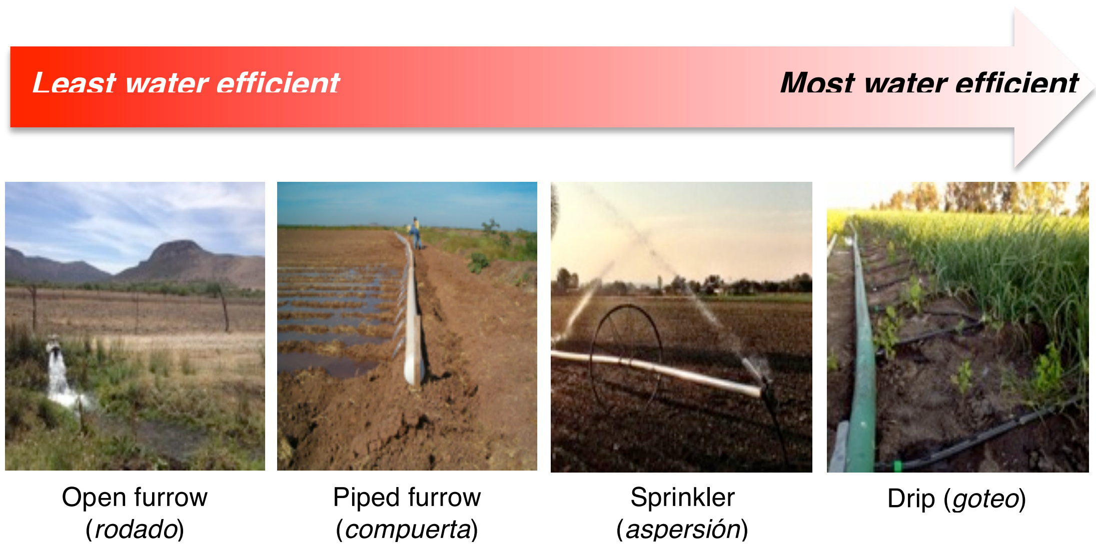

Figure 4.8 Irrigation efficiency devices, ordered by water efficiency. (Photos of open furrow, sprinkler, and drip by the author; Photo of piped furrow by ITSA Sistemas Agrícolas 2015)

First, *compuerta* refers the enclosing of open canals into piped systems of water delivery to the field, and then pipes are laid at one end of the field with holes opening into the furrows between rows of crops. The farmer can control the flow of water to the crop by opening the tap at the field and allowing the water to flow out. Farmers reported using *compuerta* systems as early as the mid 1980s, and typically for fodder crops—such as grain corn and alfalfa—but it is also used on some horticultural crops—such as peppers and broccoli. Second, sprinklers spray water onto the crops and come in varying forms, but the two most common were portable and side-roll sprinkler systems. Sprinklers were being used on farms in my study site beginning in the early 1990s and are used to irrigate both fodder and horticultural crops. Lastly, drip irrigation systems began to increase significantly in my study site around 2005 and are used almost exclusively to irrigate horticultural crops, such as broccoli, lettuce, and peppers. The tape (*cinta*) that runs through the field must be replaced approximately every two to three years, depending on the types and quantity of chemicals used which can erode the material. This makes the system relatively costly to maintain, however farmers find drip irrigation very desirable because it allows for water and energy cost savings while increasing yield per hectare by about 30%. In sum, farmers use a wide range of irrigation conservation technologies to manage soil moisture and increase water and energy efficiency. Their adoption is an ongoing and growing trend among farmers in northeastern Guanajuato as well as in the Bajío to the south.

The three types of WSP technologies—water retention, grey water, and irrigation conservation—have all become more prevalent in Mexico within the past 30 years, growing alongside shifts in governance of water and agriculture as well as increasing concerns about the decline of the groundwater table and precipitation variability. While they may not all be seen as small-scale technologies, they indeed operate to mediate the effects of a supply driven system and manage demand through ecological restoration, water recycling, and efficiency targets. Furthermore these technologies were made possible by both experiences of biophysical scarcity in the form of drought and groundwater overdraft, as well as the availability of funds and emergence of organizations to assist with the development of these technologies in the region.

4.5 Who is a farmer in northeastern Guanajuato?

The previous section described the various technologies being implemented, while this section examines to whom these technologies are directed. This section provides a context for the findings that follow first by describing class relations of farmers in Guanajuato, and second, by detailing information about the specific farmers who participated in this study, the types of farms they operated, and how they managed groundwater.

4.5.1 Class relations of farmers

Farmers in Guanajuato can be divided into three groups: agro-industrialists, ranchers, and *ejidatarios*. The divisions arise from my own observations and conversations with farmers in Guanajuato today, but also resonate with classifications of farmers in early twentieth century Mexico: "As late as 1929 an official party statement envisaged three classes in the Mexican countryside, consisting of the poor peasantry of the *ejidos*, the middle peasants with their own small-holding, and the 'agricultural entrepreneurs of more considerable means and initiatives'" (Brading 1978, p. 207 quoting Herzog 1959).

First, the term "agro-industrialist" refers to farmers who privately own nationally- and internationally-run corporate farms that can range from a few hundred to a few thousand hectares in size. Agro-industrialists often do not typically operate the day-to-day production on the farms they own. Agro-industrialists hire a farm manager (*gerente*) or have a business associate (*socio*) for this purpose. In Northeastern Guanajuato, major agro-industrialists included Taylor Farms, Monterey Mushrooms, Mr. Lucky, and several farms owned by legislative representative and former Secretary of Agriculture, Javier Usabiaga. Given the international ties and deep political connections, agro-industrialists in some ways resonate with the *hacienda* system that was dismantled with land redistribution after the Mexican Revolution.

The second group includes private landholders who often refer to themselves as *pequeño propietarios* (small-holders) or *rancheros* (ranchers). Given that the landholdings of these farmers can range from a few hectares to hundreds of hectares, I prefer to use the term "ranchers" to refer to these farmers, because the "small" in smallholder seems to be a misnomer in many cases. After the Revolution, private parcels under 500 hectares were classified as not redistributed. Unlike agro-industrialists, ranchers own the land and have a more direct influence over the actual cultivation and decision making on the farm. Furthermore, ranchers often operate the farm as a family unit within different roles in production, management, and commercialization. Historically, ranchers were thought to have concentrated and redistributed land across generations and therefore were considered less of a political threat in terms of land consolidation unlike the *hacienda* system (Brading 1978, p. 4). Within this middle class exists *arrendatarios,* or renters, who are ranchers in that they produce on privately owned land, however they themselves do not own the land on which they are producing. Historically, *arrendatarios* also tends to work as laborers on land owned by agro-industrialists or ranchers (Brading 1978).

Lastly, there are *ejidatarios* or communal farmers. These are largely subsistence farmers who have usufruct rights to the land granted to them by presidential decree following the Mexican Revolution of 1910. They often cultivate 1 to 2 hectares individually and share water resources and sometimes IE devices with other farmers, such as *compuerta* piping and portable sprinkler systems. They are often referred to as communal smallholders or the peasantry. Before the Revolution, these types of farmers constituted the laborers on *haciendas*, or large estates, and did not own any land for production. Today it is common for *ejidatarios* to engage in labor away from the parcel, including seasonal farm work on larger properties.

These categories emerged historically and have become important cruxes for self-identification among farmers. Farmers note their identities with clear political intentions for how they would like to situate themselves within future directions of land and water management in Mexico. Private landowners position themselves as rational users of the nations waters and resources, pointing out their economic contributions.

Some ranchers specifically mentioned that *ejidatarios* were in large part to blame for inefficient uses of water and expenditures of government financing. *Ejidatarios* I interviewed felt trapped in a cycle of low production, lack of market access, and an inability to access education and technologies necessary to improve upon their use of water resources. Both groups expressed sentiments of feeling forgotten, overlooked, and left behind by the government, in spite of recent displays of political power as in the case of rural energy costs.

These categorizations of farmers by land tenure, however, further obscure the range of political power and resource management strategies that exist within these groups. In line with Eric Perramond's (2010) recent analysis of cattle ranchers in Sonora, it is more appropriate to discuss class and identity in terms of a continuum rather than a disjointed set of groups. Arguably, this range extends beyond ranchers to include variability among and within *ejidos* as well.

Farmers who identified themselves as ranchers (*pequeño propietarios*), constituted the bulk of participants in this study for geographical and methodological reasons. 97% of survey participants self-identified as ranchers, while 72% of interview participants self-identified as ranchers. There are several reasons for the high proportion of ranchers. First, ranchers are the most ubiquitous groundwater irrigators in Northeastern Guanajuato. It is not as common for *ejidatarios* to cultivate using irrigation in Northeastern Guanajuato. *Ejidatarios* in northeastern Guanajuato most commonly practice temporal or rain-fed cultivation, and therefore there are not very many *ejidatarios* who actively irrigate using groundwater. However, *Ejidatarios* are active irrigators in other parts of the state where surface water is the primary source of irrigation and groundwater resources are closer to the surface and therefore more accessible, such as within irrigation districts and the surrounding Bajío region in southern Guanajuato. In northeastern Guanajuato, groundwater pumps within *ejido* communities were reserved for domestic water consumption. Second, agro-industrialists—particularly the largest agro-industrialists mentioned above—would not agree to meet with me, citing that they needed the approval of upper management before agreeing to participation in a study. I met a couple of farm managers of agro-industrialist at workshops in Dolores Hidalgo, however they were visiting from areas outside of my study site. Lastly, my key informants were also ranchers themselves and had closest contact with other ranchers through business and civil associations, and these contacts provided most survey and interview opportunities.

In comparison to other agricultural regions of Mexico, Guanajuato is characterized by stronger rancher culture than in other parts of Mexico (Brading 1978). While the Revolution worked to dismantle haciendas—particularly those owned by non-Mexicans—private property held by ranchers was allowed to persist so long as it remained under 500 hectares. Thus the redistribution of hacienda lands combined with the financial assistance of the Mexican Green Revolution aided in the proliferation of ranches and livelihood improvements of ranchers throughout the mid twentieth century. The diffusion of ranchers into northeastern Guanajuato was assisted by the implementation of groundwater lifting technologies. As in other parts of Mexico, however, ranchers livelihoods are struggling from combined pressures of neoliberal economic reforms and biophysical uncertainty (Perramond 2010). It is within this political ecological context that the Water Soft Path is introduced, and in the two chapters that follow I trace how ranchers negotiate this struggle.

4.5.2 Survey participants

All participants in the survey (n=39) were Mexican-born men, between the ages of 26 and 84 with an average age of 51. Participants in the survey ranged in their level of education. 31% of farmers surveyed had completed secondary education—the maximum level of public education available in Mexico—while 26% graduated from high school. The remaining 37% graduated with a university degree. Those who graduated from college received primarily degrees in agronomy and business, specifically accounting and international business. Most participants (69%) identified as a member of local organizations, such as the Agricultural and Livestock Associations, the COTAS, the *ejido*, and various crop-specific cooperatives. Of those who participated in local organizations, 21% held leadership positions including Secretary, Treasurer, Technical Advisor, and Legal Representative.

Survey participants were mostly full-time farmers, with only 38% reporting engagement in off-farm work. Those who said they worked outside of the farm dedicated an average of 58% of their time to farm activities, and estimated on average that 47% of their earnings came from farm work. Thus, even those who had other work off the farm dedicated the majority of their time to farm work. Furthermore, the difference between the percentage of time dedicated to farmland and the percentage of income from farm work indicates that survey participants continued to work the land even though they were able to earn more in other economic activities.

4.5.3 Farm management

Most farmers identified themselves as owners (69%) of the ranch. Another 20% identified as partners (*socios*), meaning he typically owns and operates shared land with family members or a cooperative group of farmers who share profits. Three farmers (9%) identified as ranch managers, meaning he did not own the land but operated farm production. Lastly, only one farmer (3%) classified himself as an *arrendatario*, or renter, though he also considered himself to be a rancher.

Farmers who participated in the survey planted 3 crops on average, with a range of 1 to 9 crops. Alfalfa was planted by farmers more than any other crop, followed by corn, beans, and broccoli; although broccoli was planted over more area, followed by corn, beans, and lastly alfalfa (Table 4.2). When taking into account year-round production or the planting of multiple cycles of a crop in the past year, broccoli far surpasses any other crop and represents a third of all irrigated hectares among study participants. Although fewer participants produced broccoli, those who cultivated it typically also owned larger ranches, cultivated the crop over large areas, and planted broccoli for more than one harvest cycle. Therefore, traditional and fodder crops remain an important part of the agricultural economy although there is an evident preference for broccoli cultivation, particularly among farmers who are able to cultivate it in large quantities and have a secure place to market it.

Crop	# of farmers	Pct of farmers	Avg HA plant	Total HA plant	Avg HA irrigate	Total HA irrigate	Pct total HA irrig.
broccoli	12	34%	53	640	105	1262	33%
alfalfa	19	54%	15	294	31	587	15%
corn	18	51%	27	485	27	485	13%
beans	14	40%	23	317	25	347	9%
oats	9	26%	21	185	21	192	5%
asparagus	3	9%	24	6	47	142	4%
corn (seed)	4	11%	35	139	35	139	4%
peppers	7	20%	17	117	17	117	3%
onion	4	11%	14	56	27	108	3%
wheat	4	11%	18	73	22	88	2%
tomatillo	5	14%	15	75	15	75	2%
oat (seed)	1	3%	30	30	60	60	2%
tomato	5	14%	11	56	11	57	1%
barley	3	9%	18	55	18	55	1%
bell pepper	4	11%	10	39	11	42	1%
triticale	1	3%	25	25	25	25	1%
carrot	1	3%	15	15	15	15	0%
cucumber	1	3%	6	6	12	12	0%
cilantro	1	3%	10	10	10	10	0%
wheat (seed)	1	3%	6	6	6	6	0%
beet	1	3%	5	5	5	5	0%
winter squash	1	3%	4	4	4	4	0%
grapes (wine)	1	3%	1	1	2	2	0%

Table 4.2 Crops produced by farmers, in descending order by hectares irrigated.

Animal production is also an important aspect for many farmers in northeastern Guanajuato, as indicated by range of fodder crops in the table above. 34% (n = 12) of farmers managed animals on the ranch, including beef cattle, dairy cattle, sheep, rabbits, and horses. Beef cattle (n = 9) and sheep (n = 7) were the most popular animals among farmers. Most beef cattle farmers had 40 or fewer head of cattle, though one managed 125 head and another 500 head. Sheep farmers had 100 or fewer head of sheep.

4.5.4 Water management

Farmers who participated in the survey are entirely reliant on groundwater for irrigation. Furthermore, aquifers of northeastern Guanajuato are some of the deepest in the entire state. Farmers' drilled their wells to an average 234 meters, and were pumping water from an average of 138 meters below the surface. In other words, groundwater used for irrigation travels the distance of one and half football fields before reaching the earth's surface. It is pulled up through a 6-inch pipe on average, flowing at approximately 34 liters per second. At this rate of pumping, farmers are permitted by CONAGUA to extract an average of 258,000 cubic meters of groundwater per year per farmer for the purposes of agricultural production—equivalent to nearly two Olympic sized swimming pools per week over the course of the year. Even though the drilled distance exceeded that of the water surface by 100 meters, many farmers still complained about declining water tables and decreasing pressure. Nearly 1 in 3 farmers (n = 11) had repositioned or deepened their well in the past 15 years, and another 12 had plans to do so in the works. In other words, the need to invest in well perforation was becoming increasing reality for most farmers in northeastern Guanajuato.

The extraction of water at 34 liters per second across 138 meters of pipeline requires enormous amount of energy. Pumps are operated via electricity supplied by the Federal Electric Commission (CFE). The CFE also provides a rural discount on electricity and night-time tariff to help reduce energy costs (Section 4.2.3). Nevertheless, farmers reported that they spent on average MXN $22,500 (USD $1,610) per month on electricity to operate their irrigation pumps. As a result nearly 1 in 3 (31%, n = 11) farmers reported that there had been a month in the past year in which he did not pay his electricity bill.

4.6 Summary

The increasing prevalence of the technologies of the water soft path for agriculture were made possible by a series of key moments in water and agriculture governance. Following the Revolution of 1910, natural resource policies of land, water, and energy were largely centered around the nationalistic goals that promulgated from the Revolution, and were held in place by a quasi-democracy maintained by the PRI throughout most of the twentieth century. Water was controlled by agricultural technocrats, who mitigated geographic scarcity by developing supply through the creation of irrigation districts while independent rural producers drilled wells to access groundwater outside of these networks. Agricultural development was tagged the "Mexican miracle" in reference to the rapid growth of the agricultural sector through the extensification of agriculture into new territories with the assistance of irrigation development and groundwater drilling technologies.

The 1980s and 1990s, however, marked two key decades in the transition away from the water hard path. The economic crisis of the 1980s stimulated a re-evaluation of the centralized management of natural resources that culminated the reworking of the constitution in 1989 to create a new national water agency (CONAGUA) and to revise the National Water Law in 1992. These policy shifts paved the way for decentralized surface water and groundwater councils centered on demand management strategies.

Alongside these moments in water governance, agriculture was also undergoing momentous transition guided by the principles of neoliberal economic policy. The National Water Law transformed land rights, allowing for the privatization of *ejido* lands, which coincided with the renegotiation of key agricultural policies in order to prepare Mexico for the implementation of NAFTA in 1994. The neoliberalization of natural resource governance has only deepened with the passage of the *Pacto por México* in 2012, extending privatization to energy resources and the dismantling of PEMEX and CFE.

The transition from the water hard path to the water soft path was shaped in part by international organizations, and in particular the World Bank and the International Water Management Institute (IMWI). The World Bank has been instrumental in financing the restructuring of both surface water and ground water governance, which has aided in the provision of technologies to modernize hard path infrastructure and introduce soft path technologies, including greenhouses, IE devices, and water meters. The financing of these projects has been supplemented by research and project assessments to document and redirect water governance agendas, particularly within Guanajuato and the Lerma Chapala River Basin (Garduño and Foster 2010; Millington et al. 2006; Foster et al 2004). IMWI has also supplemented World Bank investigations with research projects of their own, drawing parallels between groundwater crises in

Guanajuato and parts of India in an attempt to compare and contrast patterns and processes of groundwater governance and technology implementation (Shah et al 2004; Scott and Shah 2004). The involvement of international organizations coupled with Guanajuato's economic importance in agricultural and industrial production for global markets has extended the geographic relevance of water governance within Guanajuato. In other words, the challenges and opportunities afforded by the transition to the water soft path in Guanajuato have material effects for people and places beyond the state.

In spite of new laws, new organizations, new actors, and new devices, the water soft path—as applied in Mexico—has not meant an abandonment of the water hard path. The WSP has entailed a rolling out of the state as much as it has meant a rolling back. Rather than displacement, the WSP and the WHP are coexisting in infrastructures, institutions, and knowledge systems. It is in this coexistence that tensions arise as state surveillance is increased while state protections are withdrawn. The WSP necessarily requires a reworking of state-citizen relations that tends the politics of everyday life. How this process of negotiation is articulated by the state and the political opportunities it affords for citizens is the topic of the next chapter.

