THE POLITICS OF GROUNDWATER SCARCITY: TECHNOLOGY, INSTITUTIONS, AND GOVERNANCE IN RAJASTHANI IRRIGATION

DISSERTATION

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By

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ABSTRACT

This dissertation examines the conditions under which tubewell groundwater lifting technology in Rajasthan, India is adopted and adapted by producers, technicians, and bureaucrats, and how these adoptions later feed back into the landscape and political ecological processes. By examining the links between environmental knowledge, technology adoption, capital accumulation and ecological change, I demonstrate the ways that these processes operate recursively to produce new social institutions, alter social power relationships (including environmental knowledge) and ecologies, while informing the future creation of equitable groundwater governance strategies. My research contributes a new approach to the fields of political ecology, critical development studies, and science and technology studies (STS) through fresh exploration of the effects that agrarian technologies have on political ecological processes.

First, findings include that tubewells, as one example of a scarcity-reducing technology, actually create scarcity for particular communities, alter existing relationships of power, and condition the production of new institutions and new kinds of modern ecological people (or subjects). For instance, tubewell adoption has led to the proliferation of new informal (e.g. sharing of tubewells and/or electricity for pumping...
between farms) and formal (e.g. Central and State Groundwater Boards and irrigation departments) institutions.

Moreover, their use alters ecological conditions, including soil and groundwater quality, which undermines both their continued use and the continued production of high-yielding crops. Ironically, farmers are returning to the production of traditional crops as soils become sodic due to increasingly poor quality groundwater. Tubewell use has, therefore, undermined the original conditions under which it proliferated in a recursive process of ecological change, leading to further political ecological differentiation. Consequently, tubewells have capacity to motivate human and non-human processes, and are both cause and consequence of ecological change and social institution formation.

Second, findings from the work also suggest that groundwater knowledge systems are a hybrid drawing on diverse sources including tubewell drilling firms, groundwater departments, and Hindu spiritual leaders. Third, tensions exist between these various knowledges and institutions, in particular those between farmers and the state, which impede the future creation and implementation of groundwater governance strategies. I examine this example of a scarcity-reducing technology to illustrate the complex interaction of traditional and technical knowledge and technologies with environmental change, local and state forms of power, and development policies. This project demonstrates the contradictory effects of ecological modernization around the world.
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CHAPTER 1

INTRODUCTION

1.1 Introduction

In recent years, geographers and other social scientists have shown increased interest in investigating issues of water scarcity and distribution through the lens of political ecology. Most of this research, however, has focused on surface water or surface water-based irrigation, is dominated by urban settings, mostly in the Global North, and is concerned with the privatization of water resources and the introduction of markets under broader shifts towards neo-liberal regulation. This is in contrast to more traditional political ecological investigations, which have historically been situated in the Global South and focused on the intensive research of peasant producers and more recent work within political ecology that incorporates the insights of science and technology studies (STS) to understand nature-society-technology relations. The present study, seeks to fill this lacuna in political ecology by investigating groundwater use and concomitant technological change among peasant farmers for irrigation in the Global South.

In more general terms, it examines the relationship between technology, natural resource scarcity and social institutions. It seeks to address how resource scarcity-reducing technologies, like the tubewells used to access water in India, which are adopted
and adapted by producers, technicians, and bureaucrats, later feed back into the landscape and affect political ecological processes. Once these technologies are adopted, for instance, formal and informal institutions are created to mediate their use. These transform existing relations of inequality, sometimes reducing social differentiation but at other times exacerbating or reproducing it. In other words, the effects of resource scarcity-reducing technologies, as a form of ecological modernization, are uneven in that they may not reduce scarcity for all and worse, may exacerbate already existing inequality. Moreover, they may actually lead to scarcity, if not in the present, at some point in the future through these inconsistencies. These technologies are contradictory, therefore, in that they may resolve a resource scarcity problem for some at one particular moment, while at the same time expediting the future reappearance of that problem for which these technologies were introduced to address in the first instance. These unintended consequences, then, necessitate and lead to the production of yet new social institutions to address the contradictions set in motion from previous technological innovations. These new social institutions, along with yet more technological solutions, may lead to the more sustainable use of resources but they may also lead to further social differentiation, leading to continuing resource conflicts.

Central to conflicts over resources are the knowledges, local and expert (technical), that become enlisted to arbitrate these disputes. Resource scarcity technologies are not introduced onto a clean slate, but become enmeshed in existing knowledge systems and in existing environmental practices and social power relations and institutions. The introduction of new technologies, then, interacts with already
existing technological knowledge but also generates a variety of knowledges that are brought to bear on the use of the technology and become part and parcel of the subsequent conflicts surrounding its use. One danger here is that local knowledge and technical expertise, and resources themselves, can become reorganized and concentrated within, for example, state agencies, placing them outside of local control. The concern with access to and control over resources (including the knowledge of their husbandry and conservation) is central to the concerns of political ecology (Blaikie and Brookfield 1987; Peet and Watts 1996; Peet and Watts 2004; Robbins 2004).

For example, two primary concerns of political ecology, as practiced by geographers and anthropologists, include, first, the relationships between nature and society and the socionatures (the commingling of society and nature) that result from these interactions; and second, the associations of “diverse forms of environmental knowledge that are brought into interplay through ecological modernization efforts such as sustainable development, agrarian reform, and forestry management” (Zimmerer and Bassett 2003, p. 287). Socionature is a concept that breaks down the dualism between society and nature by recognizing the interdependency and hybridity of human and non-human nature (Castree and Braun 2001). Our drinking water, for instance, becomes a nature-society hybrid the moment humans employ some device to extract, purify and/or deliver it. It is not purely natural or social because it has been altered by human intention, while also being subjected to social power relations, which are inherent to the process. This approach to political ecological inquiry draws on science and technology studies (STS) to not only bring into question these artificial dualisms, but to also examine the
ways that skills, practices, technologies, natural systems, people, and political processes connect through heterogeneous means: epistemes (Foucault 1980); actor-networks (Latour 1993; Latour 2005); or assemblages (Deleuze and Guattari 1987). Geographers and political ecologists have been drawing from these concepts to investigate the ways that heterogeneous knowledge is produced and legitimated (Bolton 2006; Castree 2002; Demeritt 2001; Morris 2006; Robbins 2001, 2006; Whatmore 2002).

A further concern of STS is the role of technology in mediating relationships of power, knowledge systems and understandings of nature (Latour 1987; Robbins 2001; Watson-Verran and Turnbull 1995; Winner 1977). But, this literature has most often been situated in the West (see Fairhead and Leach 2003 for a critical stance on this point) or in Western urban areas (Swyngedouw 2004). And when this research has been carried out in developing contexts (see Robbins 2001), it has not examined the particular social institutions and individual adaptations that result from the recursive processes of technology adoption and socionatural change. The research explained here seeks to not only integrate the STS approach into the developing world context but to further this approach by examining recursive nature-society-technology relations, while adding both to political ecology and STS frameworks. How do local knowledge systems interact with Western-technical knowledge and resource scarcity-reducing technologies to produce new forms of knowledge and relationships of socio-economic and political power? And what does this mean for political ecological change and resource governance? This dissertation examines the links between environmental knowledge, technology adoption, capital accumulation and ecological change. I aim to show the ways that these processes
operate recursively to produce new social institutions, alter social power relationships (including environmental knowledge), and ecologies, while informing the future creation of equitable resource governance strategies.

One resource that has yet to receive adequate attention in this literature is water, specifically groundwater as it is used for irrigation and domestic purposes. Groundwater has historically had many advantages over surface water in these regards. First, it is reliable in dry seasons and during droughts. Second, it is cheaper to develop, since it requires less treatment than surface water and can be tapped by individuals, thus decentralizing costs and reducing conveyance losses and costs typically associated with surface water. Third, it is highly flexible in that it can be tapped when and where it is needed and extracted in quantities required. These factors have led to its expanded use in the twentieth century.

Groundwater use has a long history, though. For instance, archaeological evidence indicates that groundwater-based irrigation has been practiced in US southern high plains – Ogallala Aquifer – for centuries (Brooks and Emel 2000, p. 89). Before the arrival of Europeans in the area, groundwater was drawn by human power and used to irrigate relatively small areas. Europeans arrived in this area around 1860 and radically transformed groundwater lifting and irrigation by employing windmills to power groundwater extraction (ibid). There were also further advances in lifting and energy technology in the early 1890s and early 1900s (such as steam and later diesel driven pumps). Yet groundwater continued to be used on a marginal scale until the 1930s when, during the dust-bowl era, New Deal government programs were enacted to provide
subsidies and price supports as incentives to increase the exploitation of groundwater. Technological change in groundwater extraction during this period, therefore, relied on government institutional change and support (New Deal subsidies and price supports), while also being grounded in the ecological realities of the area: little surface water and drought. Government support is a common factor in the innovation and diffusion of resource scarcity-reducing technologies.

Groundwater use continued somewhat in check for the next 20 years, but drought in the mid 1950s “threaten[ed] farmers anew, the potential disaster wrought by overproduction and overutilization of marginal land was mitigated substantially by loosened credit, crop price supports, and irrigation” (Brooks and Emel 2000, p. 99). This led to a rapid expansion of year-round irrigated area (cotton and wheat production) through technological advances in drilling, pumping, and delivery, the advent of inexpensive energy, favorable financing, and government subsidies and price supports, (Green 1992) within an overall dynamic of economic growth. These price supports continue to this day. Without strong government support, agriculture in much of this area would not be possible. New Deal programs, therefore, set in motion a cycle of overcapacity in production, the shift of cultivation to more marginal lands and dependence on government subsidies. At the center of this cycle were advances in irrigation technology and increases in groundwater exploitation, supported by formal government programs but also by local farmers who were propelled into adopting groundwater irrigation by rapidly shifting economic conditions.
In some areas groundwater overexploitation began to be a problem in the 1940s. Most notably in Texas, rapid groundwater decline, a result of advances in pumping technology and the expansion of irrigated area, resulted in the local organization of groundwater management institutions, such as the High Plains Water Conservation District Number 1. In other states, such as New Mexico, it resulted in formal state regulation. The spread of the technology has also undermined its own efficacy in that as groundwater became deeper, it required more energy to lift it, thus increasing irrigation costs and reducing profit margins. By the 1970s, farmers and government officials (local, state and federal) began to advocate for the monitoring of groundwater withdrawal. This instigated a set of studies to analyze the social, ecological and economic impacts of groundwater decline at the local, state and federal levels to not only inform these questions but to inform the future provision of extension services to farmers (Kromm and White 1992). In other words, it set in motion the production of new forms of expertise and power-knowledges around this question of groundwater overdraft. It brought federal, state and local groundwater and policy experts into contact with farmers and their knowledges to bear on the groundwater question, which prior to the problem of groundwater over-exploitation was mostly the purview of individual farmers. The federal government was interested in how groundwater decline would impact the national economy for agricultural commodities, while state and local authorities were particularly interested in how groundwater overpumping in one jurisdiction would affect groundwater availability in another, ultimately leading to inter-jurisdictional social differentiation and differentiation between farmers as groundwater decline was felt unevenly. Moreover,
farmers who were already using a particular volume of groundwater wanted to formally institutionalize their rights to that same amount of water, precluding the formation of new users and demands on groundwater, resulting in social differentiation in access to and control over resources. The result has been to regulate groundwater use and withdrawal, locally and at the state level, by regulating well construction (both in number and spacing between wells), monitoring withdrawal with meters and requiring efficient irrigation techniques.

I offer this brief summary of the history of groundwater use in the US High Plains to illustrate a broader argument. Groundwater was used on a relatively small scale until there were individual and state efforts to expand production beyond subsistence farming, while mitigating unpredictable drought conditions. These efforts relied on the creation of new institutions, both informal and formal, and were successful in that for a time they reduced resource scarcity. But as a result of economic growth and a desire to irrigate year round, further innovation in groundwater lifting technologies and institutions (such as price supports) occurred. This eventually led to a problem of groundwater overdraft (with extraction surpassing recharge) and ultimately resulted in the promulgation of various groundwater and policy experts who attempted to offset these contradictions with not only regulation, but through the rearrangement of power-knowledges, displacing the knowledge-practices of groundwater practices to formal regulatory bodies and/or the state.
1.2 The Problem of Groundwater Scarcity

Groundwater over-exploitation has recently become a problem around the world for two main reasons. First, with the development of more powerful and affordable groundwater pumps and the availability of cheap electricity, farmers and municipalities are able to pump higher volumes of groundwater. And second, there are pressures to irrigate year round in response to an overall dynamic of economic growth and the shift from subsistence only farming to market-based production. According to the United Nations, groundwater use for irrigation by the world’s farmers exceeds natural recharge rates by at least 160 billion cubic meters per year so that by 2025, 50% of the world’s population will face water scarcity (Rosegrant et al. 2002). The problem of groundwater overdraft is recent, therefore and is of serious concern, as irrigation is the lynchpin of Green Revolution expanded agricultural production around the world.

Conflicts over groundwater are already occurring in the US (Emel and Roberts 1995; Glennon 2002; Roberts and Emel 1992; Wagner and Kreuter 2004), northern China (Jiang et al. 2006), Sub-Saharan Africa (Carter and Howsam 1994), Europe (Bromley et al. 2001; Klauer et al. 2006), Australia (Syme and Fenton 1993) and Bangladesh (Crow and Sultana 2002) but also between countries, such as Israel and Palestine (Froukh 2003; Medzini and Wolf 2004) and other transboundary contexts (Jarvis et al. 2005). In many areas this has resulted in specific legislation to regulate groundwater.

In the United States, for example, groundwater regulation is the purview of individual states. So there is a patchwork of different, and sometimes very different, legal doctrines that govern groundwater withdrawal. In New Mexico groundwater is regulated
by the state, while in neighboring Texas it is regulated by a series of self-organized water conservations districts, such as the High Plains Underground Water Conservation District (HPUWCD). In comparing these two states, Emel and Roberts (1995) concluded that their “analyses further offer no evidence for the conclusion that state-managed groundwater usage in the High Plains of New Mexico is in any way superior to self-organized usage management in the Texas HPUWCD” (p. 680). It has also been shown that centralized groundwater management in Britain has been slow to adapt to changing socio-environmental conditions (Foster and Grey 1997). While in China, under contrasting political conditions, planned regulation has been quite effective at balancing pricing with supply and demand especially as compared to other developing countries such as India or Mexico (Mukherji and Shah 2005). The form that regulations take, whether by the state or by self-organized local institutions, and their effectiveness is still an open question, therefore. The issues of groundwater regulation, innovation in groundwater lifting technology and expert knowledges of irrigation practices and technologies are, however, nowhere more pertinent than in India.

In India, where groundwater meets 70% of the country’s irrigation needs and 80% of its domestic water supplies, demand for both rural and urban uses is expected to exceed supply by 2020 (Briscoe 2005; World Bank 2005). As in the United States, groundwater regulation is the purview of individual states. And while groundwater model bills have been circulated by the central government through the states for decades, very few states have enacted laws. And in states that have enacted laws – West Bengal,
Maharashtra and Andhra Pradesh – they have yet to be implemented in any meaningful way (Mukherji and Shah 2005).

A recent World Bank report – “India: Bracing for a Turbulent Water Future” – identifies two major problems exacerbating the groundwater problem: 1) “indiscriminate pumping of groundwater” mostly for irrigation by farmers, and 2) “provision of free power” in the agricultural sector (Briscoe 2005; for a short summary see World Bank 2005). The World Bank’s proposed solutions are uncomplicated in their presentation and are based on four market-based principles. The first is defining and setting water entitlements – transferable rights over water. Closely related to entitlements is the second principle of clearly defining property rights over water. The third is “increasing supply and efficiency through technological expansion”, including more efficient irrigation systems and surface water dams. And the fourth is establishing water user associations, thereby localizing governance. The World Bank is supporting its recommendations through an increase of rural water sector loans from $250 million between 1999 and 2004, to $1,400 million between 2005 and 2008 (Briscoe 2005).

The World Bank’s vision for the future of groundwater management partially depends on the expansion of new resource scarcity-reducing technologies. We do not know, however, what the historical effectiveness of already existing technologies is in reducing scarcity, and increasing equity and efficiency in access to groundwater. The broad questions informing this dissertation research become: 1) what work does this technology actually do; 2) how does it influence, reduce, or produce water scarcity for different communities and to what degree; and 3) how do scarcity-reducing technologies
influence and feed back into development and political-ecological processes? In order to address these questions, we need to examine the past successes and failures of actually existing resource scarcity-reducing technologies. I explore these questions by examining one resource scarcity-reducing technology in Rajasthan, India.

Rajasthan is an ideal setting for this research. First, there is a long history of groundwater extraction and development in the region. The area has also experienced a recent history of rapid technological change and adaptation to new technology. Third there is a high degree of ecological and socio-economic variability, which allows for the investigation of the differential effects of technology adoption. Furthermore, groundwater is an extremely important resource not only in Rajasthan, but globally, and is highly utilized for domestic and agricultural purposes in this arid and semi-arid area where there is very little surface water. This aspect of groundwater and associated lifting technologies makes it a highly contentious resource in need of investigation.

1.3 Scarcity-Reducing Technologies: The Quintessential Tubewell

A paradigmatic technology in India has been the tubewell, introduced to reduce water scarcity especially for irrigation but also for domestic purposes. Tubewells tap aquifers of varying depth, volume and recharge capacity. They are based on oil well drilling technology and in northern India range mostly from 20-100 meters deep. Most tubewells utilize a submersible centrifugal pump, but historically when the distance to the water table was less, surface diesel driven pumps were also used. Diesel pumps are still in use but their efficacy is declining as they are only able to draw groundwater after the monsoon when the water table is higher.
It is commonly assumed that the tubewell was introduced into India in the 1960s with Green Revolution development programs (Shiva 2002). But it was actually introduced much earlier by the British in the late 1800s (Indian Irrigation Commission 1903). Still, it wasn’t until the late 1960s that the widespread adoption and expansion of tubewells really began. The two key moments underpinning this expansion was the nationalization of the banking system in 1969, which allowed the government to provide low-interest loans to land managers for tubewell construction and the focus on rural electrification by the central government (Narayanamoorthy and Deshpande 2005). These two key conditions have been very important in encouraging the adoption and spread of the tubewell across India.

Today there are over 20 million tubewells in India irrigating 70% of the total agricultural area or 29,842,000 hectares in 1997 (Narayanamoorthy and Deshpande 2005, p. 70; Shah 2005; World Bank 2005). Moreover, in the arid and semiarid state of Rajasthan, farmers adopted nearly 1.4 million agricultural tubewells between 1961 and 2001 (Government of Rajasthan Groundwater Board 2003). Of this growth, 33% occurred between 1999 and 2001 and even though groundwater extraction surpasses recharge in the state by nearly 410 million cubic meters per year, tubewell construction continues unabated (Government of Rajasthan Groundwater Board 2006). A subsequent state of severe groundwater overdraft is of serious concern as groundwater irrigates 71% of total irrigated area in the state, nearly 4.0 million hectares (Directorate of Economics and Statistics 2003) and 80% of domestic water supply in both rural and urban areas (World Bank 2005).
But the spread of this irrigation and agricultural productivity-enhancing technology has not been evenly felt by all of society. Much of India, and particularly Rajasthan, is sharply divided by multiple axes of difference including caste and class. The most marginal producers, therefore, may not have benefited from this technologically driven expansion in agriculture and they may be excluded from benefiting in the future. This will be due to the newly proposed regulations to limit tubewell construction and groundwater withdrawal, thereby formally institutionalizing the rights of existing users (much like with Prior Appropriation in the United States) to continue using the volume of groundwater to which they have become accustomed and upon which they are now dependent.

The rapid proliferation of the tubewell and the state’s parallel heavy reliance on groundwater is occurring, as previously mentioned, in the absence of formal groundwater regulation. Under the Indian Constitution, groundwater regulation is the purview of individual states. Rajasthan has never formally regulated groundwater use, extraction, or tubewell construction. Due to increased use and reliance, and because extraction surpasses recharge, the state under the direction of the World Bank, European Commission and Indian experts, is considering formal groundwater regulation with the recently jointly drafted Rajasthan Groundwater Rational Use and Management Act of 2005. In short the Act proposes a series of market led solutions and reforms in the water sector, mirroring the World Bank recommendations introduced previously in this Chapter. I consider this proposed regulation in light of these global shifts in water regulation and distribution.
These moves to regulate groundwater are being spearheaded by state, NGO and development agency experts, resulting in the promulgation of many new forms of groundwater expertise not only in Rajasthan, but elsewhere in India where groundwater use is contentious, such as in the states of Maharashtra, Andhra Pradesh, Gujarat, West Bengal, Haryana, and Uttar Pradesh. But these are certainly not the first or only set of formalized groundwater or irrigation experts in India. The British colonial authorities’ Indian Irrigation Commission first met in the late 1800s to form a strategy of groundwater development for irrigation (Indian Irrigation Commission 1903), even though groundwater had been used for domestic and irrigation purposes throughout northern India since before the Mogul period of the 11th century.

However, it is the increased focus on groundwater since the Green Revolution, which resulted in both the rapid spread of the tubewell, driven by individual adoption and concomitant groundwater decline that has set in motion conflicts over the production of environmental knowledge between local expertise, such as that of farmers, traditional Hindu water experts, and tubewell drilling firms, and those with a more abstract technical expertise, such as state Groundwater Board engineers and policy-makers. Through the rise of the Green Revolution since the late 1960s, Indian agriculture and irrigation has become dominated by new forms of expertise from the state, NGOs, and development agencies that simply was not possible before. But the proliferation of these multiple forms of expertise has occurred along with the continued production and incorporation of some of these expert knowledges by local people. Indeed, and following Mitchell (2002), the introduction of the tubewell, as a scarcity-reducing technological solution, does not
represent an introduction of expertise where none had been before, but a concentration and reorganization of knowledge and social power, while displacing existing knowledge to new sites, such as state agencies (Bolton 2006, p. 534; Mitchell 2002, p. 90-93). But it is not clear what groundwater and irrigation expertise there is, how they interact, and how this informs the future creation of efficient and equitable groundwater management institutions given that the prospect for future groundwater led agricultural development is dire indeed. It is clear that if we are to address the ‘water question’ in Rajasthan and elsewhere, research must attend currently existing knowledge practices and social institutions for the use of groundwater (Moench 2002; Shah et al. 2003).

This leads to three more precise research questions: 1) how do differing (local and technical) groundwater knowledges interact and to what effect; 2) how does tubewell adoption influence land use patterns, scarcity, and adaptation of water use for differing communities; and 3) what does this mean for effective resource governance strategies?

1.4 Goals of the Dissertation

In this investigation, I have three main foci. First, I am interested in whether this technology, which is intended to reduce water resource scarcity for irrigation and increase agricultural production, while insulating land managers and the broader agrarian based economy from the vagaries of unpredictable monsoon rains, actually reduces scarcity and economic inequality. Related to this is gaining an understanding of how resource scarcity-reducing technologies are cause and consequence of ecological change and social institution formation. In other words, I am interested in understanding the
capacities that this technology has to recursively motivate human and non-human natural processes.

Second, I am interested in how the proliferation of this technology has had a concomitant impact on the proliferation of new forms of groundwater expertise and the ways that these multiple knowledges interact with each other and are contested and legitimated. And third, I want to understand how the above two interrelated areas of investigation inform the future creation of more equitable resource governance strategies not only in India, but around the world.

This research points to the complex interaction of technology, environmental change, and local and state forms of power and policy, while adding to a growing body of literature that attempts to unravel the processes and effects of ecological modernization around the world and their significance for global environmental governance. So too it seeks to inform future development policies, including the potential for future management of irrigation that is both more efficient and more socially just.

1.5 Theoretical Context

1.5.1 South Asian Groundwater Resources Scholarship: Management, Markets and Distribution

It is estimated that of the 300 million hectares irrigated globally, 85-95 million depend on groundwater, while 85% of these areas are in India, Bangladesh, Pakistan, Iran, and the north China plains (Shah 2005). It is the recent changes in groundwater technology and economic demands that have led to groundwater’s increasing importance for agricultural production, while also resulting in its state of overdraft in many areas.
These factors have given rise to a burgeoning literature from social scientists in recent years especially from and within South Asia. Prior to the late 1990s, however, this research was focused on “technocratic themes” including, groundwater development, groundwater management, and groundwater markets (Dubash 2002). More current research focuses on the technical and institutional aspects of its management and distribution (Dubash 2002; Moench 2002; Shah, Roy et al. 2003). Shah et al. (2003), for instance, inventory a number of “techno-institutional solutions” to the groundwater question, such as water conservation districts, rainwater harvesting and increasing electricity tariffs, but concludes that these may not be compatible due to local environmental and social heterogeneity: “A more nuanced understanding of the peculiarities of Asia’s groundwater socio-ecology is needed” (ibid, p. 130). There is a need for research that examines the specific relationships between groundwater knowledge and institution formation, therefore. Moreover, Moench (2002) illuminates the connection between groundwater scarcity, social instability and agrarian livelihoods. He outlines “strategies” (e.g. the maintenance and creation of adaptive civil society institutions) and ‘potential issues’ (e.g. uneven accumulation between “well-off” and poor groundwater users) to be considered when helping people move through the transition from groundwater dependence to groundwater depletion. In doing so, he also calls for “institutions capable of adapting to change, while still maintaining the cultural and social continuity that grounds populations” (ibid, p. 203). Understanding the conditions under which different ‘strategies’ arise and how they relate to ‘potential
issues’, requires investigating how and what groundwater knowledge becomes institutionalized.

So too, recent work by Dubash (2002) has furthered our understanding of groundwater markets, from simply trying to understand whether or not they work, to illustrating “how and why they operate differently under different social and hydrological circumstances, and with what effects” (p. 9). He showed that social groups marginalized by caste and class were “excluded from the processes of deepening wells or the formation of caste-based partnerships for wells, forcing them into participation in the water market” during an overall period of groundwater decline (Dubash 2004, p. 240). Through this research, he further questioned the operation of markets as perfectly functioning “price-clearing” exchange mechanisms, by showing how they were embedded within “complex pressures of local ecology, local institutions, and local politics” (ibid, p. 250). But he took social institutions as a given rather than examining how they were produced around the constraints of technology and political ecologies. So too, the way that technology itself mediates cultural, political and socioecological processes has not been examined in this context.

While this research has made and continues to make important strides in our understandings of groundwater socio-ecologies, it is ill-equipped theoretically to connect the relationships between knowledge/power, institution formation, ecological change, technology adoption and governance. Political ecology, on the other hand, while theoretically equipped to examine these issues, has yet to do so in the particular,
developing society context of the present research. This dissertation, therefore, aims to fill this lacuna in the literature and the gap in our understanding of these processes.

1.5.2 Neo-Liberal Water Supply: Markets and Resource Privatization

Historically, political ecology, as a somewhat eclectic body of scholarly inquiry, has focused broadly on the relationship between access to and control over resources, livelihoods and socioecological differentiation. Investigations into water, whether surface water, groundwater or irrigation, are a notable absence in this literature. Until recently, research into water was left to theorists of common property resources (CPRs) (Meinzen-Dick 2002; Meinzen-Dick et al. 2002; Ostrom 1990, 1992) or to those coming from other institutional perspectives (Emel and Roberts 1995; Emel et al. 1992). Political ecology is late to the game in this regard.

There is, however, a growing literature that could loosely be defined as the political ecology of water but most of it is confined to urban water and/or to debates on governance reforms of a neo-liberal character in water supply and distribution. One popular approach has been to draw on regulation theory frameworks (Peck and Tickell 1994) to show how neo-liberalism is not an unchanging force but is geographically constituted (Prudham 2004) (see also Mansfield 2004), that privatization of water is a form of re-regulation rather than deregulation (Bakker 2000; Bakker 2003) or how discursive constructions of drought are employed in the re-scaling of governance (Bakker 1999). Moreover recent work on changes in governance carried out in England and Wales highlights that new water policies designed to privatize water supply have not truly commodified water (Bakker 2005), but that these policies, nevertheless, represent a shift
away from a history of water policy that prioritized inter and intra-regional equalization to ones that prioritized economic efficiency (Bakker 2001). Other work, also conducted in Britain, argued that Parliament’s takeover by the Labour Party in the late 1990s resulted in the incorporation of sustainability concepts into water regulation between 1997 and 2001, again illustrating how unexpected changes occur even within an overall climate of neo-liberalism (Cashman 2006). Moreover, Page (2005), taking this approach to the Global South, argued that the commodification of water was not only not new in Cameroon (it has been going on for 80 years) but was only partial. He further showed that companies involved in privatization efforts throughout Africa have retreated under unprofitable conditions, while recent work in Mexico has shown that privatization did not result in efficiency or equity gains (Wilder and Lankao 2006). Furthermore, Haughton (2002) showed that multilateral bodies, such as the World Bank, promoted private sector involvement in the water sector in attempts to influence national governments on how to manage water.

In contrast to a literature that has focused on the regulatory aspects of urban water, within regulation theory frameworks, Perreault (2005), examined the restructuring (re-regulation and re-scaling) of rural water management in Bolivia. In this study, again drawing on regulation theory, he illustrated how peasant irrigators mobilized against state reforms that attempted to restructure water management through a neo-liberal model. He highlighted the contradictions in neo-liberal reform policies that on the one hand undermined farmer’s economic livelihoods, but on the other hand strengthened the
resource rights of peasant irrigators through the same constitutional reforms enacted to restructure water management (see also Budds 2004; Loftus 2001).