CHAPTER V

COEXISTENCE: STATE-CITIZEN RELATIONS AND THE CO-PRODUCTION OF SOCIOTECHNICAL REGIMES

This chapter examines state-citizen relations as water soft path (WSP) technologies roll back the presence of the state through decentralization and demand management, while the legacies of the water hard path enable the state to use these WSP technologies to roll out state power and surveillance. I investigate this contradiction through the following research questions: How does the central state perpetuate its role as the arbitrator of water governance within technologies of the water soft path? What are the implications for citizens and water? I argue that the simultaneous roll out of soft path and hard path technologies constitute coexistence, and that this coexistence both challenges and perpetuates state control over water access.

5.1 Coexistence

Coexistence—defined as the "side-by-side" existence of infrastructure such as "piped water beside rainwater collection [or] tanker truck delivery"—is often a more accurate description of reality than the displacement of one system with another, particularly within the Global South (Furlong 2014, p. 139). Construction and maintenance of pipelines and treatment facilities cannot cease, although there is increasing attention toward efficiency devices, water recycling, and restoration. In the case of water, coexistence indeed emerges as a form of practical necessity for both citizens and the state due to historical interactions between the social, technical, and natural.

This apparent practicality of coexistence, however, has its origins in a specific set of political economic commitments grounded in particular visions of what water is and how it should be managed. Therefore, Ahlers and colleagues (2014, p. 2) argue that coexistence indicates systems that do not operate "side-by-side" rather are "co-produced as a result of their articulation with socio-political, economic, biophysical and infrastructural drivers" (2014, p 2). For example, patterns of human settlement today unfolded as a product of water hard path initiatives (Barnes 2015; Carse 2014; Swyngedouw 1999). Hard path investments in irrigation supply were diverted through canals from river systems, but also demonstrate political economic preferences for certain landscape patterns and processes of development and productivity. Moreover, within these areas of hard path investment there are evident archipelagos of infrastructure within human settlements that reveal geographies of water service that are incomplete and unequal (Jepson 2014; Kooy and Bakker 2008).

Upon the introduction of the water soft path at the end of the twentieth century, new technologies are *grafted onto* or to serve as a *substitute for* hard path water infrastructure. For example, the soft path technologies are grafted on through mediating technologies, such as low-flow toilets (Furlong 2010) or water meters (Loftus 2008; von Schnitzler). Coexistence also exists to serve as a substitute for hard path investments in several other cases, including: illegal diversions of municipal water supply (Meehan 2013), rainwater harvesting systems (Meehan and Moore 2014), point-of-use water filtration (Vandewalle and Jepson 2015), trucked water "mafias" (Ranganathan 2014; Birkenholtz 2010), and purified water kiosks (Jepson and Brown 2014). Together, this research examines how marginalized citizens and the state produce coexistence in order to supplement systems of intermittent, unavailable, or unreliable sources of water supply. They argue that coexistence is both a pathway for political resistance to state power, as well as the perpetuation of structural injustices. For example, Furlong (2015) and Meehan and Moore (2014) assert that dispersed technologies characteristic of the water soft path can encourage self-sufficiency and thus independence among water users. On the other hand, Vandewalle and Jepson (2015) and von Schniztler (2008) contend that coexistence exacerbates conditions of inequality and that alternative technologies are promoted by the state to gloss over obligations to serve marginalized citizens.

Meanwhile, research has also identified that recent transformations of water governance oriented toward decentralization, or soft-path strategies, have worked to re-centralize state power in practice (Birkenholtz 2015; Bridge 2014; Scott and Banister 2010). This points to a coexistence of the water hard path and soft path beyond material infrastructures and within discursive and institutional techniques of environmental governance. Some may interpret this as a form of cooptation, because cooptation refers to processes by which an organization absorbs competing elements or ideologies to avoid challenges to its stability (Selznick 1948, p. 34). Cooptation, because of its origins in theories of social organization, however does not signal specific attention to the material transformations that evolve out of and work to support the water soft path.

Therefore, I maintain that this phenomenon is best described as coexistence because of the soft path's material intention in transforming socionatures through particular technologies, and because of the origin of the concept of coexistence within literatures on science and technology studies (STS). In this respect, cooptation can help to explain processes of social and political organization, while coexistence examines the material practices that help to realize cooptation. Consequently, I rely on the notion of coexistence rather than cooptation to underline the focus on technologies and technical practices of governance throughout the chapter.

Birkenholtz's (2009) work on groundwater in India has analyzed "decentralization as recentralization"—or coexistence—within frameworks of governmentality and hegemony. In doing so, he examined the mechanisms through which the state produces environmental subjectivities compliant with the interests of elite groups, and demonstrated that this process is often complied with and resisted differentially among social groups. Antonio Ioris (2015) turns the tables to examine how the state itself is rearticulated within these global shifts in environmental governance. He argues that the state has reformed itself as the mediator of "flexible associations between market demands and environmental protection" because the "state is seen as inherently rational" (Ioris 2015, p. 177, 176). Trevor Birkenholtz (2015), drawing on Bridge (2014), has also made this connection between the state and market by asserting that the state operates as an "extra-economic" actor. The state promotes economic interests under the preface that improved productivity overall will eventually benefit all members of society. In practice, however, the state's role as an extra-economic actor in environmental governance furthers the interests of the capitalist elite rather than operating as a representative of the collective. As a consequence, both Birkenholtz and Ioris contend that the state's contemporary practices *perpetuate* rather than resolve socially differentiated socio-ecological disputes (Ioris 2015, p. 170). In spite of these contradictions, the state has managed to (temporarily) stabilize its authority as a key actor in questions of environmental governance. Consequently, coexistence is both a source of and challenge to state authority within questions of environmental governance. This chapter examines how the state utilizes coexistence to perpetuate state power, the interests of capital elite, and hard path infrastructures, which together undermine goals of sustainable development targeted by the water soft path.

5.2 Three steps of water governance

In August 2013, I attended the National Meeting for River Basin Council Operators at the UNAM campus in Morelia, Michoacan. More than 120 people overflowed a lecture hall, filling every seat and as well as space along the side stairwell. In attendance were mostly male employees from a diversity of sectors in the Mexican government, including CONAGUA, state water commissions, groundwater councils (COTAS), river basin organizations, the Forestry Ministry (CONAFOR), the Natural Resources Ministry (SEMARNAT), and the Mexican Institute for Water Technology (IMTA). Members of leadership at international water management institutes had also been invited to give keynote presentations about pertinent issues in global water management.

A leader of the International Network of Basin Organizations (INBO) led off a series of presentations with the question, "Is there a global water crisis?" He went on to highlight issues of water contamination, climate change, extreme weather events, and water conflicts that he argued indeed constituted a global water crisis. In order to resolve this crisis he outlined a water soft path agenda in which managers needed to mitigate demand, reuse water, and encourage participation at the basin level. He noted, however that "if you cannot measure, you cannot manage" ("*Si no puede medir, no puede manejar*") (27 Aug. 2013). INBO's presentation was followed by a river basin manager in Canada who recommended that river basin managers follow three steps: "information, consultation, and implications." He added, however, that this process was not always seamless, because in the basin where he worked farmers were not participating in water management because they were not paying for the water they used.

River basin management therefore did not simply mean measuring hydraulic flows and economic demand at the regional scale, but connecting regional space to the everyday practices of the users within the basin. It requires measuring people and their relation to water within hydrologically defined spaces and according to a particular form of knowing water in order to circulate "information" from the river basins to the water users. Discursively, however, this way of knowing water exceeds the boundaries of Mexico and is framed within international water management circles in terms of measuring supply (information), managing demand (consultation), and enforcing compliance with those processes (implications). In this process, human-water relations are refracted through the institutional and material mechanisms of a neoliberal political economy.

In the sections that follow I demonstrate how the state is a central actor in each of these three steps designed to carry out water soft path initiatives, and in this process further develops a hard path agenda that it has claimed to transition away from. . First, I describe how river basin management generated technical knowledge of geographies of scarcity and surplus, legitimizing hard path infrastructure alongside the circulation of a new water culture. Second, I outline the ways that the state regulates scarcity through the institutional administration of groundwater titles. Third, I describe how compliance with river basin regulations and titles is complicated by surface water and groundwater's technical materialities. Lastly, I conclude by summarizing the ways in which the technologies of the water soft path work to consolidate state power, but also explore ways in which these same technologies offer opportunities for political action.

5.3 Knowledge: River basins as geographies of scarcity and surplus

This section examines the production of river basins as a soft path tool for the circulation of knowledge about geographies of water scarcity and surplus in central Mexico. This process of knowledge circulation helped to legitimize a central state led project to construct the Realito Dam in Guanajuato, yet water provision from the dam for Guanajuato residents has been stalled by the same soft path logic that enabled the dam's construction. As a result river basin management (a soft path technology) coexists in conjunction with the construction of a new dam (a hard path technology) with contradictory outcomes for socionatural relations.

5.3.1. "They have plenty"

The sun was setting on another day of fieldwork as I stepped out into the coffee shop parking lot after meeting with a few ranchers and an export sales consultant. We were saying our goodbyes when Juan, a middle-aged rancher whose stature and reputation commanded authority, turned over to me and said in a booming voice, "Heather, what do you think is the answer to all of this?" By "all of this" he was referring to declining water availability for agriculture in northeastern Guanajuato. I hedged around an answer, "I mean, its really complicated so its hard to say—" "—I'll tell you what needs to be done," he interrupted, to my relief, "we need to use water from the Río Panuco. The government needs to invest in a system to bring their water over here, because it is just wasting away into the ocean. They have plenty" (Rancher, May 2014). Juan's assessment of "what is to be done" stems from his historical-geographical relation to transitions of sociotechnical regimes of water governance over the course of his lifetime.

The study site for this project lies on one side of a boundary between two rivers basins that essentially split central Mexico into two parts: from the southern tip of the Sierra Madre Oriental the Lerma-Santiago-Pacifico (hereafter "Lerma") flows to the west and empties into the Pacific Ocean near Tepic, Nayarit, while the Río Panuco (hereafter "Panuco") flows to the east and empties into the Gulf of Mexico at the port city of Tampico, Veracruz. Juan, together with his sons, owns several ranches in northeast Guanajuato in the headwaters of the Lerma. The Lerma represents a very contested watershed in terms of water availability. The major headwaters of the Lerma are the Río Laja in northeastern Guanajuato—where Juan has his ranches— the Río Lerma which initiates in Toluca, a large urban center and agricultural valley southwest of Mexico City, and the Río Turbio, which begins near León, the sixth largest city in Mexico with a population of 1.3 million. Together, these rivers' waters eventually flow into Lake Chapala, the largest lake in Mexico, which is important for its cultural symbolism and its economic contributions from fisheries and tourism. From there the waters—now named the Río Santiago—travel past Guadalajara, the third largest city in Mexico with a population of 1.5 million, before heading northwest to meet the ocean in Nayarit. Although similar in hydrological capacity to the Lerma, the Panuco comparatively has a much lower population and lower overall economic contribution in terms of GDP (Table 5.1).

	Lerma-Santiago-Pacífico (VIII)	**Panuco (IX)**
Population (million)	23.29	5.14
% of GDP	18.1	2.4
# of Municipalities	332	148
Renewable water (hm^3/yr)	35754.0	28114.6

Table 5.1 Statistics of Lerma-Santiago-Pacifico and Panuco hydrological regions. (CONAGUA 2015)

Juan's statement that water should be moved from the Panuco because they "have plenty" is a reflection of his historical experiences with supply driven water management of the water hard path, as well as the forms of measurements and divisions of water, people, and space made possible by technologies of the water soft path. When Juan was a young farmer, the state made flows and floods of water through dams, canals, and pipelines into new territories in order to provide water for the purposes of productive—often agricultural—use. It is also from this time period that he developed the concept that water not put to productive use is "wasted away into the ocean," because this was a key campaign strategy of the water hard path when the state set out on its "hydraulic mission" (Wester 2009).

When Juan reached his mid forties, the central state split the country into nine administrative hydrological units that could be measured, mapped, and represented in terms of capacity and economic contributions. In this process, Juan's land was identified as in the "upper" part of the river basin, which enrolled his land as an important area of precipitation runoff for farmers further downstream. Furthermore, the measurement of flows, surface waters, and populations resulted in calculations that identified the Lerma as "closed basin," meaning that water allocated exceeded water flows and therefore the waters that fell on Juan's property must not be captured and kept, but allowed to flow downstream (Wester et al. 2008). Juan and all of the other farmers who participated in this study already relied primarily on ground rather than surface water because of their geographic location in a semi-arid region outside of irrigation districts; however, the creation of a river basin and the legal institutions that accompanied that designation deepened their dependence on groundwater. This dependence exacerbated a preexisting condition of overexploitation of groundwater resources, forcing farmers and residents to move wells and drill deeper. Juan, through the implementation of water soft path technologies of measurement and mapping around watershed boundaries, comes to the realization that the Panuco, in contrast, is not faced with the same problems of scarcity. Just on the other side of the mountain was a water source that was not over-allocated, just waiting to be put to productive use. The water hard path becomes the obvious choice for Juan; the central government should alleviate scarcity in the upper Lerma by sourcing a new supply from the Panuco. In other words, it is through certain technologies of the water soft path, which aim to "roll back" the presence of the state and increase user accountability, that actually further "roll out" and legitimate the water hard path.

5.3.2 The Realito Dam

Juan's vision of taking water from the Panuco has already been partially realized through the construction of the Realito Dam, although the provision of water will be for domestic consumption rather than agricultural use. Inaugurated in October 2012, the Realito Dam is located along the Santa María River, one of the major tributaries for the Panuco watershed, in the municipality of San Luis de la Paz, Guanajuato (Figure 5.1). It is located in the one of the northernmost tips of Guanajuato, where the state borders San Luis Potosí. The Realito Dam measures 90 meters tall and holds a capacity of 50 million cubic meters, or enough water to fill 20,000 Olympic-sized swimming pools.

The construction of the dam and reservoir was funded by the federal government and cost $900 million pesos (USD$69 million). At capacity, water can be pumped from the dam at 2 cubic meters per second, which will be split between the states of San Luis Potosí and Guanajuato, and is estimated to provide nearly 1.7 million residents with drinking water. In Guanajuato, 1,000 liters per second will be pumped through 172 kilometers (107mi) of pipeline to a combined 370,000 residents of San Miguel de Allende and Celaya. Water from the dam is designated only for domestic consumption, not agricultural or industrial use.

Figure 5.1 The Realito Dam. (Photo by the author)

In the same way described in Juan's story above, measurements of river basin flows justified the dam's construction. The idea for the dam initiated from the state government under the leadership of Governor Vicente Fox in the late 1990s, due to increasing concern over the rapidly declining aquifer levels and the low availability of surface water in the northeastern region of the state (OCAS 2013a). The State Water Commission's website describes the Realito as "a project for the future of Guanajuato, to protect the water levels in the aquifers" (CEAG 2014). Though managed separately, the construction of a dam to provide surface water in order to protect groundwater recognizes that the flows of the two waters are fundamentally biophysically and sociotechnically intertwined.

Although the construction of the dam is complete, the residents of Guanajuato are still awaiting the completion of the pipeline as of February 2015. Delays on the construction of the pipeline are due to cost and infrastructure incompatibilities (OCAS 2013a). The shift from dispersed groundwater sources, to a singular source of surface water requires fundamental changes to water infrastructure within the municipality, including the construction of new storage capacity and distribution pipelines (OCAS 2013a). Of further concern are the operational costs of the pipeline once it is completed. Water will need to be pumped from the Panuco watershed over the Sierra Gorda range and back down into the Lerma-Chapala watershed, requiring large amounts of energy to complete its 172 kilometer journey. Nevertheless, 172 kilometers of pipeline seems minuscule when the thousands of groundwater wells far exceed this distance with the amount of pipeline drilled into the earth's surface for groundwater extraction. The challenge, however, is that the cost of moving that water is currently distributed among a multitude of dispersed well water users whereas the state must initially bear the cost of bringing the Realito aqueduct into operation. At this time, the completion of the pipeline would require the construction of a fourth pumping station in addition to the three that have already been built in order to move the water to San Luis Potosí. Consequently, the operation and maintenance costs of maintaining such a lengthy pipeline make it economically unviable at this point and time because the cost would be around MX $8.80 per cubic meter of water (OCAS 2013a).

In the case of the Realito Dam, the coexistence of the water hard path and the water soft path has led to uneven outcomes for state-citizen relations. The logic of the water hard path—"the central state must supply water where there is none"—presented the construction of the Realito Dam as the best option for water management in northeastern Guanajuato and used the logic of the water soft path to legitimize that intervention. However after the construction of the dam, the mandates of the WSP institutions—namely decentralization which placed the economic burden of pipeline construction on municipal and state governments—have stalled the actual provision of water to Guanajuato residents. States and municipalities are allocated a certain amount of funding for water projects to spend as they see fit. Projects that are large enough to exceed that allocation, such as the Realito, are funded separately by the federal government after awaiting an approval process.

In a discussion about the Realito with residents of San Miguel de Allende, a representative for CONAGUA stated that the impetus for the construction of the Realito was water provision for San Luis Potosí because they are a "state that has industrial and economic importance, among other things" (OCAS 2013a). He argued that comparatively the cities in Guanajuato needed to conduct socioeconomic studies to make sure that residents could afford the water from the Realito, and that leaks in the city distribution system also needed to be repaired before the federal government would decide whether to allocate funds, stating, "If the network is losing such a high percentage of its water, why would I make an investment to keep losing water?" (OCAS 2013a). In other words, the beneficence of the central state depends on the economic and technical compliance of people and water. People are rewritten as bank accounts that may or may not be able to recover the costs of water provision. As humans are made technical, infrastructure is given agency. "The network" is enrolled an active participant in preventing the central state from intervening on the basis of the network's water losses. The politics of water provision are discursively overridden, as uneven water access is brushed aside as the obvious outcome of technical failures and economic shortcomings. In this process, people and water are placed in a contentious relationship that can only be reconciled through technical expertise and economics.

5.3.3 Devolving technocratic knowledge through *la cultura del agua*

Part of the project of the water soft path involves enrolling everyday citizens as managers of water themselves. River basin management aims to decentralize institutions of water governance, which also involves devolving knowledge of water to the scale of the water users who are now enrolled to "participate" in water governance.

In other words, citizens are educated and trained within the logics of technical expertise and cost recovery economics in order to successfully implement projects of water provision, like the Realito.

Policy positions in the water and agricultural sectors in Mexico are often held by scientists with degrees in engineering and economics. These actors are often called "technocrats" to refer to their characteristics as technically trained bureaucrats (Wester 2008). Technocrats occupy an institutional culture that reflects an ethic of efficiency and calculative planning grounded in existing incentive structures (Maganda 2012). Therefore solutions to water scarcity and water availability related issues stem from a positivistic ontology that can be resolved by investments in techno-scientific approaches that often circumvent social democratic processes. However, increasing concerns over water quantity and water quality alongside institutional shifts toward decentralization required instilling a "culture of water" among all citizens, not just the technocrats (Walsh 2012). Shifting the perspective from supply to demand meant managing demand, or managing how the water users know water. In this process, knowledge must also be decentralized in the transition to the water soft path. However, the coexistence of technocratic knowledge from the water hard path in practice meant a devolution of a particular form knowledge as water users are brought in to the "culture of water." In Mexico, this devolution has taken the form of awareness education (*concientización*) and technical training (*capacitación*). These are complementary in the way that the knowledge component of the WSP is rolled out, because water scarcity formulates the problem as one that requires a solution that is also measurable.