This research illustrates the recent growth in the interest of geographical inquiries into water issues. But its focus has been on recent shifts in the regulation of water from being state centered and equity focused to being grounded in neo-liberal orthodoxy and focused on efficiency, while simultaneously highlighting the geographical inconsistencies and differences in the implementation of these approaches. But this framework does not address the nexus of relations between nature, society and technology. It is not equipped, for example, to examine the relationship between knowledge/power, the state, ecological change and social institution formation. To address this nexus, this dissertation adopts a relational perspective.

1.5.3 Technology, Knowledge, Institutions and the Social Transformation of Water

Recent work on water has examined the ways that technology is the mediator through which human and non-human nature are perpetually transformed (Kaika and Swyngedouw 2000, p. 121; Swyngedouw 2004). This research draws on recent advances at the intersection of political ecology and science and technology studies (STS), often making use of Latour’s concept of hybridity (Latour 1993), to examine technology’s capacity in mediating socio-environmental change. Central to this work is breaking down the binaries between nature/society and structure/agency to show how these things or ‘quasi-objects’ are both social and natural: socionature. This approach has two strengths. First, it opens up the associations between heterogeneous objects to displace the seemingly stable separations between them, while showing that the “competencies and
capacities of ‘things’ are not intrinsic but derive from association” (Whatmore 2002, cited in Bakker and Bridge 2006). And second, it relies on a decentering of agency away from being an inherently human capacity towards an understanding of how the non-human can enable and constrain social action through their historical relations with other human and non-humans objects. It has become clear, therefore, that the human may not always organize the non-human but that sometimes the non-human organizes the human and some of our thinking, by both enabling and constraining the possibilities for socioecological change (Agrawal 2005; Mitchell 2002).

From the standpoint of the political ecology of water, there have been very few investigations within this line of theorization and what has been performed has examined urban water infrastructure (Kaika 2005) or the ‘urbanization’ and concomitant ‘socialization’ of water (Kaika and Swyngedouw 2000; Swyngedouw 2004) in the North. Furthermore, in both cases this work did not seek to understand how specific outcomes, such as the creation of new social institutions, resulted from the nexus of nature, society and technology. This begs the question: what momentum do technologies have, once adopted, in shaping socioecological change and mediating the relationship between human and non-human nature, including the creation of new adaptive social institutions (Robbins 2001; Winner 1977)? By applying this framework to the study of groundwater socionatures and resource scarcity-reducing technologies, this dissertation furthers our understanding of the role of non-human capacity in this change, albeit an understanding which remains a highly contentious issue in geography (see Bakker and Bridge 2006; Castree 2005; Kirsch and Mitchell 2004).
Along with the proliferation of scarcity-reducing technologies, and ecological modernization more generally, is the spread of new forms of environmental knowledge, especially Western-technical knowledge, and the creation of expert bodies, particularly state agencies, such as groundwater boards and irrigation departments. The various means by which this knowledge, especially Western-technical knowledge, hybridizes with already existing local environmental knowledge is an under-explored question. And it is a critical one to ask, as the divergences between these knowledges spark intense debates, which inform the politics over nature, and development and governance processes.

As mentioned previously in this introductory chapter, geographers have been drawing on STS concepts, such as actor-networks (Latour 2005), to examine the ways that that heterogeneous knowledge is produced and legitimated. Central to this approach is the assumption that knowledge of nature is imbued with the biases of the knower(s) (Castree 2001). This research is not, however, the first to investigate the veracity of knowledge about the environment. Harvey (1974) was one of the first to illustrate the biases of supposedly neutral scientific knowledge by challenging neo-Malthusian arguments that predicted the immanent global shortage of resources because of rapid population growth, particularly in developing areas. He showed that there was actually no shortage of resources, but only an uneven distribution of resources, which were controlled by western nations. This work showed how supposedly scientific knowledges were ideologically motivated to hide the truth and serve particular interests (class, race, gender or colonialism). More recently, research has drawn on post-structuralist theories
(Foucault 1994, 2000) to show how all claims regarding nature are discursively mediated, questioning whether objective truth exists at all, but showing nonetheless that specific ecological outcomes can be connected to particular representations of the environment and to development policies (Braun 2005; Fairhead and Leach 1996; Fairhead and Leach 2003; Forsyth 1996; Leach and Mearns 1996; Robbins 2001; Robbins 2006; Willems-Braun 1997). The truthfulness of any discourse about nature becomes a question of struggles within social power relations, which have material outcomes.

The specific relationships between the spread of resource technologies, the production and contestation of environmental knowledges, the institutionalization of those knowledges and how these processes impact social differentiation and governance strategies, have not been adequately explored. More precisely, the rift(s) between local environmental knowledge and technical expertise has immense potential for fruitful inquiry in this regard and is central to concerns of political ecology. Bolton (2006), for instance, has connected neo-liberal reforms in Bolivia that encouraged llama herders to produce animal products suitable for global markets to the state introduction of new forms of expertise. The state did this through the introduction of scientifically trained livestock management experts, who worked through NGOs to ‘build capacity’ in peasant herders that would allow them to produce more and better llama products (i.e. reduce resource scarcity). In doing so, he highlighted the rifts between these experts, who wanted to “improve” herd diversity by hybridizing the herd in question with herds located elsewhere, and local herders’ who conceived that herd improvements could be derived from breeding within their existing herds to improve the “unity” of groups within
their herds. Following Mitchell (2002), this set into motion a “new politics based on technical expertise” that “represented a concentration and reorganization of knowledge rather than an introduction of expertise where none had been before” (p. 41).

Moreover, the interaction of these knowledges produces new forms of social differentiation and conflicts over which knowledges become institutionalized. As Harvey (1996) explains, the evolution of institutions involves diverse modes of competition, adaptation, cooperation, and environmental transformation that are intertwined but that vary greatly, and so are “a source of contradiction, tension, and conflict, sparking intense struggles for stability, hegemony, and control” (p. 191). Understanding the interaction of and conflicts between heterogeneous knowledges set into motion through the spread of new scarcity-reducing technologies, therefore, are central to understanding the adaptations to these changes through the creation of new social institutions. There is a general disconnect in the literature, however, between technology adoption, social institution formation, and socio-ecological change, and it is this which this dissertation seeks to remedy.

Furthermore, the way in which studies of knowledge/power, social institutions and the spread of technology inform the decentralized resource governance strategies of the state have yet to be adequately explored, particularly in the context of water. There are a few exceptions, however, that examine the role of knowledge and subjectivity in state decentralized resource governance. Agrawal (2005), for instance, examined the decentralization of forest regulation in India through a framework he pioneered called ‘environmentality’. Environmentality is a combination of environmentalism and
Foucault’s governmentality (1991). It is a method for examining the “creation of
governmentalized localities, institutional politics within regulatory communities, and the
making of environmental subjects” by the state to promote the state’s goals in the
regulation of natural resources (Agrawal 2005, p. 20). Moreover, it is a way of
understanding the effects and functions of the decentralization of environmental
governance by looking to “knowledges, politics, institutions, and subjectivities that come
to be linked together with the emergence of the environment as a domain that requires

But this research does not investigate the means through which people alter their
own political ecologies through the adoption of technologies. This dissertation, by
examining the nexus between nature, society and technology, contributes to the field of
political ecology in ways that political ecology has yet to do. It extends traditional
political ecological concerns with access to and control over resources through an
examination of groundwater socio-ecologies, while at the same time contributing to new
theoretical advances, which draw on STS approaches, in the co-production of social
institutions and ecological change, and the hybridization and contestation of
environmental knowledge within new governance frameworks.
CHAPTER 2

STUDY AREA, METHODOLOGY AND STRUCTURE OF THE DISSERTATION

This dissertation examines the links between technological and environmental change and social and political institutions, the politics of resource use and control, and the livelihoods of rural producers. It explores the relationship between environmental knowledge, technology adoption, institution formation, capital accumulation, and global ecological change and governance. Specifically, it is an investigation of how resource scarcity-reducing technologies, which are adopted and adapted by producers, technicians, and bureaucrats, set into motion recursive transformations in the landscape, while transforming political ecological processes.

In this regard, this research has three major objectives. First, I want to understand how local and Western-technical environmental knowledge interact and to what consequence. In doing so, I examine the varying degrees to which the historical development of local environmental knowledge has been impacted by and hybridized with exogenous knowledge over particular time periods, such as during colonialism, and through the spread of new technologies, such as tubewell irrigation systems. Central to my concerns with environmental knowledge are the contemporary tensions between local
environmental knowledge and Western-technical knowledge, such as that of state engineers. Second, I want to understand the capacity of these new scarcity-reducing technologies, once adopted, to set into motion a series of political ecological processes. This includes the creation of new social institutions and the disciplining of human action to adapt to the demands and constraints of the technology, recursive land use and groundwater change, and the actual production of scarcity and social differentiation rather than its elimination. Third, I want to understand how the creation and hybridization of new environmental knowledges, social institutions, and ecological change inform the future creation of equitable groundwater governance strategies.

In this chapter, I first introduce the Study Area and the advantages that it offers for this research. Then, I describe the methodology and introduce the data that I employ for the study. Third, I outline the structure of the dissertation before adding some summary comments regarding how as a whole it contributes to theoretical debates in political ecology.

2.1 Study Area: Jaipur District, Rajasthan

In a number of respects, the Study Area near Jaipur, Rajasthan in India is an ideal location for this research (Figure 2.1). It has: 1) a long history of groundwater extraction and development, which allows for an examination of the historical deployment and contemporary persistence of multiple practices and technologies; 2) a recent history of rapid technological change and adaptation to new technology, which allows for the exploration of contemporary technical and socioecological change; and 3) a high degree
of ecological and socio-economic variability; this allows for the investigation of the
differential effects of technology adoption under differing conditions.

The area of this study is administratively known as Jaipur District and is
traditionally known as the Dhundhar Region of Rajasthan (see Figure 1). The state is
divided into 32 administrative units or districts and sub-divided into 236 blocks (tehils).
Jaipur District is a semiarid region of moderately productive, yet spatially uneven,
agricultural land, assuming, that is, the availability of water for irrigation purposes, but
with nitrogen-poor alluvial soils (Singhania and Somani 1992). Situated between the arid
plains of the north and west, and the comparatively humid lowlands of the southeast, it
has moderately good groundwater recharge in years of adequate monsoon rains. Summer
temperatures commonly reach 44 degrees Celsius. The district receives, on average,
between 500 and 600 mm of rainfall per year mostly between June and September.
Rainfall is sporadic, however, with some years receiving much less. There are two
cropping seasons: the *khariph* (summer) crop, which is cultivated from July to October
(i.e., during the rainy season), and the *rabi* (winter) crop, which is cultivated between
October and March. The main *khariph* crops are millet, peanuts, sesame, multiple
varieties of legumes, spices, vegetables (for those that can grow them), and some fodder
crops; while the main *rabi* crops are wheat, barley, fodder crops and some vegetables.
The *rabi* crop is fully dependent on irrigation while the *khariph* crop relies on monsoon
rains, although those with the capability will irrigate the *khariph* as well. Summer
(*khariph*) vegetables, for example, require irrigation. The *rabi* crop, therefore, can only
be produced by those households with access to irrigation. Jaipur district is also heavily
endowed with porous limestone and soap stone, which are good sinks for groundwater, but the geology is also interspersed with numerous minerals, such as granite, making groundwater unevenly distributed even in small geographic areas.

Figure 2.1: Rajasthan, with Study Area.
2.1.1 Detailed Study Areas: Bassi Tehsil – Rajasthan

This research was conducted in three village clusters of Bassi Tehsil within Jaipur District. The town of Bassi is the administrative seat. There are three Study Areas, distinguished between three village areas. The Areas were chosen, first, for their social and ecological (in terms of groundwater) heterogeneity; and second, for their close proximity to Jaipur. The latter allows for the longitudinal investigation of the effect of urbanization on socioecologies and livelihood strategies of formerly rural areas, and this is of future research interest.

The Study Areas are located in a southeast to northwest fashion from One to Three. There is a crag offshoot from the Aravalli Mountain range, near which Study Area Three is located (see Figure 2.2). With greater distance from the crag, the soil becomes more alluvial and increasingly rich, while the potential for groundwater recharge increases. Study Area One is the furthest away from the crag and has the best groundwater and soil, whereas Area Three has the lowest quality. Area Three is the most accessible site, located near a paved road and dotted with brick kilns. Area One is the least accessible, located nearly five kilometers from the main road and is only reachable by a winding and poorly maintained road made of sand and gravel, yet many market crops are grown there. Area Two is adjacent to a poorly maintained paved road and is two-five kilometers off of the main road. Both Areas One and Two and parts of Area Three are accessible only by tractor or by foot during the monsoon rains. Figures 2.3 to 2.7 are photos which describe the overall Study Area.
Figure 2.2: Detailed map of the Study Areas.
Figure 2.3: Pre-monsoon field, divided into quadrants for future irrigation.
Figure 2.4: Pipe from a tubewell feeding an irrigation channel for the summer crop in the absence of monsoon rains.
Figure 2.5: Winter peas, intensively irrigated with sprinklers.

Figure 2.6: Summer pearl millet, with school in the distance.
General household composition, landholdings and production information are displayed in Table 2.1. The survey sample is generally representative in terms of caste and class (as indicated by landholdings) as compared to Census data (Directorate of Census Operations 2001). Study Area One is composed of predominately General Castes, relatively high agricultural incomes and landholdings, and little off-farm income. With smaller family sizes, on average, compared to the other two Study Areas they have higher per capita income. It is also characterized by good overall groundwater recharge and quality, enabling these farmers to grow a variety of crops, including vegetables, fodder
crops, and other market crops, such as wheat. Study Area Two is also composed predominately of General Castes, relatively high agricultural and livestock incomes, but large off-farm incomes and larger landholdings. This area is typified by moderate groundwater recharge but the groundwater is more saline that in Study Area One. This still enables the growing of vegetables and the other crops listed previously, but there is more spatial variation. Some farmers are growing mostly vegetables, while others are growing none. Study Area Three is composed predominately of Scheduled Castes, relatively low agricultural incomes and high off-farm incomes. Their overall incomes are still quite low, even though they are engaged to a high degree in off-farm labor. The groundwater in this area is declining rapidly, which accounts for their focus on fodder crop production rather than more water intensive market crops, such as vegetables or spices. Moreover, the groundwater is largely saline, which also inhibits the cultivation of markets crops. Farmers in Study Area Three, therefore, mostly grow fodder crops to feed their livestock and engage in off-farm employment to buy household food and supplies. Furthermore, farmers in Study Area Two have much larger landholdings than in either of the other two Study Areas, which is reflected in their higher agricultural and livestock incomes.
I also chose the Areas because of their proximity to Jaipur. Jaipur is Rajasthan’s capital and major urban center. The Study Areas are about thirty-five kilometers from the edge of Jaipur’s incorporated area off of Agra Road\(^1\). And nearly equidistant between Jaipur and the Study Areas, the Jaipur Development Authority has been buying up land for a film park and other planned developments. As Jaipur expands, the city is likely to encroach on these villages. This opens up the possibility for future longitudinal research opportunities into peri-urban agricultural areas and agrarian change, which I intend to pursue.

\(^1\) For several kilometers, however, the road winds its way through the Aravalli Hills. Therefore, actual planar distance between the current edge of Jaipur and the Study Areas is less than 20 kilometers. Distances in Rajasthan are relative, however; they depend on the quality of the road and whether it is heavily used by herders and / or camel drivers.
Table 2.1: Study Area social make-up, average landholdings and average income, with source.
(Income in rupees. 45 rps = $1)

Table 2.2 further compares the surveys stratified by Study Area. It indicates the general groundwater situation and typical crops grown. As mentioned previously overall groundwater quality and recharge, and soil quality decrease from Area One to Area Three. Although groundwater quality and land productivity vary in Area Two, some farms are highly productive, focusing on lucrative vegetables. While in Area Three, neither the groundwater nor the land will support vegetable production.

Table 2.2: General water situation and cropping patterns in Study Areas.
But stratifying the surveys by Study Area, homogenizes much diversity such as that between castes. The research area is actually more differentiated than indicated by the Study Area comparison. For instance, in Study Area Two there is considerable inter-caste variation in landholdings and agricultural incomes, whereby General Castes have larger landholdings and higher agricultural incomes than Scheduled Castes. This is typical of Rajasthan. The unevenness in landholdings is indicated by Table 2.3. This differentiation also bears itself out when looking at the discrepancies in income from various sources between Scheduled and General Castes as indicated in Table 2.4. Total monthly income is 2222 and 2761 rupees for Scheduled and General Castes respectively, while average landholdings are 1.38 and 2.16 ha. However, off-farm average monthly income is much higher at rupees 1014 for Scheduled Castes and 694 for General, indicating that Scheduled Castes must seek off-farm sources to supplement their agricultural and livestock incomes.

<table>
<thead>
<tr>
<th>Land Category (hectares)</th>
<th>Scheduled Caste</th>
<th>General Caste</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25 - .50</td>
<td>9.2%</td>
<td>5.8%</td>
</tr>
<tr>
<td>0.51 – 1.0</td>
<td>41.5%</td>
<td>27.9%</td>
</tr>
<tr>
<td>1.10 – 2.5</td>
<td>38.5%</td>
<td>32.6%</td>
</tr>
<tr>
<td>2.51 – 3.9</td>
<td>6.2%</td>
<td>20.9%</td>
</tr>
<tr>
<td>4.00 – 7.5</td>
<td>4.6%</td>
<td>12.8%</td>
</tr>
</tbody>
</table>

Table 2.3: Landholdings size by caste in Study Area.

SC: 54 Meena, 8 Bairwa, 3 Yadan (65 total)
General: 80 Sharma, 4 Jat, 2 Gujar (86 total)
(n=151)
Table 2.4: Differential incomes and landholdings by caste. 
\( (n = 151) \) (Average monthly income in rupees, 45 rupees = $1)

<table>
<thead>
<tr>
<th>Caste</th>
<th>Agricultural Income</th>
<th>Livestock Income</th>
<th>Off-farm Income</th>
<th>Total Income</th>
<th>Average Land Held in Hectares</th>
</tr>
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<tr>
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<td>Gen</td>
<td>1316</td>
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<td>694</td>
<td>2761</td>
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</tbody>
</table>

The Study Areas, therefore, represent the highly stratified socioecological environment that is typical of Rajasthan. These characteristics make the Study Area a desirable place from the standpoint of examining the three main questions motivating this research: 1) How do differing (local and technical) groundwater knowledges interact and to what effect; 2) how does tubewell adoption influence land use patterns, scarcity, and adaptation of water use for differing groups; and 3) what does this mean for effective resource governance strategies? To investigate these questions, I employ an intensive research methodology, which allows me to examine these questions both quantitatively and qualitatively. It is to the research methodology that I now turn.

2.2 Methodology

2.2.1 Pre-Dissertation Research & Methods

I first went to India and what would later become the general area of my Study Areas in the winter of 2002. Funded by Ohio State’s Office of International Affairs and the Department of Geography, I spent nearly seven weeks in Rajasthan that winter...
exploring, doing preliminary research into water issues and determining whether I wanted to do my dissertation research in India. I decided that I did and spent the following summer studying Hindi at the University of Wisconsin-Madison’s summer intensive Hindi-Urdu program with funding from Foreign Language and Area Studies (FLAS) and the Center for Institutional Cooperation (CIC). With some Hindi training, I returned for three months during summer 2003 with funding from Ohio State’s Mershon Center and again from the Department of Geography to form dissertation research questions, choose Study Areas and further my Hindi language skills.

During those three months I first obtained and analyzed secondary data from the Indian Census and Rajasthan Directorate of Economics and Statistics to get a general sense of the Study Areas. Second, I established contacts at the Government of Rajasthan and Central Groundwater Boards and the Jaipur Public Health Engineering Department (PHED). I later interviewed two supervisory engineers at each of the two Groundwater Boards and found them to be very resistant to substantive discussions of groundwater issues. They gave me data on groundwater levels and the structure of the organization, however, and these visits helped pave the way for future, more substantive, interviews during my dissertation research. After meeting with the PHED engineer it became apparent to me that they were responsible for urban water development and not yet involved with rural water and not relevant for the present research. Third I interviewed five tubewell drilling firms in and around Jaipur where I gained an understanding of their expertise, drilling methods and history of technological adaptations. They also offered much insight into the spatial distribution of groundwater reserves in the area.
After reviewing the census data and interviewing the tubewell drilling firms and to a lesser degree the government engineers, I gained a general sense of the socio-ecology of the area. This allowed me to perform an informed preliminary investigation of potential Study Areas around Jaipur District. I conducted multiple semi-structured interviews with thirty-three farmers during this time. This research exposed multiple and competing forms of groundwater knowledge, multiple informal institutions that result from these competing forms of knowledge and ecological conditions, and unexpected outcomes of tubewell adoption such as new patterns of capital accumulation, social differentiation and ecological change. This previous work allowed me to form more precise dissertation questions, while positioning me to apply for funding for the present research.

2.2.2 Dissertation Research Methods

In January of 2005 I returned to Rajasthan for thirteen months on a Fulbright-Hays Doctoral Dissertation Research Abroad (DDRA) fellowship. My research methodology for this research had four aspects: 1) secondary and GIS data analysis; 2) archival research; 3) household surveys; and 4) structured and semi-structured interviews with land managers, bureaucrats, tubewell drilling firms, Indian development experts, and local Hindu water experts.

2.2.2.1 Secondary Data Analysis

I analyzed district-level secondary data from Rajasthan’s Directorate of Economics and Statistics to understand the relationship between the change in
landholding size and number of landholdings, the change in irrigated area and in the different sources of irrigation (such as from canals, tanks\textsuperscript{2}, or tubewells) and the change in tubewell adoption. I started with this because as I initiated my research it wasn’t clear if, for example landholding size was decreasing, increasing or staying the same, what direction tubewell construction was taking or what was happening to area under irrigation. First, I mapped out the relationships between the change in landholding size, tubewell adoption and tubewell irrigated area over the five-year period from 1995 to 2000. I found that landholdings are getting smaller on average, while tubewell adoption and tubewell irrigated area are both increasing. I found a statistically significant relationship between these three variables. It is, moreover, the most marginal producers who are adopting the most tubewells (intensification) and expanding irrigated area (extensification) rather than the largest producers.

\subsection{2.2.2.2 Archival Research}

I performed archival research at the State of Rajasthan Archives in Bikaner, Rajasthan and at the National Archives in Delhi in an attempt to understand the historical relationship between the farmers and the state as mediated through groundwater irrigation schemes, technologies and groundwater regulation. I thought that archival research would also shed light onto the various state efforts towards land reform and redistribution, which would have an impact on technology adoption and socioecological differentiation.

These data consisted primarily of government reports especially during the colonial period, reports from private-sector contractors, many of whom were again

\footnote{On the Indian sub-continent, “tank” refers to a water reservoir that has been artificially constructed, but designed to take advantage of depressions in the landscape not made by humans.}
operating during the colonial period, and regulatory documents. There were also some materials that were based on Indian scholarship, many of which were out-of-print books. The materials, however, were divided between the State Archives in Bikaner and the National Archives in Delhi. In other words, the materials did not overlap at least from the perspective of the researcher, who has limited access to these sources. It was likely that many materials were not catalogued properly or at all, which was an obvious hindrance. Next I detail the conditions of research and specific materials available in each Archive.

Bikaner is located in northwestern Rajasthan on the fringe of the Great Thar Desert. The climate is hot and dry, maintaining temperatures of over 40 degrees Celsius for weeks at a time in the summer. This makes it extremely dusty, therefore, with piles of sand lining the streets. The visibility at night is zero when the smoke from the fires of street dwellers and the auto-rickshaws mixes with the dust in the air. Chest and sinus infections are common. The streets are surrounded by above ground open sewers, some of which are held back by one meter high concrete walls, which are particularly common around the archives. The strange juxtaposition of aromas is unforgettable: chai vendors, sweet and curry shops on the one hand and sewage on the other, always in competition. The Archives are located just beyond this, on the northwestern edge of the city where there is a joint project with the Bikaner Public Health Engineering Department (PHED) and the Asian Development Bank (ADB) to build sewage treatment plants and to bring water to the city. The roads to the Archives were passable only by foot. Currently the city is served water from the Indira Gandhi Canal, which begins in the Punjab and delivers saline water in insufficient quantities to this dusty city.
In the summer, in particular, rolling power outages were the standard. I spent fifteen days total at the Bikaner Archives over a two month period between July and August, two of the hottest months. The non-air-conditioned Archives opened daily at 10:30. The first power outage occurred from 11:00 am to 1:00 pm. The staff left at 1:00 pm for their one and one-half hour lunch. The next power outage typically occurred between 3:30 and 4:00 pm and lasted past closing, which was at 5:00 pm. This left about two hours per day for research under artificial light and fans, in a building that was poorly served with windows.

Moving past these obstacles, the conditions of research at the Bikaner Archives were actually quite good. I showed up the first day with letters of introduction from the United States Education Foundation in India (USEFI), the Indian administrators of Fulbright, and my research affiliation in Jodhpur, the School of Desert Sciences, and with my Government of India research permit (with another letter of introduction) and Foreign Registration permit. After a few hours of questioning, the working of the Archives was explained to me. There was not an index or a card catalog. I would be permitted to browse the shelves, while under supervision, and collect up to three items per browsing session (not per day). Then I had to get approval for these items and formally check them out. Next, I took them to the reading room where they were to be checked in again. I was allowed to read the materials and take notes and put in requests for photo-copying, which would be performed on the following business day. No computers were allowed. Over time I ingratiated myself to the staff, who were remarkably amicable and understanding,
and was eventually allowed to browse the shelves without supervision and to take out more than three materials at one time\(^3\).

The Bikaner Archives have a vast collection and for the purposes of my research contained reports from the Indian Irrigation Commission under the British administration, District Gazetteers, which began under the British but continued into the 1980s, and a few books on land reform. Almost all of the British administrative documents pertaining to Rajasthan are in the Bikaner Archives, as opposed to the National Archives.

Most post independence documents are located in the National Archives, which is in Delhi. I found very little here to inform my work and the administrative hurdles were far greater. The card catalogs were poorly maintained and access to documents and books were strictly restricted, making it difficult to get very far. I spent several days here, yet came away with very little. A strict three item checkout limit was adhered to, as was the set time for document retrieval and dispersal. Retrieval orders had to be placed before 11:00 am and were delivered after 1:00 pm. The other document retrieval time was at 1:00 pm for a 2:30 delivery. The juxtaposition of the two timings made it difficult to utilize more than one retrieval window in any given day.

There is also a National Archives office in Jaipur but they informed me that they did not have anything of interest to me and sent me on my way. And that furthermore, their collection was not organized in a manner that I could manually search it as they had not the staff to maintain a card catalog (even though there was staff sleeping in multiple locations during each visit). I returned on two additional occasions, but never went

\(^3\) I still had to perform the cumbersome procedure of signing in and out materials multiple times for each piece. But part of the Archives funding and justification for being hinges on the volume of their circulation so I was happy to do it.
beyond chai tea with the director. The Bikaner Archives were very helpful, though and I would highly recommend them.

2.2.2.3 Farmer Surveys

For farmer surveys, I hired two research assistants through a contact at an academic development institute in Jaipur. We conducted surveys of farmers to collect both household production information and also detailed information on their wells. I employed an ‘every third household’ sampling technique. This method worked well for the most part, although on three or four separate occasions I discovered that we had sampled brothers who shared a tubewell. Once I realized that the sample contained partners of the same tubewell, which would skew statistical analyses, these surveys were discarded. We originally conducted 170 surveys, but nineteen were subsequently eliminated from the analyses because of this internal-collinearity⁴.

The farmer survey format is located in the Appendix. The survey detailed: household composition; landholdings; capital assets; amount and source of income; household and agricultural expenses; debt; crops grown and proportion irrigated by season; agricultural inputs; labor hired in; and more open-ended questions on their attitudes towards the groundwater problem and future solutions. The survey also queried detailed well information: date of construction; depth; type of well; horsepower of pump; installation costs; and whether the well required a loan. I tried to administer the survey

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⁴ I had originally intended to collect at least 180 surveys, which would have included thirty surveys of each caste category in each Study Area. This would have allowed a statistical analysis of inter and intra Study Area variation across caste and class. But due to multiple difficulties (and the eventual elimination of several surveys due to collinearity bias), I settled with 151. This still allowed for the statistical analysis of the data stratified by caste and class. Furthermore, I found caste and class to be sound predictors of particular viewpoints when conducting the interviews, with some variation of course, which didn’t seem to be caused by neighborhood effects.
questionnaires in homes and/or fields, thus trying to avoid public settings. But even these settings often would become public when neighbors and passersby would see an outsider present (especially one as tall and as fair as me!). The one real negative impact this had on the surveys was that respondents became hesitant to give debt information, not wanting their neighbors and colleagues to know how badly in debt they were in. Not collecting accurate debt information is the one great regret that I have with my research. I have six respondents that I feel accurately conveyed their debt information to me and it was staggering. This finding is not written up in subsequent chapters, but I hope to do something with it in the future.