La cultura del agua, or the "culture of water," seeks to transform individual and collective attitudes, perceptions, and behaviors as they relate to water in order to promote a water conservation ethic (CONAGUA 2010a). The formal culture of water campaign is prevalent in urban areas and particularly among schoolchildren where policy makers believe they can make a lasting impact. Water culture promoters develop movies, books, and posters of animated characters to educate children about water use, including series such as "*Los Hidro Kids*" (Water Kids) in Guanajuato and "*Supergótico contra el siniestro Dr. Gastón*" (Superdrop versus the sinister Mr. Waste-a-lot) in Matamoros (Walsh 2011). Both cases play off of common superhero motifs, where the enemy is involved in crimes of irrational water use and must be stopped. The culture of water campaign has also directly targeted adult domestic water users with campaigns that encourage users to "Take care of water! Take care of yourself!" (*Cuídela! Cuídete!*) (Figure 5.2). The message is that water conservation is fundamental to one's own body and well-being, and emphasizes individual responsibility for water conservation efforts. The underlining characteristic of the water culture in these cases was to create a culture that understood the "value" of water, which in a technocratic sense of the word is a value that could be measured and grounded in the principles of cost-recovery economics.

Figure 5.2 Culture of water campaign. Postcard circulated at a World Water Day event in San Miguel de Allende in March 2013, which reads "Take care of water, take care of yourself. Every minute that you leave the hose running you waste 12L of water." (Scanned photo by author)

Casey Walsh (2011) critiques the culture of water campaign for primarily targeting schoolchildren as well as urban households, conveniently displacing the burden and blame for water scarcity away from water managers while also overlooking the agricultural water users who use most of the water. After attending the Water Expos in 2011 and 2013 in Guanajuato and visiting the headquarters of CEAG, I too had only witnessed *cultura del agua* materials being generated and circulated for schools and domestic water users. How were farmers being brought into the logic of demand management? The specific materials of the culture of water campaign were not distributed to farmers through pamphlets or superhero motifs; rather farmers were enrolled into a "culture of payment" through legal institutions and technical devices (detailed in Sections 5.3 and 5.4 below).

5.3.4 Coexistence: Soft knowledge, hard outcomes

This section worked within the framing of coexistence to demonstrate how the construction of scale is a political process with uneven outcomes for geographies of water access. By framing a particular scale of water governance as "natural" the state and citizens were able to identify geographies of scarcity and surplus and represent those imbalances on maps and data reports in order to justify water hard path interventions. Therefore "environmental rescaling" in the case of river basin management works to "create new objects of governance" that are at once material and discursive (Cohen and McCarthy 2015, p. 10). For example, the Realito dam was physically constructed in the riparian landscape for the purposes of water provision, but also stands as a symbol of continuing state relevance in water management despite decentralization efforts. The flexibility of the river basin as a concept, enabled it to be sufficiently vague to garner support among citizens, policy makers, scientists, and international lending organizations; however its execution in practice held closer to the practices of central-state led water governance than integrated river basin management (Cohen 2012). Therefore the politics of river basin management ironically work to legitimize state-centered configurations of socionatures.

River basin rescaling, as in other areas of environmental governance, corresponded to a "strong and growing focus on individuals as sites, scales, and objects of governance" in a process referred to as a "responsibilization" of individuals (Cohen and McCarthy 2015, p. 14). The "culture of water" was rolled out as a necessary component of establishing demand management and incorporating water users into the everyday practice of governing water. Among schoolchildren and domestic water users, the campaign targeted the establishment of a water ethic among users that remained firmly within the top-down techno-scientific ideology of water management that characterized the water hard path. Hard path legacies of technical water management therefore aimed to produce a culture of measurement and calculation among citizens that matched how the technocrats knew water and people. Therefore, soft path tools generated knowledge that not only coexisted alongside, but also was actually *coproduced by* the sociopolitical knowledge of the hard path. This coproduction is relevant for the ways in which the institutions and devices detailed in the sections below are implemented. Consequently, the patterns and processes of uneven development persist with the coexistence of the water hard path and the water soft path in part because coexistence does not challenge the systems of knowledge and power that worked to create them. In practice this meant that the technocratic water culture was translated as "culture of payment" among agricultural water users, which materialized in the National Water Law with the creation of groundwater titles (Section 5.3) and the enforcement of that legislation through water meters (Section 5.4).

5.4 Institutions: Regulating demand management

This section examines the institutions through which the central government aims to regulate the principles of demand management among groundwater farmers. I argue that the institutions of the water soft path regulate the "culture of water" discussed above by establishing a "culture of payment." Conditioned by the legacies of technocratic decision-making of the water hard path, the water soft path emerges in a similarly calculating manner; however the focus is more so on regulating individual's relation to water (water demand) through the implementation of a titling program for groundwater extraction, rather than the regulation of waters' flows (water supply).

5.4.1 Groundwater titles

In order to set up a system of measurement and accountability of the "nation's resources," as described in the 1917 Constitution, the federal government created the Public Registry of Water Rights (REPDA; *Registro Público de Derechos de Agua*). REPDA was one product of the 1992 revision to LAN that creates a concession-based system of water rights. The title indicates how many cubic meters of water are allocated over the course of a given year and the use of the extracted water, such as agricultural (*agrícola*), livestock (*agropecuario*), or domestic (*doméstico*). There are fines (*multas*) if the title is being used incorrectly. Agricultural leaders claimed that many farmers would have agricultural title, which was easier and cheaper to procure than the livestock title, that they also used for rearing livestock. Despite these allegations, none of the farmers I surveyed reported that they were using an agricultural title for this dual purpose.

According to CONAGUA's website, REPDA is "an instrument of support within the framework of modernization, planning and programming of water administration and the efficient and rational use of natural resources" (CONAGUA 2010a). REPDA, therefore is recognized by the central state as a technology or "instrument" that fulfills soft path goals of "modernization…effien[cy] and rational use." This framing of REPDA indicates an attempt to legitimize the implementation of a new instrument as superior to previous forms of water administration that were classified as "bureaucratic" and "inefficient" during the 1980s economic crisis. However, contrary to discourses of "decentralization" that also characterized water soft path implementation, REPDA actually constitutes an *extension* of central state power into the countryside rather than a retraction.

In order to maintain the water right, farmers must renew their title with CONAGUA every 10 years. The title is tied to the well, and in turn the land on which the well is located. Therefore water rights can be sold and transferred when land is sold. In order to reposition or drill a new well, a title must either be renewed or a new title must be given. When I asked a farmer how it was possible for him to procure a new title for repositioning a well in an area where *vedas* had existed for more than 50 years, he simply replied, "It is not impossible. But it is *very* expensive'' (February 2015). Another farmer reiterated this claim and complained that the high cost of getting the title represented a form of extortion on the part of CONAGUA:

> "This well that I have is going down. I already put in a lot of money into it over the past year—to clean it, to put in [new equipment], and to fix the pump—and it is still going down. I have to reposition it, right? And we are fighting with the men over there at CONAGUA, because they extort us a lot. Every ten years you have to do the title regulations for the concession and they make us really fight for it…They are all the same over there. When the time comes to reposition a well, you need to plow up the money. Upwards of $30,000 to $50,000 pesos just so they can give you this paper." (Rancher, April 2013)

According to these farmers, the administration of titles constitutes a source of revenue for CONAGUA. Therefore, CONAGUA's revenue increases as water scarcity increases because wells must be moved more often, and therefore retitled, which increases the cost of procuring titles. Farmers who have land within the Laguna Seca district claimed that they pay a higher price to maintain their groundwater title than farmers in the neighboring Rio Laja district. The state classifies the Laguna Seca as a "closed aquifer," meaning that its flows are contained within aquifer, making recharge much more difficult and perhaps impossible. The economics of groundwater titles therefore converge with the biophysical classifications of groundwater flows. Farmers, who are able, move production operations just to the other side of the line in order to avoid the high title costs and declining groundwater levels.

CONAGUA's authority to administer groundwater titles legally originates in the 1917 Constitution, however in practice the state is discursively normalized as a representation of the collective good and therefore essential to sustainably managing water resources. At a community meeting about drought and desertification in San Miguel de Allende in June 2013, an agricultural water expert was asked why farmers did not invest in drip irrigation to improve their efficiency and conserve water. He responded:

> "It's awareness. [Farmers] believe that the water is a private right. And that's a problem. When the use of water represents a risk to the sustainability of the area, the state should restrict it. (OCAS 2013b)

CONAGUA's central authority over the administration of groundwater titles is validated in this claim, because titles represent an attempt by the state to put a limit on farmers' "use of water." However, rather than absolutely restricting the use of groundwater, the state attempts to disincentivize groundwater extraction in particular areas by driving up the cost of renewing and procuring groundwater titles. CONAGUA is able to justify these high prices for groundwater titles, because domestic water users (who share groundwater resources with farmers) want documentation that the central government is attempting to rein in unruly farmers.

CONAGUA, therefore, uses the administration of groundwater titles as a spectacle for publicizing their authority over water resources and water users. CONAGUA holds registration events like the one in Dolores Hidalgo on October 21, 2014 in order to encourage users to register their wells (Figure 5.3). A local news article that covered the event titled the article, "Guanajuato, 2nd place in exploitation of aquifers" and quoted the regional director for CONAGUA saying that he aimed to address this issue by increasing supervision on groundwater wells and closing wells that did not have a corresponding title (Rubio 2014). CONAGUA's ability to continue to control water management therefore hinged not only on the delegation of groundwater titles, but also the enforcement of compliance with the title as a technology of rule. This required a device that could measure individual extractions of water—the meter (detailed in section 5.4).

Figure 5.3 Groundwater title registration event. Local Director for CONAGUA, Humberto Carlo Navarro de Alva, speaking in Dolores Hidalgo, Guanajuato. (Rubio 2014)

5.4.2 Coexistence: Participation as payment

Within the logic of "if it cannot be measured, it cannot be managed," groundwater titling makes economic sense. First, river basin management produced knowledge of regional geographies of scarcity classified in terms of supply and demand ("information"). Water users within those regions needed to be mobilized and brought into the collective management of that resource and identify the classification of the problem as one of supply and demand through a comparative pricing system ("consultation"). This enables the enrollment of farmers into cost-based systems of groundwater titling managed by the state, which is legitimized in this role as representing the collective of both people and water. However, within this economic logic, which includes growth as a priority, productivity will not simply decline but will mobilize to spaces of lower cost, as seen with the shifting geographies of production and extraction over to the Upper Laja River Aquifer. The ability to engage in spatial mobility or continue producing in spaces of high cost, however, is not equally available to all producers. As a result, groundwater conservation regulations grounded in water pricing produce uneven access to water and fail to reduce the overextraction of groundwater resources.

REPDA was rolled out as a necessary component of demand management, however it represents an extension of state power in order to make executive decisions over the supply and cost of groundwater titles. The ownership of a title is discursively framed as farmer "participation," yet rather than equitably empowering farmers to participate in water governance it uses market logic to "rationally" select which farmers are enabled to continue cultivation and therefore "participate" in water management. When water user participation in practice is translated as payment, centralized control over water management is stabilized within regulatory instruments of the water soft path. Much like irrigation systems built during the water hard path, groundwater titles enable the state to have a central role in the production of geographies of agriculture and water extraction. Consequently, instruments of measurement put in place to manage demand within the framework of the water soft path consolidate and legitimate state power rather than facilitate the devolution of power over to water users. Regulatory instruments of the water soft path therefore coexist with, rather than replace, the water hard path.

5.5 Devices: Enforcing demand management

This section describes how the water soft path renegotiates the relationship between citizens and the devices of water provision in order to enforce the principles of demand management. In order to outline how enforcement "happens" I describe how the sociotechnical histories of surface water and groundwater are significant in terms of how enforcement is rolled out with the implementation of the water soft path. For surface water, farmers were transferred control over the maintenance and operation of irrigation canals. For groundwater, farmer's compliance is measured through water and electricity meters. I argue that the social and technical histories of water extraction under the water hard path provided divergent pathways of compliance and contestation upon the introduction of the water soft path.

5.5.1 The material conditions of state-citizen-water relations

The centralization of water management began during the Porfiriato (or the rule of Porfirio Díaz) in the late 1800s, yet it accelerated with the nationalistic goals of the Revolution (Wester 2009). Managing surface water supply meant damming major rivers and then redistributing reservoirs of water along canal systems to irrigate farmland. From a technical and political standpoint, this system of water distribution follows a hierarchical design. Referring to the case of India but relating to irrigation systems globally, Peter Mollinga (2010, p. 424) writes:

> Canal systems have been technically designed in a way that creates a government domain ('above the outlet') and an irrigator domain ('below the outlet'). The 'outlet' is the device that connects these two domains; it is used by state managers to direct water flows to irrigators from the 'main system,' and to determine the size and timing of those flows. Outlets are thus the main 'points of contact' of managers and irrigators.

The investments in these extensive projects of engineering required major investments on the part of the central government, however the government benefitted from these projects through a technical design of irrigation districts that aided in the administration and control of the countryside. In the 1920s President Calles used the construction of irrigation districts to facilitate processes of land redistribution after the Revolution by breaking up large landholdings (*latifundios*) of the Porfiriato into smaller settlements (Wester 2009; Aboites 1988). Like in other parts of the world in the early to mid twentieth century, the resettlement of land through federally led infrastructure projects mobilized the development of a state-led political economy and in turn a taxable citizenry through tools of measurement (Mitchell 2002).

Groundwater provision, on the other hand, is decentralized in its sociotechnical design. In central and northern Mexico outside of irrigation districts, groundwater was the only reliable source of water year round. For groundwater users, it was land tenure—rather than water canals—that determined the degree of a farmer's connection to the federal government. For *ejidatarios* who were legally occupying state-owned territories, lift wells were drilled with the assistance of financing from the federal government. However outside of *ejido* communities and irrigation districts, groundwater-lifting technologies were left to individual citizens. Although groundwater has legally been the property of the nation since 1917, individual citizens' groundwater extraction was virtually left unmonitored for most of the twentieth century. The formalization of regulation through *vedas* during of the middle of the century only aimed to prevent new groundwater wells from being drilled, however it did not necessarily regulate groundwater extraction of those already using the water. In addition, the *vedas* proved ineffective because of a lack of enforcement. As a consequence, groundwater extraction was a "cowboy" enterprise unto itself. Though some ranchers own and operate wells in cooperation with one another, most do so independently. Importantly, until the implementation of REPDA, they also operated independently of central state surveillance that characterized surface water management.

The divergent sociotechnical designs of groundwater and surface water throughout the twentieth century became significant with the implementation of the National Water Law (LAN) in the early 1990s. Shifting paradigms of water governance to water demand management and away from supply management meant a renegotiation of the very "culture of water" and mechanisms needed to be put in place to ensure compliance with the culture of water. In other words, citizens' demand of water needed to be "disciplined" and strategies for doing so were contingent upon the sociotechnical histories described above. In development discourse, this disciplining is discursively framed as participation, although in practice the relationship between citizens and water is "rendered technical" through devices of measurement (Li 2008).

5.5.2 Surface water: Irrigation Management Transfer (IMT)

For surface water users in irrigation districts, LAN formalized the decentralization of water governance and introduced irrigation management transfer (IMT)[8] as a way to restructure federal control over irrigation management and promote self-sufficiency among water users:

> The philosophy behind IMT lies in the perception that increased ownership, decision-making authority, and active participation in the operation and maintenance (O&M) of irrigation systems would create or force a binding commitment from water users to be more effective and responsible towards their obligations. (Garces-Restrepo, Vermillion, and Muñoz 2007)

IMT therefore arose in response the federal control of water resources and consequently required the rearrangement of relations between the state, citizens, and sociotechnical interface for surface water provision.

Farmers within irrigation districts were now expected to cover the cost of operation and management of canals, pay for the water they extracted, devise budgets, and allocate resources within the district. Invariably the sudden abandonment of state support met with contestation. The transfer of irrigation management over to irrigation districts and water user associations was controversially marked by a geographical unevenness in the dispersion of financial benefits to support IMT (Rap and Wester 2013). Nevertheless policy makers and circulators had an interest in smoothing over the challenges and problems faced in the implementation of IMT in order to internationally promote the case of Mexico as a policy model to be followed (Rap 2006). The central

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[8] For a more detailed account of the origins and implications of IMT in Mexico see (Rap, Wester, and Pérez-Prado 2004).

government therefore had an established interest in fomenting irrigation districts and water users associations that were not only institutionally successful in terms of financial responsibility, but also as stewards of the nation's vital resource—water.

Consequently, historical financial ties to the state with water hard path infrastructure combined with the state's interest in maintaining its "policy model status" has led to continuing investments in the "technification" of irrigation infrastructure within irrigation districts in order to make production more water-efficient. Loans, such as the USD $303 million Irrigation Modernization Program (PRIM) by the World Bank, were directed specifically at farmers within irrigation districts (World Bank 2010). However, this is not to say that all farmers within irrigation districts benefited evenly:

> "Poor farmers had fewer opportunities to participate in the Project. Not only could they not meet the co-financing requirements to participate in the Project (50% of the total investment cost), but also because of their limited organizational capacity, they had limited access to information about the various components of the Project." (World Bank 2010)

Poor farmers, however, were not the only farmers who had "fewer opportunities to participate in the Project." Groundwater farmers also had a much more difficult time accessing loans like PRIM and others.

5.5.3 Groundwater: Meters

At a National Groundwater Council (COTAS) Meeting in Guanajuato in 2013, a COTAS manager described to me his attempt to secure funding for an irrigation modernization project for farmers in his region. He said that he had been in conversation with a supplier to provide irrigation infrastructure for 100 projects in his region, and had arranged for a warehouse on his own property to store the infrastructure while it was being installed. However, when he went to SAGARPA (the Federal Agricultural Ministry) to ask for financial support he was declined and told that he was going beyond the role of the COTAS. The project never materialized, and the COTAS manager was frustrated, calling the government's lack of coordination "*puro desmadre*," (a derogatory term that roughly translates to "a big mess"). If irrigation modernization projects are not considered to be within the scope of the COTAS' responsibilities, how did the central government envision their role?

At the same meeting where I was told this story, a CONAGUA representative outlined the responsibilities of the COTAS as: (1) promoting compliance with the National Water Law, (2) promoting water sustainability, and (3) encouraging participation. COTAS managers were aware of their responsibilities, often defining themselves as the "link" (*enlace*) between water users and the central government. This link was established through a system of reporting, which one manager described as "generating information about users" (COTAS manager, 28 August 2013). "Generating information about users" is translated as the measurement and monitoring of groundwater extraction through the installation of water meters.

COTAS managers are expected to ensure farmers and communities equip wells—which are identified through REPDA—within their region with a water meter and regularly monitor extraction. Data reports are submitted to the Guanajuato state government as well as CONAGUA. At both the 2011 and 2013 National COTAS meetings there were presentations by private firms on cutting edge water monitoring technologies involving satellite transmission and automatic recording of water usage, as well as electronic monitoring of water levels in wells. These presentations generated significant interest among the COTAS managers in attendance because data collection represented a significant labor burden. In November 2013, I travelled with a COTAS manager to monitor several wells in his region, which constituted more than a full day's work—we left at 7:30AM and did not return until after 10:00PM. COTAS managers reported that they would rather be spending that time generating projects through school presentations or helping farmers solicit credit for irrigation infrastructure.