2.2.2.4 Structured and Semi-Structured Interviews

I performed interviews with a sub-set of the survey respondents, and also with, government engineers and hydrologists, tubewell drilling firms, and Hindu groundwater experts (Sunghas). I interviewed farmers at their homes, in their fields, and also in more public settings, such as chai shops or central public spaces. I would often meet with the same farmer on multiple occasions. I found that asking them for more than an hour of their time at any one setting, would begin to irritate them or make them anxious. Moreover, returning for another interview would allow me to review my notes and reformulate my questions for them, while allowing them to think about our previous conversations as well.

I spent on average one day per week with government engineers and hydrologists of varying levels in the bureaucratic hierarchy. I first met with these bureaucrats during my pre-dissertation trip in 2003. They were very cold then and were even a little hesitant
to talk with me initially in 2005. But after a few visits, they became increasingly at ease with my presence. While it was always difficult to get them to discuss substantive issues, I could usually glean tidbits in their conversations between themselves or with me directly, in between their attempts to expand my Hindi with colorful adjectives. Moreover, I arranged several ‘field trips’ to accompany hydrologists making their rounds of the monitoring wells. These plans always seemed to fall through at the last minute due to changes in their daily programs, which may or may not have been manufactured.

In 2003, I also met several tubewell drilling firms that I followed up with in 2005. I interviewed them in various settings from their offices in Jaipur, their storage and fabrication facilities outside of Jaipur, and in actual field areas. Finally, I sat with aged Hindu Sunghas in an attempt to understand their methods for determining well placement and construction timing. They would share their conclusions but not their methods for arriving at those conclusions. They were fearful that I wanted to commodify their techniques. But nonetheless, they were very informative about traditional groundwater location practices and the power that belief has, even in the absence of results.

2.3 Structure of the Dissertation

This dissertation is organized into three further chapters. Chapters Three through Five are stand-alone chapters, which investigate the three broad research questions posed in this introduction.
2.3.1 Chapter 3: Politics of Nature: Environmental Knowledge and Expertise

In Chapter Three I attempt to shed light on the politics of nature by illustrating how science, society and environmental knowledge practices are co-evolving. In this chapter, I draw mainly on Scott (1998), Corbridge (2005) and Mitchell (2002) to examine three questions: 1) how do differing (local and technical) groundwater knowledges interact and to what effect; 2) where does groundwater expertise come from; and 3) how do the state and its subjects view each other and their knowledges?

I analyze pre-colonial, colonial, and post-independence groundwater and irrigation knowledge and technologies to, first, show how hierarchies of knowledge and expertise are reproduced through the state, whether it is the colonial administration, Scott’s (1998) high-modern development state or the postmodern development state. Then, I show that multiple and disparate forms of knowledge and expertise have co-evolved along with the proliferation of the tubewell since the late 1960s. In doing so, I show first the continuities between knowledge and technologies through these dominant periods; then second, I show how and why it is still important to query how the state interacts with and sees its objects of development, as even in the so-called postmodern development state local expertise continues to be dismissed.

2.3.2 Chapter 4: Resource Scarcity, Non-human Capacity and Adaptive Institutions

In Chapter Four, I draw on recent advances in political ecology and science and technology studies (STS), including Latour’s concept of hybridity, to examine the tubewell’s capacity to mediate socio-environmental change. The concept of hybridity
(Latour 1993) attempts to break down the binaries of nature/society, structure/agency to show how these reductionist categories have never existed but that things or ‘quasi-objects’ are both social and natural: socionature. The strength in this approach is that it opens up the associations between heterogeneous objects to displace the stabilities between them, while showing that the “competencies and capacities of ‘things’ are not intrinsic but derive from association” (Whatmore 2002, cited in Bakker and Bridge 2006).

This approach calls for a decentering of agency away from being solely a human capacity to allow for the interrogation of the capabilities of non-human objects (tubewells or groundwater) in shaping socio-environmental change. With this in mind, I raise three questions in this chapter: 1) how does tubewell adoption influence land use patterns, water scarcity and adaptation of water use for different communities at both the individual and social-institutional levels; 2) what kind of natures do these interactions and associated adaptations produce; and 3) in a broad sense, how do objects (in this case tubewells) in virtue of their particular requirements discipline the subject (farmers) and to what effect for nature-society-technology processes?

Analyzing survey and interview data, I show how the ability to harness the productivity capacity of the tubewell varies by community (i.e. caste), and by landholdings (indicative of class). Scheduled Castes are still able to adopt tubewells, however, through the creation of new social institutions of cooperation. This still does not lead to equality in access, though, because the sharing of one tubewell by multiple farmers limits its overall availability and the amount of irrigation available to each
partner. This conditions the production of particular crops. For instance, the data show that through tubewell adoption General Castes are able to produce lucrative crops such as vegetables, which are heavily dependent on irrigation, while Scheduled Castes produce more fodder crops, which are less dependent on irrigation. Thus even though Scheduled Castes have gained access to irrigation by dividing the costs of construction through partners, there is still relative scarcity within the partnerships. The expansion of irrigation has also recursively changed groundwater quantity and quality, which has further impacted the types of crops that can be grown leading to political ecological differentiation. The adoption of tubewells has consequences which enable and constrain future production decisions and ecological transformation. At different moments in the economic process, therefore, the tubewell has different capacities to effect its associations, and bring about socioecological and political change, while also enabling and constraining the daily activities of tubewell users. The ultimate result is the recursive remaking of human and non-human nature in an overall process that is socio-natural.

2.3.3 Chapter 5: ‘Environmentality’ and Environmental Subject-making in Groundwater Conservation

In Chapter Five, I draw on Agrawal’s conceptual framework of ‘environmentality’ (2005) to examine the decentralization of environmental governance in India. The more precise goal is to exemplify how environmentally aware subjects – i.e. ‘environmental subjects’ – are actively produced by the state, how the state and its subjects understand each other, and what this means for the future creation of formal groundwater management institutions. This chapter focuses on three distinct questions: 1)
how and why does the state produce environmental subjects and what are the tensions in this process; 2) how does looking to divergent state and local environmental knowledges inform this process; and 3) what does this mean for the future efficacy of decentralized environmental regulation?

Environmentality is a combination of environmentalism and Foucault’s governmentality (1991). It is a method for examining the “creation of governmentalized localities, institutional politics within regulatory communities, and the making of environmental subjects” (Agrawal 2005, p. 20). Moreover, it is a way of understanding the effects and functions of the decentralization of environmental governance by looking to “knowledges, politics, institutions, and subjectivities that come to be linked together with the emergence of the environment as a domain that requires regulation and protection” (Agrawal 2005, p. 226).

In this chapter, I analyze interviews with farmers, government engineers, local Hindu water experts and government efforts to create groundwater regulation to understand the relationship between the political tensions of groundwater decline, future conservation strategies, and the making of environmental subjects. In doing so, I demonstrate, that the proposed regulation is hierarchical in that it does not provide a democratic mechanism. Then, I find that current regulatory efforts do not incorporate locally existing knowledge, practices or institutions of groundwater use, but instead plan to alter the way people currently see groundwater. Finally, I demonstrate that the likely implications of this failure – impediments to the future creation of effective groundwater
governance strategies – are highlighted by divergences between local and state groundwater knowledge in deep tubewell construction.
CHAPTER 3

CONTESTING EXPERTISE: THE POLITICS OF ENVIRONMENTAL KNOWLEDGE IN NORTHERN INDIAN GROUNDWATER PRACTICES

3.1 Introduction

Central to the politics of nature is the question of environmental knowledge, of how it is produced, contested and legitimated. The production of environmental knowledge and various forms of expertise are also central to the question of development. Nearly a decade ago, James Scott (1998) posed the question – “why have so many well intended schemes to improve the human condition gone so tragically awry?” A significant part of Scott’s overall explanation was that states failed to take into account local knowledge, while at the same time having a blind faith in scientific and technological progress.

Scott’s original question has been furthered by asking: “what do these schemes do; what are their messy, contradictory, conjunctural effects” (Li 2005)? Important to these questions is an understanding that expertise comes not only from the state but also from the legions of nongovernmental organizations, development institutes, donor agencies and private firms (on firms see Ferguson 2005). While he has been criticized for his singular focus on the state and state expertise, Scott’s work continues to draw critical

Central to Scott’s account was the high-modernist state’s positivist technocrat, who dismissed local knowledge (which Scott termed métis) as unscientific. Since his account, and after nearly a decade of various forms of participatory development schemes, such as Joint Forest Management (JFM), Participatory Rural Appraisal (PRA), or World Bank/IMF-sponsored Poverty Reduction Strategy Papers (PRSPs) that sought to rectify this oversight, participatory development has taken center stage under a so-called postmodern development state (Escobar 1995; Ferguson 1999; Li 2005; Sivaramakrishnan 2005). The fabled technocrat is no longer strictly a positivist (Wilson 2006, p. 509); s/he is engaged in integrating the particularity of local knowledge practices and socio-ecologies into development schemes. But are these new, post-technocrats really taking local knowledge seriously or are they equally dismissive of local environmental and/or agricultural praxis, even while representing themselves as understanding its importance? If so why? In other words, does the state still “see like a state”, but with a more powerful lens, a lens that could underpin the more complete subjectification of its objects of development? Who is the postmodern development state? And, in an inversion of Scott’s original question: how do people see the state (Corbridge et al. 2005)? The interaction and potential tensions between local and technocratic expertise (broadly defined) is still an open question.

Recent efforts, drawing on post-structuralist thought and Science and Technology Studies (STS) approaches have called for a more nuanced understanding of the
interaction and historical contingency of various knowledge claims (and the practices of knowledge) on the subject of nature and how these questions inform equitable governance strategies (Escobar 1999; Kaika and Swyngedouw 2000; Peet and Watts 2004; Robbins 2001). While much research of this kind has focused on forest management (Agrawal 2005; Klooster 2002; Robbins 2000, 2003; Sivaramakrishnan 2000), conservation areas (Bryant 2000; Fairhead and Leach 2003; Hunn et al. 2003; West 2006), or biodiversity (e.g. bioprospecting or ethnobotany) (see Rosenthal 2006 for a review), there have been fewer critical examinations of local and technical expertise in agro-ecology (but see Armitage 2003; Dove 2003; Morris 2006). During the same period, other work has focused on the continuity between the ‘techno-politics’ of the colonial, the modern and postmodern development state (Bolton 2006; Mitchell 2002). But none have focused expressly on the tensions between local and expert knowledge practices of water use and its management, particularly regarding groundwater.

Groundwater is heavily exploited throughout the world and understanding the knowledges that inform its utilization is paramount in its future effective development. The importance for this research then stems from the water crisis that much of the world is facing. According to the United Nations, groundwater use for irrigation by the world’s farmers exceeds natural recharge rates by at least 160 billion cubic meters per year so that by 2025, 50% of the world’s population will face water scarcity (Rosegrant, Cai et al. 2002). In India, groundwater meets 70% of the country’s irrigation needs and 80% of its domestic water supplies and its demand is expected to exceed supply by 2020 (World Bank 2005). This is of particular concern in the state of Rajasthan, where groundwater
extraction currently surpasses recharge in the state by 409.65 million cubic meters per year, resulting in drastically falling groundwater levels (Directorate of Economics and Statistics 2003; Government of Rajasthan Groundwater Board 2003). This has prompted recent calls by the state and development donor agencies for the creation of formal groundwater regulation, where none exists today. The successful implementation of groundwater regulation hinges on the interaction between the crafters and enforcers of the regulation and groundwater users. Examining the interaction of existing local and state forms of knowledge of groundwater and irrigation is a useful starting point, therefore.

In northern India, groundwater continues to be utilized for agricultural and domestic purposes after centuries of adaptation of lifting techniques. So too, along with these adaptations has been the development, in various forms, of knowledge of water and water related technologies, including those originating from local, colonial, state and development sources. The questions become: 1) how do differing (local and technical) groundwater knowledges interact and to what effect; 2) where does groundwater expertise come from; how is it reworked and displaced through time; and 3) how do these processes and the specific character of the resource, inform the ways that the state and its subjects view each other’s knowledge? These three questions continue to resonate within both the politics of nature and development literature, while also informing the question of groundwater development and its future management.

This chapter attempts to shed light on the politics of nature by illustrating how science, society and environmental knowledge practices are co-evolving. In this chapter, I analyze pre-colonial, colonial, and post-independence groundwater and irrigation
knowledge and technologies to, first, show how hierarchies of knowledge and expertise are reproduced through the state, whether it is the colonial administration, Scott’s hi-modern development state or the postmodern development state. In doing so, I show the continuities between knowledge and technologies through these different periods. Second, by drawing on the research outlined above, I show how and why it is still important to query how particular state agencies, in this case those dealing with groundwater, interact with and see its objects of development, as even in the so-called postmodern development state local expertise continues to be dismissed. This finding is in contrast to current theorizations of other state agencies that are responsible for common property resources management, such as forest departments, which have shown these agencies to be internally socially differentiated, integrated with local people and porous. The basis for my argument, in this regard, is that the nature of groundwater is different from other common pool resources. Forests can be re-grown, contested, encroached upon, bought, and sold in a way that groundwater cannot. The character of the resource then, influences the bureaucratic conditions of its management.

In Rajasthan, groundwater is a very hot button issue between farmers who need access to groundwater for irrigation and the state who recognizes a looming groundwater shortage. State groundwater agencies are caught in the middle, causing them to keep a low profile, under political, economic and ecological conditions over which they have little power. Therefore, it is the unique character of this particular common property and the political struggles over it, which feeds into what groundwater related agencies can and cannot do, and ultimately in they way that they interact with the state's subjects. This
is not to argue, however, that the state is all the same only that this particular part of the state acts differently than other agencies, such as the forest department.

Third, I show that due to divergent epistemologies of knowledge production between farmers and state groundwater experts, the fraught history that farmers have with the state, and the political predicament facing groundwater agencies, there is a lack of government visibility causing a general distrust of the state as it has come to be embodied in various state groundwater experts. These tensions will undoubtedly negatively impact future groundwater governance strategies.

This Chapter is further divided into six sections. In the first section I outline Scott’s 1998 work and situate it in relation to Corbridge et al. 2005. Then, I show how both of these works can be further understood in terms of Mitchell’s (2002) understanding of knowledge and technology in the colonial and post-colonial context. In the second section, I introduce my Study Area near Jaipur, Rajasthan, an ideal place to study these processes for reasons that I outline. In the third section, I chart three periods of groundwater use and technology adaptation: pre-colonial, colonial, and post-independence. In doing so, I illustrate the continuities that persist throughout these broad frames of reference. In the fourth section, I attempt to understand just where and how groundwater and lifting technology (e.g. tubewells) expertise is produced. Then, in the fifth section I examine how these knowledges interact between the state, farmers, Hindu groundwater experts and tubewell drilling firms. The final section is a conclusion.
3.2 Rethinking Expert and Local Knowledges

This section sets out the work of Scott (1998), Corbridge (2005) and Mitchell (2002) which informs the questions posed above. The interrelation between these works is defined by their attention to colonial, modern and postmodern development states’ attempts to take existing knowledge practices and incorporate them into their systems of governmentality (Foucault 1991). Following my introduction, according to Scott, grand development schemes failed because the state did not incorporate local knowledge and practices into them. He theorized that this happened because state expertise was embodied in a ‘positivist technocrat’, who viewed development as a technical problem, while discounting the practical experience of the objects of development (e.g. farmers). According to him, the state did this though acts of ‘simplification’, such as creating standardized last names, census taking or installing electrical meters, which rendered people the same and comparable making them easier to control. Furthering this argument, Scott suggested that the state did not incorporate local knowledge purposefully, but tried to actually eliminate it as a ‘precondition’ for its replacement with administrative or scientific ‘order’ (Scott 1998, p. 335-336), which ultimately led to failed development schemes however well intentioned.

More recent work has questioned whether the state’s aim (today) is indeed a ‘simplification’. Li (2005), drawing on Scott and offering a sympathetic critique, argued that rather than a simplification based on the elimination of difference, the state now actually tries to understand difference through the production of particular knowledge (not its elimination or displacement) about its subjects through active participation in
development schemes, for example. So too, the present paper argues that the postmodern
development state attempts to integrate as much local knowledge, understandings and
expertise (what the World Bank terms “social capital”) as is needed for a ‘successful’
project. What is needed then, according to the postmodern development state is,
supposedly, not a simplification of the objects of development, but a better understanding
of them in order to more completely subjectify them. In doing so, however, and parallel
to both Scott’s hi-modernist state and the colonial state, environmental knowledge is
‘displaced’ to new sites, such as within state agencies (Bolton 2006, p. 534; Mitchell
2002, p. 90-93). It becomes resituated within formal expert institutions, such as the
colonial Indian Irrigation Commission or the state’s groundwater boards. The
displacement of knowledge is also a redistribution of knowledge-power.

Moreover, following Li (2005), the state no longer has (nor has ever had) a
monopoly on expertise or governance. She argues that we need “to look beyond ‘the
state’ to the range of parties that attempt to govern”: a role that the state shares, in other
words, with “social reformers, scientists, missionaries, the so-called nongovernmental
agencies, and, in the global south, donor agencies with their teams of expert consultants”
(Li 2005, p. 384). So while Scott’s high-modern state attempted to replace local
knowledge with technocratic knowledge, Li’s postmodern state and other producers of
expertise attempt to incorporate (and even colonize) local knowledge for their own
purposes (for other examples, see Davis 2005; Wilson 2006).

But the ‘success’ of this strategy still depends on a series of encounters that
people have with the state and the differentiated agencies and individuals within it. While
India has more than its share of nongovernmental organizations\(^5\) (which deserve attention), the state continues to be at the frontline of development interventions, perhaps more so than in other developing countries. Corbridge et al (2005), drawing on Foucault (1991) and Rose (1999), described “human technologies of rule” as the knowledges, vocabularies, “non-human objects devices”, and practices of calculation that the state has used to designate particular social groups and bring them into contact with their respective government agencies (p. 49-50). Examining India’s Employment Assurance Scheme, Corbridge et al showed that people had to be conditioned to accept expertise (p. 36), which “presupposes[d] the construction of an individual [who was ready to accept state expertise] that [was] uncommon in [their] field areas,” (p. 152). These efforts were also hindered by local distrust of the state, which was exacerbated by the invisibility of the state at the local level, negatively impacting peoples’ view of it (ibid, p. 169).

Development and post-colonial theorists differ on their assessment of these encounters. Development theorists such as Chambers (1997) argue that participatory development (in particular Participatory Rural Appraisal) can be empowering to the poor and that these projects cannot be carried out without their participation, while others draw parallels between development projects’ recent focus on individual rights and entitlements, and neo-liberal economic theories that stress the same (Corbridge, Williams et al. 2005; Redclift 2005; Reid 2005). Post-colonial theorists, on the other hand, such as Mitchell (2002), Agrawal (2005), Chatterjee (1993), Ferguson (1994) and Escobar (1995) point out the subversive character of development and question its ability to bring about

positive social change, while being immersed in existing power structures and tendencies to depoliticize development.

In Rule of Experts, Mitchell (2002) wrote in reference to the construction of the Aswan dam that it ushered in a “new politics based on technical expertise” that “represented a concentration and reorganization of knowledge rather than an introduction of expertise where none had been before” (p. 41). Specifically, he was referring to the reorganization of existing irrigation knowledge practices through United States’ “technical assistance” programs, but also through a system of classification and social (re)organization that began in the colonial period. But he goes on to note that “existing practice, like the old knowledge of irrigation, involved an expertise that was too widely dispersed to provide a means for building imperial power – or the profits of a Boston consulting firm” (ibid, p. 41). The state seemed to have difficulty in assimilating local knowledge and practices. According to Mitchell, local knowledge resists assimilation because it is too dispersed and situated. But as Agrawal (2005) showed in his study of decentralized governance strategies in Indian forestry, this could lead to the appropriation of local knowledge through decentralized governance strategies that seek to change peoples’ thinking and subjectify them in terms amenable to the state.

Even though we now know the state to be differentiated and the state’s technocrats to not be strictly positivist, the twin questions of how the state sees its subjects and how people see the state are still pertinent. And while expertise comes from multiple locations the state remains a very powerful, if not the most visible, site of expertise in many (developing) contexts.
3.3 Study Area

In a number of respects, Rajasthan is an ideal place in which to study the tensions between local and expert groundwater knowledge practices. First, the area has a long history of groundwater use for irrigation and domestic purposes. Second, these practices were catalogued and systematized during the colonial period. And third, it has a more recent history of rapid expansion of groundwater lifting technologies and associated knowledge practices under a modern and postmodern state.

Research for the present study took place over an 18 month period between the summer of 2003 and the winter of 2006. I surveyed over 150 farmers in six villages of Bassi Tehsil, around 60 kilometers east of Rajasthan’s capital city, Jaipur (see figure 1)⁶. Then, over the next several months I followed up on these surveys with in-depth interviews of over 78 farmers, multiple government technocrats, several tubewell drilling firms and local Hindu water diviners (Sunghas). The villages are socially and ecological diverse, comprising a highly stratified social environment of low and high caste Hindus, small, medium and large landholders, and moderately to rapidly declining groundwater levels in their respective vicinities. Even though we should not take social categories, such as caste and class, to assume difference, they are still important considerations (Jeffrey 2001).

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⁶ Rajasthan is divided into 236 blocks (tehsils), which are contained within 32 administrative districts.
Like much of Rajasthan, the people in this area are groundwater-dependent for their irrigation and domestic needs. There is no government water supply, except for sporadically functioning village hand pumps. All village residents, therefore, rely on tubewells for water. Tubewells tap aquifers of varying depth, volume and recharge capacity. They are based on oil well drilling technology and in northern India typically range from 20-100 meters deep (with test bores in western Rajasthan reaching 400 meters). Most tubewells utilize a submersible centrifugal pump, but historically when the
water table was nearer the surface, surface diesel driven pumps were also used. Diesel pumps are still in use but their efficacy is declining as they are only able to draw groundwater after the monsoon when the water table is sufficiently high. But the proliferation of tubewells is only the latest incarnation of groundwater lifting technology in a long history of technological innovation and adaptation.

3.4 Regimes of Groundwater and Irrigation Use: The Reorganization and Displacement of Groundwater Knowledge and Technologies

In this section, I examine the historical development of groundwater and irrigation knowledge practices. Following Rosin (1993), discrete timeframes are difficult to demarcate, but three broad dominant “timeframes of transformation” (following Mitchell 2002) are useful and defensible: pre-colonial, colonial and post-colonial. As will be shown, institutionalized knowledge practices endure through each of the periods and they interact with new ideas and techniques of doing irrigation in hybrid ways. Moreover the continuities in the state’s treatment of environmental knowledge between these periods are illuminated.

3.4.1 Pre-colonial Practices and Technologies

Throughout northern India groundwater has been utilized for production (irrigation) and reproduction (domestic) activities for centuries. State-mediated

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7 Mitchell (2002) used the term postcolonial not to demarcate time periods, but to “refer to the forms of critical practice that address the significance of colonialism in the formation and practice of social theory. Colonialism, from this perspective, was not incidental to the development of the modern West, nor to the emergence there of new forms of technical expertise, including the modern social sciences” (p. 7). It locates colonialism within the history and practice of science rather than outside it. I agree with Mitchell’s use of the term and therefore use the term “post-independence” to denote the time period since India’s independence in 1947.

groundwater use in the Indian imagination dates back to at least the Arthashashtra, a Hindu treatise on state and economy building (Kautilya 1992). Written no later than 150 AD, the text sets out rules and regulations for the use and taxation of irrigation water. Moreover, groundwater lifting technologies permeated the region over this period. The use of the Persian Wheel, for example, is well documented in northern India since before 900 A.D. and is still in use in the Mewar region of southwestern Rajasthan today, to which this author can testify (see Figure 3.2) (see also Rosin 1993). So too, not only the technology to lift groundwater but also knowledge of groundwater, groundwater based irrigation, groundwater location, its flow and recharge has been in a process of development for centuries. Following Rosin, “residents perceive a direct relationship between their surface water storage facilities and the quality and supply of both soil and groundwater” (Rosin 1993, p. 66). He further noted that numerous villagers referred to the earth as a filter for groundwater, while Kurin explained that water from deep underground tubewells was considered “lighter, purer, and cleaner” than surface water or groundwater from shallow wells because of this filtration (Kurin 1983, cited in Rosin 1993). My own research also bears this out, according to one farmer: “the ground filters the water; we do not need to treat it, therefore. It is better than in the city.” The idea that the earth filters water and the known relationship between surface water and groundwater is an example of local knowledge that continues to be in a process of development.
Throughout (especially western) Rajasthan there continue to be particular castes entirely devoted to groundwater. For example, Munshi Hardyan Singh identified the Beldar caste of Marwar as historically devoted to “digging the earth, quarrying stones, and the like” (Singh 1894, p. 210). The Beldar claim descent from Bhagirat (a Hindu mythical figure with expertise in water), who “vowed never to drink water twice out of the same well, and so dug a fresh one every day till one day he dug down and down, and never came up again” (ibid). In imitation of him, the Beldar are said to bury their dead even though they are Hindu. Myths such as these that deal with groundwater use,
recharge, extraction and management abound today and are very powerful metaphors, which are invoked by farmers and other users of groundwater to make sense of contemporary groundwater issues and technological change (see Gold and Gujar 2002). For instance, several farmers in the Study Area thought it was their duty to provide drinking water to passersby if they had sufficient supply because their own supply was up to the gods and if they failed to share it they would be punished. Others noted that sharing water for drinking was simply the right thing to do. But this only applied to the sharing of drinking water and not to irrigation water, which was seen as not essential and outside of their spiritual and/or moral duty. The duty to supply drinking water to passersby probably dates back to before the colonial period and is rooted in a some sort of moral economy (Scott 1976) or the ‘jajmani system’ of social reciprocity (Commander 1983; Mayer 1993).

### 3.4.2 Colonial Groundwater Practices & Technologies

The colonial reorganization of groundwater use in and around the Study Area really began in the late 1800s when the British introduced the tubewell as a source of “preventative irrigation” (Indian Irrigation Commission 1903, p. 49). The State (of

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8 The British divided irrigated area into areas of “preventative irrigation” and “productive irrigation”. The latter included large, mostly surface water, schemes from which the colonial administration expected to accrue royalties. The former were minor schemes of surface and groundwater into which the administration invested capital, but from which they did not (at first) expect to levy duties, as their sole purpose was to reduce the possibility of drought induced famine (such as those in 1897-1900) Indian Irrigation Commission (1903). Report of the Indian Irrigation Commission, 1901-1903. Part I - General. Calcutta: Office of the Superintendent of Government Printing, India. In this way the British were trying to separate or insulate agricultural productivity from the vagaries of nature. Of course famine was also the result of changing production relations imposed by the British colonial state, much like those identified by Watts Watts, M. (1983). "Hazards and Crises: A Political Economy of Drought and Famine in Northern Nigeria." *Antipode* 15(1): 120-130. in the African Sahel. Therefore, in the first instance the introduction of the
Jaipur) Public Works Department, established in 1860, had a special Irrigation Branch (with a Minor Irrigation Works division that oversaw well construction and repair) which was charged with the development of surface water and groundwater irrigation. The Irrigation Branch was later organized as a separate unit in 1942, after significant expansion in 1867 and again in 1902. According to one report, their director had “been sent to the United States of America for advanced training in agriculture”, while “a highly qualified technical staff [was] maintained” (Jaipur State 1943, p. 52). They had a team of researchers including irrigation experts, economic botanists, agricultural chemists, and even a “locust control officer” to catalog existing local environmental knowledge and improve on it. In the process, existing knowledge was displaced into government agencies, which was then extended back to farmers by expert technicians (e.g. extension agents).

The British were already awed, however, by the degree to which groundwater irrigation was already being practiced, without colonial intervention. The first Indian Irrigation Commission in 1903 was formed to take stock of existing irrigation facilities and produce a plan to develop India’s irrigation potential. In the process, it served to redistribute and destabilize already existing irrigation knowledge practices. The Commission reported that, the large “figures [including total number of wells, area irrigated by wells, and average area irrigated per well] relating to the distribution of well-irrigation are exceedingly striking” throughout northern India (ibid, p. 49). These were the sentiments of colonial administrators (and engineers), who were seeking new avenues.

tubewell was a prescription meant to repair a broader problem of production increasingly motivated towards generating exchange value.
to extract a surplus, while also attempting to reorganize the knowledge practices of irrigation and resituate them in the offices of colonial engineers in order to bring them under colonial control and, to the degree that was required, its subjects as well.

However, neither groundwater nor the knowledge practices of irrigation (Mitchell 2002) lent themselves easily to direct profit through commodification as did state-sponsored surface water systems. The British did look into the possibility of taxing groundwater irrigation, as it did surface water irrigation, but quickly concluded it as untenable owing to the potential difficulty of “superintending” such a large number of wells dispersed over such a vast area. The administrators were also hesitant to interfere in a system that already worked: “there is scarcely a witness who does not agree that the cultivator is able to make wells for himself much more cheaply and quite as effectually for his purposes as Government can make them for him” (ibid, p. 49).

This prompted further attempts to reorganize existing irrigation knowledges and technologies to make them more productive and so to enhance production and the state’s taxation revenues. In Rajasthan’s arid northwestern district of Bikaner, the British undertook a large research program to improve existing, and to develop new, groundwater lifting devices. As mentioned previously, the Persian Wheel arrived with the Moguls sometime before 900 A.D. In Rajasthan, it was originally constructed of wood and driven by two bullocks. The British experimented with using camel versus bovine traction, steel wheels versus wooden wheels, and leather water bags versus wooden or fiber water containers, all in various combinations. They concluded that a camel drawn steel wheel, with leather bags was the most efficient at lifting water and could irrigate
about 1.5 acres per day (Bikaner State 1930). The state then set out a plan to aid in the adoption of these improved groundwater lifting devices by providing Takavi Loans.

The Takavi Loan system began with the Moguls and was traditionally a monetary advance made by a landowner (zamindar) to one of his tenants for production enhancing improvements. The etymology of this term exemplifies the difficulty in distinguishing what is local knowledge: “taka” comes from Sanskrit and means money and “kavi” comes from Arabic and means to reinforce. The term and practice is a hybrid. The British provided money for and capitalized on this entrenched system to encourage the development of productive assets by cultivators. This included the adoption of new technologies; the maintenance of which initially required state expertise, thus increasing farmers’ reliance on the state by replacing existing practices and displacing already existing knowledge systems. Therefore, the Persian Wheel in use in Rajasthan today was “improved” during the colonial period through directed colonial research into enhancing the efficiency and productivity of groundwater lifting technology and through loans to encourage its adoption, but this was only possible by building on knowledge from farmers and local irrigation experts who had originally designed the systems (see Mitchell 2002, p. 37).

In areas where well irrigation was not commonplace, the British did recommend government intervention: “In places where, notwithstanding that there is probably scope for well-irrigation, the people out of apathy or ignorance neglect it,” the government should intervene (ibid, p. 53). They gave the example of Chhattisgarh (a state in east-central India), where “the people have such a strong antipathy against wells that they
even refuse to use them for drinking purposes, when they have been provided for them and no other decent water is to be had” (ibid, p. 53). It is possible that the reluctance on the part of cultivators to use groundwater was rooted in the type of thinking pointed out by Rosin previously where shallow water was (legitimately) recognized as polluted (due to shallow water tables) or considered polluted on Hindu grounds (e.g. if it had been used to water cattle or lower caste Hindu people at some previous time). Recent research has shown, however, that groundwater in much of Chhattisgarh is contaminated by naturally occurring arsenic, which could explain why people were reluctant to use it (Charyya et al. 2005). This is yet another striking example of local resistance to the “reorganization and concentration” of local environmental knowledge by (colonial) state experts, who viewed local resistance as motivated by ignorance.

Both colonial administrators and missionaries during this period further intervened in groundwater irrigation. It was the colonial state that first investigated the possibility of tubewell irrigation in an attempt to more radically reorganize groundwater lifting knowledge practices and technology, while increasing their taxable production. Scattered throughout the four-volume Indian Irrigation Commission Report (1903), are references to possible benefits and types of tubewells: the Kazusa system of boring in Japan, which “is said to have been found exceedingly cheap and efficient in Japan” (p. 54); the possibility of using small-diameter borings for locating groundwater (utilizing local understandings of hydrology and soil characteristics no less), or for irrigating state managed or “Kalsa” land; and the “Jetting Process” in America and Europe where “borings were successfully drilled” to 382 feet and 1,003 feet respectively (Scottish
Mission in India 1905, p. 14). Furthermore, the Scottish Mission to India, working with both private firms (see Scott 1905) and under the tutelage of the colonial state, researched many possibilities for expanding the capacity of groundwater lifting technologies, These included: submersible three-phase electric pumps; compressed air through a steam “Pulsometer device” (i.e. pulsating steam engine); and wind power. By 1905, the Scottish Mission had drilled 500,000 wells in what was Rajputana, including “oil wells and prospecting bores”, while precisely detailing costs and overall drilling conditions to make the case for the further expansion of tube well irrigation systems (ibid, p. 17). They concluded, however, as did the Indian Irrigation Commission, that widespread tube well irrigation would not be possible at that time due to the cost of constructing an electrical grid and because “scanty population retards irrigation. It is hoped that in time this will gradually improve. To provide water and encourage settlers are the best ways to secure this result” (ibid, p. 31). But this would not come to pass until the Green Revolution.

The colonial introduction of the tube well, rather than through Green Revolution development programs (which is a standard assumption, see Shiva 2002), not only increases the temporal scale over which this technology has interacted with local knowledge practices and institutions, it also shows how the technology and associated knowledge systems have a genealogy infused with the politics of the colonial period. Both the contemporary use of the Persian Wheel and the tube well are embedded in the complexities of the colonial and postcolonial periods. Again, following Mitchell (2002): “expert knowledge works to format social relations, never simply to report or picture them” (p., 118). In other words, colonial experts attempted to not only increase the
efficiency of existing groundwater lifting technology; they wanted to reconfigure the social relations of production through colonizing existing groundwater knowledge practices. Colonial administrators were not merely ‘reporting’ (to borrow Mitchell’s term) existing expertise, they were trying to catalog it, in order to reorganize it and remove its production from the local and subordinate it to the state’s needs. To borrow from Mitchell again, this ushered in a new “politics based on technical expertise” that “represented a concentration and reorganization of knowledge rather than an introduction of expertise where none had been before” (2002 p. 41). The attempt to reorganize groundwater and irrigation knowledge began in the colonial period, but the scale of its expansion if firmly rooted in post-independence.

3.4.3 Post-Independence: High-Modernisms’ Tubewell Proliferation

The post-independence Indian state has created a host of bureaucratic institutions for the production and dissemination of groundwater and irrigation expertise. The Rajasthan Groundwater Board was constituted in 1956 (Government of Rajasthan 1987, p. 113), the (Rajasthan) Minor Irrigation Department in 1947-48 (Jaipur State 1928), and the Central Groundwater Board in 1970. The Rajasthan Groundwater Board’s original task was to create a state-wide survey of groundwater resources. The Minor Irrigation Department (which has been subsumed within the Irrigation Department) was charged with supervising any irrigation scheme that required a state investment of less than 15,000 rupees. Any benefits accrued to a farmer by these schemes, however, “whether due to the supply of direct irrigation or to percolation, submersion, improvement of the water supply in wells or drainage of excessive water or otherwise, shall be deemed a
ground for enhancement of rent” (Government of Rajasthan 1953, p.1239), thus leaving open the possibility of taxing government schemes’ incidental benefits to private irrigation. Today, however, the Irrigation Department oversees only surface water projects, even though groundwater dominates irrigation.

The creation of these state bureaucracies for groundwater mapping and irrigation control must be viewed as an extension of the colonial administration’s reorganization and displacement of local environmental knowledge and the emergence of new forms of technical expertise. Moreover, following Mitchell (2002), “for many post-colonial governments, this ability to rearrange the natural and social environment became a means to demonstrate the strength of the modern state as a techno-economic power” (p. 21). The tubewell was wrapped in post-independence (Nehruvian) modernization and nation-building, as was dam building, viewed as “India’s Modern Temples” (see Klingensmith 2003). It is also significant that the Central Groundwater Board came into existence during the beginning of the Green Revolution, which marked the beginning of the era of the tubewell’s proliferation.

While it was not the Green Revolution that introduced the tubewell into India, it did, nevertheless, drive its expansion. In the late 1960s the tubewell began its proliferation with the Central Government’s departure from 20 years of five-year plans that had emphasized large-scale surface water irrigation projects, which, moreover, were not paying for themselves (Narayanamoorthy and Deshpande 2005). They decided that the government should, with the help of international donors and development agencies (such as the Ford Foundation and the World Bank), create the conditions under which
individual farmers could adopt private tubewells (ibid). The two key moments underpinning this expansion were the nationalization of the banking system in 1969, which allowed the government to provide low-interest loans to land managers for tubewell construction, and the expansion of rural electricity (Narayanamoorthy and Deshpande 2005). The ‘hands-off’ program of decentralizing and shifting irrigation from large-scale state run projects to individual small-scale ones has been very successful throughout India. Today there are over 20 million tubewells in the country, irrigating over 70% of total agricultural area or 29,842,000 hectares in 1997 (Narayanamoorthy and Deshpande 2005, p. 70; Shah 2005; World Bank 2005).

This strategy has also been very successful in Rajasthan. Between 1962 and 2001, farmers constructed over 1.4 million agricultural tubewells, albeit in the absence of formal state regulations for tubewell construction or groundwater use. This is a growth rate of 149.41% in a state that was already densely populated with dug wells (Government of Rajasthan Groundwater Board 2003). And rather than the pace of tubewell construction tapering off, it is accelerating. For example, between 1995 and 1999 the number of tubewells rose 44.75% and between 1999 and 2001 they grew by 33% with the further expansion of rural electricity (Directorate of Economics and Statistics 1997, 2000, 2003). Nevertheless, tubewell construction continues unabated even as groundwater extraction surpasses recharge in the state by nearly 410 million cubic meters per year (Government of Rajasthan Groundwater Board 2006).

Falling groundwater levels, a consequence of the rapid spread and adoption of the tubewell, has, in part, been the basis for the expansion and continued legitimacy of
formal state institutions, such as the Central and Rajasthan Groundwater Boards. So while these bureaucracies were constituted in a time of groundwater abundance, it is groundwater’s scarcity that continues to justify them. And to be sure, the spread of the tubewell in Rajasthan (and India as well), the concomitant fall in groundwater levels and the reorganization of groundwater knowledge into formal state institutions represents one of the most dramatic transformations of socionature in twentieth century India.

In this section, I have demonstrated how the colonial state was an active producer of groundwater and groundwater lifting technological expertise. I have also shown how this represented a displacement of environmental expertise rather than an introduction of expertise where none had existed previously. Third, I demonstrated how during the post-independence period, the high-modern state influenced the rapid spread of the tubewell, and together with the creation of formal state institutions, formed another means of state reorganization and displacement of groundwater and irrigation expertise. In short, Rajasthan’s long history of extracting groundwater for irrigation, and innovating and improving groundwater lifting devices and the more recent rapid technological proliferation of the tubewell, has resulted in the promulgation of a variety of groundwater and irrigation experts. Focusing on the post-colonial period, the next section asks, just who is a groundwater or tubewell expert today?

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The Groundwater Boards are now involved mainly in conservation outreach programs and rainwater harvesting schemes.
3.5 Who Embodies Groundwater Knowledge/Expertise?

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<thead>
<tr>
<th>Source</th>
<th>Predominant Form of Knowledge</th>
<th>Practices</th>
</tr>
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<tbody>
<tr>
<td>Government Engineers</td>
<td>Formal Expertise</td>
<td>monitor &amp; survey; policy-making community; drill tubewells</td>
</tr>
<tr>
<td>Development Experts/Academics</td>
<td>Formal Expertise</td>
<td>research; policy-making community</td>
</tr>
<tr>
<td>Tubewell Drilling Firms</td>
<td>Local</td>
<td>tubewell location and construction; technological innovation; maintenance groundwater location; technological adaptation; tubewell maintenance groundwater location</td>
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<tr>
<td>Land Managers</td>
<td>Local</td>
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<tr>
<td>Hindu groundwater diviners</td>
<td>Local</td>
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Table 3.1: Holders and practitioners of groundwater and tubewell knowledge practices.

Table 3.1 distinguishes groundwater and tubewell irrigation experts into five observable categories: 1) government engineers; 2) development experts and academics; 3) tubewell drilling firms; 4) land managers; and 5) Hindu groundwater diviners (Sunghas). Government engineers working for the Central Groundwater Board, Rajasthan Groundwater Board, and Rajasthan Irrigation Department are trained in the Western academic tradition of groundwater hydrology or engineering positivist science. They are responsible for mapping groundwater supply, monitoring groundwater quality, drawdown and recharge. They are also part of the national policy-making community with high and low-level appointments on the State of Rajasthan’s recently assembled “Expert Committee” on groundwater, which drafted the first piece of formal groundwater
legislation in the state: “Rajasthan Groundwater Rational Use and Management Act of 2005”, which has yet to be enacted.

Development experts and academics who work for nongovernmental organizations, development institutions, such as the Institute for Development Studies in Jaipur, or work (either on temporary contract or as full-time employees) for development agencies such as the European Commission or World Bank are also trained in the Western positivist tradition (of neo-classical economics, for example), but are also cognizant that they ‘learn by doing’ (see Armitage 2003; Davis 2005). In Rajasthan, these various organizations perform a small amount of research into groundwater conditions and use, but mostly inform the making of state groundwater policy, and design and administer groundwater development programs. They direct the shape and planning of the policies with individual development programs, in that new ‘projects’ are outlined in phases and funding is provided for individual phases. After one phase is complete, funding is provided for the next. In this way, development agencies heavily influence the direction of projects and policies, remaking policies and government agencies in their own vision, which in this case foster the general neo-liberal goals of privatization and market-based solutions (see Haughton 2002). The projects have goals for policy but also attempt to reorganize socio-environmental relations according to their own distinctive vision (O'Reilly 2004). They typically assume that a ‘tragedy of the commons’ scenario exists and that some combination of private property rights and entitlements, implemented through local bodies (which are romanticized as egalitarian repositories of traditional knowledge) and targeted regulation, such as limits on tubewell construction
and groundwater pricing, is the solution. But there are also multiple forms of local expertise.

Tubewell drilling firms’ expertise in groundwater location, and tubewell drilling and technological adaptation is based on local knowledge of a generational sort. In the Study Area, there are local tubewell drilling firms and non-local entrepreneurial firms. They distinguish themselves. Local tubewell drilling firms typically have long histories, a deep familiarity with the socio-environment of the area, and require advance payment as a ‘good’ business practice. They pride themselves on innovating tubewell technology and constructing productive wells, which require knowledge of groundwater location. They are innovative in adapting and improving tubewell irrigation technology. For instance, one firm interviewed, which has been in business since the colonial period, advanced piping and screen technology to meet the demands of the sandy Rajasthani substrate. They even fabricated a Fordist style production line to produce these screened pipes. Further, they make their own drilling tools, which are specially adapted for local drilling conditions.

Non-local tubewell drilling firms on the other hand, began arriving with the tubewell drilling boom of the late 1990s. As shown earlier, this period (which continues) of rapid tubewell construction, is driven not by easily accessible groundwater but by its absence, which requires farmers to chase the water table downward with new constructions\(^\text{10}\). Non-local firms, from as far away as Allahabad, roam the countryside in

search of groundwater-dependent farmers who are in desperate need of a new tubewell (for irrigation, livestock and domestic purposes) because they have drawn down the water table below their current tubewell and have no other source of (much needed) water. These firms, which have little local ecological knowledge, work with usurious local moneylenders to rapidly construct tubewells. The local firms are quick to distinguish themselves from these practices, both as a marketing strategy and, as local firms, as a point of pride.

Land managers also rely on generational local knowledge. They know from experience where they will find groundwater. Following one farmer: “There are two reservoirs nearby; one is close and we get water from it, but the other – Benera Lake – is about 4 km away. It is too far for the groundwater to come.” So too, during the colonial period, land managers’ knowledge of their environment was well known and taken advantage of:

Over the greater part of the alluvial tract of Northern India the people have a very good local knowledge of the nature of the substrata and of the subsoil water-supply; all that seems to be required in this tract is to render assistance, where necessary, in making trial borings by providing boring tools and expert workers at a small charge; and to have mapped out from local inquiries, all tracts in which the construction of ... tubewells can be usefully pushed (Indian Irrigation Commission 1903, p. 54).

The colonial administration sought to take advantage of existing local hydrological knowledge not only to facilitate tubewell construction. As represented in the above quote, they wanted to render local knowledge of groundwater bureaucratic (i.e. concentrating it into formal expertise) by mapping it out and then using their newly acquired knowledge to sell it back to its subjects in the form of tubewell drilling experts.
This was also one other way that local groundwater knowledge was reorganized and displaced into the hands of colonial administrators and later the modern development state.

The colonial administration was also aware of local water diviners, who still operate today. Local Hindu water diviners, called Sunghas, rely on local knowledge but are also formally trained by elder Sunghas to locate groundwater and place wells (and tubewells). Colonial administrators, speaking of Sungha knowledge and the ease of digging wells wrote: “their [private wells] construction offers no special difficulties and the sites are usually selected by local water-diviners whose judgment is said to be unerring” (Indian Irrigation Commission 1903, p. 226). Locally, they are considered groundwater experts. They use astrological principles and draw on local ecological conditions to locate groundwater. These principles also inform their recommendation of auspicious dates and location for tubewell construction, which are followed, quite literally, religiously. In other words, a Sungha determines an exact location, date and time for tubewell location. However, the subsequent requests of land managers to have a tubewell constructed under such precise conditions can create problems for tubewell drilling firms. Land managers and Sunghas work around this problem by performing a ceremonial well digging at the precise time and location specified by the Sungha, the actual tubewell to be constructed at a later date. Their prominence continues today and even intersects with development practitioners.\(^{11}\) It also forms a major object of farmer

\(^{11}\) In the summer of 2005, this researcher met an elderly Austrian water diviner trained in the Hindu tradition of groundwater location in India. She was meeting with the State’s “Expert Committee” on groundwater. She also scorned the committee and local people for forgetting ‘their traditional ways’, failing
thinking about groundwater, which is sometimes in contradiction with not only tubewell drilling firms but state scientific rationality.

These findings highlight the means through which local environmental knowledge and technologies have been cataloged, reorganized, and displaced by successive states. This section further shows how with the rise in the importance of groundwater and later the proliferation of tubewell technology, state involvement increased through extension programs and the creation of formal state bureaucracies charged with groundwater management. But the role of these bureaucracies has evolved along with the changing nature of the resource in that groundwater decline has led the Groundwater Boards to become engaged in groundwater conservation rather than development. Moreover, these findings show the continuity in knowledge across the three periods outlined earlier. They also reflect conflicting viewpoints on the legitimacy of expertise and ultimately on the epistemology of knowledge production. This creates tensions between differently situated individuals (e.g. farmers and government engineers) about the origin and reliability of groundwater/tubewell expertise and its practitioners.

3.6 Conflicting Views on Expertise

With the various practitioners of groundwater expertise outlined above in mind, I queried farmers about those from whom they would seek advice before digging a tubewell. Their consultancy options included: 1) government engineers from the
to recognize that it was modernist development programs beginning in the 1960s, which scoffed at these ideas.
Groundwater Board; 2) tubewell drilling firms; and 3) Sunghas. The responses of the 151 tubewell owning farmers I interviewed in the summer of 2005 were intriguing but not surprising. None indicated that they would consult a government engineer, 24.5% indicated that they would consult a Sungha, 63.5% indicated that they would consult a tubewell drilling firm, and 12% indicated that they would consult both the Sungha and the tubewell drilling firm. The question is; Why? Why do land managers choose to rely on tubewell drilling firms and Hindu spiritual experts rather than government expertise? What does it have to do with the forms of groundwater knowledge set out previously and / or how people and the state view each other?

3.6.1 Seeing the State

There is widespread trust in the abilities of tubewell drillers and Sunghas, and relative distrust of state engineers for two primary reasons. The first has to do with the divergences in belief between farmers and state engineers about how expertise is produced and legitimated. And the second is wrapped up in the way that farmers see the state, which has to do first with their historically fraught relationship with state engineers, second with their interaction with other state agencies and third, with the recent lack of visibility in the field of these state engineers and the Groundwater Boards more generally.

First tubewell drillers and Sungha expertise is derived through practice, and by knowledge of and experience with the area, much like that of the farmer. In other words, tubewell drillers and Sunghas are trusted because their knowledge and technical know-

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12While this author recognizes the importance of the development community, broadly defined, in producing expert knowledge; the people in my Study Area did not intersect directly with them. However, it is likely that the state expertise they interacted with had been influenced to some degree by this community.
how is derived in the same way as that of the farmer, through practice in the area. This expands the development of their – area-specific – skills and their knowledge of the area, which makes their practice more effective. This process occurs in a cumulative spiral of causation, with knowledge and skill constantly informing and expanding one another. Of course while building their skill and knowledge base, tubewell drillers and Sunghas spend a great deal of time in the area and gain a reputation throughout the region in which they work. In other words, they are highly visible, as are their successes and failures. The relationship that farmers have with both Sunghas and tubewell drillers is a comfortable one, therefore.

Second, farmers harbor a general skepticism of the state, which is grounded in the historical, fraught relationship that farmers have had with it. But it is also related to the point number one regarding the divergences in the value that farmers place on knowledge gained by practice as opposed to that gained by formal education. These tensions are represented by what this farmer had to say about the Groundwater Board engineer:

If we hire the government engineer [for tubewell placement], they don’t know our area and we pay them rupees 2,000 and they don’t come back. Also, they have all these formalities that we don’t understand.

The Sungha is more accurate and cheaper. The Sungha is only charging rupees 50 [about $1]. The Sungha is better than the engineer because the engineer doesn’t care or know about the cost of drilling a tubewell, where the Sungha cares more and is more sympathetic.

The engineer relies on physical methods that are not good for all areas. Sungha’s methods are not only for this area, they are more universal and could be used anywhere; he could find water in Ajmer, for example (Farmer – July 22, 2005).

This quote sheds light on four issues that farmers have with government engineers: 1) the government is unreliable; 2) the engineer is more expensive (there is the
cost of the service plus the cost of bribes, which will minimally double the cost); 3) the enginee...ern’s methods are thought to be less accurate because their knowledge is regarded as particular, whereas the Sunghas’ knowledge is thought to be universal and; 4) that the government is ambivalent to their plight. Therefore farmers do not believe in the engineers’ methods, which embody a particular form of knowledge that is not gained through practice and is viewed as myopic in a way that practice-based experience is not.

The other issues raised by this quote, namely that of reliability and advantage taken by state engineers (in terms of requiring bribes, for example) are examined below in greater detail. Moreover, they do not believe in the results achieved by the government engineers either. Eighty percent of survey respondents indicated that the Sunghas’ results were better than the engineers’.

But it is more complicated that this alone. The way the methods are presented, by state engineers for example, exacerbates this tension as well. There is a general sense from state engineers that farmers do not ‘understand technical language’, and this conditions their treatment of farmers. According to one farmer:

if we go to seek advice from the engineer they treat us like we are fools (murkh). They say ‘you are irrigating too much, that is why there is scarcity of water. Do you not know how to irrigate?’ They are not farmers, though. But what can we do? Our crops will perish, cattle will die. Then we will have nothing to sell or eat. (Interview #75 October 20, 2005).

This sheds further light on the historical relationship between farmers and state engineers; it draws out the power asymmetries between the state engineers who are the embodiment of expertise and authority, and farmers who are denigrated as ignorant fools, consuming
too much water. But by affirming that the state engineers were ‘not farmers’ indicates
that farmers question the engineers’ understanding of their conditions. At the same time,
however, farmers understand that their current usage of groundwater is not sustainable
but that in the present they have no better livelihood options.

The general lack of understanding of the livelihood options available to farmers
and their degree of desperation for access to water is further apparent in this farmer’s
perspective:

If I consulted the engineer, he would laugh and say a tubewell [construction] is not worth it here. The driller must hit the channel in
the rock and even then maybe I will only get enough water to fill a one
and one-half to two inch pipe. But for me this is worth it. The other
option is nothing. But for the engineer this is not good enough. I will
not create a surplus with this, but I can grow fodder crops (jowar).
Rather than consulting the engineer, I would consult a person with Devi
Shakti [goddess of power].

Most engineers that I interviewed would argue that the construction of
more tubewells by farmers is pointless as they will not be productive (see
below), but what they really mean is that they will not be productive to their
fullest capacity. Therefore, when a farmer constructs a new tubewell in this area,
they are viewed as ignorant. But farmers are aware that their new constructions
will not produce at full capacity, but that some water is better than none, as
water is an absolute necessity.

The farmer continued:

Maybe if I had a bigger pump, I could create a surplus. The engineers
tell the electricity board that irrigation in this area requires a 7.5 hp
pump. So we pay a [electricity] tariff for a 7.5 hp pump, even though I
only have 5 hp pump. I could create a surplus with a 7.5 hp pump.
What do these engineers know?
The tension between farmers and engineers is further exemplified in this quote, where the farmer perceives a lack of understanding in the engineer’s formulation of pump requirements, which is in part evidenced by the farmer’s overall financial position (where rather than creating a surplus he is merely scraping by). Moreover, the electricity tariff in rural Rajasthan is a fixed one based on the size of the irrigation pump. But the electricity board does not survey farmers to verify their pump size. Instead the Groundwater Board designates particular areas with particular pump requirements based on the results of their groundwater surveys, and regardless of the actual conditions experienced by individual farmers. Here the farmer further questions the engineers’ expertise by pointing out that even though the engineer asserted that his tubewell was in an area that required a 7.5 hp pump, he only had a 5 hp pump. Apart from the fact that this farmer is overpaying, it provides an additional point of contention, which leads to further distrust, between the farmer and the Groundwater Board.

This distrust is further explained by a lack of continuity in state visibility. In Corbridge et al.’s example, the state became visible through actual encounters with its subjects, which in turn informed local ideas about the state. In the present research, the state’s groundwater experts (i.e. technocrats from the Groundwater Boards) formerly came into regular contact with farmers because they were the overseers of government tubewell construction programs. But since this heyday of groundwater availability and tubewell construction (when the news regarding groundwater and tubewell construction
was positive), farmers’ encounter the state much less often, and when they do, it is in a negative capacity.

But according to the Groundwater Board, they are not invisible: “We monitor wells regularly for groundwater decline and groundwater quality in all villages” (Groundwater Board Technocrat – August 02, 2005). According to their website, they have 1337 groundwater observations wells in Rajasthan (Central Groundwater Board 2006). It is not clear, however, when data are collected from them. This author saw no evidence of Groundwater Board data collection in his eighteen months of field research. So too, according to locals in all study villages, farmers have not seen data collected from them either. In one village, the sentiment was: “we haven’t seen anybody from the groundwater board or irrigation department in fifteen years. They made this well over there but nobody looks at it.” Moreover, the groundwater situation in Rajasthan is so politically charged that individuals within the Groundwater Board are very selective in releasing information. According to the chief hydrologist, the Groundwater Board unofficially will not give written recommendations on groundwater location or tubewell construction for fear of lawsuits (by farmers) or political reprisals. These actions on the part of the Groundwater Board remove them from encounters with farmers, while exacerbating farmer skepticism and distrust.

The history of groundwater development and state involvement (or lack thereof) has fostered local distrust of government expertise. This is also reflected in local attitudes on the future regulation of groundwater, which is tied into farmers’ experiences with other state agencies. One form of regulation being proposed, which farmers are well
aware of, is the licensing of existing and future tubewell constructions, including the imposition of quotas, which would presumably have the greatest impact on those farmers who do not currently have tubewells. On this issue of future regulation and licensing, many expressed the view that ‘the government is already regulating groundwater by only supplying electricity six hours/day’\(^{13}\) and that if tubewell construction regulations were imposed it “would just mean more bribes to government officials and the wealthy would get their tubewells anyway.” But there are divergences in attitudes between farmers of different socio-economic standing. According to one, low caste Hindu who only owned 6 bighas (1.5 hectares) of land:

Licensing would be a problem, not a solution. Electricity availability already controls it. If new wells are needed and permission has to be sought, then documentation procedures are required. This is problematic because the government doesn’t have a good history in this.

This quote points out that licensing would be a problem because historically the government issuance of licenses (such as for an electrical connection or to grow particular crops) requires bribes from farmers to government workers. However, according to one Brahmin (high caste Hindu):

If the government started regulation and permitting [including meters for electricity and water], the judicious use of water by farmers would increase and groundwater decline will decrease or stop. These days a plant needs 1 liter and farmers give it 3. If there was a check on groundwater then people would use less. The government should have a license and permit system. If the electricity supply was 24 hours and the rate was flat then farmers would run their borings 24 hours too.

\(^{13}\) According to the electricity board - Jaipur Vidyat Vitran Nigam Limited -, electricity is only provided for six hours per day and is on a rolling schedule (Jaipur Vidyat Vitran Nigam Limited (2005). Personal Communication. T. Birkenholtz.). Limiting electricity availability is used to both reduce electricity consumption and groundwater use.
This represents the sentiments of (elite) high caste farmers, who currently have adequate access to high-quality irrigation water and want to keep it that way. For them, regulation would be one way to prevent the future expansion of irrigation by others (who in their view are mostly low caste farmers), allowing them to maintain their position. This farmer went on to point out that through “poor” irrigation practices, low caste members of the community were using too much groundwater. While this is a different form of local knowledge, one that deals with actual agricultural and irrigation practices, it points to the highly contentious divergences within local knowledge (and understandings of each other) as to the origins of and solutions to the current groundwater situation. Overall, though, the above references point to a widespread distrust of state expertise based on past experience, with both engineers and electricity department bureaucrats. Similar to the subjects of Corbridge et al’s Employment Assurance Scheme who have not been ‘constructed’ by the state, groundwater dependent farmers have yet to be manufactured by the state as to render them sympathetic to state expertise (see also Agrawal 2005). In Corbridge et al’s account, this was due to a lack of state capacity, but in addition to what I have shown here to be a general distrust of the state, it may also be the result of a state that continues to “see like a state.”