The enrollment of COTAS managers as responsible for monitoring well extraction also complicated their responsibility of "encouraging participation." Failures to comply with participation—defined as enrollment with REPDA and installation of a meter—are supposed to be reported to CONAGUA. COTAS managers, who often lived and held other jobs within the aquifers where they worked, complained that closures (*clausuras*) and fines complicated the "relationships they had built and the doors they had worked to open" (COTAS manager, 27 August 2013). Even so, closures were uncommon and even one COTAS manager said that, "If CONAGUA would simply enforce what was on the books, Mexico would not be in the place we are now with water." When I pressed him on who would be responsible for enforcing the law, he looked defeated and said, "It is very complicated" (COTAS manager, 26 August 2013).

The state has attempted to overcome these complications by enforcing groundwater extraction through electricity meters instead. Groundwater extraction in Mexico is heavily dependent on fossil fuels to lift groundwater to the surface (Scott

2013). Whereas groundwater flows are difficult to monitor, electricity flows are more tightly linked to the technical and institutional infrastructure of the central state through the Federal Electricity Commission (CFE). Therefore, restructuring subsidies for agricultural electricity use represents one mechanism the central state can use to disincentivize, though not directly enforce, groundwater extraction.

Compliance with the electricity meter, however, is contested by farmers through protests and unions of nonpayment against perceived corruption on the part of the federal government (see also Section 4.2.3). Farmers have engaged in visible forms of resistance by blocking lanes of a major transportation highway, and have also simply refused to pay electricity bills that they thought were egregious. In April 2013—late in the dry season and the beginning of summer planting—there were rumors in my study site that farmers' electricity bills were not being paid. When I asked a farmer about how the government allowed farmers to continue pumping without payment, he told me that the political consequences of cutting off the power would be far too great—farmers were much too powerful, and the government did not want to provoke an uprising. Farmers, in other words, have resisted the electricity meter as a device of rule, and instead utilized it as a tool of political contention.

5.5.4 Coexistence: Devices of rule and resistance

While the soft path introduced new devices for managing agricultural water use—such as irrigation efficiency devices—it did so in the context of rearranging citizens' relationship to hard path devices and the state. The management of devices for surface water provision was transferred from central state control over to members within irrigation districts and user associations. Groundwater users became legible by the state through the administration of groundwater titles and the measurement of extraction through water meters. Thus the transition to the water soft path did not displace material forms of water provision—nor was it intended to—rather it constituted a coexistence of the water hard path and water soft path. This coexistence shifted citizens' relation to devices—such as canal gates and lift wells—through legal changes, funding sources, and "mediating" devices. As discussed in the sections above, the coexistence of devices also meant a coexistence of power geometries with the central state maintaining, and in some cases extending, its authority over water governance despite legal revisions that aimed to foster decentralization.

In turn, this technopolitical coexistence produces uneven outcomes depending on the infrastructural conditions of water extraction, indicating that the materiality of water has implications for the pathways of power in state-citizen relations. Surface water farmers are able to exploit the state's desire to occupy "model status" for IMT programs worldwide by capitalizing on their preexisting financial ties to the state, although not all users are able to benefit equally from this relationship. Groundwater farmers are linked to the state through the meter, which represents a form of recentralization—rather than decentralization—because it has increased surveillance of farmers and used participatory aquifer organizations to facilitate this surveillance. Interestingly, some farmers have exploited this connection to the state through the water meter to use it as an opportunity to make political claims on the state. In other words, the divergent sociotechnical and political histories of surface water and groundwater complicate outcomes for farmers as the water soft path is rolled out; however, the materiality of water does not determine who benefits from recentralization through decentralization, rather is intimately tied to the forms and processes of social organization and political power. Thus in order to effect sustainable changes in water governance requires a deeper consideration of sociohistorical legacies of power and sociotechnical organization when implementing a transition to soft path knowledges, institutions, and devices.

5.6 Conclusion

The water soft path is altering the axes of power among citizens and the state by simultaneously decentralizing and recentralizing authority over water governance through knowledge institutional, and devices. Coexisting sociotechnical regimes for water toward decentralization with the WSP necessitates the reconfiguring of powers and accountabilities among the various actors in water management (Agrawal and Ribot 1999). Water Law (LAN) created the category of "water users" as defined by productive sector—industrial, domestic, and agricultural—and created leaders among each sector to be responsible for water conservation and management within the produced scales of the watershed and aquifer. This same system created a centralized state agency dedicated entirely to national water governance—CONAGUA—and gave this agency control over the administration and registration of water rights, thereby connecting the newly formed "water user" to the state through institutions and devices of measurement. Rather than participate in policy making, decentralized groundwater councils work to strengthen the ties between the state and groundwater users—installing and monitoring the meters on groundwater wells—making groundwater users countable and therefore accountable. Groundwater users, and in particular the leaders of groundwater councils, are enrolled in this process of groundwater governmentality—or the assumption of state goals as ones own—though as in other cases this process is highly contested (see also Birkenholtz 2009). Groundwater titles, rolled out as a necessary component of equitably managing a scarce resource, are also a requirement for obtaining state loans and subsidies for irrigation technologies. The terms of the titles perpetuate groundwater overextraction, and further underline the role of the state in developing WHP infrastructures. Thus, the WSP for groundwater users works through institutional and material infrastructures to recentralize power and resource access contrary to claims of decentralization of institutional and technological infrastructures.

Mexico's transition to the WSP is not coincidental to ongoing economic policies and processes, most notably the redesign of the constitution and water management just two years before the enactment of NAFTA. The technologies of rule that emerged from the rebranding of Mexican water management were fundamental paving a pathway out of a nearly century-old quasi-dictatorship held by the PRI and the legacies of post-revolution nationalism. This meant training the collective Mexico as a set of self-responsible individuals in all aspects of everyday life, which also included their relation to water. The greatest overhaul with regards to water management would have to come from the countryside, where the ejido system of state paternalism had come to represent the errors of productivity and efficiency—the absolute contradiction to the ideologies of global capitalism. That meant handing over responsibility to the campesinos and rancheros, through meters and maintenance and the bills that accompanied them. As a consequence, the state asked more from its people, but did so at an historical moment in which it had lost credit—both culturally and financially speaking—in the wake of the 1982 economic crisis.

More than two decades into this experiment with global capitalism, which has only been given a boost with the Pacto (see section 4.4.3), Mexicans are increasingly untrustworthy of the state as a representative of the collective. The corruption that pervades the state—assisted by decades of everyday citizen compliance with such a system under the rule of the PRI—is lamented in every meeting I attended, whether in a whispered aside or in an outright accusation depending on the company kept in the meeting. Although this chapter has focused on the ways that the state has utilized technologies of the water soft path to further entrench claims to natural resources, the murmurs in meetings and protests on highways indicate that coexistence does not necessarily equate to an uncontested governmentality. Sites and processes of coexistence are as much social as they are material, and present opportunities for alternative pathways because of the ways that they are grounded in political practice.

CHAPTER VI

"IT IS EASY TO FALL": ACCESS AND UNCERTAINTY IN THE WATER SOFT PATH FOR AGRICULTURE

This chapter furthers the argument made in Chapter 5 to analyze how the coexistence of the water hard path and the water soft path exacerbates uncertainties in agricultural production. I describe how the malfunction of the water hard path led to a transition to the water soft path, but also allowed for the hard path to coexist within the institutions, knowledges, and devices of the soft path, resulting in uncertainty. Coexistence and uncertainty therefore is mitigated by farmers through access to technology. This chapter therefore outlines three key manifestations of uncertainty for farmers: biophysical, economic, and political. I detail how each uncertainty manifests for farmers, and attend to the mechanisms of access to IE devices that enable farmers to mitigate this uncertainty. Farmers who can access IE devices are therefore able to benefit from the coexistence of the WHP and WSP by enabling them to continue to production and potentially accumulate land and water resources abandoned by those who are forced out of production. The chapter concludes by discussing the ways in which these pathways of differentiation associated with the WSP are highly contingent even for those farmers who are able to access IE devices and participate in the WSP.

6.1 Uncertainty and a theory of access

6.1.1 Malfunction as coexistence

The transition to the water soft path from the water hard path in the early 1990s in part stemmed from domestic and international pressures to renegotiate the terms of environmental governance in order to reduce the power of the central state over natural resources—such as water and land (see also Chapter 4). The concept was that the water hard path as a sociotechnical regime was malfunctioning because the governance paradigm of the hard path promoted a use and management of water resources that was bureaucratic, inefficient, and unequal, and therefore failed to curb the overexploitation of freshwater resources. This perception of malfunction by citizens within Mexico as well as international lending organizations provided opportunities for changes in environmental governance toward the water soft path with the goal of alleviating these symptoms of malfunction. However, as demonstrated in Chapter 5, these symptoms of malfunction proved more obdurate than originally assumed, even with the "transition" to the water soft path. As a result the water hard path coexisted alongside and was co-produced by the technologies of the water soft path. This relationship between malfunction and coexistence is not coincidental.

Kathryn Furlong (2014, p. 143) describes how malfunction complicates transition between sociotechnical regimes:

> Malfunction opens opportunities for transition, but can also create barriers to change. That is, what they call an "unstable" system can prove rather stable; it can exhibit "momentum". Barriers arise because malfunction, and the governance issues from which it emanates, create uncertainty for investment in new technologies, limiting their diffusion…Persistent malfunction favors change

> until it creates too much uncertainty, at which point the potential for change is reduced.

Malfunction, therefore, exists in a co-productive relationship with coexistence. As described above, malfunction both “opens opportunities for transition”—in this case leading to support for the WSP—but also “[creates] barriers to change”—or the persistence of the WHP within technologies of the WSP as shown in Chapter 5. In doing so, the malfunction of the WHP has “exhibit[ed] ‘momentum’.” In other words, the momentum of malfunction of the WHP did not prevent the transition from occurring; rather it embedded itself within new structures of the WSP, constituting coexistence. This malfunction then works through the tools of the WSP to foster conditions of uncertainty that impede the even integration of the WSP among various actors in water governance. In other words, farmers identified multiple sources of uncertainty—biophysical, economic, and political—that prevented them from adopting WSP technologies to varying degrees. Contrary to the excerpt above, change is not simply *reduced* by malfunction, rather it is *experienced differently* depending upon the ability to mitigate uncertainties produced by the coexistence of the WHP and the WSP. In order to examine how farmers differentially experience malfunction and the coexistence of the WHP and WSP, I turn to Ribot and Peluso’s (2003) theory of access.

6.1.2 A theory of access to technology

Access theory “analyses the ability to benefit from things” through a range of rights based as well as structural and relational mechanisms—or “means, processes, and relations” (Ribot and Peluso 2003, p. 153, 160). Although normally applied within studies of land use and agrarian change, access theory is a relevant optic for examining sociotechnical regime transitions because:

> "Locating access in a political-economic framework provides a theoretical model of social change. Social relations and differentiation emerge from cooperation and conflict over benefits (value in Marx's terms) within particular political-economic moments. Laws may be formed from these relations or precede them. Benefits can be redistributed and captured in the course of changing social relations and legal frameworks as new conflicts and cooperative arrangements emerge." (Ribot and Peluso 2003, p. 160)

In other words, access theory enables a closer examination of the mechanisms that enable (or prevent) farmers to capture benefits that are redistributed as the WSP is integrated into the countryside. Unlike Ribot and Peluso (2003, p. 154) who "focus on natural resources as the 'things' in question," I instead shift the emphasis to *technology*—or specifically the sociotechnical regime of the WSP—as the thing in question; rather than positioning technology as one structural and relational mechanism among many.

This tweak in the analytical formulation of access theory is significant because it argues that maintaining access to water—through the ownership of land, a well, or a groundwater title—is highly contingent upon also maintaining access to the instruments of production within new sociotechnical regimes. Technology and its intimate connections to "modern water" (Linton 2010) becomes not one of a myriad of mechanisms for analyzing water access, but is central to the "bundles of power" that constitute water access (Ribot and Peluso 2003, p. 154). Therefore an examination of technology access, unlike water access alone, enables us to see how and which strands of power are maintained, controlled, and renegotiated through the "instruments of labor" particular to the contemporary "economic epoch" (Marx 1867[2004], p. 286). In doing so, the intention is not to position technology as deterministic of water access, but to assert that technology access becomes a visible artifact of compliance with normative discourses of the current political economic framework of neoliberalism—namely progress, productivity, and development. The focus on technology within access theory therefore aims to address "how power 'gets at' people…[by] looking at the way in which this power is *enacted* at particular moments through material practices" (Ekers and Loftus 2008, p. 710, emphasis in original). Following Ribot and Peluso (2003, p. 158), the question then becomes: what are the circumstances by which some farmers are able to benefit from the integration of the WSP while others are not?

6.1.3 Measuring WSP access through irrigation efficiency devices

In Chapter 5, I argued that the enrollment in REPDA and installation of water and electricity meters were a few of the instruments through which the state identified farmers as "participating" in the water soft path. This chapter furthers this argument to suggest that irrigation efficiency (IE) devices—such as drip, sprinklers, and piped gravity systems—constitute another metric of farmer participation in the WSP. The adoption of IE devices, rather than continued reliance on open gravity systems, constitutes compliance with demand management and the principles of development economics because it increases water efficiency while simultaneously increasing productivity. However, unlike REPDA and water meters, farmers are not legally forced to comply with the adoption of IE devices.

Desired but not always adopted by farmers, IE devices therefore constitute a metric for addressing the question above to examine how farmers benefit from the integration of the WSP by adopting IE devices. IE device access enables farmers to benefit from the WSP because they provide material benefits—by increasing productivity and therefore profits, while also reducing water and electricity costs—while also fulfilling sociopolitical benefits—by complying with normative goods of the WSP including efficiency and productivity. Failure to gain access to IE devices therefore is presented as a choice to not participate in the WSP and irrationally deny the material and sociopolitical benefits of participation.

This chapter demonstrates, however, that this choice of participation through IE device access is an illusion. Malfunction, through the coexistence of the WHP and the WSP, generates uncertainties that preempt farmers' ability to access IE devices. These uncertainties are experienced by all farmers, however some farmers are able to mitigate these uncertainties. It is these sources of mitigation that constitute the mechanisms of IE device access, and allow those farmers to form alliances with those "strands of power" in order to maintain access to land and water.

6.2 "It is easy to fall" to uncertainty

I sat in the formal living room of Raul's parent's house, below a collage of family pictures assembled for his father's birthday celebration a few years back. Just infants in the pictures, I could now hear the grandchildren squealing and playing tag in the indoor courtyard down the hall. We were nearly an hour and a half into our conversation when Raul rubbed his hands on his stained jeans from the morning's work in the field, nervously adjusted his John Deere ball-cap, and looked down at the floor: "Half of my friends aren't even farmers anymore," he lamented, "because it is really easy to fall due to the market, water, and insecurity" (Feb. 2015). He grimaced as the words left his mouth—the pain and the frustration he felt were evident in his body language and tone. I paused and delicately asked him what he meant by "fall." He was looking me in the eyes, but his mind was visualizing something else when he responded, "In the past, to be a farmer in this town used to mean something. But now, now we [farmers] are merely middle class."

Raul's statement seemed to perfectly encapsulate the conversations I was having with farmers since 2012—water scarcity and sociotechnical change are bound up with questions of political economics. Uncertainties associated with biophysical factors, including climate change and declining aquifers, were intimately tied to economic and political uncertainty. Raul's phrasing also further illuminates how uncertainty is tied to technology access and consequently asymmetries of power and shifting social relations. He used the term "fall" (*caer*) deliberately in order to indicate a decline in status, a loosening grip on certain strands of power. As a result, these uncertainties not only limit the ability to benefit from the WSP, but also stimulate the unraveling of the "bundles of power" once held by most farmers within the region. In the sections that follow I detail each of these uncertainties and how they limit farmers' capacity to access technology, and then describe the mechanisms through which some farmers are able to circumvent these uncertainties and thereby derive benefits and bundle powers made available by the technologies of the WSP.

6.3 Biophysical uncertainty

This section outlines the two main biophysical uncertainties related to water for farming: precipitation variability and aquifer hydrogeology. The section concludes by describing how biophysical uncertainty prevent many farmers from investing in WSP technologies, and how some farmers have been able to access greenhouses to mitigate biophysical uncertainty and continue production.

6.3.1 Precipitation variability

Climate change is expected to alter the patters of precipitation availability in my study site. Popular media discussions of climate change and agriculture focus on drought and precipitation scarcity as the “new normal” but often overlook the day-to-day variability that is also associated with climate change. Climatologists examined two extreme precipitation factors at a coarse scale over Mexico and Central America, and found that overall climate change is predicted to increase the annual maximum 5-day rainfall total (RX5D) as well as increase the annual maximum number of consecutive dry days (CDD) in the region (Nakaegawa et al. 2014). In other words, when it does rain, rainfall will be heavier and the number of back-to-back days without rainfall will increase.

Although this study was done at a coarse scale, farmers in my study site reiterated these findings. When asked if they thought there were any changes in precipitation patterns and climate change in recent years, they unanimously said yes. They elaborated that whereas it used to rain daily during the summer in small amounts, now it would rain in heavy downpours followed by days and sometimes more than a week without any rainfall. This further complicates agricultural production because heavy rainfall can cause erosion, carrying away rich topsoil and sometimes young crops. Heavy rainfalls can also make production in open furrow systems, such as furrow irrigation, more arduous because it can wash out the furrows, which must be leveled out with manual labor. Heavy rainfall often carries the threat of hail, which depending on the timing of the hail event can quickly destroy a farmer's entire season of production by damaging plants beyond viability.

In addition to heavier precipitation events during the rainy season, many farmers also noted that the wet season seemed to be starting later each year. In May 2013 an *ejidatario* invited me to visit his alfalfa field where I noticed a dry creek bed at the edge of the property. I asked him if it this was typical, or if there was usually water running it year round. He replied that it as usually dry this late in the dry season, but he was hoping that it would be moving again soon, saying "It used to rain in May, and now we sometimes don't see any rainfall until the beginning of June or later" (Ejidatario, May 2013). This shift toward a later wet season can change the timing of planting in the spring, and also potentially shorten the growing season overall resulting in a lower yield. For farmers, a changing climate brings uncertainty not only in the amount of water available, but also in the timing of its availability—a crucial element of agricultural production and decision making for water management.

Uncertainty in precipitation patterns in turn causes an increased reliance on groundwater resources to offset dry weeks during summer months, and also to irrigate crops cultivated year-round—like alfalfa—or during the winter cycle when there is little to no rainfall—like broccoli. Due to these cultivation and precipitation patterns coupled with legal regulations that prevent farmers in my study site from using scarce surface water sources, groundwater is essential for agricultural production year-round. Groundwater also helps to alleviate some of the uncertainty associated with precipitation variability and the increasing number of consecutive dry days. Groundwater therefore serves as an essential supplemental source of water supply for farmers and communities in northeastern Guanajuato, however the following section describes how it has also increasingly represented a source of uncertainty.

6.3.2 Aquifer hydrogeology

Aquifers in my study site are some of the deepest in the entire state, and according to official estimates range from 36 to 175 meters (118 - 574 ft.) (CEAG 2014). The farmers surveyed for this project, however, cited even further depths ranging from 10 to 210 meters (33 - 689 ft.) with an average depth of 132 meters (433 ft.). Furthermore, the state water commission estimates that the aquifers in my study site are declining at a rate of 2 meters per year on average, with a range of 1.3 to 3.6 meters per year (CEAG 2014). Deep, declining aquifers are a key manifestation of uncertainty for farmers dependent only on groundwater for irrigation. In spite of significant advances over the last twenty years in terms of mapping and monitoring aquifer levels and sites of groundwater extraction, a lot remains unknown about the quantity and quality of groundwater available, as well as the hydrogeology of the aquifer which has implications for recharge initiatives.

First, remaining quantities of water in aquifer reserves are uncertain. Estimates from the state and other scientists claim that there are between 10 and 16 years of water left in Guanajuato (Huerta 2013; Romo 2010). This estimate, however, does not distinguish between surface water and groundwater resources, nor does it provide a timeline for the subregional water geographies that vary climatically and politically in terms of hydrosocial relations. Furthermore the accuracy of these models' predictions is unclear given precipitation uncertainties and the geological uncertainty in terms of filtration and water availability.

While state policy often focuses on groundwater quantity, hydrologic models and discussions at water policy meetings do not specify whether projections account for groundwater *quality*. Environmental justice advocates and scientists have identified groundwater sources in the northeastern region of Guanajuato that contain high levels of fluoride and arsenic deemed dangerous for human health (Terrell 2013; and Ortega-Guerrero 2009). In a 2013 survey of 58 wells in 94 communities in northeastern Guanajuato, more than half of wells (n = 30) exceeded national standards for fluoride contamination, and 6 wells exceeded state levels of arsenic (Terrell 2013). The contamination is due to the use of very old water that has leached heavy metal deposits into the aquifer reserves over thousands of years (Ortega-Guerrero, field notes, March 2013). For this study, none of the farmers surveyed confirmed high levels of arsenic or fluoride in their groundwater wells, although a few (n=5) were uncertain because they had not tested the water quality. These data, however, were self reported and not confirmed by scientific testing. The variable distribution of these heavy metal concentrations in the aquifer raises uncertainty about whether groundwater in this region should continue to be extracted given growing concerns about human health.

Questions regarding groundwater quantity and quality are further complicated by incongruences between government policies and scientific findings regarding the hydrogeology of the region—specifically, the debate over the scientifically supported Independence Aquifer and the state managed Laguna Seca and Alto Río Laja aquifers in northern Guanajuato (see section 5.3.2). These debates about aquifer boundaries and connectivity raise questions of aquifer recharge. At a 2013 World Water Day presentation in San Miguel de Allende, Ortega Guerrero argued that the water used from the Independence Aquifer was "fossil water," meaning that rates of recharge are too slow to be able to actually infiltrate and reuse. He argued that fossil water was an issue even beyond Guanajuato, stating that "the annual balance [of groundwater infiltration and extraction] does not apply to aquifers in central and northern Mexico…[because] recharge practically does not exist" (field notes, 20 March 2013).

In spite of these claims, civil society organizers and some farmers claimed that they had identified sites of recharge situated throughout the aquifer that worked in "real time." For example, one farmer was the owner of two ranches in two separate municipalities and two separate aquifers (as identified by the state). He claimed that at one ranch the well level had stayed static over the nearly twenty years he had been working that land, while at another ranch with equivalent water extraction rates the water level in the well was declining by about 1 to 2 meters per year. To him, this indicated recharge in one aquifer, but not at another. Conversations with other farmers and civil society organizers seemed to confirm that depending on the well location, some wells were more "stable" or "resistant" to aquifer decline than others.

COTAS managers and farmers in northern Guanajuato have discussed the possibility of situating reforestation projects and water capture infrastructure in geologically specific areas in order to facilitate recharge. Scientific accounts of these areas of recharge, however, are not well documented nor are these sites mapped by farmers or organizers. Motivations by farmers and civil society organizers to invest labor and money into locating these recharge sites, however, is undermined by the National Water Law because any construction of new reservoirs or channels to redirect rainfall to certain sites is illegal. Consequently, questions of recharge in the upper part of the Lerma Chapala River Basin will likely remain unanswered.

6.3.3 Mitigation and differentiation

Biophysical uncertainties, in the form of climate change and groundwater availability, present an interesting paradox in terms of outcomes for the WSP depending on which actors in the ST-regime you examine. The economic impact of hydrologic variability on heavily water-dependent sectors, such as agriculture, helps to direct financial support to the sectors for adaptation and resilience (Hall et al. 2014). Many farmers had received financial support for installation of IE devices, and in particular for drip irrigation. Therefore the implications of these biophysical uncertainties in agricultural production for the WSP are twofold, moving the WSP forward at the institutional level in terms of investments in the WSP sociotechnical regime—such as through the World Bank PMIR program (see section 5.2.4)—while also fostering institutional changes that can facilitate citizen participation in water governance.

Biophysical uncertainty, however, also works to undermine the integration of the tools of WSP at the level of individual farmers. Climate change undercuts profits from droughts, flash floods, and extreme weather events such as hail, while declining aquifers drive up costs of production because they require ever increasing amounts of energy for groundwater extraction. Rather than set aside money for WSP technologies, farmers are forced to continue to invest in the hard path out of necessity. Farmers were consistently concerned about no longer being able to access water on their property, because most of the land's value resided in its ability to continue agricultural production. During an interview one farmer lowered his voice and looked out the window of the office on his ranch and out over the field and said,

> This land I share with my brothers. It was given to us by our father. I always thought that I would give it to my kids. Now I don't know. I am worried I will have nothing to leave them." (Rancher, April 2013)

Large amounts of money must be allocated for deepening and repositioning existing wells, or drilling new wells, and the associated costs with re-titling the well. Farmers were worried that even if water remained in the aquifer, they might not be able to afford to pump it.

When these hard-path costs are compounded with crop losses from extreme weather, it can also undermine investments in IE devices despite government initiatives directed toward those outcomes and farmer desires to invest in irrigation efficiency devices. All participants either used or expressed an interest in making their irrigation and on-farm water management more efficient, however declining profits and increased costs can reduce the availability of funds and make it riskier to invest. Farmers therefore were consistently faced with a paradox: biophysical uncertainties in the form of climate change and groundwater availability made it both necessary and nearly impossible to adopt IE devices and participate in the WSP.

In order to mitigate weather risks and increase the efficiency and productivity of the farm, some farmers invested in greenhouses. When discussing challenges to adopting more drip irrigation on his farm, one farmer thought that climate concerns—specifically hail—should be included alongside the other factors (10 February 2015). He and other farmers mentioned that greenhouses were particularly beneficial in this regard because they protected the crop from erratic weather patterns. Greenhouses extend the growing season and allow for calculated inputs in farm production by controlling the environment under production. Despite their benefits, greenhouses are used in limited, although increasing, capacity in northern Guanajuato. Only 6 survey participants (16%) had greenhouse production on the ranch, with a maximum area of 2

HA. All but one of the greenhouse owners used it to supplement other production on the farm—meaning that they also produced crops in the open air.

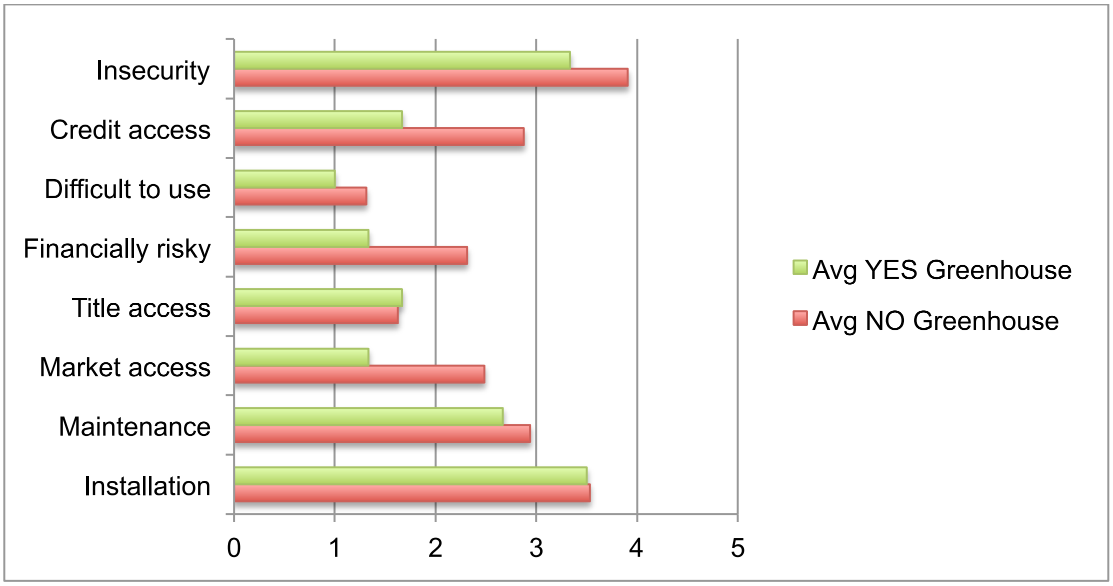


Figure 6.1 Comparison of greenhouse owners' perception of IE device limitations to farmers without greenhouses.

The main access mechanisms for greenhouses are economic (capital and market) and knowledge-based. First, greenhouses were expensive and could range in price depending on the area of the installation. A representative for an irrigation supply company (*proveedor*) working in the region quoted an average of MX$300 pesos per square meter, which equates to MX$3 million pesos (USD$182,000) per hectare (personal communication, 17 April 2013). The high cost of greenhouse installation makes them inaccessible to many farmers, and requires access to government supports and bank loans that can be difficult to acquire. Because greenhouses incur debt, they require stable market relationships to ensure that crops can be sold. Many farmers grew horticultural crops for export in greenhouses, while others sold to the national market. When asked about the challenges for adopting IE devices, farmers without greenhouses were much more likely to rank economic concerns such as financial risk, market access, and access to government supports or credit systems higher on average than farmers who operated greenhouses (6.1).

(A) (B)

Figure 6.2 Challenges of greenhouse production. (A) A woman ties up young bell pepper plants. (B) Greenhouse grown cucumber vines are infected with fungal disease. (Photos by the author)

Second, greenhouses are complicated to operate because they require a particular form of agronomic expertise. Greenhouses create a much more humid environment than is familiar to farmers in northeastern Guanajuato, which can lead to fungal and microbial diseases with which they are less experienced (Figure 6.2). They also require additional equipment such as drip irrigation systems and vertical production ties. Vertical production is a technique employed among greenhouse growers to cultivate indeterminate crops such as tomatoes, cucumbers, and bell peppers for an extended growing season (Figure 6.2). One farmer who did not have a greenhouse at the time of the survey proudly told me that his daughter was currently at the university specializing in greenhouse production so they could improve operations on the farm. A COTAS manager also spearheaded a small greenhouse installation project that was used to give local high school students an opportunity to learn how to produce in greenhouse environments. These experiences indicate that extra-governmental organizations and personal finances helped farmers develop specialized techniques necessary for greenhouse production.

Climate change is altering precipitation patterns in terms of both the overall quantity of water available as well as the timing of its availability. This climatic uncertainty has resulted in even heavier dependence on deep and declining aquifers for irrigation. This reliance on groundwater is further complicated by uncertainties regarding the quantity and quality of remaining groundwater as well as the hydrogeologic characteristics of the aquifer, which in turn have implications for groundwater flows and aquifer recharge. These uncertainties make it difficult to farmers to invest in WSP technologies because of dried up wells and crop losses due to hail or drought.

Some farmers are circumventing these biophysical challenges by creating stable micro-environments within greenhouses, however there are economic and knowledge based barriers to greenhouse adoption. Farmers who are able to access and successfully maintain these devices are able to produce higher yields and sustain profitability on the farm and in turn have available finances for investing in hard path technologies to mitigate aquifer decline. For most farmers, greenhouses are not an option and therefore biophysical uncertainties threaten to undercut profits until they "fall" out of the business of farming.

6.4 Market uncertainty

This section describes how market uncertainty has increased alongside the implementation of the WSP, as trade liberalization initiatives combined with concerns about water scarcity have led the state to promote horticultural production. Horticultural production, however, represents a shift in production patterns in northeastern Guanajuato and is marked by conditions of market instability and requires new forms of expertise in order to grow and commercialize these crops outside of the regional economy. In the final section, I draw on survey data to demonstrate how farmers' mitigation strategies for this market uncertainty are positively associated with IE device access. Therefore the ability to mitigate market uncertainty and access IE devices contributes to processes of uneven development, although through pathways that are unpredictable in their outcomes for people and water.

6.4.1 The rise of horticultural crops

After the Mexican Revolution, economic development was centered on a nationalistic agenda for most of the twentieth century, however the economic recession of the 1980s precipitated a shift toward free trade policies, opening Mexican agriculture to global competition. This globalizing shift has mirrored a likewise shift toward horticultural crops in my study site. Horticultural crops are supported by the government because they are seen as producing a two-fold good: (1) producing more economic value per drop of water consumed, and (2) encouraging investment in IE devices, thereby improving water efficiency and theoretically in turn reducing water use and aquifer overexploitation. The idea is that the production of horticultural crops helps farmers move away from subsistence crops (corn, squash, beans) and fodder crops (corn, alfalfa), which produce very little economic value after the passage of NAFTA and some of which require year-round irrigation.

On a visit to the state water commission (CEAG) for a meeting, I saw a poster featured prominently in the lobby sponsored by the state hydraulic (CEH) and groundwater councils (COTAS) (Figure 6.3). The poster depicts horticultural products such as watermelon and bell peppers encapsulated in a droplet of water and reads: "Without water there are no products. Train yourself. Make your harvest profitable." Inherent in this poster there are three assumptions: (1) horticultural products are profitable, (2) the profits gained from these horticultural products will result in water conservation, and (3) growing horticultural products requires education or training.

Figure 6.3 Poster at the Guanajuato State Water Commission headquarters that reads: "Without water there are no products, train yourself, make your harvest profitable." (Photo by the author)

This message seemed to be getting out to farmers. All of the ranchers I interviewed and surveyed (excluding those who operated strict livestock or dairy operations) produced at least one type of horticultural crop in the past year. *Ejidatarios* were much less likely to produce horticultural crops, however all *ejidatarios* I interviewed expressed an explicit interest in diversifying their production and becoming more actively involved in production of horticultural crops for commercial sale. In fact, with the assistance of the local aquifer council (COTAS), one ejido community was able to solicit financial assistance for a drip irrigation project which in turn led to the production of dried peppers for sale in the regional market. Government water agencies and farmers, therefore, both support the production of horticultural crops. In spite of the opportunities, the production of these crops brings a new set of uncertainty for farmers, particularly in terms of market instability as well as the expertise required to grow and commercialize horticultural crops.

6.4.2 Market instability

As I sat down with a farmer in his living room for a survey, he asked me if I wanted some *agua fresca de melón*—a juice made with water, filtered cantaloupe flesh, and sugar. I kindly obliged his offer, and as he walked back from the kitchen with a glass in hand he chuckled to himself, and in a sarcastic tone said: "Have all that you would like. Right now cantaloupe isn't worth anything, so it isn't even worth the effort to harvest and sell. Same goes for carrots right now" (Rancher, Jun 2014). Labor costs for harvest exceeded profits able to be earned given the current market price, and therefore he had no current plans to harvest the current crop. Some melons would be used for *agua fresca*, but much of it would be left in the field to rot and later tilled into the soil.

The story is indicative of a frequently discussed narrative on the incompatibilities of agriculture and global capitalism. Agricultural production is not well poised for the fast paced market, and this market instability in terms of price volatility presents significant challenges for farmer investments in innovation, or as one farmer succinctly told me, “You don’t know when [a crop] will be worth something or which” (Rancher, Feb. 2015). While the opening of trade markets has given farmers the opportunity to sell to a broader market and diversify production, that same market can be unpredictable and unforgiving when the crops are ready to sell. Time is one of the greatest limiting factors in agricultural production, and is further complicated in the production of fresh fruits and vegetables. Farmers cannot speed up the amount of time it takes for a broccoli seed to actually produce a head of broccoli, and when those heads of broccoli are ready, farmers have a very short window of time in which to harvest and sell fresh fruits and vegetables.

6.4.2.1 Mitigation and differentiation

Farmers used a variety of techniques to mitigate market instability, including purchasing crop insurance, differentiating production to include traditional and fodder crops, and using organic production techniques and certification. First, crop insurance was purchased by some farmers (34%, n = 12) from a private company to protect losses. Unlike common practice in the United States, crop insurance was often a requirement of contract farming and the cost of purchasing insurance was incurred by the farmers rather than the produce buyer. One farmer made sure to point this out during the survey and added, “The insurance is for [the contract company], not us [farmers]” (Rancher, February 2015). Farmers purchased crop insurance to cover risk for buyers but not for themselves. Farmers, in other words, still had to fulfill their quotas for contract production whether through insurance claims or an actual harvest. Therefore it helped prevent total loss for farmers, but still represented a significant economic burden.

Many farmers continued to produce traditional and fodder crops, such as alfalfa, corn, and beans. In particular, alfalfa was consistently reported as the least risky crop to grow because it did not damage easily, did not have many disease and pest problems, and brought in a modest though steady income. Although time still presents complications for crops such as beans, alfalfa, and corn, they are much less vulnerable to the volatilities of the market on a month-to-month basis because they present opportunities for storage. Furthermore, they form the foundation of the Mexican diet and provide subsistence when sale is not an option. Fresh fruits and vegetables, on the other hand, must be sold in a very short window of time. The shift toward horticultural crops is designed to fill an economic gap in the networks of global commerce, increasing income for Mexican farmers and enabling investments in IE devices. Nevertheless, this shift cannot completely erase the production of traditional and fodder crops for many farmers because of the need for an economic safety net from the market instability and timing incompatibilities that is a particular stressor for horticultural production.

Lastly, in order to mitigate market instability a few farmers (n = 5) produced certified organic crops. They sold alfalfa, cucumbers, tomatoes, broccoli, beans, tomatillos, bell peppers, and oats. Farmers produced organic crops because they thought it gave them market advantage, their product was more unique, and they would often be able to sell at a higher price. Over the long term, farmers also thought it helped them reduce production costs and cope with currency variability better than conventional farmers because organic farmers tended to earn money in dollars rather than pesos, while also avoiding spending money in dollars. For example, synthetic pesticides, fungicides, and fertilizers must be bought abroad, often from the United States, and therefore must be paid in dollars. Furthermore, USDA certified organic produce is often destined for US markets with US buyers who pay in dollars.

Producers who can benefit from currency variability, such as organic producers, have fared much better than others during the devaluation of the peso during the implementation of the fiscal and energy reforms (see Section 4.4.3). In February 2015, I spoke with one farmer whose family operated both a conventional and organic ranch about the currency issue and economic impact on farmers. He said in a matter-of-fact tone that organic may no longer be a choice one day rather an imperative, because conventional production was simply not worth it from an economic standpoint because of burden of inputs on producers. Thus an unintended consequence of economic reforms may be to reduce Mexican farmers' dependence on foreign inputs. However, which farmers are able to continue to cultivate through the peso devaluation and unstable energy prices remain to be seen.

6.4.3 Negotiating horticultural expertise

Negotiating the challenges of horticultural crops also requires a new set of expertise in crop production techniques and crop commercialization. The introduction of non-traditional crops requires knowledge of the nuances of growing that particular plant.