3.6.2 Seeing Like a State

The Rajasthan and Central Groundwater Boards are responsible for mapping groundwater, collecting groundwater quality data and locating well sites. They are also involved in the policy-making process and classify Rajasthan’s 236 blocks (which were set up by the British) based on their groundwater producing capacity: safe, semi-critical,
critical, and over-exploited. These classifications are important as government subsidized loans for tubewells are only available in “safe” blocks, which number less than 50. Prior to the tubewell construction rush that began in the mid 1990s and continues today, these loan programs brought the state (the Groundwater Boards) into multiple encounters with farmers because the Groundwater Boards were the technical administrators of tubewell construction, especially before the proliferation of private tubewell drilling firms. Therefore, falling groundwater levels caused the majority of Rajasthan’s blocks to be ineligible for government tubewell loans, which resulted in the de-facto removal of the state (in terms of groundwater) from farmers’ daily encounters.

I first visited the Rajasthan Groundwater Board in July and August of 2003. Over the duration of several visits with a supervisory hydrologist, all I came away with were some statistics that were readily available elsewhere. I returned in 2005-06 and spent at least one day per week for an entire year with the same supervisory hydrologist in addition to other hydrologists, engineers and statisticians. On my first visit the chief hydrologist told me: “Farmers have a greater knowledge of their local area and groundwater location than the Groundwater Board because they have these places as their ancestral homes.” I asked him what he thought of local understandings of groundwater and irrigation and received a similar positive response. I spoke with several other groundwater hydrologists, engineers and technicians that day and they also responded that farmers have a great knowledge of local groundwater conditions and irrigation practices.
But, my first visit to the Groundwater Board in 2005 was soon after attending the high-profile conference “Groundwater Management in Rajasthan: Issues, Perspectives and Policy” in Jaipur, Rajasthan (in February 2005), organized by UNDP and the Jal Bhagirathi Foundation – a groundwater development NGO, whose primary focus is to integrate “traditional knowledge” into policy-making and engineering processes. They have much support from UNDP, the European Commission and the state secretary’s office. The goal of the conference was to produce the first ever statewide groundwater legislation. Many of the mid-level technocrats attended and were educated on the postmodern state’s development strategy, which included building on “traditional expertise.”

The state and Groundwater Boards’ official position exemplified during my post-conference visit began to unravel as my year with them wore on and as my presence became less scrutinized and more familiar. For instance, in contrast to the way I was first led to believe that the Board’s engineers respected local knowledge, on following occasions, it became clear that they actually believed something quite different. One sentiment expressed was that while farmers may have traditionally known where groundwater could or could not be located, they did not know today because the ecological conditions have changed. “They [farmers] only knew before because groundwater was everywhere” (Groundwater Board Hydrologist – October, 2005). And that when trying to reason with farmers about new well locations or the reasons for not constructing a new tubewell, the sentiment was that “farmers don’t understand technical language” (PHED Technocrat – August 02, 2005). Instead of understanding that farmers,
who needed irrigation and domestic water, had no other choice but to construct a
tubewell, the state technicians questioned their ability to understand the knowledge of
science and of expertise.

So too, technocrats denigrated farmers’ use of ‘traditional’ groundwater location
techniques, which rely on local Hindu water diviners (Sunghas):

They [farmers] hire these Sunghas who walk around the field until they
get the feeling and then they tell them to place the well there. There is
no science in this. Their wells work sometimes, but they are not the
most productive wells. It’s luck. (Groundwater Board Engineer – May
20, 2005. Speaker’s emphasis.)

These sentiments echo previous farmer assertions that engineers only see validity in a
well that produces at maximum capacity, while a less productive well is invalid.
Moreover, it illustrates the rift in hydrologists’ attitudes towards practices that have not
been acquired through formal scientific training.

In this section, I have drawn into question whether Scott’s technocratic “hi-
modern” state has transformed into the postmodern participatory development state.
While state hydrological experts know well what they are supposed to say and think
regarding local knowledge, their truer feelings came out in due course, bringing into
question the actual character of the encounters that the state (in this case the Groundwater
Boards) has with its subjects.

3.7 Conclusions

This chapter challenged current research in developing contexts, which has
argued that our understanding of development schemes has moved beyond Scott’s high-
modern development state. This other work has shown that state agencies charged with
governing common property resources, such as forests and conservation areas, or with implementing poverty reduction schemes, are internally differentiated and porous, and that Scott’s positivist technocrat in the high-modern development state no longer exists.

The present study does not dispute this, but rather questioned how other agencies operate, particularly those that deal with common property resources, through a case study examination of the relationship between state agencies in India charged with groundwater monitoring and management, and farmers through various historical periods. First, I showed the continuities in the interaction local groundwater knowledges and technologies with state expertise through pre-colonial, colonial and post-independence periods, while highlighting the ways that the state has continuously tried to displace and undermine local control over these. In doing so, I illustrated that local and Western-technical groundwater knowledges are often in conflict due to the dismissal of local knowledge by Groundwater Board engineers and the general distrust of these engineers on the part of local people (farmers). This rift was only partly the result of differing epistemologies of knowledge production, however. Also of importance was the tensions in the historical interactions between the Groundwater Boards and farmers and farmers and the state more generally, such as with the electricity board, which conditioned how the state and its subjects viewed each other.

The interaction of the Groundwater Boards or lack thereof with farmers is conditioned by the political, economic, and ecological character of the resource. Groundwater is distinguishable from other common pool resources, such as forests. Forests can be propagated, commodified, encroached upon and contested in ways that
groundwater cannot. The state cannot make more groundwater. This character influences the options available for addressing groundwater development, conservation and regulation.

In Rajasthan as elsewhere in India and globally, groundwater is a contentious issue that has farmers agitating over it and elected officials afraid to legislate it. The state groundwater agencies are caught in the middle, which causes them to retreat from the public gaze, under political, economic and ecological conditions over which they have little power. Therefore, it is the unique character of this particular common property and the political struggles over it, which feeds into what the Groundwater Boards can and cannot do, and ultimately in they way that they interact with the state's subjects. This is not to argue, however, that the Groundwater Boards are internally undifferentiated, only that this particular part of the state acts differently than other agencies, such as the Forest Department. This divergence is at least partly due to the specific nature of groundwater. Moreover, it may also be that the structure and constraints of this particular agency produces a particular kind of subject of its own, but this will only be born out through future research.

Finally, the tension between local and Western-technical groundwater knowledge, the historical fraught relationship between farmers and Groundwater Boards and the state more generally, and the more recent retreat of the Groundwater Boards from the vision of farmers has created a situation of mutual animosity, which will need to be overcome for the future creation equitable groundwater management institutions and the implementation of conservation strategies.
CHAPTER 4

THE CAPACITY OF IRRIGATION TECHNOLOGY IN SOCIOECOLOGICAL CHANGE: IRRIGATED LANDSCAPES, PRODUCED SCARCITY, AND ADAPTIVE SOCIAL INSTITUTIONS

It is clear that the Indian Government cannot go digging canals and making dams for ever, and in any case large tracts of country could never be reached by such means. Surely in such places Electric Irrigation is the thing (Scottish Mission in India 1905, p. 16).

In a sense, the way technology has rendered nature artificial has produced a technonature which must be maintained by society, and that is the new situation. There is a kind of technological saturation of nature which is starting in return to affect our existence ... Any malfunctioning at any level in nature becomes a political problem and it is interesting to ask why (European Commission 2006).

4.1 Introduction

In recent years much scholarship in geography (Braun and Castree 1998; Castree and Braun 2001; Robbins 2001; Robbins 2001; Whatmore 2002; Zimmerer 1994, 2000; Zimmerer and Young 1998), anthropology (Agrawal 2005; Escobar 1999; Mitchell 2002), history (Klingensmith 2003) and science and technology studies (STS) (Latour 1993; Latour 2005) has focused on the interaction of human and non-human processes in shaping nature-society-technology relations. This body of research seeks to understand the implications that the interaction of human and non-human nature, and technologies have for the directedness of socioecological change. Is it human action from which all
other socioecological processes and outcomes follow? Or can it be instructive to look at how the non-human and their associations are implicated in producing socioecological differentiation? Ultimately, these questions are about how we account for the non-human in geography and how it informs our understanding of nature-society-technology relations, which continues to be very contentious and is far from resolved (Bakker and Bridge 2006; Castree 2002, 2005; Harvey 1996; Kirsch and Mitchell 2004).

The commingling of technology with human and non-human nature is increasingly apparent (but certainly not new, see Botkin 1990; Cronon 1995). Some of the more spectacular examples of this post-natural condition include “Frankenstein Food”, produced from transgenic crops such as StarLink corn (containing \textit{Bacillus thuringiensis} (Bt), a natural insecticide) (see Bingham 2006) and Monsanto’s Roundup Ready\textsuperscript{TM} soybeans (Whatmore 2002, p. 119), to novel living beings such as DuPont’s proprietary OncoMouse\textsuperscript{®}, so skillfully elaborated upon by Haraway (1997).

These examples highlight the most dramatic intersections of technology and socionature (Bakker and Bridge 2006, p. 18). What is lost in some of these more glaring examples of the convergence of technology and socionature, however, are the seemingly everyday transformations that cover our landscape. These mundane, but highly technologically transformed, natures are everywhere.\textsuperscript{14} Take the case of groundwater irrigation. For millennia, global irrigation has been primarily a surface water phenomenon. So too, distinct practices and social institutions have formed by and for the

particular demands and constraints of surface water irrigation (Meinzen-Dick 2002; Mosse 2003; Mosse 2006; Ostrom 1992; Wescoat et al. 2000; Wittfogel 1957). But over the last half century, groundwater-based irrigation has become increasingly prominent, resulting in a highly transformed groundwater landscape. In the United States, for example, groundwater withdrawals, as a percentage of total water withdrawals for irrigation, have climbed from 23 percent in 1950 to 42 percent in 2000 (Hutson et al. 2005). Moreover, in India, groundwater-based irrigated rose from 7,455,000 hectares in 1962 to 29,842,000 hectares in 1997 (Narayamoorthy and Deshpande 2005, p. 70), currently accounting for 70 percent of total irrigated area (World Bank 2005). This recent transformation is due to radical technological shift in groundwater lifting technology, which has led to dramatic changes in socionatures, including the production of new social institutions around the demands and constraints of this technology. The questions become: how do human and non-human nature and technology interact in ways that transform and adapt each other? What kind of socioecologies follow from these interactions?

The research explained in the present study examines these questions using a case study from the semiarid northern Indian state of Rajasthan. Since the 1960s, tubewell irrigation systems have proliferated across Rajasthan, transforming the landscape and production relations, while agrarian practices and institutions (standardized practices, procedures, rules and conventions) have been reworked around them. As one example of

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15 It is estimated that of the 300 million hectares irrigated globally, 85-95 million depend on groundwater, while 85% of these areas are in India, Bangladesh, Pakistan, Iran, and the north China plains. Shah, T. (2005). “Groundwater and human development: challenges and opportunities in livelihoods and environment.” Water Science and Technology 51(8): 27-37.
a resource scarcity-reducing technology, it is not clear how the tubewell has impacted social, political and ecological relations or how it has influenced the development of social institutions. Given that similar technologies (such as high-yielding seeds, GMO crops, surface water dam projects, and even agricultural forestry) have proliferated in recent years, their effects on political ecological relationships are of particular concern.

In this chapter, I draw on the literature outlined above, on traditional theories of technology adoption (Blaikie 1978; Brown 1981; Glendinning et al. 2001; Gotsch 1972; Herath 1985; Mercer 2004) and on work concerned with the momentum that technologies have, once adopted, on shaping the production of social institutions (Winner 1977), to understand the impacts of tubewell technology and associated irrigation systems adoption on social institutions and the landscape. The more precise questions are: 1) how does tubewell adoption influence land use patterns, water scarcity and adaptation of water use for different communities at both the individual and social-institutional levels; 2) what kind of natures do these interactions and associated adaptations produce; and 3) in a broad sense, how do objects (in this case tubewells) in virtue of their particular requirements discipline the subject (farmers) and to what effect for nature-society-technology processes? The research utilizes household production information and interviews with land managers, tubewell drilling firms, and local and government groundwater experts, as well as archival data, to examine these processes in the Dhundhar Region (Jaipur District) of Rajasthan near its capital, Jaipur.

I analyze tubewell technology adoption to understand the capacity that this technology has, as one example of resource scarcity-reducing technology, in driving
processes of social institution formation and political ecological change. Instead of attributing what happens in the world to more abstract processes, such as the logic of capital accumulation, it means examining the hybrid objects that effect change through varying capacities and in various configurations. This doesn’t mean that all these objects and configurations or networks are equally powerful in their capability to effect change. It means, though, that by taking technology and non-human processes out of an explanation something goes missing, some part of the explanation becomes compromised and attributed to more abstract processes. By focusing on various actors within these hybrid networks, we can understand not only how they affect the relationship but also understand their capacity to condition human and non-human differentiation. Examining technology and the non-human in social and ecological change renders the issue of power and agency a “question rather than an answer” (Mitchell 2002, p. 53).

First, I demonstrate, by examining household production information stratified by caste and class in the Study Area, that there is differentiation in agricultural income and productivity. But, I find that this variation is much less apparent when comparing the proportion of irrigated area to total agricultural landholdings at the household level. Second, I find that the resultant caste-based inequality in production and the relative lack of inequality in the proportion of irrigated area, is explained by the creation of a new institution around tubewell adoption: tubewell partnerships. The smallest farmers are able to harness the productive capacity of (expensive and risky) tubewell irrigation systems only by forming partnerships for their construction, maintenance and use. After tubewells are adopted, however, unique social institutions are formed around them, with distinct
and differential political ecological outcomes. Political ecological differentiation occurs through the process of tubewell adoption and concomitant institution formation. So that third, at different moments in the economic process, the tubewell has different capacities to effect its associations and bring about change in the hybrid network to which it belongs. Fourth, irrigation practices and daily household production activities follow from the demands and constraints of the tubewell, enabling and constraining both human and non-human action (ecological and institutional differentiation). The immediate result is the differential reconfiguring of social systems (e.g. institutions of adaptation) around the demands, constraints and opportunities set in motion through the adoption of the technology. The reconfiguring is differential because the form of the social institution depends on both prior and shifting political ecological realities (such as changing soil and groundwater conditions, commodity prices or circumstances within the partnership) of the adopters. And finally, these processes also result in the material remaking of non-human nature through massive changes in cropping patterns and in a highly technologically-dependent landscape, while enabling and constraining the future of groundwater-dependent agrarian and non-agrarian development. The nature-society-technology relations and the resultant patterns of production and accumulation illustrated here are both cause and consequence of these hybrid interactions.

I divide this chapter into four sections. In the first, I evaluate that past and recent literature that has engaged the issues of technology adoption under different assumptions, including traditional theories of technology adoption and more recent work on the intersections of technology with nature-society relations. Then I describe the Study Area,
focusing on recent irrigation-driven changes in both the character and amount of the area devoted to agriculture. In the third section, I present the findings of research into the formation of hybrid practices and institutions, and landscape change around tubewell technology adoption. I discuss these findings in the fourth section in terms of their relation to the prevailing theories on technology adoption presented previously. At the same time, I advance these theories by re-thinking the ways that political-ecological processes (including social institutions) are shaped around technology adoption.

4.2 Rethinking Nature-Society-Technology Relations

This section first explores how technology has traditionally been theorized within agrarian production systems. After briefly outlining this historical research, it shows that while that work has been and continues to be important, it is ill-equipped to explain the ways that technology adoption interacts within complex and dynamic political ecologies.

4.2.1 Theories of Technology Adoption I: Innovation-Diffusion

In the 1980s Brown and others showed that variables such as landholding size (indicative of class), other capital asset holdings (such as tractors) and/or distance to market were sound predictors of future technological diffusion (Biggs and Clay 1981; Brown 1981; Gotsch 1972; Herath 1985). This research showed that in agricultural societies characterized by comparatively equal size landholdings, tubewells diffused evenly and their income impacts were more evenly distributed than in areas characterized by social class disparities and unequal landholdings (Gotsch 1972; Brown 1981; Herath 1985). Further, in areas characterized by landholding and income disparities, “income
and power are aggravated” (Brown 1981, p. 238), while early adopters often enjoy economic benefits of early adoption referred to as “adoption rent” (ibid). Adoption rent is the economic benefit that accrues to early adopters who are able to take advantage of nascent production and market conditions (see also Yapa 1977).

This work was further advanced and challenged by Blaikie (1978), who criticized its poor account of capitalist production relations and markets. Specifically he was concerned with the lack of critical inquiry into the political economy of capitalist production relations (such as rent-seeking by better off farmers) among peasant producers. Similarly, Freeman (1985) showed how oligopoly powers were gained by early adopters who were able to turn their “adoption rents” into permanent surplus incomes termed “preemption rents.” This they were able to do by influencing the political regulatory process in such a way as to limit the access of others to those technologies.

Parallel work undertaken by Boyce (1987) concluded that stagnation in Bengali agriculture, specifically the lack of irrigation (diffusion of innovation), was the result of an unequal agrarian structure, specifically in landholdings. He theorized that the region had the technical and physical potential for growth but that there were ‘institutional barriers’, such as unequal landholdings that obstructed cooperation and lack of public sector-led investment in extension services and innovative technologies, which were barriers to achieving economies of scale through collective farmer action. West Bengal experienced tremendous agricultural growth in the 1990s, however, displacing Boyce’s original thesis (see Rogaly et al. 1999). Similarly, Harriss (1993), also working in West Bengal, found that market-based innovations, such as entrepreneurial investment in
irrigation, resulted in expanded irrigation and agricultural production. This was in contrast to the prioritization of public institutions argued by Boyce. So too, Dubash (2002) working in the Indian state of Gujarat, found that the need for irrigation sparked both entrepreneurial investment by local non-farming ‘capitalists’, and the creation of informal market institutions for the buying and selling of water across caste and class. In other words, the barriers of caste and class to cooperation argued by Boyce, did not seem to apply in Dubash’s case, and nor did they feature as significant in the work of Rogaly or Harriss.

More recent work is advancing innovation diffusion theory by analyzing the particular conditions under which past technological innovations diffused. Intending to influence contemporary policy decisions, Miller and Hope (2000) analyzed the diffusion of World Bank sponsored solar photovoltaic (PV) technology for off-grid applications in India, Sri Lanka and Indonesia. The authors found that important factors influencing diffusion on the demand side included perceptions of risk and access to credit; while important supply side factors included the availability of technological innovations to adopt! The supply side availability of technologies depended heavily on government intervention but also on the development of private sector marketing and distribution infrastructures. They concluded that “policies to accelerate diffusion must equally seek to integrate the supply and demand side of the diffusion process” (Miller and Hope 2000, p. 90).

The research presented first in this section – classical innovation-diffusion research – studied the diffusion of technologies as related to a variety of correlated
factors. But it did not examine why particular individuals did or did not adopt technologies outside of these particular conditions, nor did it adequately integrate complex political-economic production conditions into its explanations. The second body of research outlined here, advanced the classical innovation-diffusion research by seeking to understand the institutional barriers and facilitators of technology adoption. But again, neither looked to why farmers actually adopted agrarian technologies. This question was taken up by more recent, but closely related work, which attempted to understand the reasons that farmers chose to adopt or not to adopt technology.

4.2.2 *Theories of Technology Adoption II: Perceptions and Attitudes of Adoption*

Research related to that outlined above, has focused on the individual decisions of potential adopters, examining the conditions required for and enhancing the diffusion of technology. It has shown that technology adoption rates were linked to land manager perceptions of the technology and of those diffusing it (Glendinning, Mahapatra et al. 2001; for a review see Mercer 2004). Further, it has demonstrated that effective modes of communication, such as agricultural extension through participatory exchange techniques, could foster technology adoption and diffusion between disparate groups (Fagerberg and Verspagen 2002; Glendinning, Mahapatra et al. 2001).

Other work in this thread, performed firmly in the neo-classical tradition, also drew on classical innovation-diffusion theory and focused on explanatory factors, such as income, perceptions of marginal utility (social or environmental benefit, for example), availability of information, and the level of education and experience of potential
adopters to explain adoption of technologies (Caviglia and Kahn. 2001; Feder and Umali. 1993; Upadhyay et al. 2003).

Thinking about and investigating technology in the above ways, however, says nothing of social power relations, of how existing (agricultural or forestry) practices change around technology adoption, of socio-ecological outcomes or how new social institutions form around their adoption. In short they cannot address the political ecology of new technology adoption. This former research leads to the questions I posed previously, but it cannot address them. In order to address these questions we need a new approach.

4.2.3 Beyond Diffusion and Perceptions: Nature-Society-Technology Relations & Political Ecology

Actor-network theory is one, but not the first, theoretical framework to attempt to understand the way that human and non-human natures interact with technology to produce things. Most notably, David Harvey in *Justice, Nature and the Geography of Difference* (1996), adopting a relational perspective in an approach he called the ‘new dialectics’, draws on Marxist (1990) political economy to show how capitalist production relations bring together and are embodied within otherwise seemingly disparate objects. It is the relationships that things have with other things that make them unique. But these processes are seen as ancillary to the central or overarching process, which is the capitalist mode of production.

Erik Swyngedouw (2004) drew on this approach and ANT in his work on Ecuadorian urban water development to argue that “the urban transformation of water is a
manifestation and expression of wider relations that clearly transcend the simple question as to who does and who does not have access to water.” Furthermore, the “water problem is not merely a question of management and technology, but rather, and perhaps in the first instance, a question of social power” (ibid, p. 175). For Swyngedouw, these “wider relations” are those defined by the process of capital accumulation, and the transformation of water (non-human nature) and technological patterns are “expressions” of the general logic of capital. This implies directedness in the transformation of society-nature relations by the imperatives of capital accumulation. Any failures in this process, such as the uneven socio-spatial distribution of water availability or new institutions of water use (e.g. usurious private water vendors) in Swyngedouw’s story, are the result of the reconfiguration of social power relations and nature under capitalism. These are outcomes or “particular moments (physical things) [that] contradict the ‘demands’ being placed on them by the logic of the process” (Castree 2005, p. 234).

Central to this work is the notion of hybridity and agency. The concept of hybridity (Latour 1993) attempts to break down the binaries of nature/society, structure/agency to show how these reductionist categories have never existed but that things or ‘quasi-objects’ are both social and natural: socionature. The strength in this approach is that it opens up the associations between heterogeneous objects to displace the stabilities between these objects, while showing that the “competencies and capacities of ‘things’ are not intrinsic but derive from association” (Whatmore 2002, cited in Bakker and Bridge 2006). Thus, second, the approach relies on a decentering of agency away from it being an inherently human capacity towards an understanding of how the non-
human can enable and constrain social action because of their historical relations with other human and non-humans objects. For instance, the capacities of groundwater, crops or tubewells are not intrinsic to the object (or equal) but derive from their historical relations (of production and consumption) with each other. So too, their capacities to drive change in these relationships vary from moment to moment in the economic process.

The more constructivist approaches to this topic have been accused of being apolitical and incapable of assigning causality or responsibility for understanding the natures we have (Bakker and Bridge 2006; Kirsch and Mitchell 2004). It is important from a normative standpoint, therefore, to engage the question of non-human agency within human geography by means of a framework that provides for the possibility of assigning “causality, accountability, and the directedness of social relations” without being deterministic (Kirsch & Mitchell 2004, p. 687). This means that specific drivers of the social process cannot be assumed a priori, lest they structure our analyses (Mitchell 2002, p. 43). Therefore, rather than prioritizing the association of the hybrid (as in strict versions of ANT), we ought to focus on the process of hybridization (i.e. the production of quasi-objects) to understand both the associations between heterogeneous objects but also the differentiation that results from this hybridization (Swyngedouw 2004).

Further research in this strand of thought has sought to understand how resource scarcity-reducing technologies, once adopted, affect the organization of human action and the making of social institutions (to adapt to them). In his work on Indian forests, Robbins drew on Langdon Winner’s notion of ‘reverse adaptation’ to show how existing
forester and forest-dependent peoples’ practices were reworked to meet the demands of and categories of land cover embedded in satellite imagery technology. Once adopted, he showed that these technologies had momentum in shaping social and political institutions, and ecologies (Robbins 2001; Winner 1977).

It is in this way that the human does not always organize the non-human, but sometimes the non-human organizes the human (Agrawal 2005; Mitchell 2002). So rather than thinking of non-human processes as always the outcome of prior human intention, we need to think of the possibility of them driving (both enabling and constraining) change in human and non-human nature as well. Specifically, applying this framework to the study of groundwater socionatures and resource scarcity-reducing technologies will advance both our understandings of these processes but also this body of theory. It furthers our understanding of the role of non-human capacity; something which remains a highly contentious issue in geography (see Bakker and Bridge 2006; Castree 2005; Kirsch and Mitchell 2004) as well as other disciplines.

4.3 Scarcity-reducing Technologies: The Quintessential Tubewell

To examine the unresolved tension in our understanding of nature-society-technology relation in geography, we need to examine how individual technologies in specific contexts become embedded within and condition the reworking of existing social power relationships and ecologies. One such paradigmatic technology is the tubewell in India, originally introduced in the 19th century to reduce water scarcity and the incidence of famine, especially in drought years. The tubewell is exemplary for furthering our understanding of these relations for three primary reasons: 1) it operates within social
processes such as caste and class, but is not completely subservient to of them; 2) it can be adapted to meet changing social and ecological conditions; and 3) its adoption intersects with both the material (production and reproduction) and the discursive (representation and signification).

Tubewells tap aquifers of varying depth, volume and recharge capacity. They are based on oil well drilling technology and in northern India range from 20-100 meters deep. Most tubewells utilize a submersible centrifugal pump, but historically when the water table was nearer the surface, ground-level diesel driven pumps were also used. Diesel pumps are still in use but their efficacy is declining as they are only able to draw groundwater after the monsoon when the water table is high.

The tubewell is not by any means the first technology in India for lifting groundwater, however. The use of the Persian Wheel is well documented in northern India since before 900 A.D. (Rosin 1993) and is still in use in the Mewar region of southwestern Rajasthan today. So too, not only the technology to lift groundwater but also knowledge of groundwater, groundwater based irrigation, groundwater location, its flow and recharge has also been in a process of development for centuries.

Groundwater use in the Indian imagination dates back to at least the Arthashashtra (Kautilya 1992). Written no later than 150 AD, the Arthashashtra sets out rules and regulations for the use and taxation of irrigation water. More recently, writing in 1894 for example, Munshi Hardyan Singh identified the Beldar caste of Marwar as historically devoted to groundwater knowledge and practices, such as “digging the earth, quarrying stones, and the like” (Singh 1894, p. 210). Following Mitchell (2002), the tubewell did
not simply diffuse throughout India but became enmeshed in previously existing ways of knowing, in previous practices of groundwater use and irrigation, and in previous social relations. And second, it does not merely provide water but is adopted and adapted by land managers, bureaucrats, and tubewell drilling firms, and is for that reason enmeshed synergistically within multiple changes in social relations.

It is commonly assumed that the tube well was introduced into India in the 1960s with Green Revolution development programs (Shiva 2002). But it was actually introduced much earlier by the British in the late 1800s as a source of “preventative irrigation” (Indian Irrigation Commission 1903, p. 49). The British divided irrigated area into “preventative irrigation” and “productive irrigation”. The latter included irrigated area and large, mostly surface water, schemes on which the colonial administration levied direct taxes on the irrigation water (in addition to the produce). The former, on the other hand, were minor schemes of surface and groundwater into which the administration invested capital, but from which they did not expect to levy duties. This is because their sole purpose was to reduce the possibility of drought-induced famine by diminishing agriculture’s reliance on unpredictable natural systems (i.e. the monsoon) (Indian Irrigation Commission 1903, p. 21 & 48). In this way the British were trying to separate or insulate agricultural productivity from the vagaries of nature. However, low population densities and lack of a rural electrical network made the widespread use of the tubewell not cost effective, and the former tended to inhibit the latter (Indian Irrigation Commission 1903)\textsuperscript{16}.

\textsuperscript{16} The colonial introduction of the tubewell rather than through Green Revolution development programs not only increases the temporal scale over which this technology has interacted with multi-scalar political
It wasn’t until the late 1960s that the tubewell began to proliferate. The central government in Delhi concluded, after 20 years of five-year plans, that the previously emphasized large-scale surface water irrigation projects were not paying for themselves and that the government should, with the help of international donors and development agencies (such as the Ford Foundation and the World Bank), create the conditions under which individual farmers could adopt private tubewells (Narayanamoorthy and Deshpande 2005). The two key moments underpinning this expansion were the nationalization of the banking system in 1969, which allowed the government to provide low-interest loans to land managers for tube well construction, and the expansion of rural electricity (Narayanamoorthy and Deshpande 2005). The ‘hands-off’ program of decentralizing and shifting irrigation from large-scale state run projects to individual small-scale ones has been wildly successful throughout India. Today there are over 20 million tubewells in India irrigating 70% of total agricultural area or 29,842,000 hectares in 1997 (Narayanamoorthy and Deshpande 2005, p. 70; Shah 2005; World Bank 2005).