Crops have unique nutrient requirements and as well as distinct pest and fungus problems. One ejidatario produced corn, oats, and alfalfa on two hectares, irrigated with a portable sprinkler system that he shared in rotation with 5 other neighboring ejidatarios. He lamented the price he received for the fodder crops, and told me he would like to grow lettuce or broccoli, but did not know how. He had gone to a workshop put on by a local civil society organization but did not find it helpful enough to start his own production. He thought the government was just out to help the ranchers innovate, not the ejidatarios (May 2013). His allegations were corroborated by some of the trainings I attended which were comprised entirely of ranchers or employees of agroindustrialists.

While this might seem indicative of cronyism among wealthier farmers and government employees, and in some cases that may be true, it fails to capture the complexity of what drives this system of uneven assistance for innovation. As indicated by the poster, training is considered successful when it leads to increased profits. Civil society organizers who help farmers access crediting systems and provide guidance on questions of crop production are evaluated on their ability to produce quantifiable results. As one water organizer repeatedly told me, “The government [who provided most funding for his organization] only cares about the numbers and assessment. They don’t care about the projects” (Oct 2013). The output of an individual ejidatario with an average of 2 hectares when compared quantitatively to that of a rancher with anywhere from 50 to 500 hectares is miniscule. In order for there to be sufficient results the entire ejido, or community, must agree to install the IE devices on every ejidatarios’ property as in the case of the drip irrigation project for dried pepper production mentioned above. Therefore, training for horticultural production is contingent upon a farmers' ability to operate economies of scale, which further exacerbates unevenness in the integration of the WSP.

Economies of scale are also important for horticultural crops because it enables access to markets for commercialization. Horticultural production therefore necessitates expertise in logistics and commercialization in order to be profitable—"You have to know the whole [commodity] chain" (Rancher, April 2013). Among ejidatarios and even some ranchers who have significantly smaller landholdings, the ability to participate in these markets is difficult because they do not operate sufficiently large economies of scale. Even some ranchers said they sometimes had difficulty accessing markets, or faced challenges in maintaining relationships with processors and buyers. One rancher had a contract with a freezing plant that fell through the day before harvest: "We had a contract to fill with [the buyer], and we had spinach that had to be cut. We ended up shipping it overnight all the way to a freezing plant just on the other side of the [U.S/Mexico] border. Now we are in talks with [the buyer] to build our own freezing facility." (Rancher, February 2015).

Ranchers, therefore, saw the need to vertically integrate as they scaled up production—processing, packaging, and freezing on site while organizing commercial contracts and managing farm production. This is obviously not a one-person operation and many ranches were operated by families, each member with a distinct role in production and commercialization of horticultural products—legal consultant, agronomist, accountant, logistics coordinator, and business administrator. Younger family members in their 20s and 30s were often university educated to fulfill these specialized roles, while older members of the family had learned to manage farm operations through experience and social networks. This shift toward advanced off-farm education and the specialization of particular roles for each family member further confirms the complexity and level of expertise required to maintain sufficient profit margins for agricultural production.

These processes of commercialization have been even further complicated by the Fiscal Reform pushed through legislation in the first months of Peña Nieto's presidency. Even the most localized sales—at the neighborhood store, in the weekly markets, and along the streets in nearby cities—must be registered and documented for tax purposes. Failure to formalize sales with the state can result in fines. Thus farmers who have no experience with this paperwork, many of whom live in rural communities and lack formal education past second grade, are now required to file paperwork with the government even if the government failed to provide them with sufficient education to read and write without external assistance. Thus, those farmers who have been able to participate in formal education or provide that education for their children push further ahead with the Reform, while more marginalized farmers face yet another hurdle in the attempt to commercialize their production.

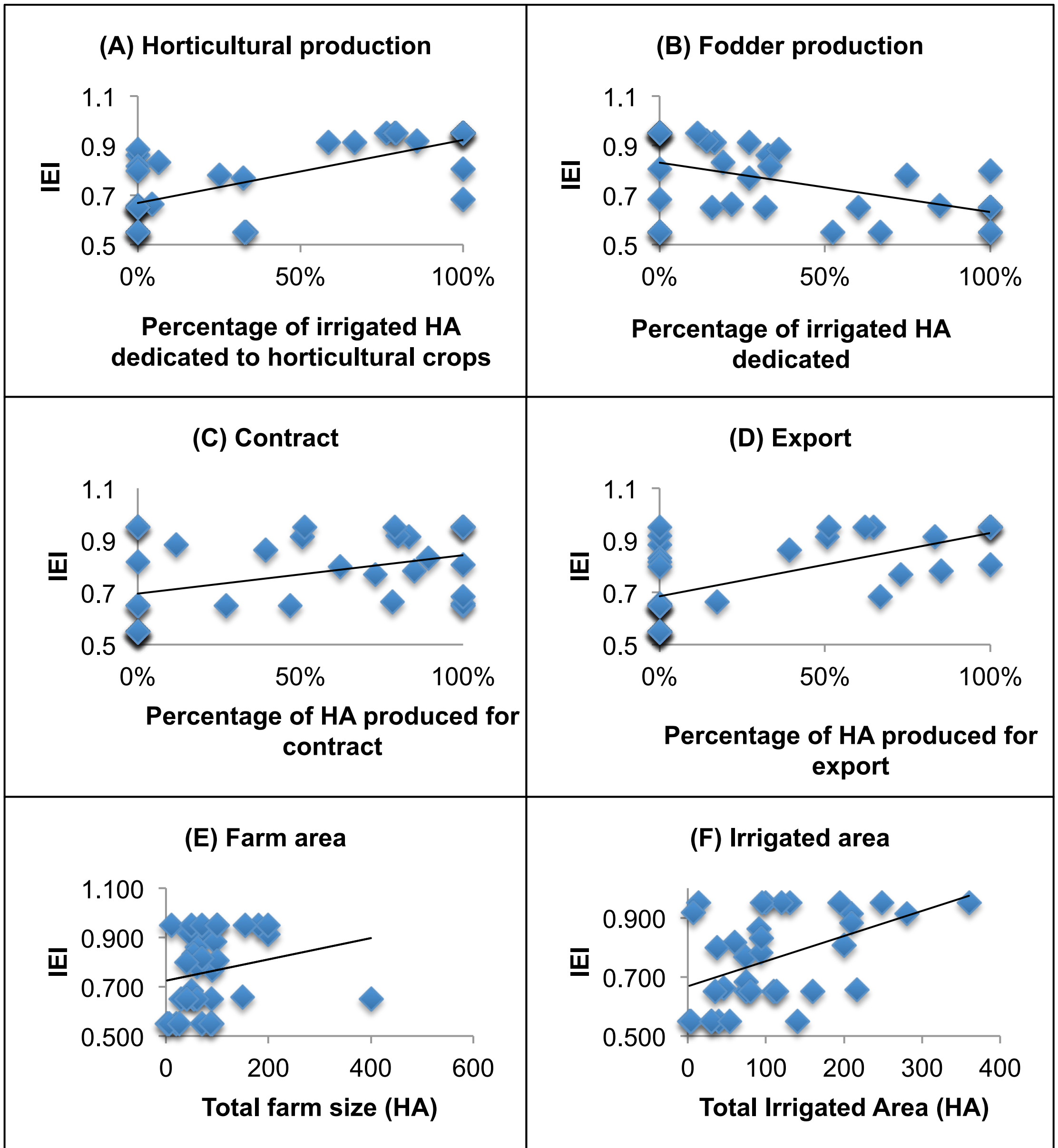
6.4.4 IE device access and mitigation strategies

Survey data showed that the ability to mitigate market uncertainty through several of the strategies above indeed enabled farmers to access IE devices. The results displayed in Figure 6.4 show the relationship between the Irrigation Efficiency Index[9] and the production of horticultural crops, forage crops, production of export crops, contract production, and farm size.

The production of horticultural crops was the most strongly related to high irrigation efficiency (Figure 6.4(A)). This indicates that the poster hanging in CEAG encouraging horticultural production to increase irrigation efficiency and productivity was correct in its assumptions. Whether or not this is leading to water savings, however, is uncertain, given that increased irrigation efficiency is also positively associated with area of land under irrigation (Figure 6.4(F)). This is demonstrative of Jevon's paradox, in which increasing efficiency has only resulted in an expansion of irrigated area and therefore water use.

The data, however, show that Jevon's paradox only applies to some irrigators. Interestingly there were key differences in the perceptions of the benefits farmers who

[9] Detailed in Section 3.3.3.2, the IEI can be roughly translated to a percentage of irrigation efficiency. For example, farmers on the highest end of the y-axis (0.95) operate at approximately 95% efficiency, which is the efficiency of a 100% drip irrigation operation.



	(A)	(B)	(C)	(D)	(E)	(F)
r^2 =	0.49	0.24	0.16	0.40	0.04	0.22

Figure 6.4 Relationship between irrigation efficiency factor (IEF) and mitigation strategies, with r^2 values.

irrigated all of their crops with drip irrigation (IEI = 0.95), than farmers of lower irrigation efficiency. Figure 6.5 shows what farmers perceived to be the principle benefit for using IE devices divided by IEI group, and those who irrigated with only drip irrigation overwhelmingly thought that expanding the area under irrigation was the primary benefit, while those with slightly less irrigation efficiency overwhelmingly chose water efficiency as the primary benefit. This indicates that Jevon's paradox has thresholds, with implications for water conservation and appropriation of land resources.

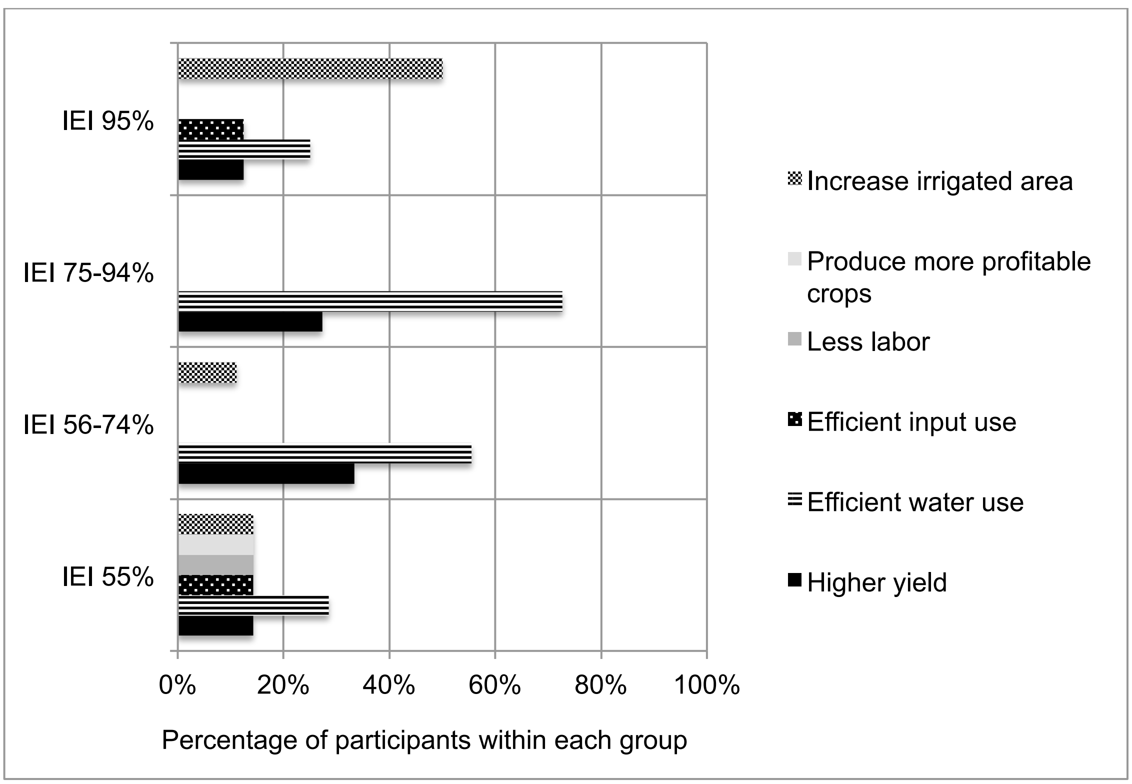


Figure 6.5 Comparison of IEI groups by principle benefit for accessing IE devices

Unlike horticultural crops, the production of fodder crops is negatively correlated with irrigation efficiency (Figure 6.4(B)). This points to a shift in the patterns of production in northeastern Guanajuato with the introduction of IE devices and the WSP, because fodder crops have traditionally been the staple production crops in this region. As mentioned above, fodder crops like alfalfa constitute a secure source of income and represent relatively low risk in terms of production and commercialization. Therefore, in spite of government efforts to promote IE devices, it is unlikely that farmers will convert to horticultural production and therefore increase their use of IE devices unless market uncertainty is reduced.

The ability to secure market access through contract production is positively correlated with irrigation efficiency, but the relationship is low (Figure 6.4(C)). This indicates that although contracts are perceived as providing security for farmers, this may not be the case for all farmers who engage in contracts. This then begs the question of who *is* benefitting from contractual arrangements. As suggested by the farmers' comment above, and supplemented by research in political ecology, benefits are largely accrued by those who are the "buyers" in contractual arrangements (Little and Watts 1994). A positive, yet mild, correlation signifies that contract farming contributes to this research, and raises important questions about whether contractual farming is the right approach to improve farmer productivity and increase water efficiency.

Export production, however, has a higher correlation to irrigation efficiency (Figure 6.4(D)). Export production has the second strongest relation to irrigation efficiency next to horticultural production. The correlation between export production and IE device adoption raises questions about the implications for regional food and water security with the implementation of the water soft path. This presents concern for farmers who produce for the regional market, urban citizens, and civil society organizers, because, as one COTAS manager told me, “We are practically exporting water” (February 2013).

Lastly, there is a positive, although weak, relationship between factors of land size and irrigation efficiency. There was almost no relationship between total land holding and irrigation efficiency (Figure 6.4(E)). There was a slightly higher, though still weak, relationship between area irrigated and irrigation efficiency (Figure 6.4(F)). Therefore, landed capital holdings are associated with, but not strongly significant for the adoption of IE devices. These results were surprising, given that large land holdings enable farmers to benefit from economies of scale. However, the results demonstrate the ways in which social and market relationships, as well as knowledge of how to grow horticultural crops are also key to benefitting from those economies of scale.

Taken together, these findings therefore contribute to Ribot and Peluso’s (2003) theory of access, by demonstrating that the ability to benefit from the land is also dependent upon the ability to access markets, technology, and particular forms of expertise. Furthermore, these findings signify that IE devices are indeed indicative of the multiple ways that farmers mitigate market uncertainty; however they also show that these mitigation strategies do not have predictable outcomes for all farmers or in terms of their ability to conserve water and promote sustainability in the region. Therefore, at best, the ability to mitigate market uncertainty and access IE devices enables some farmers to continue to produce under conditions of climate change and aquifer decline, although the benefits of this relationship are uneven and highly contingent.

6.4.5 Differentiation through normative compliance

The proposed governmental response to the "double exposure" of climate change and globalization (Leichenko and O'Brien 2008) is to grow horticultural crops, as described in the poster above and observed at government and civil society meetings. Ironically, the push for horticultural crops is not alleviating the woes of water scarcity and market liberalization, and for some farmers this "double exposure" feels all the more acute. Paradoxically farmers do not resist the production of horticultural crops, rather they pursue it. This is because the shift toward horticultural crops has resulted in increased productivity, increased profits, and increased water efficiency for some farmers. These farmers have typically secured contracts with suppliers sometimes for national markets but often for export, with a secure buyer and relatively stable price (though contract prices are often subject to change based on market price).

Unlike similar findings regarding regulatory pressure on pesticide residues (Galt 2007), the pressure for "greener" export horticultural crops in this case comes from the market sector and exporting state, rather than the regulatory demands of the importing state. Therefore, the production and commercialization of horticultural crops has allowed some farmers to be able to meet state standards of water conservation and profitability, while complying with the "green" marketing strategies of international buyers. The mitigation of "regulatory risk" becomes a differentiation strategy in and of itself (Galt 2007). As the sign instructed, farmers are expected to "train themselves" to be in compliance with the government's logic in order to improve water efficiency within the state. In spite of challenges, farmers' desire for horticultural production becomes evident: when it works, farmers are able to discursively and materially comply with powerful ideologies of sustainable agricultural production. As clearly demonstrated in this section, this normative compliance is not possible for most farmers. The contradictions of horticultural production and its ties to the WSP, therefore presents questions about who and what is indeed being sustained by globalization and conservation projects.

As farmers increasingly enter into horticultural production the risk of market vulnerability is exacerbated because increasing supply can level prices and undercut profits. This vulnerability has already been seen in other groundwater economies that have attempted to shift to horticultural crops to increase productivity and alleviate groundwater scarcity (Birkenholtz 2009). Market uncertainty therefore prevents many farmers from participating in the WSP, as they are hesitant to invest in more expensive technologies, such as drip irrigation, for fear of not receiving a return on their investment. The market, therefore, serves as a driver of WSP investments for farmers with the social and political capital to engage in horticultural production.

For other farmers, WSP participation is undermined because the market provides a source of uncertainty and insecurity—what will carry a good price at harvest time, how to negotiate sales with national and international buyers, how to maintain within regulatory standards, and how to secure sufficient funds for vertical integration. This process leads to uneven participation among farmers in the WSP, which has material implications in terms of earned capital but also carries normative implications. Farmers that do participate in the WSP through horticultural production are discursively framed as compliant with the goals of the nation as well as international consumers—while those who do not or cannot are relegated as not trained and even greedy to be irresponsibly utilizing the nation's scarce waters.

6.5 Political uncertainty

This section outlines two key sources of political uncertainty for farmers: insecurity and regulatory uncertainty.

6.5.1 Insecurity

In a recent autobiographical piece, writer Álvaro Enrigue (2015) describes what it was like to grow up in Mexico in the 1980s as the country underwent dramatic political and economic change. Outlining international geopolitics alongside internal political economic dynamics within Mexico, he describes his interpretation of what has resulted in the ongoing War on Drugs in Mexico:

> Mexico really changed during the government of Miguel de la Madrid. It changed because Ronald Reagan was chasing a madman's vision of winning the Cold War, and that could not be accomplished without suppressing and crushing many countries' independent wills, among them Mexico's. The hammer that the United States wielded against its neighboring economy was the financial aid that followed the crisis in 1982, but the wedge it pounded to crack the whole country open was the war on drugs…I don't believe it was a coincidence that Mexico's full incorporation into the worldwide capitalist system occurred simultaneously with the emergence of the sinister phantom state generated by the largest drug

> traffickers; after all, narcotraffickers occupy ground zero in the liberation of commerce, the dystopia of global capitalism. (Enrigue 2015, no page)

In 2006, President Felipe Calderón launched the War on Drugs in Mexico that continues today. Most of the drug related violence is regionalized in northern and Pacific coast states, however the implications of an ongoing war can be felt throughout the country. Since 2009, there have been an estimated 120,000 fatalities related to the war, and 26,000 reported people missing (Heinle, Rodríguez Ferreira, and Shirk 2014). Although Mexico has a lower homicide rate on average than the rest of Latin America, it has nearly tripled since 2007—an indication that increased violent crime is linked to the broader War on Drugs (Heinle, Rodríguez Ferreira, and Shirk 2014).

President Peña Nieto has shifted toward less aggressive tactics than his predecessor, however drug related violence continues. Journalists have suggested that Peña Nieto's strategy of arresting high-profile cartel leaders has been to pave the way for foreign direct investment associated with his *Pacto por México* (Thornton and Goodman 2014). After its passage, the Pacto was heralded by international economists as a progressive and aggressive policy that will lead to economic growth (OECD 2015). Mexico, however, continues to have high rates of inequality, with the top 10% of people earning more (39.2% of pesos earned) than the bottom 60% combined (34.2% of pesos earned) (Krozer and Moreno-Brid 2014). Since the enactment of key *Pacto* reforms, the poverty rate has increased from 45.5% in 2012 to 46.2% in 2014—or the equivalent of 2 million more people living below the poverty line (Rama and Yukhananov 2015). The combined effects of an ongoing drug war and high levels of inequality result in an persistent climate of physical insecurity for everyday citizens in Mexico, particularly in rural areas where policing is more difficult and job security more tenuous.

6.5.1.1 Insecurity in the countryside

Problems with physical insecurity and crime came up repeatedly in conversations with farmers—in my own interviews and surveys, at groundwater council meetings, and at a quarterly statewide meeting of leaders of the Guanajuato State Agricultural Association. In fact, 28% (n = 11) of farmers surveyed claimed that concerns about insecurity were the *primary* limitation to adopting IE devices, and security concerns were only second to the capital costs necessary for installation (n = 14).

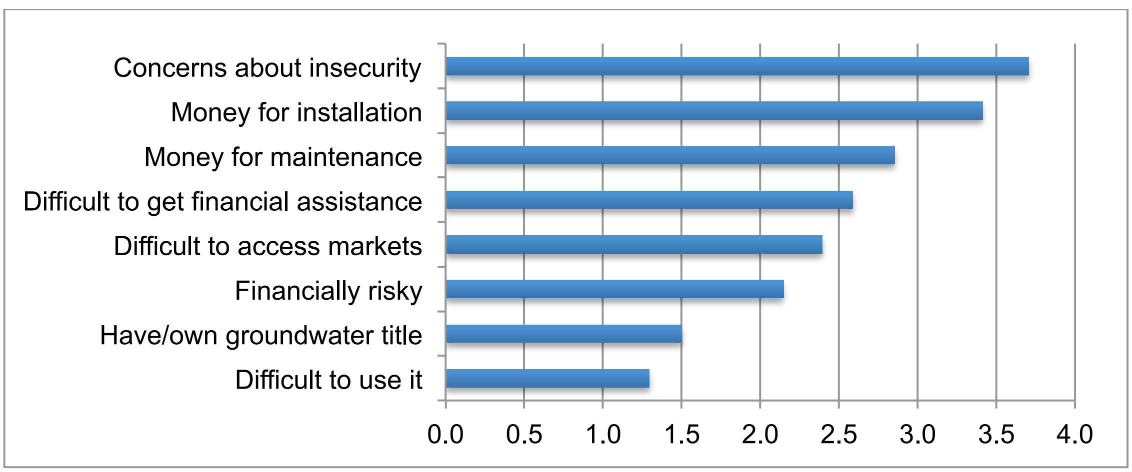


Figure 6.6 Farmers ratings of challenges to accessing IE devices. 1 indicates it is not an issue, while 5 indicates it is the principle issue.

Farmers were also asked to rank factors limiting their adoption of IE devices on a scale from 1 to 5, with 5 indicating it was an issue of high importance. Farmers on average gave concerns about insecurity a 3.82, which is a higher average than any other limiting factor, including installation costs and market concerns (Figure 6.6). Therefore, even when physical security was not the primary limitation, it remained a strong concern for farmers. Furthermore, insecurity was an issue for farmers operating at all levels of irrigation efficiency (Figure 6.7). This is indicates that physical insecurity is a counter-mechanism that challenges farmers' ability both gain and maintain access to IE devices.

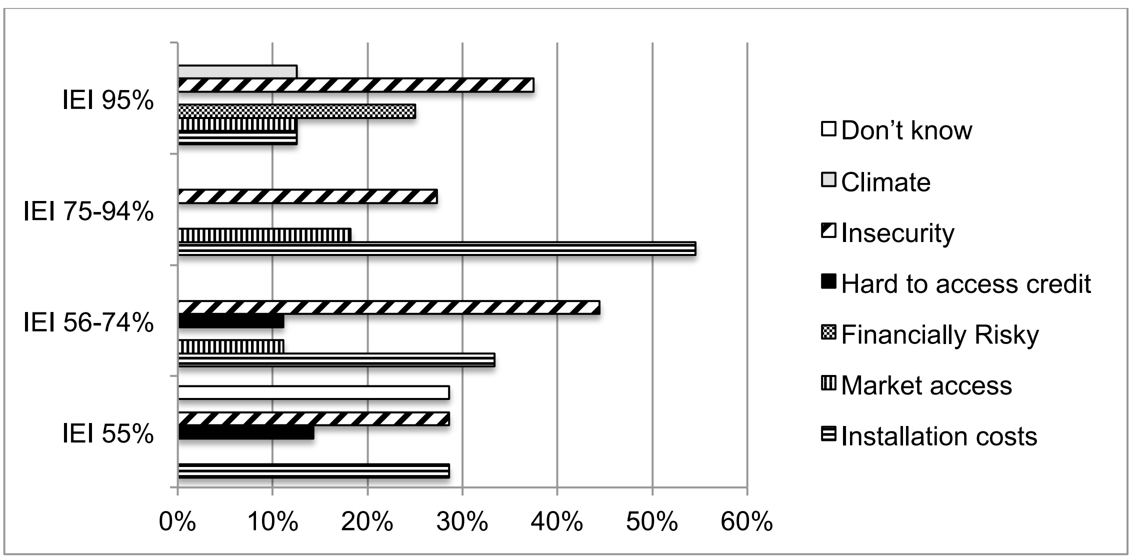


Figure 6.7 Comparison of farmers' ratings of IE device access limitations by IEI.

The two security issues that farmers faced were the kidnapping of family members and theft of farm materials. Kidnapping was not a distant reality, but an everyday concern. In my own research I travelled with a key informant for my own protection, but also as a mechanism for verifying my identity with my research participants as a person that could be trusted. On more than one occasion the key informant would warn me, “Pardon him if he seems skeptical or reserved. His cousin (or nephew or brother) was kidnapped and he has been on edge about new people ever since.” The fear of kidnapping and subsequent extortion therefore has a direct link to the farmer’s ability to form and maintain social networks and alliances, because it made farmers untrustworthy of strangers outside existing social networks. Forming new social alliances is crucial to overcoming uncertainties in market barriers. It is also key to participating in collective groundwater councils, which provide assistance with credit access, commercialization, and technical support. Indeed farmers with access to IE devices also had higher rates of membership in civil organizations (Figure 6.8). Consequently, political uncertainty exacerbates conditions of market uncertainty and undermines collective groundwater councils. Persistent fear of kidnapping therefore has direct implications for farmers’ abilities to adopt IE devices and in turn participate in the WSP.

Robberies were also a common complaint for farmers. Among participants in this study, there were no reported robberies of drip irrigation devices, however farmers noted theft of groundwater pump parts, electricity connectors, and the metal heads of portable sprinkler systems. Small, “mediating,” technologies are highly mobile. This mobility is beneficial in terms of distribution but problematic in climates of low physical security that are difficult to protect—like farmland. One cannot easily steal a dam, or water supply piping (for cases where citizens divert water supply by investing in their own "hard path technologies" see Meehan 2013).

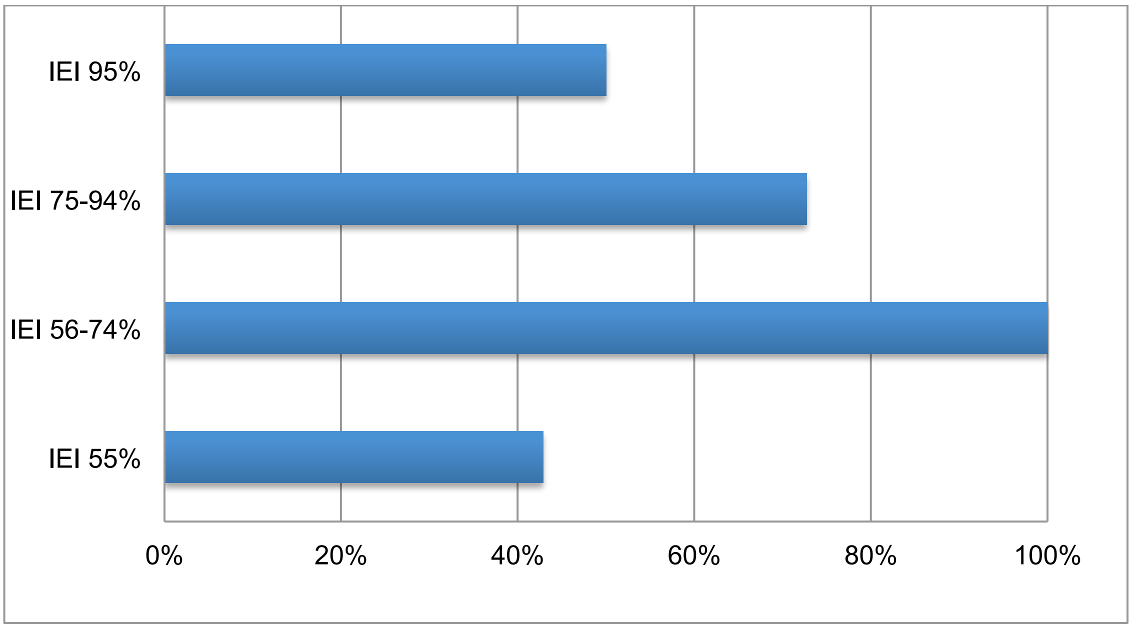


Figure 6.8 Percentage of each IEI who has membership in a civil organization.

Farmers often complained that the "government has forgotten about [them]," and therefore used their own capital to invest in personal security when they could. Farmers with contracts for export often had a gate at the front of the ranch, as well as a 24-hour guard at the gate to maintain surveillance and regulate farm access. Some ranches, often those with greenhouses, lined the property with chain link fence and barbed wire, and sometimes kept dogs within the fence to heighten security (Figure 6.9). While this militarization of export farming in Mexico has recently been reported as a mechanism to imprison farm laborers inside the gates (Marosi 2014), in some cases they exist to keep others out who may steal farmer investments.

Figure 6.9 Greenhouses protected by barbed wire fence. (Photo by the author)

Physical insecurity therefore negatively impacts the WSP because it is linked to exclusionary technologies that undermine common resource management. Participation in the WSP is supposed to be associated with innovative management through participatory governance, however it is ironically also associated with exclusionary and individualizing technologies to keep out neighbors with whom the common resources are purportedly shared.

6.5.2 Regulatory uncertainty

While physical insecurity is blamed on a persistent absence of the state, regulatory uncertainty is targeted at the heightened surveillance of the state, explored in more detail in Chapter 5 but further elaborated here to explain how it contributes to uncertainty. This simultaneous absence and surveillance is acutely experienced by farmers and civil society leaders through increased accountability (measurement) without the mechanisms (funding or personnel) to fulfill them. As discussed above, regulatory uncertainty is intimately tied to the other forms of uncertainty; it couples with biophysical uncertainty through legal prohibitions for water capture, and with economic uncertainty through increasing tax and sales surveillance of sales with the Fiscal Reform.

Regulatory uncertainty also manifests from REPDA and CONAGUA's administration of groundwater titles. The creation of REPDA was intended to facilitate *more* certainty in terms of groundwater extraction through the installation of water meters at each registered groundwater well. It was also designed to provide farmers with the security of knowing how much water they are legally allocated to ensure even distribution.

Written into the law, however, is a "use it or lose it" caveat; in other words, CONAGUA has the right to reclaim any portion of a water concession that goes unused over the course of a year. Although farmers never reported an actual experience with CONAGUA enforcing this law, and a COTAS manager confirmed that CONAGUA did not typically enforce this regulation, it remained a prevalent concern among farmers. As one farmer explained to me, “the purpose of the title is to put in a meter so they can make sure you are taking advantage of your cubic meters" (Rancher, February 2015). For farmers the title did not represent a mechanism to protect their allocation of water, nor as a mechanism for encouraging water conservation, but as a regulatory oversight that enabled the government to monitor and potentially reallocate their “cubic meters” when not being used to full capacity.

Another farmer who worked as part of a cooperative group further explained how this regulation was devastating for farmers in particular: “This year the rains are good, and we do not want to irrigate too much because it can lead to plagues and sicknesses in the plants. But, what if they take it away? Next year might be dry and we will need it then” (Rancher, February 2015). In other words, climatic uncertainty, in the form of intermittent precipitation patterns, is further compounded by regulatory uncertainty. Therefore farmers feel pressured to maximize their groundwater consumption to the full capacity allocated in their concession, in spite of the biophysical pressures that encouraged them to use less groundwater. Precipitation variability therefore aligns with institutional regulations—like REPDA and the “use it or lose it” regulation—to produce conditions of groundwater scarcity in the region.

Against their best interests, farmers therefore continue to pump groundwater because to maintain the title is to maintain land access and also preserve the value of the land. One farmer put it this way: “Without a title, the land is not worth anything.” “Nothing? Zero?” I pressed him. “Well,” he conceded, “practically nothing” (Rancher, February 2015). If farmers’ fail to use the water allocated they risk losing their land, which, in turn is tied to their notions of legacy and identity (as mentioned in Section 6.3.3).

The consequence of "use it or lose it" is that there is no incentive to conserve water and invest in IE devices, with twofold implications. First, even with efficiency gains from IE devices, there is no reason for farmers not to extend the area under production in order to maintain the groundwater concession. This complicates Jevons' paradox—or the concept that increasing technological efficiency does not reduce resource consumption due to economic growth from resulting efficiency gains—because there is also an institutional dimension driving the failure of efficiency. Regulatory demands *coupled with* a drive for economic growth maintain the status quo in terms of resource extraction.

Second, the regulation and resulting lack of conservation also normalizes the need for continuing investments in hard path infrastructure. It therefore justifies claims for the need for inter basin water transfer as proposed in the 2015 revisions to the National Water Law which is contributing to political unrest and protesting as a direct result of political uncertainty and overall malfunction of the WSP. It also creates a need for central state intervention through projects such as the Realito Dam discussed above.

The "use it or lose it" caveat goes unexamined by the state because it represents a reach of power over farmers in the long history of struggle between agronomists' and hydrologists' interests in managing the nations' waters. Furthermore, the central state has a particular interest in maintaining its control over the countryside, and this clause is one way that authority is established. To concede the water rights would in part concede central state hydrologists' power over the "national water" to the farmers. "Use it or lose it" therefore helps CONAGUA remain in a position of power in terms of water access, not only as an allocator of water rights, but also through the control of funds and the development of hard-path infrastructure.

6.5.3 Differentiation

This section outlined insecurity and regulatory uncertainty as two key political barriers to accessing IE devices, and can be understood as the complications that arise both in the state's absence and presence. Insecurity is emergent from the ongoing War on Drugs combined with high and increasing levels of inequality that have resulted in experiences with crime and feelings of insecurity for citizens across the socioeconomic spectrum. It creates uncertainty for IE device adoption because of financial losses through extortion, and issues of theft. Unlike other sources of uncertainty, mitigation of insecurity through fences and general lack of trust actually further undermines the ability to access IE devices because it compromises conditions for social cooperation. For regulatory uncertainty, or "use it or lose it," farmers did not identify any strategies for mitigation. Farmers simply kept extracting their allocated amount of groundwater.

Political uncertainty therefore does not emerge as a differentiating factor unto itself, however it acts as a multiplier effect for the other sources of uncertainty. It challenges the ability for farmers to collectively mobilize by eroding trust with neighboring producers outside of pre-existing economic cooperatives. COTAS managers are faced with the dual challenge of encouraging collaboration, communication, and organization among farmers who are increasingly isolated from one another. Farmers then establish their own collaborative operations on the basis of economics, but not necessarily over water conservation. Regulatory uncertainty acts as a multiplier for biophysical uncertainty by exacerbating conditions of groundwater overexploitation. As discussed in Chapter 5, farmers who can financially afford to spatially mobilize are less affected by aquifer decline.

6.6 Uncertainty, mitigation, and uneven access to the WSP

The malfunction of the water hard path—water scarcity, social inequality, and power inequalities—is mirrored in the uncertainties that challenge the integration of the WSP: biophysical, economic, and political. The findings confirm Furlong's (2014) assertion that malfunction can exhibit momentum and therefore curb innovative potential. Malfunction, however, does not simply reduce the potential for innovation—it creates pathways of access and exclusion.

The findings in this chapter show how malfunction has indeed moved the WSP forward for certain WSP objectives and some actors, but for many people, participation in the WSP has been difficult or nearly impossible. Therefore, the emergent characteristic of the momentum of malfunction is persistent unevenness. Notably, this unevenness is not an unintended consequence of WSP integration, rather it is dependent on networks of power that work to redistribute conservation benefits and redirect WSP objectives in the processes of its integration. Thus access theory with its attention to "strands of power" and "mechanisms of access" make necessary observations of agency, as actors intentionally strengthen and sever connections to other human and non-human actors. These (dis)connections are historically and geographically contingent.

Access to WSP technologies is differentiated among farmers. Just as hard path urban pipelines have been described as an "archipelago," so too can be said for soft path devices (Kooy and Bakker 2008). The landscape of WSP participation through IE device adoption is uneven. Rather than circumscribed as "state failure" in the case of supply technologies, individualizing efficiency devices of the soft path present the illusion of choice, where in fact there often is none. Farmers' failures to conserve water are seen as driven by personal choice and self-interest. This chapter has complicated this notion of choice, and shown that participation in the WSP contingent upon the capacity to mitigate the uncertainties of malfunction. For example, farmers are encouraged to train themselves in order to grow and commercialize horticultural products, with the objective of increasing profits while decreasing water consumption through the adoption of IE devices. The findings in this chapter complicate the notion of "environmentality," or the state-led project of making environmental subjects, by demonstrating the ways that environmental conservation is often part of a broader set of social, political, and economic objectives that constitute the subject. These findings therefore support previous observations of *partial* environmental subjects (Jepson, Brannstrom, and Persons 2012; Shoreman and Haenn 2009), and indicate that further research is needed into how and why mechanisms of access both integrate and conflict with environmental subjectivities and produce differentiated outcomes for people and water.

For example, biophysical uncertainty is mitigated by forming relationships with the state to negotiate water concessions for the repositioning or deepening of wells, and to access state credit for IE devices. Economic uncertainty is mitigated by the ability to operate economies of scale and negotiate contracts. Farmers must therefore must operate large farms or enter into cooperative agreements with neighboring farmers. This also requires that they develop expertise in production, processing, and commercialization of new crops. This requires forming and maintaining social alliances with neighboring farmers and local businessmen, as well as specialization of farm staff in order to manage all aspects of the business. Lastly, political uncertainty works to erode collective institutions and behaviors, rather than foster them. Farmers who have the financial capital to mitigate this uncertainty do so with further individualizing practices—building fences and maximizing their extraction of groundwater so as not to lose their concession. Consequently, while biophysical and economic uncertainty work to divide farmers into those who can fortify relationships with the state and market and those who cannot, political uncertainty exacerbates those divisions by isolating farmers further from one another. The momentum of malfunction of the WHP therefore manifests in WSP integration in the differential capacity of farmers to participate in and benefit from the WSP. Rather than being a "choice," farmers' pathways of (non)participation are contingent upon their historical and geographical capacity to form alliances with the state, market actors, and one another.