4.3.1 Tubewells in Arid India: Rajasthan

Nowhere has this strategy been more successful than in the arid and semiarid northwestern state of Rajasthan. Between 1962 and 2001, farmers adopted over 1.4 million agricultural tubewells, and in the absence of any regulations for tubewell construction or groundwater use. This is a growth rate of 149.41% in a state that was already densely populated with dug wells (Government of Rajasthan Groundwater Board ecological systems, it also draws into question its relationship with the ‘Colonial Present’ of proposed reforms in the Indian water sector Gregory, D. (2004). the Colonial Present. Malden, MA: Blackwell.
Moreover, this is an area that had been the object of state planning for expanded groundwater irrigation since at least the late 1800s (Indian Irrigation Commission 1903) but probably before the writing of the Arthashashtra, before 150 AD (Kautilya 1992). And rather than the pace of tubewell construction tapering off, it is accelerating. For example, over the five-year period between 1995 and 1999 the number of tubewells rose 44.75% (Directorate of Economics and Statistics 1997, 2000). Between 1999 and 2001 they grew by 33%, while irrigated area rose from 3,076,957 to 3,801,119 hectares (ha), including an increase in net irrigated area of over 1.27 million ha during the same period (Directorate of Economics and Statistics 2000, 2003). And even though groundwater extraction currently surpasses recharge in the state by 410 million cubic meters per year, tubewell construction continues unabated (Government of Rajasthan Groundwater Board 2006). This growth resulted in rapidly declining groundwater levels, in some areas by over 60 meters between 1981 and 2000 (Government of Rajasthan Groundwater Board 2003). The severe state of groundwater overdraft is of serious concern as groundwater irrigates 71% of total irrigated area in the state, or nearly 4.0 million hectares (Directorate of Economics and Statistics 2003). Groundwater also provides over 80% of domestic water supply in both rural and urban areas (World Bank 2005). The future, therefore, of groundwater-led agricultural development (as well as groundwater-dependent urban development) is a matter of serious concern.

4.3.2 Irrigated Landscapes: The Jaipur District Region

In a number of respects, the Study Area near Jaipur, Rajasthan (see Figure 4.1) is the ideal place for this research. It has: 1) a long history of groundwater extraction and
development, 2) a recent history of rapid technological change and adaptation to new technology, and 3) a high degree of ecological and socio-economic variability, which allows for the investigation of the differential effects of technology adoption. Furthermore, groundwater is an extremely important resource and is highly utilized for domestic and agricultural purposes in this arid and semiarid area where there is very little surface water. This aspect of groundwater and associated lifting technologies makes it not only a highly contentious resource in need of investigation, but also, because of the resource’s seemingly pedestrian character, one well suited to the study of nature-society-technology relations.

Rajasthan is divided into 32 districts and each district is divided into numerous blocks or tehsils (there are 236 in all). Research for the present study took place during an 18 month period between 2002 and 2005. I surveyed over 150 farmers in six villages of Bassi Tehsil, around 60 kilometers east of Rajasthan’s capital city, Jaipur. Then, over the next several months I followed up on these surveys with multiple in-depth interviews of over 78 farmers, multiple government technocrats, two Hindu groundwater experts, and several tubewell drilling firms. Chosen for their social and ecological diversity, the villages comprise a highly stratified social environment of low and high caste Hindus, small, medium and large landholders, and moderately to rapidly declining groundwater levels in their respective vicinities. Even though we should not take social categories, such as caste and class, to assume difference (Agrawal 2005), they are still important considerations (Jeffrey 2001). For example, Table 4.1 shows average landholdings, by caste, in the Study Area. The relationship between caste and landholdings is significant.
(i.e. they are not independent) with $\chi^2 (4, N = 151) = 17.556, p = .001$. The noteworthy relationship between caste and landholding size is important in terms of their effects on tubewell adoption, institution formation and capital accumulation.

<table>
<thead>
<tr>
<th>Land Category (hectares)</th>
<th>Scheduled Caste %</th>
<th>General Caste %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25 - .50</td>
<td>9.2%</td>
<td>5.8%</td>
</tr>
<tr>
<td>0.51 – 1.0</td>
<td>41.5%</td>
<td>27.9%</td>
</tr>
<tr>
<td>1.10 – 2.5</td>
<td>38.5%</td>
<td>32.6%</td>
</tr>
<tr>
<td>2.51 – 3.9</td>
<td>6.2%</td>
<td>20.9%</td>
</tr>
<tr>
<td>4.00 – 7.5</td>
<td>4.6%</td>
<td>12.8%</td>
</tr>
</tbody>
</table>

Table 4.1: Landholdings size by caste in Study Area (n=151).

Jaipur District is a semiarid region of productive agricultural land, with nitrogen-poor alluvial soils (Singhania and Somani 1992). Situated between the arid plains of the north and west, and the comparatively humid lowlands of the southeast, it has moderately good groundwater recharge in years of adequate monsoon rains. Summer temperatures commonly reach 44 degrees Celsius. There are two cropping seasons: Khariph (summer) and Rabi (winter). The first is mostly rain fed and the other is dependent on intensive groundwater irrigation, respectively (see Figure 4.2). Like much of Rajasthan, the people in this area are groundwater-dependent for their irrigation and domestic needs. There is no government water supply, save sporadically functioning village hand pumps. All village residents, therefore, rely on tubewells for water.

4.4.1 Land Use, Soil and Groundwater Synergistic Change

In the last decade, the region has undergone dramatic land use change as a result of deep tubewell irrigation. In the eight year period between 1993-94 and 2001-02 (the longest period for which comparable district-wide data were available), total net irrigated
area rose dramatically in Jaipur District from 302,428 ha to 330,569 ha, a 9.3% increase. During the same period, total net irrigated area rose throughout the state from 4,597,355 ha (3,634,970 in 1989-90) to 5,419,769 ha, an 18% increase. With these increases in irrigated area, the tubewell became more prominent in irrigation with an increase in net tubewell irrigated area in Jaipur District from 296,421 ha to 329,230 ha (11% increase) between 1993-94 and 2001-02 and in the state from 2,458,411 ha to 3,816,342 ha (55% increase) over the same period (with much of this growth occurring between 1999 and 2001. See previous).

This expansion has two meanings. First, the expansion of tubewell irrigated area outpaced the rate of growth in total net irrigated area (i.e. area not formerly irrigated) in Jaipur District and Rajasthan. Therefore, the tubewell has taken over irrigation on previously irrigated land as the percentage change in tubewell irrigated area of the growth in total irrigated area (of formerly non-irrigated area) is 116.5% in Jaipur District and over 165% in Rajasthan. And second, nearly four decades after the Green Revolution, the tubewell is still expanding. But what is the character of this expansion in irrigated area and what does it mean for production?

As shown in Table 4.2, the character and productivity of the agricultural landscape has changed dramatically in the district between 1993-94 and 2001-02. The most dramatic changes occurred in commercial crops. There was a decline in the production and area of oil seeds (including “Total Oilseed” as well as Rape/Mustard and Linseed) and a rise in sesame, groundnut, condiments and spices, and vegetables (the latter are limited to non-maize vegetables: tomato – classified as a vegetable even though
it is a fruit – squash, onion, pea, potato and okra). Area and production of subsistence crops such as wheat, pearl millet, and sorghum and the commercial crops groundnut and sesame have also risen. Moreover, the area planted in barley, pulses and maize has stayed steady but the production of barley and maize has increased exponentially. Therefore, the yields per unit area have greatly increased. A possible shift in commodity prices over the time period could offer one explanation.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Area Δ</th>
<th>Production Δ</th>
<th>Subsistence or Commercial</th>
<th>Irrigation Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linseed</td>
<td>-96.55</td>
<td>-90.91</td>
<td>C</td>
<td>Hi</td>
</tr>
<tr>
<td>Rape/Mustard</td>
<td>-60.12</td>
<td>-66.97</td>
<td>C</td>
<td>Hi</td>
</tr>
<tr>
<td>Red Chili</td>
<td>-36.82</td>
<td>-36.61</td>
<td>C</td>
<td>Hi</td>
</tr>
<tr>
<td>Total Oilseed</td>
<td>-38.97</td>
<td>-25.75</td>
<td>C</td>
<td>Hi</td>
</tr>
<tr>
<td>Maize</td>
<td>-6.42</td>
<td>132.91</td>
<td>S</td>
<td>Hi</td>
</tr>
<tr>
<td>Pulses</td>
<td>-1.04</td>
<td>-6.41</td>
<td>S</td>
<td>None</td>
</tr>
<tr>
<td>Barley</td>
<td>6.69</td>
<td>71.17</td>
<td>S</td>
<td>Low</td>
</tr>
<tr>
<td>Total Food Grain</td>
<td>10.17</td>
<td>42.61</td>
<td>C</td>
<td>-----</td>
</tr>
<tr>
<td>Wheat</td>
<td>12.30</td>
<td>56.23</td>
<td>C/S</td>
<td>Hi</td>
</tr>
<tr>
<td>Pearl Millet</td>
<td>13.73</td>
<td>37.15</td>
<td>S</td>
<td>Low</td>
</tr>
<tr>
<td>Sorghum</td>
<td>23.39</td>
<td>-60.97</td>
<td>S</td>
<td>Low</td>
</tr>
<tr>
<td>Total Condiments &amp; Spices</td>
<td>32.10</td>
<td>-41.02</td>
<td>C</td>
<td>-----</td>
</tr>
<tr>
<td>Sesame</td>
<td>48.96</td>
<td>27.14</td>
<td>C</td>
<td>Low</td>
</tr>
<tr>
<td>Groundnut</td>
<td>52.93</td>
<td>171.94</td>
<td>C</td>
<td>Low</td>
</tr>
<tr>
<td>Total Vegetables</td>
<td>53.58</td>
<td>11.01</td>
<td>C</td>
<td>Hi</td>
</tr>
</tbody>
</table>

Table 4.2: Percentage change in area and production of principal crops in Jaipur District, Rajasthan between 1993-94 and 2001-02. (Table arranged by “area change” from most negative to most positive.)
There has been an overall downward shift in commodity prices (Barker and Molle 2005). According to the Food and Agricultural Organization’s (FAO) FAOSTAT (2006) online commodity price index, all prices for the products listed in Table 4.2 have fallen between 1993-94 and 2001-02. But this does not fully explain the rise in the production of some crops, such as sorghum, sesame or groundnut. So too, the change in the type of crops being produced is not simply the result of irrigation (in the sense that the availability of irrigation leads directly to increases in irrigated area and to high-yielding or lucrative crops production) or political economic factors.

One possibility here are the edaphic effects of tubewell adoption. Groundwater extraction for the irrigation of water-intensive crops over the last four decades has indeed
altered groundwater and soil chemistry. Jacks et al. (2005) showed that evapotranspiration of groundwater irrigation in Rajasthan lead to sodic soils and changes in overall soil chemistry (e.g. increased alkalinity) (see also Ramesam and Barua 1973). These changes cause the soil to release fluoride into the soil and groundwater, and in the precipitation of calcite into the soil, producing conditions that can facilitate desertification (whether temporary or not) (see Davis 2005; Rasmussena et al. 2001). The authors further indicate that remedial measures include rainwater harvesting and the addition of gypsum to the soil; the latter reduces alkalinity. These processes affect the kinds of crops that can be grown, as well as how irrigation is practiced: not just the balance between surface and tube well irrigation, but also soil beneficiation practices.

These possibilities are corroborated in farmer survey and interview responses. Of 152 farmers surveyed, 100% indicated that they had at least seasonal groundwater salinity and/or hardness (talia), and 100% indicated that they had at some time added gypsum to their soil to “loosen” it up. Suva Lal Sharma and his brother irrigate a little over 25 bighas (6.33 hectares) near Kanota, about 25 kilometers from Jaipur. They do not irrigate their summer crop, but in preparing their fields for the winter crop, they spread over $275 worth of gypsum yearly on the fields to break up the calcification of the soil: “The groundwater becomes more saline throughout the summer. It did not used to be like this; it [the salinity of the water and the calcification/sodic soil] happened with the irrigation. If we did not use gypsum to break-up the soil and we had a good rainfall, it wouldn’t soak in for 2 months.” Again quoting Sharma: “Formerly we could grow tomatoes, bindi [okra], mirchi [chili peppers], and baigan [eggplant], but now we do not
like to because we cannot produce much of it due to the salty water. So now we grow mostly sesame, wheat [in the winter], fodder crops and some lentils.” The result is a situation where irrigation intensive crops or less hardy crops cannot be grown because as groundwater is withdrawn throughout the season, with little or no rainwater recharge, either the productive capacity (in terms of volume lifted) of the tubewell decreases and/or the groundwater’s salinity increases. It is the association between these objects that leads to the particular outcomes (i.e. the production of particular social institutions, groundwater and soil chemistry change, and crops produced) that I am demonstrating. The result, therefore, is the production of crops that are less water-demanding and/or of more saline tolerant crops. This situation is confirmed by others who said that “we have increased our sesame production because it only requires one irrigation [per season].” The same is true with groundnuts. Farmers have increased their production of sesame and groundnuts throughout the district by nearly 49% and 53% respectively.

This illustrates the arguments above in three ways: 1) that groundwater use for irrigation has increased the salinity of groundwater; 2) the increase in the salinity of groundwater causes other minerals to leach into the soil, requiring the application of expensive gypsum to reduce the alkalinity; and 3) these alterations of soil and groundwater chemistry, the result of irrigation-intensive crops, has resulted in a reduced ability to grow these crops and instead encouraged the production of other kinds of crops that are less sensitive to these chemical changes in the soil and groundwater.

As with the rest of Rajasthan (and much of India), Jaipur District’s socio-ecology has been massively transformed through technological intervention. But what is the
capacity of tubewell technology in driving these shifting relations: those between producers, those between producers and the state, and producers and ecologies? Are these technologies alleviating or exacerbating natural resource scarcity and, once adopted, how do they impact people’s daily practices and the making of social institutions? For instance, how has land use change, a result of tubewell adoption, influenced further tubewell adoption and adaptation of the technology, which further influences land use change and institutional adaptation? The next two sub-sections take on these questions.

4.4.2 Differential Scarcity in Irrigation

The research area is a highly stratified social environment, typical of Rajasthan, where scheduled or marginal castes have the smallest landholdings (see Table 4.1). And in agrarian societies landholding size is a sound predictor of local power and wealth (Bernstein 1998; Ghimire 2002). This bears itself out when looking at the discrepancies in income from various sources between Scheduled and General Castes. Table 4.3 shows differential scarcity in average monthly income and landholdings by caste.

<table>
<thead>
<tr>
<th>Caste</th>
<th>Farm Income</th>
<th>Livestock Income</th>
<th>Off-farm Income</th>
<th>Total Income</th>
<th>Prop. Summer Irrigated</th>
<th>Prop. Winter Irrigated</th>
<th>Average Land – Hectares</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC</td>
<td>732</td>
<td>127</td>
<td>476</td>
<td>101</td>
<td>1014</td>
<td>2222</td>
<td>0.62</td>
</tr>
<tr>
<td>Gen</td>
<td>1316</td>
<td>170</td>
<td>751</td>
<td>112</td>
<td>694</td>
<td>2761</td>
<td>0.79</td>
</tr>
</tbody>
</table>

Table 4.3: Differential incomes and landholdings by caste.

\( n = 151 \) (Average monthly income in rupees, 45 rupees = $1)

Scheduled Castes (SC): 54 Meena, 8 Bairwa, 3 Yadan (65 total)
General Castes (Gen): 80 Sharma, 4 Jat, 2 Gujar (86 total)
Total monthly income is 2222 and 2761 rupees for general and Scheduled Castes respectively, while average landholdings are 1.38 and 2.16 ha. Off-farm income is much higher at rupees 1014 for Scheduled Castes and 694 for general. The trend in higher off-farm income among the most marginal of peasant farmers has been shown by many (Bryceson 1997, 2002) as they are propelled into off-farm labor to supplement inadequate farm related income. The Table also shows that on average General Castes irrigate higher proportions of their holdings in both summer and winter. Scheduled Castes irrigate 62% of their land in the summer and 71% in the winter, while General Castes irrigated 79% and 83% respectively. The difference in the percentage of irrigated area between castes is surprisingly small at 17% in the summer and 12% in the winter. Scheduled Castes are actually irrigating a lot of land, therefore. The question is, how are they doing it?

4.4.3 Adapting Institutions to Solve Scarcity and Access Issues

Table 4.4 shows the average number of owners for their first tubewell adoption (some farms have more than one) based on landholding size. The smallest landholders, in the category of 0.25 to 0.5, have on average 7.1 partners, meaning that one tubewell is being used to irrigate 7.1 farmsteads on average. This chapter established that the most marginal producers in landholding terms were Scheduled Castes. Therefore, looking to caste indicates that Scheduled Castes should average the most tubewell partners per tubewell, and they do (see Tables 4.5a and 4.5b).
<table>
<thead>
<tr>
<th>Land Category (hectares)</th>
<th>Tubewell Partners Tubewell #1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25 – 0.5</td>
<td>7.1</td>
</tr>
<tr>
<td>0.51 – 1.0</td>
<td>3.11</td>
</tr>
<tr>
<td>1.10 – 2.5</td>
<td>2.96</td>
</tr>
<tr>
<td>2.51 – 3.9</td>
<td>2.68</td>
</tr>
<tr>
<td>4.00 – 7.5</td>
<td>2.15</td>
</tr>
</tbody>
</table>

Table 4.4: Number of tubewell partners on average by landholding category. 

$(n = 141)$

Tables 4.5 and 4.6 indicate the average number of partners for each tubewell adopted, stratified by scheduled and General Caste respectively. In both tables “T1” through “T4” refers to the first through fourth tubewell adopted. They also show the mean water depth at which their first tubewell is placed. Implicitly, the tables also indicate tubewell failure (where failure denotes that the water table has been drawn down past the depth of the tubewell.). Typically farmers don’t own more than one functioning tubewell. The table shows therefore, that 12 Scheduled Caste partnership had 1 failed tubewell (as indicated by the number of partnerships under T2), while 4 had 2 failed tubewells and 2 had 3 failed tubewells, as compared to General Caste partnerships who had 12 failures on their first tubewell and no second tubewell failures, which would force them into a third adoption.
The tables also indicate that Scheduled Castes have on average 3.74 partners for their first tubewell, while General Castes have only 2.76 on average. So too, Scheduled Castes have twice the number of partners for their second tubewell at 4.08 compared to 2.0 for General Castes, while General Castes have not had more than one tubewell failure. The table further shows that Scheduled Castes dig deeper for groundwater, which, it has been argued, is a result of being allotted the poorest land after land reforms (Gupta 1994). They also have more well failures, as evidenced by their adoption in some cases of up to 4 tubewells (not all of which function).
It could be argued that the high numbers of tubewell partners among the most marginal landholders is due in part to the indivisibility of the technology (Boyce 1987; Dubash 2002). In this case, where one tubewell is capable of irrigating more than 0.25 or even .5 ha, it is possible that it would make sense to share the input. But this is not the case. Tubewell sharing is due to the high risk of failure in installing a tubewell, high construction, electricity and maintenance expenses, and barriers, in this particular case, to acquiring an electricity connection. But it is also a cause and consequence of social institutional innovations making it possible to share tubewell use, and this in a context where farmers would prefer not to share technology. According to farmers, they would much rather have their own tubewell:

Farmers that have partners are generally not happy because it is too difficult to coordinate. In the old times partnerships were ok. A dug well required partners to build, and also to irrigate required more than one person, but now it only requires one person to irrigate, but it does require more money. Now partnerships are not good because population has increased, groundwater has declined, pressures have increased – we need money now. It is also a problem because we only get 6 hours of electricity per day. Life is more complicated. (Farmer, July 19, 2005).

This indicates that partnerships are a necessity rather than an option and that they are a burden because of interrelationships between social and ecological factors. Moreover, the process for acquiring an electricity connection is an arduous and a lengthy one, further compelling farmers to form partnerships:

[Electricity] connections applied for before 1990 have been completed. We are now working on connections applied for after 1990. It takes 12-13 years to get a connection if you are in the general [caste] category. Currently there are 2 categories: SC and General. SC normally get their
connection immediately. General takes 12-13 years (Jaipur Vigut Vitran Nigam Ltd, July 2005)

And the process doesn’t end with the application. The average bribe is between 10,000 and 25,000 rupees ($222 – $555). Taken together, these factors favor sharing irrigation capacity through cooperative institutions. But why, as in the case of Dubash (2002), Rogaly (1999) and Harriss (1993), do private market-based institutions (such as entrepreneurial investors that sell groundwater for irrigation as in Dubash) not develop but rather institutions of cooperation? The present study shows that it may be due to the unpredictability of electricity supply, the scarcity of water, and an existing history of cooperative agrarian institutions.¹⁷ So too, given that the latter institutional arrangement is operating in Rajasthan, how do these institutional arrangements for sharing of tubewells and irrigation time work?

4.4.3.1 Coordinating Irrigation

Rajasthani farmers have developed institutions of collective ownership and operation around the tubewell. The tubewell is adopted to both intensify and extensify production, but once adopted, it demands the creation of social institutions. Farmers share tubewells for drinking-water and irrigation, splitting associated operating and maintenance costs between them. In addition, they coordinate their crops under changing ecological conditions, which are affected synergistically by their agricultural decisions. For example, in a water-scarce region, such as the Study Area, cropping decisions must

follow not only from the availability of water but also from the availability of the tubewell, both of which impact cropping decisions, which in turn affect the form of the cooperative institution. In this section, I illustrate the functioning of the partnerships by way of three fact-based cases. Before detailing these, I outline the basic characteristics of the cooperative institutions.

In the survey, 83% of all tubewell owners had partners. All partnerships were formed on kinship lines and the author found no indication that there were any existing partnerships in the Study Area (or beyond, based on 78 respondents’ comments) not founded on kinship. There are, minimally, seven steps (which are the making of new social institutions) in setting up a tubewell partnership: 1) form the partnership; 2) determine construction costs and arrange for the availability of construction funds; 3) determine a location for the tubewell; 4) acquire an electrical connection; 5) hire the construction firm and construct the tubewell; 6) decide seasonally on the crops to be grown and the rotation schedule; 7) coordinate operation and maintenance costs for the life of the equipment.

As mentioned, the partnership forms around patrilineal kinship relations. Typically, the eldest is the main decision maker although occasionally, a more junior partner may be the prime decision maker if he is viewed as more skilled or possessing more mental acuity (such as a higher degree of education). This person also makes his cropping decisions first, and the others follow. Cropping decisions must be coordinated because different crops have different irrigation demands and tolerances for not getting irrigation at crucial times, which is always a possibility. Vegetables are typically very
sensitive to the timing of irrigation, for example, while many traditional fodder crops are not. After the members are decided upon, the location is determined. The location is determined on the basis of a variety of factors beginning with nearness to an electrical connection, centrality to the partners, and technical consultations with tubewell drilling firms and local Hindu groundwater consultants as to the location of groundwater. The relative proximity to an existing electrical connection, capable of powering the three-phase tubewell pump-set, is not inconsequential. Even though a farmer may have an electrical connection, he or she is likely to have a single or dual phase connection – not the proper connection required to power the tubewell. And because farmers are required to pay a portion of the three-phase hookup cost, including for the required number of poles, transformers and distance of power line installed, this is a carefully planned endeavor. Typically, the electrical connection is acquired and installed before construction begins, but this is not always the case, especially if the farmers have an opportunity to drill a tubewell at a lower cost. There is competition between tubewell firms that sometimes (especially seasonally) drive down construction costs, which may attract farmers to construct a tubewell before acquiring an electrical connection. After the tubewell is constructed, the members coordinate which crops they will grow and determine a rotation schedule. The more partners there are, the more difficult this becomes, because even though each person is allocated an equal share, availability of electricity and the crop’s sensitivity to the timing of irrigation (i.e. the crop’s resiliency to not getting irrigation water at critical times) play a crucial role. In all three cases, electricity is only available for six hours per day and there is no set supply schedule.
Electricity could be available one day from 12 p.m. to 6 p.m. and the next day from 2 a.m. to 8 a.m., commonly with interruptions in-between. The tubewell cannot be left in the ‘on’ position for two reasons: 1) the tubewell must be powered up through a manual sequence; and 2) the practice of irrigation is not automated and requires user input. Therefore, somebody in each partner’s household must stay awake during the night in the event that the electricity becomes operational.

If the head partner plants an irrigation-intensive crop that is very sensitive to irrigation timing, he will exert pressure on the other partners to irrigate his crop even if it is not his turn. Then at the end of the season he may be pressured by the others to redistribute some of his profits (either directly, in kind, or indirectly through wedding gifts, for example) from that successful crop and/or pay more of the operational costs, especially if others’ crops fail. The partnerships are very complex and ad hoc. They depend on constant negotiation. However, the present research documents no instances of failure.

The institution of tubewell partnerships is best exemplified through the three, fact-based cases below. Table 4.7 presents the basic configuration of the partnerships. At first glance there is a clear advantage, in terms of the irrigation schedule and the kinds of crops that small partnerships enable, to have fewer partners. Each case follows.
<table>
<thead>
<tr>
<th>Number of Partners</th>
<th>Total Cost</th>
<th>Average Income Per Partner</th>
<th>Annual Costs: Total</th>
<th>Winter Crops</th>
<th>Summer Crops</th>
<th>Rotation Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1: ID 062</td>
<td>2</td>
<td>72,000*</td>
<td>2,000 = maintenance 10,800** = electricity</td>
<td>1, 2, 6</td>
<td>3, 4, 5</td>
<td>Every other day</td>
</tr>
<tr>
<td>Case 2: ID 126</td>
<td>7</td>
<td>56,000</td>
<td>3,500 = maintenance 10,800 = electricity</td>
<td>1, 3</td>
<td></td>
<td>Once every 7 days</td>
</tr>
<tr>
<td>Case 3: ID 013</td>
<td>9</td>
<td>90,000</td>
<td>10,800 = maintenance 10,800 = electricity</td>
<td>1, 6, 9</td>
<td>3, 4, 5, 7, 8, 9</td>
<td>Once every 9 days</td>
</tr>
</tbody>
</table>

Table 4.7: Three tubewell partnership cases.
* Prices and Costs in rupees, 45 rupees = $1.
**Currently there is a fixed agricultural electricity tariff in Rajasthan of rupees 900/month. This is changing, however, as meters are being installed throughout the state.
Crops: 1 = wheat, 2 = barley, 3 = pearl millet, 4 = sorghum, 5 = groundnut, 6 = vegetables, 7 = gram, 8 = til/guar, 9 = fodder

Case One

Two upper caste Brahmins (General Caste census category) formed this partnership in 2002, when they constructed their first tubewell for a total of 72,000 rupees, 36,000 per partner. It is 75 meters deep with a 7 ½ HP pump, with a discharge of no more than 275 liters per minute (lpm). Their average annual agricultural income on 2.03 hectares each was rupees 125,000. They divide maintenance and electricity costs evenly. They make their cropping decisions jointly and are equals in the decision-making process. Their incomes are distributed roughly equally. They have good quality groundwater and are, therefore, able to grow a highly lucrative tomato cash crop, which
they sell by the kilogram to resellers from Delhi. The women in these families do not work outside of the home and all of their children of school age attend school.

In order to augment against the possibility of failed electricity on an irrigation day, one partner built a 10 x 12 feet (1131 ft³ or 32,026 liters) cement holding tank, an institutional innovation. He keeps this tank full to the best of his ability and then if an electricity outage occurs he can use this water to irrigate a small area of his more sensitive crops, such as vegetables (tomatoes, for example). If there were more farmers in the partnership, he would not be able to afford this luxury because he would have fewer days of tubewell access, so limiting the amount of water he could draw off for his holding tank. So too, it is rare that the electricity would be off for more than 24 hours, decreasing the prospect of crop failure for the members of small partnerships.

Case Two

Seven Scheduled Caste Meenas formed this partnership also in 2002, when they constructed their tubewell for a total cost of 56,000 rupees, 8,000 per partner. It is 57 meters deep with a 7 ½ HP pump, with a discharge of no more than 300 lpm. Their average agricultural income was rupees 8,000 on 1.39 hectares, with the primary holder earning a little more. This income is much smaller than in Case One due to poorer land and groundwater quality (which is partially the result of many partners). Each partner produces the same crops (but in varying combinations) due to poor groundwater quality, which is partly the result of the heavy demands that the seven users place on it. There is little negotiating of the crops to be grown or of the irrigation schedule, because poor groundwater quality limits the variety of potential crops, as I explain below. It also limits
them from producing lucrative vegetables, as in Case One, which drastically and negatively impacts their profits. They share maintenance and electricity costs equally. Each partner is allocated one day of the week in which to irrigate and each partner follows consecutively. If on one day, there is no electricity or there is a maintenance problem with the tubewell and it is not possible to irrigate, then that partner loses a turn. This person may buy a day or particular number of hours from one of the other partners, but this is rare as each partner’s allocation to the tubewell is already maximized. In the event that they do buy, then they only pay for the electricity cost as water is viewed as common property. The women in these families work in the fields and their daughters do not attend school beyond the 5th grade.

This partnership has very little ability to weather sporadic electricity supply and tubewell availability, which follows from the gaps in electricity accessibility. Partly for this reason, they are not able to cultivate vegetables and instead focus on grain crops (wheat and pearl millet), which are more drought tolerant, less sensitive to seasonal irrigation timing, and can be used as animal fodder whether or not they produce a seed crop. Vegetable production would also require more care for this partnership because historical, seasonal and daily groundwater drawdown in the area makes their water saline and mineral-rich. Furthermore, they are irrigating nearly 10 hectares (1.39 x 7 = 9.73) with one tubewell, as compared to Case One, which is irrigating only 4.06 hectares. The increased irrigation in Case Two probably results in irrigation water that is more saline and with higher mineral concentrations on a daily basis, making it impossible to irrigate anything but more tolerant fodder crops. The result is more irrigated area in Case Two,
but with a character of irrigation that is distinguishable both in terms of groundwater quality and the kinds of crops that can be grown, which would impact soil quality over time (as is the situation in Case Three).

Case Three

Nine Meenas formed this partnership in 2001, when they constructed their tubewell for a total cost of 90,000 rupees, 10,000 per partner. It is 66 meters deep with a 7 ½ HP pump, with a maximum discharge 275 lpm. As opposed to a typical tubewell construction, which is located at the ground surface, this one is constructed in a 20 meters dug well. Near the bottom of the dug well, they constructed 5, 10 meter, horizontal feeder tubes (with considerable time and effort) that emanate spoke-like from the center to increase the efficiency in drawing in surrounding groundwater. This is actually a very common adaptation for two reasons. First, the cost of digging a tubewell is reduced by utilizing the depth of the existing dug well. Second, the horizontal feeder tubes utilize the cavity of the dug well to create a sink for groundwater.\(^\text{18}\)

Their average agricultural income was rupees 22,700 with the eldest holder earning rupees 35,000 on 1.01 hectares. Each partner is allocated one day every nine days in which to irrigate and each partner follows consecutively. Electricity and maintenance costs are shared equally. Negotiating which crops to produce is less contentious in this partnership as the groundwater quality is better than in Case Two, but not as good as in Case One. Even though they are irrigating over 9 hectares with one tubewell, they are able to grow vegetables, but one tubewell cannot provide enough irrigation water to

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\(^{18}\) Partially or completely defunct dug wells are also increasingly being utilized for rainwater harvesting. Farmers drain their rooftops into them after running the rainwater through a small settling box, where the silt is allowed to drop (gravity drop-box) before the water enters the well.
irrigate 9 hectares of tomatoes or some other water intensive crops. This accounts for their diversity of crop production. Groundnuts, a cash crop, require more water than pearl millet but not as much as tomatoes. They could split the partnership or construct a new tubewell but a combination of the long wait for an electrical connection, and the cost and the fear of over-pumping in a small area (indicating hydrogeological knowledge) are all factors in not constructing an additional tubewell and limiting this institutional innovation. The combination of groundwater quality, the high number of partners and the desire to produce cash crops result in an intensively irrigated landscape, but one that is polycultural as well, as opposed to the monocultural landscapes produced by a different confluence of factors in Cases One (where two partners with access to high quality groundwater focused on lucrative cash crops, but also grew fodder crops) and Two (where seven partners with access to low quality groundwater focused on fodder crops).

The Three Cases Reviewed

In the survey, 76.6% of tubewell owners, coordinated irrigation timing with their partners. Cases One and Three were both able to coordinate irrigation timing to produce vegetables (mostly tomatoes: a water intensive crop that is sensitive to the quality and timing of irrigation water). Case Two, even though it had fewer partners than Case Three, grew fewer types of crops (pearl millet and wheat) that were less water-intensive and would also grow with poorer quality irrigation water. Even though the partners in Case Two were located in the same proximity as the other cases, the high degree of ecological variation in groundwater – where Case Two had poor quality groundwater with low
recharge – made it difficult to irrigate sensitive crops. Their lower agricultural incomes reflect this ecological reality.

Case Three shows how tubewell technology is adapted by farmers to meet changing ecological demands. The method of placing a tubewell within an existing dug well (“dug-cum-bore well”) is both cheaper and more productive, even though labor intensive. A second adaptation, not represented in the case studies above, is rainwater harvesting. Farmers are increasingly setting up rooftop harvesting (or some other small drainage area) systems that empty directly (after being filtered for sediment) into the existing borehole. Third, as mentioned previously tubewell pumps require special electrical connections, which often take months or years to acquire. One way around this is to rewire the pump to work on a standard electrical connection. However, this diminishes the capacity of the pump and also its ability to lift water, and so confines the practice to shallower tubewells. This modification also often requires the use of a surface “accelerator” pump to provide extra dispersion power. These technological adaptations further demonstrate how techno-ecological constraints prompt particular kinds of adaptations.

Finally, the Cases show how struggles over production occur within these partnerships. But there are also struggles in the aggregate. For example, following one upper caste Brahmin:

The Meenas [low castes] are using too much water with their poor farming practices. The [ground] water doesn’t come to us anymore. They are excavating their land to sell it to the brick kilns. This causes the rain to settle into their land and not into ours” (Brahmin Farmer, July 30, 2005).
Sentiments such as these are widely held, whether or not the beliefs on which they are based actually reflect irrigation practices.

4.5 Discussion: Ecological Change & Social Institution adaptation

The present situation of ecological change, technology adoption and human adaptation cannot be understood unless the roles of non-human actors are examined. Specifically, human and non-human nature, tubewells and irrigation, cropping constraints, and changes in groundwater quality act synergistically as both cause and consequence in the processes of ecological (groundwater and land use) change and dynamic social institution formation. Table 2 showed that agriculture in Jaipur District has undergone tremendous change over the past several years. While the changes in type and productivity of the crops being grown cannot be attributed solely to irrigation (character of the monsoon, high-yielding seed varieties, variation in market demand and price, and availability of fertilizer and pesticides are also factors), these changes would not be possible without it. This change is the result of the most marginal producers’ abilities to harness irrigation water and bring more land under the plow.19 So too, the ability of the most marginal producers to harness the productive capacity of groundwater irrigation depends on their ability to coordinate with others to construct tubewells. The ecological effects of coordination are clear at the district level, in the increased groundwater dependent irrigated area of commercial crops. And they show up between

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19 Results of OLS regression comparing the change in marginal landholdings (a census category of landholdings less than 1.0 hectares) and the change in tubewell irrigated area show a strong, positive relationship between the two with $R^2 = 0.724$ at the 99% confidence level.
groups of users (see previous section) and in the aggregate between groundwater users and the state (Birkenholtz Forthcoming).

But when these data are disaggregated, as in the last section, a more complicated political ecology emerges. It is a political ecology of differential scarcity grounded in caste and class, as exemplified by the higher number of tubewell partners among Scheduled Caste respondents. But scarcity does not follow directly from these categories of difference. In this case, the politics of groundwater scarcity play themselves out both between partnerships, but also within partnerships. Between partnerships, the association between the number of members in the partnership, the availability of groundwater and its quality, land use and the change in land use that results from the changes in water and soil quality via irrigation produced differentiation. Within partnerships, these processes are made material in the kinds of institutions and practices that farmers devise to overcome the hurdles of access to groundwater including: cost of the tubewell, risk of failure, and the lengthy wait and high cost of an electrical connection. But they also overcome hurdles in the use of groundwater. Daily practices follow from these institutions, including: waiting on electricity, waiting on water, negotiating between partners for tubewell access, and cropping constraints that follows from groundwater change (which impacts the negotiations). In this way the object (tubewell) disciplines the subject (farmers).

The tubewell does not cause groundwater decline any more than it forces people to adopt it. But once it is adopted it becomes active, in that it enables and constrains (it has demands such as electricity and maintenance) particular relationships, between
adopters, and adopters and the state (such as the expertise that forms around irrigation).\textsuperscript{20}

It has capacity that is a product of its associations with other objects. But it may remain more or less passive in other relationships. If the tubewell were pulled out of the network, then the network and the associations would not be the same. Without the tubewell in this network of relations, groundwater use, agricultural production, and social institutions would look very different. And if we don’t look to technics then the economy becomes reified as the main agent of social change.

\textbf{4.6 Conclusions}

In this chapter, I have demonstrated that there is inequality in agricultural income and productivity based on caste and class between tubewell adopting farmer households. However, this variation is much less apparent when comparing the proportion of irrigated area to total agricultural landholdings at the household level.

Second, I illustrated how this inequality was partially mitigated by the creation of a new institution around tubewell adoption: tubewell partnerships. The smallest farmers harness the productive capacity of (expensive) tubewell irrigation systems, but only by forming partnerships. The partnership is a site of political struggle in crop selection and benefits accrued. Moreover, they are not completely equal within or between themselves. Smaller partnerships, for example, have more flexibility in crop selection and are able to better irrigate their crops, which positively impacts their ability to accumulate capital. However, their economic prospects cannot be separated from the constraints imposed on

\textsuperscript{20} So too, the widespread of the tubewell in Rajasthan, over especially the last decade, has set in motion the production of multiple forms of local and formal expertise on tubewell irrigation systems and groundwater knowledge practices.
them by ecological conditions that are both a result of the prior physical reality of groundwater and of historical inequality in landholdings, and also a result of their cropping decisions. In other words, groundwater chemistry and availability (absolutely, in terms of the actual physical amount of groundwater) are physical realties but are also directly affected by cropping decisions, which synergistically impact groundwater and this restricts the types of crops that it is possible to grow. Access to groundwater is also relative, in that within larger partnerships, which predominate among low caste groups, the amount of tubewell time is negatively impacted by the increased number of partners, which limits the types of crops that can be grown (especially the more irrigation-intensive but economically lucrative crops). And, inequality between partnerships exists because of the history of marginal people holding marginal lands (with poor groundwater reserves) as well as because of the institutional form that are a product of tubewell adoption under differential political ecological conditions. Thus, the physical and changing essence of the resource – groundwater – coupled with historical inequality in landholdings and groundwater, and the demands and constraints of the technology to lift it (tubewells) forms a hybrid network, in which ecological and institutional differentiation is a cause and consequence.

Third, at different moments in the economic process, the tubewell has differential capacities to effect its associations in the hybrid network to which it belongs and which it transforms by reconfiguring relationships between human and non-human nature. Technology’s capacity to influence change is not intrinsic, therefore but is something that
is produced through its relationships with other objects. The tubewell may clearly matter, therefore, but it does not have to matter.

Fourth, irrigation practices and daily household production activities follow from the demands and constraints of the tubewell, enabling and constraining both human and non-human action (ecological and institutional differentiation). The immediate result is the differential reconfiguring of social systems (e.g. institutions of adaptation) around the demands, constraints and opportunities set in motion through the adoption of the technology. The reconfiguring is differential because the form of the social institution depends on both the historical and current political ecological realities of the adopters.

Finally, these processes result in the material remaking of technonature through massive changes in cropping patterns and in a highly technologically dependent landscape, while enabling and constraining the future of groundwater dependent agrarian and non-agrarian development.
CHAPTER 5

‘ENVIRONMENTALITY’ IN RAJASTHAN’S GROUNDWATER SECTOR:
DIVERGENT ENVIRONMENTAL KNOWLEDGES AND SUBJECTIVITIES

5.1 Introduction

This chapter draws on Agrawal’s conceptual framework of ‘environmentality’ (2005) to examine the decentralization of environmental governance in India. The more precise goal is to exemplify how environmentally aware subjects – i.e. ‘environmental subjects’ – are actively produced by the state, how the state and its subjects understand each other, and what this means for the future creation of formal groundwater management institutions in Rajasthan, India. A combination of environmentalism and Foucault’s governmentality (1991), environmentality is a method for examining the “creation of governmentalized localities, institutional politics within regulatory communities, and the making of environmental subjects” (Agrawal 2005, p. 20). It is a way of understanding the effects and functions of the decentralization of environmental governance by looking to “knowledges, politics, institutions, and subjectivities that come to be linked together with the emergence of the environment as a domain that requires regulation and protection” (Agrawal 2005, p. 226).
This interpretive framework informs the present work, conceptually and methodologically, in four distinct ways. First, it is concerned with the ways in which the environment is discursively framed as an object of concern by the state and, in this instance, as something that needs to be conserved and protected. Second, it examines the ways in which this new environmental awareness relies on the interaction of different forms of knowledge, but especially the deployment of that knowledge by the state that is commonly defined both by regulator and regulated as ‘expert’ and on which the authority of conservation rests. Looking here opens up a space in which to understand both how people understand or ‘see the state’ (Corbridge, Williams et al. 2005) and what this might mean for successful regulation. Third, it shows how these ideas, and the rules needed to promote them, are most effective when their production and enforcement is decentralized. And fourth, it highlights that the legitimation of these ideas cannot be imposed but must be instilled, in accordance with the norm of decentralization, through ‘governmentalized localities’; this depends on the simultaneous production of environmental subjects, who will willingly perform the tasks of monitoring and enforcement. These concrete concerns can be expressed in the form of three distinct questions: 1) how and why does the state produce environmental subjects and what are the tensions in this process; 2) how does looking to divergent state and local environmental knowledges inform this process; and 3) what does this mean for the future efficacy of decentralized environmental regulation? The future of regulation, at least in the short-term, depends upon the bridging the gap between state and lay environmental knowledge and how these two articulate in particular mutual understandings.
In an attempt to better understand the active production of environmental subjects by the state and the implications for groundwater governance, I examine the state’s recent efforts to create decentralized regulation in the proposed Rajasthan Groundwater Rational Use and Management Act of 2005 (hereafter the Act). The Act has two key provisions. First, it sets up a new hierarchical Groundwater Authority to implement the Act’s regulations, whose future effectiveness rests (secondly) on its aim to create a sense of environmental awareness in groundwater among peasant farmers. Given that the Groundwater Authority has yet to come into being and begin work, my analysis is limited to 1) an examination of the provisions for the organization of the Authority, which are top-down and provide limited opportunities for the mutual exchange, between the Authority and farmers, of understandings and knowledge of groundwater practices and management institutions, and 2) the actions of current state agencies in Rajasthan that work with farmers on groundwater issues and, how and why farmers relate negatively to them.

In this chapter, I analyze the structure and character of the proposed Act to evaluate the prospects for the creation of successful groundwater regulation. First, I demonstrate, that the proposed regulation is hierarchical in that it does not provide a democratic mechanism. Second, by examining the proposed groundwater regulation, I find that current regulatory efforts do not incorporate locally existing knowledge, practices or institutions of groundwater use, but instead plan to alter the way people currently see groundwater. Third, the likely implications of this failure are highlighted by divergences between local and state groundwater knowledge in deep tubewell
construction. So while the Rajasthan state is indeed trying to foster a widely held sense of environmentalism in water resources, as both a precondition of decentralized environmental governance and as a critical element of self-regulating environmental people, the effect is likely to be compromised, due in part to the rift between local and state groundwater knowledge. The other part of the problem is that these efforts seem to be part of an overall strategy to decentralize state power, rather than to decentralize governance, and this could work counter to the creation of environmental subjects and ‘successful’ groundwater governance. Following Agrawal, successful natural resource regulation – whether to the actual benefit of people or not – is dependent both on the state enrolling people into its environmental cause and creating a non-hierarchical and democratic means of ensuring local input (whether real and imagined) into the policy making and enforcing process. This work evaluates the prospects for successful groundwater regulation along the lines of successful forest regulation outlined by Agrawal. It also offers an opportunity to advance our understanding of the processes of decentralized environmental governance through active state environmental subject making and the contentious geographies they make.

This chapter first outlines the four aspects of environmentality outlined above: 1) framing the environment as something in need of protection; 2) which relies on the deployment of expert knowledge; 3) to institutions of decentralized governance that result in the creation of ‘governmentalized localities’ and 4) the making of environmental subjects. In the second section, I lay out recent attempts by the State of Rajasthan to draft new groundwater legislation, which has yet to be fully implemented. In the third section,
I advance the lessons from Agrawal, by applying the concepts of environmentality to the problem of groundwater conservation and regulation in Rajasthan.

5.2 Environmentality, Governance, and Technologies of Rule

In his book *Environmentality* (2005), Agrawal analyzed how villagers in the Kumaon region of India’s Himalayan state of Uttaranchal, went from setting forest fires in the early 1920s, protesting British colonial efforts of forest enclosure and extractive conservation, to being active environmental stewards in the 1990s. The key to this transformation, he argued, was the decentralization of environmental governance through the environmental subjectification of forest users. Agrawal identified three aspects of decentralized environmental governance: 1) “the redefinition of political and administrative links between the state and localities”, terming the latter “governmentalized localities”; 2) “the realignment of institutional and social relationships within local communities, and 3) the emergence of a more widespread concern with the environment and the making of environmental subjects” (Agrawal 2005, p. 89). In Rajasthani groundwater governance, these relationships are still in a process of becoming. Since the Act has yet to come into force, it is not yet possible to follow through on the second point above; i.e., “the realignment of institutional and social relationships within local communities.” Consequently, I examine points one and three by using examples from his text.
The British East India Company took control of Kumaon in 1815. At this time, the forests were thought to be inexhaustible. Initially they were not heavily used and “for years nothing was done to protect forests in any way” (Bailey 1924, cited in Agrawal 2005, p. 68). But in the latter half of the 19th century, Indian railway construction demanded increasing amounts of wood for railroad ties, which increased the value of the forests. This led to rampant speculation as the government leased out vast areas to private forestry contractors at negligible rents and without oversight. These clear-cut their leased areas and, with disregard, took only the largest timbers. This prompted the first official survey in 1869 that concluded “the forests have been worked to desolation”, even though the contract system had been abolished over ten years previously in 1858 (Pearson 1869, cited in Agrawal 2005, p. 68).

The drastic deterioration in the condition of forests led to the Forest Act of 1865, which brought the most valuable areas under state control. This Act marked the beginning of scientific forestry in India grounded in formal expertise. Foresters defined what forest was and what was not, how it should be managed, and what activities should be allowed or excluded. The Forest Department also measured tree girth, took surveys, and used statistics to quantify the forest growth, determine sustained yields and inform reforestation objectives. The increased reliance on statistics to manage forests created a “new generation of foresters who had faith and confidence in the technologies of government of which they were a part” (Agrawal 2005, p. 60).
This led to increasing disregard for peasant forest use and management, which was viewed as ‘unscientific.’ The numbers were used as “automatic pilots” in decision making, with the effect of depoliticizing and justifying environmental government, including the exclusion of peasant activities and peasants themselves (Rose 1999, cited in Agrawal 2005, p. 60). But displaced and otherwise affected villagers rejected this proposition, leading to increased peasant unrest and protests. The Forest Act of 1878 added to this tension by demarcating forests and dividing them into reserved forests, protected forests, and village forests. This increased the area under state control dramatically. As a result, by 1916 the state had 3,000 square miles of reserved forests (up from 200 in 1911) (Agrawal 2005, p. 72). The Forest Department now had the authority to restrict and regulate all activities in reserved forests, but it did not have adequate staff to enforce the new regulations. This had two effects.

First, it led to yet more peasant protests, including the burning of 200,000 acres of forest in 1916 (ibid p. 3). Second, the scarcity of regulatory officials, the economic and political costs and inefficiencies of centralized regulation, and the continuing peasant protests prompted a new regulatory approach embodied in the Forest Council Rules of 1931. The rules created a system of decentralized forestry management by bringing nearly 2,000 square miles under the shared regulatory jurisdiction of the Forest Department, the Revenue Department and village residents (even though forest officials were still skeptical that villagers could manage their forests) (ibid p. 83). Enrolling villagers into the system of forest conservation (ultimately for maximum sustained yield and profit) required changing their attitudes towards Forest Department policies, while
bringing them into the fold of regulation. The solution was found through what Agrawal termed “governmentalized localities” (ibid p. 101).

Governmentalized localities were both a strategy and an outcome of these processes. The Forest Council Rules resulted in more than 3,500 such councils today (one-third of all villages in Kumaon) and were the precursor of today’s Joint Forest Management (JFM) (ibid, p. 79 & 119). They represented and continue to represent a shift in environmental governance and a new technology of government that is less costly, both economically and politically. But they are also the outcome of peasant resistance to centralized, non-representative government. The forest councils radically transformed the regulatory landscape, but instead of creating localized mirror images of the state, they relied on existing forms of cooperation and institutions, and existing local governments (panchayats). Therefore, the Rules created ‘governmentalized localities’, which localized some authority and encouraged (and depended for their success on) “the willing participation of those subject to rule and rules” (ibid, p. 125). In other words, it depended on the third aspect of Agrawal’s decentralized environmental governance – the state inscription of environmental awareness and the making of environmental subjects. It needed to produce a particular kind of local subject to carry forward its strategies, but the subjects the process produced were not always predictable and not everyone became an environmentalist. It is to environmental subjects that I now turn.

5.2.2 Environmental Subjects

For those who have become environmental subjects, the “environment constitutes...a conceptual category that organizes some of their thinking; it is also a
domain in conscious relation to which they perform some of their actions” (Agrawal 2005, p. 165). The human turns himself or herself into a subject “by following certain practices and modes of thought” (Agrawal 2005, p. 221). The process of subject formation depends, therefore, on the intersection of power/knowledge, but is also dependent upon prior political, economic and social positioning. This is why not all people subjected to the same conservation message will become environmentally aware. The questions are: how does the state make environmental subjects; is this process one-sided and antagonistic, or mutually dependent; why do some come to care for the environment while others do not?

Agrawal contends that active participants in the regulatory process, such as those who make rules, monitor forests or allocate resources, gain an understanding of the natural resources that are in their charge and see the effects of human use, both positive and negative as they view them from their situated position within this process. Therefore, regulations cultivated through governmentalized localities and mutual exchange and obligation are technologies of state power, based on the mobilization of knowledge, which encourages subjects to define themselves in relation to it: “Regulatory rule, creates awareness and knowledge through direct participation in the various elements and stages of regulations” (Agrawal 2005, p. 163). So too, the subject does not simply emerge and exist independently of historical, political and social conditions. But, again following Agrawal, the subject cannot be understood simply as a product of particular social differences such as those of caste, class or gender. He argues that it is practice that differentiates various kinds of subjects. Therefore, while social categories
are important it is more than looking simply to them. We need to examine individual practices of articulating with these new regulatory regimes (such as rule making and enforcement), which guide particular understandings and perceptions of environmental problems and their solutions (ibid, p. 197).

Over time, communities assume a sense of ownership over their resources as they define and carry out rules and regulations. In what Agrawal termed ‘imagined autonomy’, villagers used the state language of regulation and protection in pursuit of management goals that they perceived to be their own, while in fact, they came from the state. Imagined autonomy actually derived from performing the conservation practices encouraged by the state. This produced a sense of environmentalist identity that was crucial for successful decentralized environmental governance. It also produced a sense of democratic rule making and enforcement that was both real and imagined. It was real in the sense that some of the peoples’ goals were met (through protest), such as the granting of fodder harvests. But it was imagined in the sense that the environmentalist subjectivities that people took to be of their own making, actually came from the state. It is this real and imagined democratic autonomy that made forest regulation successful. And while Agrawal contended that this form of governance has led to mutually beneficial conservation outcomes, it is also possible that it could be a form of government that allows more effective control over local populations and their resources.

The twin concepts of governmentalized localities and environmental subjectivity are critical to the recent Rajasthan state efforts to regulate groundwater use. Thinking through what Agrawal’s conceptual framework and recent regulatory reforms
respectively mean for the water sector in India is particularly timely. This is because groundwater is a contentious issue in the country due to its importance for irrigation and domestic purposes as well as being the object of newly proposed regulation.

5.3 Regulating Groundwater in Rajasthan: The proposed GW Bill & Making Environmental Subjects

5.3.1 Study Area – Jaipur District, Rajasthan

Rajasthan is divided into 32 districts and each district is divided into numerous blocks or tehsils (there are 237 in all). Research for the present study took place in the summer of 2005. I surveyed over 150 farmers in six villages of Bassi Tehsil, around 60 kilometers east of Rajasthan’s capital city, Jaipur (see Figure 5.1). Then, over the next several months I followed up on these surveys with in-depth interviews of over 78 farmers, multiple government technocrats, and several tubewell drilling firms. Chosen for their social and ecological diversity, the villages comprise a highly stratified social environment of low and high caste Hindus, small, medium and large landholders, and moderately to rapidly declining groundwater levels in their respective vicinities. Even though we should not take social categories, such as caste and class, to assume difference, they are still important considerations (Jeffrey 2001).
Like much of Rajasthan, the people in this area are groundwater-dependent for their irrigation and domestic needs. There is no government water supply, save sporadically functioning village hand pumps. All village residents, therefore, rely on tubewells for water. Tubewells tap aquifers of varying depth, volume and recharge capacity. They were first introduced by the British in the late 1800s (Indian Irrigation Commission 1903) but didn’t come to dominate groundwater supply until after they were promoted in 1960s Green Revolution development programs. Today there are at least 1.4
million, unregulated, agricultural tubewells in the state (Government of Rajasthan Groundwater Board 2003).

In a number of respects, Rajasthan is an ideal place in which to study the process of environmental subject making. There is no history of formal state groundwater regulation, little historical state involvement in groundwater supply, and the resource is highly utilized, making it a facet of the environment that everyone has a particular prior understanding of, and something that people feel strongly about. This salience allows furthermore for the examination of differing viewpoints that are well grounded in practical experience. Following Agrawal, there are “variations in the transformation” of subjects (2005, p. 186).

The Problem of Water Scarcity

The world is facing a severe water crisis. According to the United Nations, groundwater use for irrigation by the world’s farmers exceeds natural recharge rates by at least 160 billion cubic meters per year so that by 2025, 50% of the world’s population will face water scarcity (Rosegrant, Cai et al. 2002). In India, where groundwater meets 70% of the country’s irrigation needs and 80% of its domestic water supplies, demand for both rural and urban uses is expected to exceed supply by 2020 (World Bank 2005). This is of particular concern in the state of Rajasthan, where groundwater is an increasingly important source of both irrigation and domestic water. In 1990, 60% of Rajasthani gross irrigated area was irrigated with groundwater (Directorate of Economics and Statistics 1997). By 2000, nearly 71% of irrigated area was groundwater-dependent. This includes an increase in net irrigated area between 1990 and 2000 of over 1.27 million hectares in
the state (Directorate of Economics and Statistics 2003). Further, 70% of Rajasthan’s population is groundwater-dependent for its drinking water (Black and Talbot 2005). The alarm bell is ringing in the state as groundwater extraction currently surpasses recharge by 409.65 million cubic meters per year, resulting in falling groundwater levels in many areas by as much as 60 meters (Directorate of Economics and Statistics 2003; Government of Rajasthan Groundwater Board 2003). The groundwater situation is dire and there is a legitimate need for rethinking groundwater governance and development. It is not a question whether to regulate or not, but the particular character these reforms will take.

**Rajasthan Groundwater Bill**

The groundwater situation has sparked serious debate in Indian and Rajasthani development and government circles around the question of regulation. The Indian Constitution grants individual states the authority to regulate groundwater and currently Rajasthan has no groundwater regulation. And while the central government does not have the authority to regulate water resources, it has a history of providing guidance. For example, the Ministry of Water Resources drafted a model National Water Policy of 1992 and then updated it in 2002. More recently they drafted the “Model Bill to Regulate and Control the Development and Management of Ground Water, 2005”. Both of these were intended to serve as a ‘model’ of surface water and groundwater regulation for states. All three of these bills encourage state governments to set up a ‘Groundwater Authority’ (hereafter Authority). Following the Central Government’s 2005 draft bill, the State of Rajasthan, working with multiple development agencies such as the World Bank and
European Commission, and Indian NGOs (e.g. the Maharaja of Jodhpur’s Jal Bhagirathi Foundation), formed an ‘Expert Committee’ to prepare the “Rajasthan Groundwater Rational Use and Management Act of 2005” (the Act).

The framing of the groundwater problem and the provisions that the Act lays down follow from a recent World Bank report titled, “India: Bracing for a Turbulent Water Future.” The report identifies two major problems exacerbating the groundwater problem: 1) “indiscriminate pumping of groundwater” mostly for irrigation by farmers, and 2) “provision of free power” in the agricultural sector (Briscoe 2005; for a short summary see World Bank 2005). The World Bank’s proposed solutions are uncomplicated in their presentation and are based on four market-based principles. The first is defining and setting water entitlements – transferable rights over water. Closely related to entitlements is the second principle of clearly defining property rights over water. The third is “increasing supply and efficiency through technological expansion”, including more efficient irrigation systems and surface water dams. And the fourth is establishing water user associations, thereby localizing governance. The World Bank is supporting its recommendations through an increase of rural water sector loans from $250 million between 1999 and 2004, to $1,400 million between 2005 and 2008 (Briscoe 2005).

The Act follows the World Bank recommendations, highlighting ownership, pricing, local governing bodies and technological expansion as the foundation for groundwater reform. But the Act also emphasizes setting up a “State Ground Water Authority”, a regulatory mechanism, and the dissemination of awareness and knowledge
relating to water issues. The Expert Committee agrees with these provisions, but the subsequent Act is vague on a number of issues. These include determining entitlements (for example, would a water entitlement be based on land holdings or household size?), setting the price of water, and how to compose and form user groups. Under the Act, the Authority has the power to define and settle these points. The rest of this section focuses on the composition and powers of the Authority, especially its hierarchical structure and its mandate to disseminate knowledge and awareness of groundwater conservation. This is very similar to the Forest Department efforts detailed by Agrawal in the effort to subjectify in terms of the environment.