In this context, Raul's observation that "it is easy to fall" is an indication that these exclusionary processes central to the implementation of the water soft path in

Mexico do not fall cleanly along the lines of land tenureship—or between collective *ejidatarios* and private ranchers. The farmers who participated in this project, mostly ranchers, expressed divergent sentiments about their abilities to access and participate in the WSP. Raul specifically uses the term "fall" to indicate disconnection from political power and socioeconomic status once held more firmly by ranchers in northeastern Guanajuato. Ranchers felt an acute pressure to industrialize production or forgo the business of farming altogether. Moreover these pressures are not alleviated by the water soft path, as a socially benign sustainable transition may suggest, yet they are further exacerbated.

Sociotechnical malfunction is productive. Its productive capacities stem from its simultaneous stimulation and stifling of the integration of new technologies. The malfunction of the WHP stimulated a shift toward WSP institutions, knowledges, and devices—formalized in the revision to the National Water Law and worked out in everyday practice. However, the ability to benefit from and effectively exhibit authority in the WSP has not been even across all actors in the sociotechnical regime. Historical and geographical legacies of power enable certain actors to participate and profit from the uncertainties perpetuated by WHP malfunction. The implication is that rearranging the institutional and technical infrastructures of water governance has not fundamentally challenged the socio-political networks of power that constituted the WHP. Consequently, transition to the WSP has been partial, which has enabled the further fortification of networks and alliances of power that existed under the WHP.

CHAPTER VII

CONCLUSION

7.1 Summary

The water soft path emerged as a twenty-first century alternative to the deleterious effects of water hard path in twentieth century. Through strategies of demand management, decentralization, and re-imagination of water as a service, the water soft path proposed social, political, and artifactual tools for shifting global water governance toward more just and sustainable outcomes for ecosystems and communities. However, there has been limited critical research on the implications of water soft path integration into the countryside for agricultural production. Therefore, this dissertation interrogated the specific structural and relational mechanisms that lead to technology access, and in turn processes of capital and resource accumulation. The research question was: How does the water soft path create new pathways of accessing and using water resources that contribute to larger processes of social and political change in the countryside?

I began by conceptually framing this project as a combined science and technology studies (STS) and political ecology approach (Chapter II). I situated the water hard path and water soft path as sociotechnical regimes—or a politically complex arrangement of knowledges, institutions, and devices—within the framework of the Multi-Level Perspective in STS. By framing the water soft path as a sociotechnical regime, I direct attention to the ways in which technology is indicative of "economic epochs" and social relations. A political ecological perspective directs questions about how hegemonies of water governance produce asymmetries of power within the discourses and materialities of the water soft path. Political ecology, with its history of critical research on agrarian change, also encourages an inquiry into how these power dynamics renegotiate the mechanisms of access to technology, water, and land.

Research design consisted of a mixed method case study approach grounded in a constructionist epistemology (Chapter III). The case study for this project is groundwater for agricultural production in Guanajuato, Mexico. I chose Guanajuato for biophysical and political reasons. Biophysically, Guanajuato is experiencing precipitation variability with impacts on agricultural production. Additionally, farmers in the northeastern part of the state are reliant on deep, declining aquifers for agricultural production. Politically, Guanajuato along with the rest of Mexico underwent dramatic legal changes in water governance with the implementation of the National Water Law. Due to problems of water scarcity, Guanajuato has been considered a leader in spearheading institutional initiatives directed at curbing aquifer overexploitation. I conducted 14 months of ethnographic fieldwork over 5 trips to Guanajuato. During the course of fieldwork I engaged in a range of participant observation events, and conducted interviews and surveys with groundwater farmers. In spite of research challenges, this long-term involvement enabled me to reflect on the processes of data collection to ensure data quality.

Chapters IV through VI presented the research findings. Chapter IV described the emergence of the water soft path as a response to the water hard path. Findings showed that in spite of definitive legal changes in the water and agricultural sectors that marked a shift toward the water soft path and globalization, the central state maintained control over land and water resources. These findings led to the development of the thesis of coexistence described in Chapter V. Chapter V demonstrated that central state power and the legacies of the water hard path worked through the water soft path in order to maintain this control over natural resources. Coexistence shifted state-citizen relations in ways that both led to increased state surveillance as well as emergent forms of citizen resistance. Coexistence has exacerbated conditions of uncertainty already characteristic of agricultural production, as shown in Chapter VI. This production of uncertainty has been mitigated by some farmers, and enabled them to benefit from access to the water soft path and continue production. To elaborate on these findings in more detail, I return to the story about buying land with which I started.

7.2 Buying land, revisited

At the beginning of this dissertation I promised to start at the end. I introduced four men on a ranch in Dolores Hidalgo evaluating piece of farm land for sale: Jorge, a civil organizer and farmer, Martin, a farm owner and prospective buyer, Enrique, the farm manager for Martin, and Daniel, a commercialization consultant for Martin and other farmers as well as a farmer himself. The men observed the infrastructure on site—soil, well house, and pump—and chatted about the challenges of bringing the land into production again, including whether or not there would be groundwater for irrigation. The men were similar in age—in their upper 30s and low 40s—meaning that they came of age in the transition to the water soft path and were young men in their early 20s when the National Water Law was re-written and programs of land reform revised in the early 1990s.

In many respects this was an uneventful encounter for the men involved, yet it seemed to encapsulate the processes described by many of the farmers with whom I spoke in interviews, surveys, and civil organization meetings both formal and informal. There was no mention as to why the person who owned this land was selling it but, as this dissertation indicates, it could have been one or a number of factors. Maybe the groundwater table had gotten too deep, and his or her pockets were not deep enough. Or the title expired and the cost too great to renew it—or it is very possible that there was never a title to begin with and this was one of the state's "closures." Perhaps the drought of 2012 had ruined an entire season's production, or the markets prices fell so low that they made harvest unprofitable. It is possible that the family had a run-in with the *narcos* and robberies had become too frequent. Maybe alfalfa no longer made economic sense to grow, and the learning curve was too steep for horticultural production. Most likely it was a combination of factors and now the land was for sale, and the result was accumulation among those who were already considered to be "participating" in the water soft path.

Martin, who was interested in purchasing the land, operated a ranch greater than 100 hectares that was entirely irrigated with drip irrigation. He followed the advice on the poster in the State Water Commission, and grew only horticultural crops. His operation started with only broccoli, but now he also grew a number of other specialty crops including beets, winter squash, and cilantro. He had buyers in China and the U.S. and diversified production to respond to their needs. Daniel was essential to gaining and maintaining those market arrangements. When Martin introduced me to Daniel he smiled and clapped Daniel on the shoulder, saying, "Meet the boss man!" to which Daniel responded, "Ha! No way. He is really the boss" (February 2015). Martin, in other words, was fully aware that market access enabled him to continue to produce and that maintaining social ties was one key aspect of market access. Earlier that day Martin had also shown me his packing operation and newly installed freezing facility on site, and explained how that gave him better market relationships by preserving the harvest. This vertical integration also maximized profits earned on the farm. When we arrived at the piece of land for sale, we did not stop and pace the field to check whether it was level and if the soil quality was consistent. We headed straight for the groundwater infrastructure. Martin and his associates' keen interest in the groundwater well and pump on the land for sale, as well as concerns about CONAGUA, further affirms that the land's worth in northeastern Guanajuato is greatly tied to its water infrastructure—both political and material.

Accumulation by dispossession is often described and imagined as a violent process. Witnessing this process in action in Dolores Hidalgo shows how space, time, and power render this violence largely invisible. As a consequence, accumulation by dispossession is not mass media worthy—it will not make headlines and will not be trending on social media. This lack of visibility is inherent to the ways power most often "gets at people" (Ekers and Loftus 2008). As acutely observed in the works of Foucault and Gramsci and those who draw from them, accumulation emerges from subtle yet influential networks of power that are so multiple and cumulative in their impacts that it is nearly impossible to draw clear lines of cause and effect. Martin's ability to buy land stems from his multiple connections—or "strands of power"—that are social, economic, and political. Moreover, they involve material alliances with non-human artifacts, forging relations that are sociotechnical and socionatural—forming a cyborg that is regenerated rather than reborn (Haraway 1991). The water soft path in its successes and failures cannot be understood independent of the political economic processes of production that emerged alongside it, or the historical materialist processes that worked to produce it. Likewise, to comprehend how the water soft path alters social relations requires situating it within the broader political economy, but with specific attention to the everyday discourses, practices, and artifacts that enable pathways of accumulation by dispossession. Producing more just pathways of water governance—for people and nature—necessitates confronting the omnipresence of history and power that too often are blindly overlooked in the implementation of sustainability initiatives.

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APPENDIX A

SURVEY OF GROUNDWATER IRRIGATORS

Governance of water through technology in Guanajuato, Mexico

Survey

Code: _______________ Date: _________________ Time start:_______________

Enumerator: HLB Other:

Location of survey:
□ Agricultural Association; □ Cattle Association; □ Peasant Union; □ Parcel; □ Other: _____

Data entry only:		
Who entered: HLB Other:		Date: __________________
Who quality control: HLB Other:		Date: __________________

A. FARM DESCRIPTION

In which municipality is your farm located?
□ San Miguel de Allende; □ Dolores Hidalgo; □ San Luis de la Paz; □ Doctor Mora; □ San Felipe
□ San Jose Iturbide; □ San Diego de la Union □ Other: _______________

In which COTAS is your farm located?
□ Alto Rio Laja; □ Laguna Seca; □ Other: _______________

Do you consider yourself…
□ Private landowner ; □ Communal landowner; □ Other: _______________

Do you consider yourself…
□ Land owner; □ Business associate; □ Manager; □ Renter; □ Other: _______________

¿How much land do you have?: ____________ ¿How much do you cultivate?: ____________

¿How much do you irrigate? ____________ ¿How much is technified?: ____________

¿Which types? □ Piped gravity; □ Sprinkler; □ Drip; □ Other: _______________

¿What year did you begin farming this land? ______________

¿How many years have you been a farmer? ______________ or □ All my life

¿What type of soils do you have? □ I don't know; _______________________

¿How would you describe your soil quality? □ Poor; □ Good; □ Regular

¿Does the groundwater come out hot? □ Yes; □ No

¿Do you have high levels of fluoride or arsenic in your water? □ Yes; □ No; □ I don't know

¿Do you hire workers? □ Yes, year round # people___________; □ Yes, seasonally
months___________, # people _____________; □ No

Crop	**HA**	**Irrigate**	**Who eat**	**Sell**	**Where sell**	**Contract**
		□ Open gravity □ Pipe gravity □ Sprinkler □ Drip	□ Forrage □ Human consumption □ Both	□ Yes □ No	□ **Local**, in Gto. □ **National**, other states □ **Export**	□ Yes □ No
		□ Open gravity □ Pipe gravity □ Sprinkler □ Drip	□ Forrage □ Human consumption □ Both	□ Yes □ No	□ **Local**, in Gto. □ **National**, other states □ **Export**	□ Yes □ No
		□ Open gravity □ Pipe gravity □ Sprinkler □ Drip	□ Forrage □ Human consumption □ Both	□ Yes □ No	□ **Local**, in Gto. □ **National**, other states □ **Export**	□ Yes □ No
		□ Open gravity □ Pipe gravity □ Sprinkler □ Drip	□ Forrage □ Human consumption □ Both	□ Yes □ No	□ **Local**, in Gto. □ **National**, other states □ **Export**	□ Yes □ No
		□ Open gravity □ Pipe gravity □ Sprinkler □ Drip	□ Forrage □ Human consumption □ Both	□ Yes □ No	□ **Local**, in Gto. □ **National**, other states □ **Export**	□ Yes □ No
		□ Open gravity □ Pipe gravity □ Sprinkler □ Drip	□ Forrage □ Human consumption □ Both	□ Yes □ No	□ **Local**, in Gto. □ **National**, other states □ **Export**	□ Yes □ No
		□ Open gravity □ Pipe gravity □ Sprinkler □ Drip	□ Forrage □ Human consumption □ Both	□ Yes □ No	□ **Local**, in Gto. □ **National**, other states □ **Export**	□ Yes □ No
		□ Open gravity □ Pipe gravity □ Sprinkler □ Drip	□ Forrage □ Human consumption □ Both	□ Yes □ No	□ **Local**, in Gto. □ **National**, other states	□ Yes □ No

					□ **Export**	
		□ Open gravity □ Pipe gravity □ Sprinkler □ Drip	□ Forrage □ Human consumption □ Both	□ Yes □ No	□ **Local**, in Gto. □ **National**, other states □ **Export**	□ Yes □ No
		□ Open gravity □ Pipe gravity □ Sprinkler □ Drip	□ Forrage □ Human consumption □ Both	□ Yes □ No	□ **Local**, in Gto. □ **National**, other states □ **Export**	□ Yes □ No

If you produce more than 10 types of crops, only write those with the largest area of production above, and note the others here____
____

Do you sell crops at the organic market □ Yes; □ No

¿Which crop is the most profitable? ____________________________
¿Which crop is the **<u>least</u> profitable**? ____________________________
¿Which crop is the most **<u>most</u> risky**? ____________________________
¿Why? ____

¿Which crop **<u>least</u> risky**? ____________________________
¿Why? ____

¿How many heads of each animal do you have intended for human consumption (meat or other products)?

□ None __________Cattle (beef); __________Cattle (dairy);
__________Goat; __________Sheep; __________Chickens;
__________Turkey; __________Rabbit; __________Other:

Do you receive insurance for your harvest? □ Yes; □ No

From who? □ N/A; □ Federal government; □ State government; □ Local government;

□ Private company; □ Civil organization: _________________

□ Other: _________________

B. WATER MANAGEMENT

How many wells do you have? ____________

Do you rent any of your wells to other people? ______________

Do you have wells that don't work? □ Yes; □ No, # ___________

Do all of your wells have titles with CONAGUA? □ Yes; □ No

What type of title is it? □ Agricultural; □ Livestock; □ Domestic; □ Other: ____________

# Well	Perforation depth (m)	Water depth (m)	Inch.	L/Sec	Amt. concessioned	Year of Perforation	Year Titled
1							
2							
3							
4							

Have you repositioned or deepened the well? □ Yes, the year _______________; □ No

Do you have any plans to reposition or deepen the well? □ Yes; □ No

Do you have a water meter? □ Yes; □ No

Do you have an electricity meter? □ Yes; □ No

Is the electricity supply reliable? □ Yes; □ No

Do you receive subsidies for your electricity? □ Yes; □ No

In the past year, what was the **most** you paid for your electricity bill?
____

In the past year, what was the **least** you paid for your electricity bill?
____

¿Was there a time in the last year that you did not pay the electricity bill? □ Yes; □ No

If yes, ¿why?
____
____

C. IRRIGATION MANAGEMENT

System	# HA	Year	Cost/HA	Support	Source	Pct.	# Laborers / Ha
Open gravity							
Piped gravity			□ <$5000 MX □ $5-15,000 MX □ $15-25,000 MX	□ Yes □			

			□ $25-35,000 MX □ $35-45,000 MX □ >$45,000 MX	No			
Sprinkler			□ <$5000 MX □ $5-15,000 MX □ $15-25,000 MX □ $25-35,000 MX □ $35-45,000 MX □ >$45,000 MX	□ Yes □ No			
Drip			□ <$5000 MX □ $5-15,000 MX □ $15-25,000 MX □ $25-35,000 MX □ $35-45,000 MX □ >$45,000 MX	□ Yes □ No			

Was there a company or organization that trained you when you installed the irrigation system (did they teach you how to maintain and use the system) □ Yes; □ No

Which system? □ Open gravity; □ Piped gravity; □ Sprinkler; □ Drip

Was it… □ Private company; □ Federal government; □ State government;

□ Local/municipal government; □ Civil organization

Did you pay for the training? □ Yes, all; □ Yes, part; □ No, it was included; □ No, it was free

Was there an organization or company that helped you with the process of receiving credit or support for your irrigation system? □ Yes; □ No

Which system? □ Open gravity; □ Piped gravity; □ Sprinkler; □ Drip

Was it… □ Private company; □ Federal government; □ State government;

□ Local/municipal government; □ Civil organization

Did you pay? □ Yes, all; □ Yes, part; □ No, it was included; □ No, it was free

In the **las five** years, has your irrigation area □ increased, □ decreased, or □ stayed the same?

How much: + or - ___________________________ HA

Do you use something to maintain the soil moisture?

□ No; □ greenhouses; □ high tunnels; □ plastic covering; □ other:___________________

Chose the most efficient system you use or if you only use open gravity, choose the system you would most like to install:

□ Open gravity; □ Piped gravity; □ Sprinkler; □ Drip

In the table below I will ask you about the various benefits of using ____*efficient irrigation system*_____. For each benefit, I would like you tell me the importance of each one and chose ONE as the principal benefit. For example, maybe lower energy costs are an important benefit, but maybe higher crop yield is the most important benefit, and you only choose this on as the principal benefit. Also it is possible that there are some important benefits that are missing from the list below. There is an option to write it below. Do you have any questions before we begin?

	Not a benefit	It's a benefit, but it not that important	It's a benefit, and its only a LiTTLE important	It's a benefit, and its VERY important	It is the PRINCIPAL benefit
Higher crop yield					
Efficient use of water					
Requires less labor					
Produce more profitable crops					
Increase irrigated area					
Less cost/use of energy					
Other 1					
Other 2					

Other 1: ____

Other 2: ____

This table is almost exactly the same as the one above, but now we are talking about problems that prevent you from installing more ____*efficient irrigation system*_____ o that make it difficult to use.

	I don't consider this a problem	It's a problem, but not significant	Its and problem, and its significant	It's a problem and its VERY significant	It's the PRINCIPAL problem
Money for installation					
Money to maintain					
Lack of access to markets for crops					
I don't have a groundwater title					
Too risky					
I don't know how to use it					
I don't know how to get access to credit or support					
I'm worried someone will steal the parts					
Other 1					
Other 2					

Other 1: ____

Other 2: ____

D. PARTICIPANT CHARACTERISTICS

Year you were born: ____________________

Do you consider yourself □ Mexican; □ Foreigner

Gender: □ Male; □ Female

Highest level of education: □ Primary; □ Secondary; □ High School; □ 4-year; □ Graduate

If you attended university, what was your degree? □ N/A

____

Are you a member of any organizations? □ Yes; □ No

Which? □ COTAS; □ Cattle Association; □ Agricultural Association; □ Eijio;

□ Other: ____

Do you have a position? □ Yes; □ No; If yes, what is your title:_________________________

Do you work off farm for additional income? □ Yes; □ No

On average, how many hours to dedicate to farm activities per week?

____

Approximately what percentage of your income comes from farm production?

____

Time finished: ______________________________________

Code: ______________________

Participant name: ____

Email: ____

House phone: ____

Cell phone: ____

Farm address: ____

____
__

Can I contact you again in the future if I have any further questions regarding this project?
□ Yes; □ No

**This page is not attached to the other part of the survey and I will keep it in a separate location. I will enter these data in a file separate from the survey data. These questions are only for the purposes of contacting participants in the future and I will not use them for analysis or share with anyone else. Survey data are confidential.