The Act appoints a “Chief Ground Water Officer” and forms a three-tiered hierarchical Ground Water Authority: the first tier is the “Rajasthan Groundwater Authority” at the state level, composed of 7 high-level elected officials and 15 appointed members; the second tier is the “District Groundwater Authority”, composed of 2 elected officials and 10 appointed members; and the third tier is the “Block Ground Water Authority”, composed of 1 elected official and 8 appointed members. These new Authorities are proposed not to replace the current bureaucracies charged with groundwater research and development but are in addition to them and draw on their personnel. For example, the Rajasthan Groundwater Authority is composed of the Chief Engineer for the Rajasthan Groundwater Board and the state’s Chief Groundwater Officer. The Rajasthan Groundwater Board is responsible for mapping groundwater, collecting groundwater quality data and locating well sites. The Authority also includes one appointed representative from each the Human Rights and Women’s Commissions,
and several state secretaries: Agriculture, Industries, Irrigation, Power, and Forest. Therefore, the Authorities are disproportionately composed of appointed rather than elected members. Similar to forester skepticism in Agrawal that villagers could not manage their own forests (2005 p. 84), this shows that the Expert Committee drafting the Act does not want to fully entrust groundwater management to local bodies, calling into question whether the goal is to decentralize and democratize governance, or to increase state control through decentralization.

Each tier of the Authority is allocated its own set of “duties, functions, and powers.” The proposed Rajasthan Groundwater Authority would have 28 of these in addition to a mandatory meeting once every three months. Two of these powers, “to supervise and control the District Ground Water Authority” and “to spread knowledge and awareness regarding water issues”, show the hierarchical top-down structure of decentralization as well as the goal to subjectify farmers with respect to environmental awareness (Expert Committee 2005). This is further exemplified in the District and Block Groundwater Authority functions. The District Ground Water Authority has seven functions, two of which include “to follow and comply with the directions of the Rajasthan Ground Water Authority” and “to spread knowledge and awareness regarding water issues”. And the Block Ground Water Authority has eight functions, three of which include “to carry out the directions of the District Ground Water Authority”, “to spread knowledge and awareness regarding water issues”, and to advise the Gram Panchayats (locally elected decision making bodies) “to properly utilize funds which are made available to them for the purpose of water conservation” (ibid). The Authorities, in
addition to being predominately appointed rather than elected, function from top to bottom. The state level directs the district level and the district level directs the block or local level. The hierarchical structure and the mandate to carry out groundwater awareness activities to subjectify in terms of the environment, ensure that the demands of the state are carried out at the local level, but do not provide for a democratic process. The Forest Department’s success in Agrawal, stemmed from the incorporation of peasant demands, albeit after much protesting. Recent state actions in groundwater indicate that rather than incorporating existing ways of knowing, practicing and institutionalizing groundwater use, the state plans to try to alter the existing, time-honored, ways people think about groundwater, its use, and management to facilitate its regulatory efforts.

Making groundwater subjects

Farmer protests over inadequate irrigation water have become commonplace in Rajasthan, and the outcomes have often been violent. In October 2004, farmers in Sriganganagar District protested against not receiving their share of irrigation water from the Indira Gandhi Nahar Pariyojana project. Six were shot and killed by police. In June 2005, farmers in Tonk District protested against not receiving their share of irrigation water from the Bisalpur dam project. Five were shot and killed by police. In February of 2005, I attended the conference “Groundwater Management in Rajasthan: Issues, Perspectives and Policy” in Jaipur, Rajasthan, organized by UNDP and the Jal Bhagirathi Foundation. Chief Minister of Rajasthan, Vasundhara Raje, gave the keynote address. With recent protests as the backdrop, she said in relation to future groundwater management:
The government cannot do everything. It has to be a people's movement. I don't want to give scope for any anti-Government movement on this count. In the past we had gone out of the way in providing everything they asked for and we were taken by surprise, then I realized that it was absolutely important to be in touch with the people. The future is going to be terrible unless this aspect is taken care of. The growing groundwater crisis in Rajasthan can be stalled only if every section of society supports the urgent task of building mass awareness about the need for conservation and regulation of groundwater resources. (Raje address, February 25, Jaipur GW Conference).

Much like peasant forest users through the early 20th century, therefore, Rajasthani farmers find themselves outside of the regulatory process and are protesting their lack of access to government and to water. Similar to provisions in the Act to ‘disseminate knowledge and awareness’, the Chief Minister also believes that people’s perceptions must be changed. As she makes clear, the state is also trying to transform them into self-regulating subjects. As she went on to state, “If people become conscious then we can even combat [a] situation like drought” (Raje, quoted by Times News Network 2005). But statements such as these reveal something more ambivalent in government thinking. On the one hand, it implies that the current groundwater situation is the people’s fault and if the state can just get people to become conscious and take responsibility then the problem can be solved. But on the other hand, the state does not integrate people into the regulatory decision making process. This is apparent both in the suppression of farmer protests and in the non-representative character of the institutions set up by the Act. Contrary to Agrawal, the state is not yet incorporating local input into the regulation (on which successful regulation depended) but as in Agrawal, the state is trying to condition
peoples’ thinking to be in line with state needs, and this may or may not benefit local people.

Even though the Act has yet to be adopted, in December 2005 Rajasthan’s ‘Expert Committee’, who drafted the Act, orchestrated and launched the statewide ‘Jal Abhiyaan’ (water awareness campaign), as a result of their desire to subjectify groundwater users towards conservation. Conservation outreach, such as the Jal Abhiyaan, is one of the duties of the Authority, but because the Authority and the Act have yet to be enacted, the Expert Committee carried forward this provision in an attempt to cultivate a sense of conservation ahead of the Act’s formal adoption. At the center of Jal Abhiyaan was the “Jal Chetana Yatra” (water awareness march), a statewide march that began in May 2006 and went through 18,000 Rajasthani villages (Special Correspondent 2006). Jal Chetana Yatra tried to raise awareness of groundwater use, protection, conservation and pollution, while informing farmers of more efficient irrigation practices. A second goal of Jal Abhiyaan was its statewide Rainwater Harvesting Campaign. Utilizing television, radio and newspaper advertising, as well as other outreach activities, it attempted to train villagers to construct 100,000 rainwater harvesting structures across the state by June 2006. The Campaign, furthermore, was not just about building rainwater harvesting structures; it was also about cultivating a sense of desire and need in groundwater users to do so.

Prior to this campaign, I spent a great deal of time in the field attempting to understand what Rajasthani farmers thought of the present water situation and government actions to combat it. I found many tensions. In the next section, I first
compare the proposed institutional changes in groundwater governance with those in Agrawal’s case. Then, I turn to the tension between government expertise and local knowledge and practices to demonstrate the high level of distrust that local people have for government expertise and authority. I illustrate these divergences by focusing on the variations between local and government tubewell location techniques.

5.3 The Mirage of Decentralized Groundwater Governance: Rifts in Local and State Groundwater Expertise

It would be expensive, inefficient and politically costly to regulate groundwater without enlisting citizens in conservation efforts. Similar to the forest peasants in Agrawal’s study with respect to their access to forest resources, Rajasthani farmers are already protesting insufficient water supply. Further government crackdowns, such as the police shootings of 2004 and 2005, would be counterproductive and politically detrimental in a state where elections hinge on opinion in the agrarian sector (Corbridge 2000). Following the Forestry Department’s lessons, Rajasthan’s Expert Committee is attempting to regulate groundwater by creating governmentalized localities in the form of the Authority through subjecting groundwater users towards groundwater environmentalism. This could put farmers in a policy making and enforcing position, but the current structure of the Act does not ensure this. It reproduces the hierarchical structure of the state, while ensuring that the prominence of existing channels of state power (e.g. the Groundwater Board’s) is maintained. Unlike in Agrawal where rule making is partially democratized, the Act institutionalizes a process to localize state power through its three-tiered Authority, each responsible for carrying out the dictates of
the upper level. This would lead to the creation of ‘governmentalized localities’ where autonomy from the state would be ‘imagined’ indeed. Again, Agrawal designated ‘imagined autonomy’ for the process whereby villagers adopted the goals of regulation as their own, but which actually came from the state. Finally, critical to the Act, is its mandate to spread environmental awareness. The 18,000 village Water Awareness March, advertisements, and the state-wide Rainwater Harvesting campaign are major initiatives to subjectify (rural and urban) populations towards groundwater environmentalism, transforming them into self-governing subjects. But the effectiveness of this process will depend on the particular position of the individual as well as their historical interaction with the state. For example, a farmer who has reliable access to groundwater may support regulations that will limit access to others.

The Rajasthan Groundwater Board is responsible for monitoring groundwater quality and quantity, and provides well location services to farmers. However, as groundwater becomes scarcer they are changing their focus to water conservation. They also sit on the Expert Committee responsible for drafting legislation. The transition to a policy making role makes sense from the standpoint that they are familiar with the groundwater situation, but the Groundwater Board’s traditional role is redundant. Groundwater is sufficiently mapped and there are few highly productive wells left to place. The future of groundwater bureaucracy in Rajasthan is in conservation and this is why the Groundwater Board is remaking itself in the image of conservation expert. But Rajasthani farmers historically intersected with the Groundwater Board in their role as groundwater monitor and well locator. These historical intersections have implications
for the efficacy of the Groundwater Board’s outreach activities, such as the Water Awareness March, Rainwater Harvesting Campaign and future governance. How do the Groundwater Board and farmers view each other based on their historical interactions? Examining these interactions is one lens through which to understand how these groups interacted, but also predict how they might interact in the future.

With these roles of the Groundwater Board in mind, rather than asking people what they thought of the Groundwater Board, I queried farmers about from whom they would seek advice before digging a tubewell. Their consultancy options include: 1) government engineers from the Groundwater Board, who base their recommendations on historical hydro-geological maps and monitoring wells in the area; 2) tubewell drilling firms, who base their recommendations on accumulated experience in the area; and 3) Sunghas – local water diviners that utilize traditional Hindu astrological principles.

I asked 151 tubewell owning farmers who they would consult before constructing a tubewell. I was intrigued but not surprised by their responses. None indicated that they would consult a government engineer, 25% indicated that they would consult a Sungha, 64% indicated that they would consult a tubewell drilling firm, and 12% indicated that they would consult both the Sungha and the tubewell drilling firm. Nobody would consult the government engineer, the future agents of groundwater conservation. The question is why? Why do farmers choose to rely on tubewell drilling firms and Hindu spiritual experts rather than government expertise? There is widespread trust in tubewell driller and Sungha abilities because their expertise is derived through practice, and by knowledge of and experience with the area, much like that of the farmer. Peasant farmers
identify more easily with Sunghas and tubewell drillers than the government engineer, who relies on formal expertise (and is not afraid to exert it). Part of the answer lies in the following farmer quote:

If we hire the government engineer [for tubewell placement], they don’t know our area and we pay them rupees 2,000 and they don’t come back. Also, they have all these formalities that we don’t understand.

The Sungha is more accurate and cheaper. The Sungha is only charging rupees 50 [about $1]. The Sungha is better than the engineer because the engineer doesn’t care or know about the cost of drilling a tubewell, where the Sungha cares more and is more sympathetic.

The engineer relies on physical methods that are not good for all areas. Sungha’s methods are not only for this area, they are more universal and could be used anywhere; he could find water in Ajmer, for example (Farmer – July 22, 2005).

This quote sheds light on four issues that farmers have with government engineers and the particular form of expertise they embody: 1) the government is unreliable; 2) the engineer is more expensive (there is the cost of the service and at least as much in bribes); 3) the engineer’s methods are thought to be less accurate because their knowledge is regarded as particular, where the Sunghas’ knowledge is thought to be universal and; 4) that the government doesn’t really care about their plight. Therefore farmers do not believe in the engineers’ methods and, while not represented in this quote, they do not believe in their results either – 80% of survey respondents indicated that the Sungha’s results were better than the engineers’.

This rift is further exemplified, but in the reverse, through the words of two engineers with the Groundwater Board:

They [farmers] hire these Sunghas who walk around the field until they get the feeling and then they tell them to place the well there. There is no science in this. Their wells work sometimes, but they are not the
most productive wells. *It’s luck.* (Groundwater Board Engineer – May 20, 2005. Speaker’s emphasis.)

Farmers don’t understand technical language (Groundwater Board Engineer – August 02, 2005).

These engineers’ sentiments question Rajasthani farmers’ traditional methods and abilities to manage groundwater and their ability to understand the language of science (e.g. conservation). Much like the Forest Department skepticism towards forest users, the Engineers’ thoughts are in contrast to the official policy position that decentralized regulation is the solution. Groundwater Board engineers are on the “Expert Committee” which drafted the Act, which accounts for its top-down hierarchical structure. Furthermore, mutual distrust between farmers and the Groundwater Board engineers will diminish state abilities to subjectify environmentally as it is the Groundwater Board engineers who are the first line of government in spreading environmental awareness. So too, it could result in further conflict over water resources. In sum, the rift in environmental knowledge between farmers and the state will result in the failure to institutionalize governmentalized localities and environmental subjectivities. But, as with the peasant protests in Agrawal, farmer protests could also result in revising the Act to make government more responsive to groundwater users (democratic), while incorporating existing groundwater knowledges and institutions.

5.4 Conclusions

This chapter applied Agrawal’s environmentality framework to understand recent state efforts in Rajasthan, India to regulate groundwater through decentralized governance institutions. It found that the state is trying to produce individuals with
environmental subjectivities in groundwater to further its groundwater regulation goals. Centralized regulation is too politically, socially, and economically costly. If regulation is going to be effective, the state understands it must foster decentralized governance institutions, such as environmental subjectivities, making groundwater users self-regulating and active participants in the regulatory process. It does this through various water awareness campaigns designed to instill a sense of groundwater scarcity and a need for conservation. But the state does not incorporate local groundwater knowledge and institutions into the proposed regulation. Instead it sets up a hierarchical regulatory mechanism that does not decentralize governance, but creates a means to govern localities from the center, while imposing its own sense of environmentalism. These proposed ‘governmentalized localities’ are both similar to Agrawal’s case in that they seek to create a sense of environmental awareness of and ‘imagined autonomy’ over regulating local resources but they diverge in that the state’s vision does not incorporate groundwater users into a decision making role, thus retaining the power to regulate water with the state.

It exemplified the tensions in this process by looking at the divergences between local and state groundwater knowledge and perceptions in well location, which indicate both future resistance to government regulatory and conservation agents (i.e. Groundwater Board engineers). Finally, it concludes that these tensions will impede the future regulation of groundwater in Rajasthan, which is in a serious state of over exploitation. One possible way out of this downward spiral, is to first rewrite the existing Act to make it less hierarchical, which would make it more democratically responsive
from the bottom-up. And second, there is a need to incorporate existing groundwater knowledge, practices and institutions to help foster a sense of conservation that may already exist. But if state repression of recent water user protests is any indication of future cooperation, this process has a long way to go indeed.
As I set out in the introduction, political ecology as an approach to the study of nature-society relations has traditionally been concerned with access to and control over resources and with the causal links between environmental change and social processes. Research utilizing this framework has had a rather particular history. This has been one focused on struggles over land use including land use change, degradation, marginalization, and conservation and, access and control, with particular reference to the Global South. Classical political ecology combined the insights of cultural ecology and Marxist-inspired political economy to question, for instance, colonial models of soil erosion that blamed ‘ignorant’ peasant producers for land degradation, and to show how ecological and social relations of production created opportunities and constraints for production strategies; strategies which sometimes led to land degradation not as a general condition but as a dialectical outcome of these relations (Blaikie 1985).

The approach has been extended in at least two ways that particularly inform this dissertation. First, over the past decade, it has expanded by taking on new objects of study (such as, new social movements, environmental histories and industrial environments), often in more developed societies. Second, it has incorporated both post-structuralist theories of discourse analysis, recognizing that one person’s degradation is
another’s productive land, and theories from science and technology studies (STS), which is concerned with the role of technology in mediating relationships of power, knowledge systems and understandings of nature.

Political ecologists and geographers, more generally, have been drawing from these two conceptual frameworks (post-structuralist thought and STS theory) to investigate the ways that heterogeneous knowledge is produced and legitimated. But another lacuna in political ecological research has been investigations involving these core concerns in terms of water resources. And while over the past five to seven years there has been an expansion of research into water resources in geography as a whole, there has been little work that has brought post-structuralist thought and STS approaches to bear on them, and on water resource scarcity-reducing technologies and the effects of ecological modernization. Furthermore, the investigations that have been carried out have been situated in Western urban settings. It is in this research context that the present study returned to the setting in which political ecology began, the Global South, but with a theoretical framework that, although a product of political ecological thinking, had heretofore yet to be applied to that setting.

This dissertation has demonstrated that technologies deployed and adopted to reduce natural resource scarcity, in this case the tubewell, were not introduced onto a clean slate but became enmeshed within previously existing social power relations and inequality. It has shown that groundwater lifting technologies and the technical expertise to fabricate and adapt them have a long history and intersect with pre-colonial, colonial and post-independence relations of state power. The British colonial administration, for
example, undertook coordinated investigations into maximizing the output and propagation of groundwater lifting technologies, including the already existing Persian Wheel and the colonially introduced tubewell.

But the rapid spread of the tubewell occurred as a result of state interventions, during the Green Revolution beginning in the 1970s; in particular the creation of a rural electrical grid and a program of government subsidized loans for tubewell construction. For an historical moment, this brought the state into contact with farmers and would-be tubewell users. It set into motion the creation of state bureaucracies, including the Central and State of Rajasthan Groundwater Boards, which were charged with increasing the utilization of groundwater. This entailed the mapping, quantification and monitoring of groundwater reserves, and also the administration of groundwater location and tubewell construction through government loan programs. The result was the further appropriation and displacement, by the state, of groundwater knowledge and expertise, rather than an introduction of expertise where none had previously existed. The success of encouraging farmers to adopt tubewells outside of further state intervention was very successful. It was so successful that it resulted in serious groundwater overdraft and the withdrawal of state subsidies for further tubewell construction. This caused the state, in the form of its Groundwater Boards, to effectively retreat from the line of vision of groundwater users and tubewell adopters – farmers – as the effectiveness and desirability of their services were undermined by ecological conditions; an outcome in significant part of their prior interventions. This lack of interaction has contributed to a lack of understanding and mutual respect between Groundwater Board engineers and farmers.
But this was not the only source of tension between farmers and engineers. Of further importance, were the diverging viewpoints on what constituted expertise between the two parties. On the one hand, government engineers, trained in the Western tradition of positivist science, viewed expertise (in groundwater location, for instance) as something that was derived through formal training and methods relying on precise calculation often of a seemingly arcane sort. On the other hand, farmers viewed engineers’ methods as particular and not universal, such as those of the Sungha. This had the effect of making the engineers’ methods appear questionable to farmers. Moreover, the engineers’ methods were not derived through practice, as were the tubewell drillers’ (and the Sunghas’), which made them even more suspect in the eyes of farmers.

These tensions are of particular concern today as it is the Groundwater Boards that are the first line of interaction between the state and farmers in future groundwater conservation efforts. This brings up two further issues. First, groundwater is not like other common property resources, such as forests, that could be afforested or reforested, easily quantified, allocated, bought, sold, and encroached upon. So too, groundwater does not conform to surface property lines, while its withdrawal by one farmer will encroach on the water supply available to neighbors. Groundwater is unique, therefore. This particular character of groundwater impacts the management strategies available to the agencies responsible for it, particularly since no formal groundwater regulation currently exists in Rajasthan and groundwater remains an extremely volatile political issue. This places the Groundwater Boards, who are heading these conservation efforts, in an awkward position between a state which does not have the political will to formally regulate groundwater or
tubewell construction, as their continued political lives depend on it, and farmers who are constantly agitating for more water. The Groundwater Boards are caught in the middle, therefore, operating within political, economic and ecological conditions over which they have little control. This, along with the tensions between them and farmers outlined above, further encourages the Groundwater Boards to keep a low profile, ultimately conditioning the way that they interact with the state's subjects.

Second, and to pursue the contrast with forest resources, the Forest Department has a long history, beginning in the colonial period, of working with local producers towards forest management. These interactions have often been antagonistic, but recent research shows hope in the form of mutually beneficial conservation practices between the state and local producers; practices which actually incorporate locals into the decision-making process (Agrawal 2005). This relies on a process of environmental subject-making, however, where forest users are steered by the state towards incorporating the state’s stance on forest conservation to the degree that they adopt the state’s position towards conservation. Eventually the state’s position becomes the position of forest users, who come to believe that it was theirs’ originally when in fact it was imposed on them.

I remain skeptical of just how successful this has been and will be for local producers in the case of groundwater in Rajasthan. Moreover, the state will find this kind of environmental subject-making extremely difficult in the groundwater sector for three primary reasons. First, this is due to the already existing tensions between the state Groundwater Boards and farmers, and second, because of the particular character of
groundwater, which unlike forests, cannot be produced without major effort, such as artificial recharge.\textsuperscript{21} Third, the Groundwater Boards, which have never had regulatory powers like those of the Forest Department, lack regulatory backing, which limits what they can do. Thus the ‘state’ as embodied in the Forest Department and the ‘state’ as embodied in the Groundwater Boards are very different parts of the same state. This has led the state agencies responsible for groundwater to behave very differently than other state agencies involved in the management of other common property resources. It remains to be seen what consequences these tensions between the state engineers and farmers will have for the future creation of groundwater governance strategies.

The divergent forms of knowledge and thinking about groundwater resources further bear themselves out in the institutions that farmers themselves have created for accessing groundwater. In the Study Area, farmers, stratified by caste, have traditionally had unequal access to resources. Scheduled Castes, who are typically the most marginal producers, have historically had smaller landholdings of inferior quality, with poor groundwater recharge as compared to General Castes. In order to adopt (relatively) expensive tubewell irrigation systems, these farmers, particularly the most marginal of them, formed partnerships to collectively own, operate and maintain tubewells. The creation of these adaptive social institutions of cooperation increased access to the technology and groundwater, but they did not lead to the full alleviation of scarcity or necessarily to the reduction of poverty. The effects of adoption were differential,

\textsuperscript{21} Rainwater harvesting is one method of groundwater recharge that is gaining in use throughout Rajasthan and arid India. But this method is dependent on unpredictable monsoon rains, which limits its efficacy. The other method is through inter-basin transfers of surface water, which would entail a massive engineering effort, making it less feasible.
therefore, in that all sections of agrarian society did not feel their benefits equally. By
demonstrating the effects of tubewell adoption for differing communities, stratified by
caste and class, this dissertation further demonstrated the importance of the existing
socioecological conditions under which the tubewell had proliferated throughout India
over the past decade. The historical inequality in landholding area, and land and
groundwater quality among Scheduled Castes translated into differing contemporary
capacities to take full advantage of tubewell irrigation systems. Therefore, it showed that
scarcity-reducing technologies do not always reduce the scarcity of a particular resource,
but sometimes exacerbate scarcity and already existing inequality.

Moreover, once adopted, the tubewell showed momentum in that it transformed
the possibilities of present and future trajectories of social, economic, political and
ecological change. In other words, the adoption and spread of the tubewell produced a
socionature that is recursively dependent on human and non-human natural processes.
For instance, tubewell adoption made possible the cultivation of crops, such as water-
intensive spices and vegetables, which were not possible to grow under traditional forms
of irrigation that produced a lower volume of irrigation water. The adoption of tubewells
also necessitated the production of these more water-demanding, and more lucrative,
crops so that farmers could recoup the expenses of tubewell construction. By adopting
tubewells, farmers become locked into a set of production relations, including specific
knowledge practices and distribution networks, which further enable and constrain their
production activities and options.
This rapid expansion in irrigation capacity, however, led to rapid groundwater decline, which also transformed groundwater chemistry in many places, increasing the concentrations of naturally occurring minerals. This led to the creation of sodic soils. Both poor groundwater quality (and quantity) and sodic soils (e.g. calcified soils), a product of the employment of tubewell irrigation, have undermined the original conditions of a scarcity that had been alleviated by the tubewell, once again returning farmers (especially the most marginal) to producing low water-demanding and environmentally resilient crops, such as fodder varieties. But these transformations were not evenly felt by differentiated social communities. Scheduled Castes, who were also the smallest landholders, also tended to be the most negatively impacted by these socioecological shifts leading to further economic differentiation and marginalization.

Political ecology, integrated with STS approaches, has heretofore not shown how people adapt social institutions, knowledges, and individual action around the demands and constraints, but also the facilitative properties, of recursive technology in dynamic political ecological conditions, and how these may reduce resource scarcity for a time, but exacerbate it and social differentiation at some later date. The findings of this dissertation, therefore, specifically its exposition of the tensions between farmers and the future purveyors of groundwater regulation (i.e. Groundwater Boards), and adaptive social institutions for water use and the unintended social and ecological effects of resource scarcity-reducing technologies, inform future management and governance decisions.
The Future of Groundwater Governance in Rajasthan

The future of groundwater conservation and governance in Rajasthan as it is currently seen is based on neo-liberal assumptions, including the establishment of private property rights and transferable entitlement over resources including water, market solutions and decentralized environmental governance, and on the hope of ecological modernization. Zimmerer refers to this powerful global trend over the past ten to fifteen years of neo-liberal-informed decentralized conservation, characterized by the increased role of “globally organized management institutions, knowledge systems and monitoring, and coordinated strategies aimed at resource, energy, and conservation issues” as “environmental globalization” (Zimmerer 2006, p. 1). However, in practice decentralized conservation strategies are often contradictory. On the one hand, there is the hope that decentralization will increase local participation in and control over resources, thus empowering local people. But on the other hand, many attempts to decentralize environmental governance have failed to empower local people or to alleviate poverty. Decentralization has instead resulted in local elite capture of the political process. So too, in some instances, rather than a decentralization of the state, there has instead been a devolution of state oversight. A devolution of the state increases state control over localities through enlisting local actors in monitoring activities, actors who are not held accountable and are unrepresentative (Jiang 2006). These shifts in resource governance towards environmental globalization raise fundamental questions about continued local access to and control over resources and the future creation of democratic institutions more generally.
So too, in the case of groundwater regulation and conservation in Rajasthan, there are several tensions between the future vision of decentralized groundwater governance and existing local institutions of groundwater use. For instance, future governance strategies are predicated on neo-liberal assumptions of market solutions and the centrality of private property and the privatization of resources, which is thought to enhance efficiency in supply. These strategies assume a set of institutional conditions among Rajasthani farmers, such as the existence of individual tubewell owners rather than the collectives of tubewell partnerships detailed in the present study that do not exist, and are in fact in contrast to the assumptions of neo-liberal approaches.

This dissertation has shown that groundwater is used in collectives of farmers, which defy the establishment of individual private property rights over groundwater and bypass already existing local institutions of use, which could be groomed towards conservation and management efforts. Yet individual rights and transferable entitlement over groundwater are being proposed. I think, therefore, that we need to treat efforts to establish private property rights over, and transferable entitlements to, groundwater with skepticism. Moreover, local politics have a history of being ridden with social power relations, with local elites able to wield their influence for personal gain. This could result in further social, political, economic and ecological differentiation as transferable entitlements to groundwater are later transformed into fluid capital. These entitlements would then flow from the most marginal producers to the agrarian elite or to urban users (including municipalities, private users, and firm) during times when the poorest

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22I do not think we will see private water markets for irrigation because the availability of large volumes of high quality groundwater is too unpredictable to be marketed profitably and efficiently.
communities find themselves under economic pressure resulting from unforeseeable circumstances such as drought, illness, or other family expenses, such as weddings. In the final instance, this would result in the increased urbanization of Rajasthan’s peasants, landholding consolidation into the hands of already existing large landholders (as marginal farmers sell their water rights) and the creation of a surplus of landless laborers. The state may already be preparing for this, with major (state) expenditures going into much needed urban infrastructure development in Rajasthan and India more generally, but with little investment going on in rural areas. The most marginal producers may ultimately be better off as urban wage earners, but in the short-term it is likely that we will continue to see farmers maintain their smallholdings while engaging in increasing amounts of off-farm labor.23

The hope that decentralized groundwater governance will bring local people into the decision-making process is further confounded by the historical and current relationship that farmers have with the state, as shown in this dissertation. Furthermore, farmers currently have little disposition towards conservation for conservation’s sake. They are already operating under extremely thin margins, which make conservation without any kind of subsidization out of the question. And a centralized groundwater regulatory body does not currently exist in Rajasthan or India. Therefore, there is nothing to decentralize. Any groundwater governance strategy would need to start from scratch. And the Groundwater Boards, as opposed to the Forest Department, are ill-equipped to regulate groundwater. They have no history or expertise in doing so.

23 This will, of course, depend on other state efforts in social provisioning such as education, the Employment Assurance Scheme, healthcare provision and some sort of social pension system. These are all things that would further encourage farmers to urbanize.
This could result in the further expansion of NGOs in India to do the work of promoting conservation and introducing efficiency-enhancing technologies, such as drip irrigation systems, as recommended by the World Bank. In some places, such as Latin America and Africa, collaboration between donor agencies and NGOs has led to the effective by-passing of the state, with donor agencies working directly with local people, further exacerbating democratic concerns (see Sundberg 2006). This role for NGOs seems improbable in the Indian case, however, especially as the Groundwater Boards are attempting to refashion themselves as groundwater conservators rather than developers, so as to maintain their relevance. But there remains considerable scope for the expansion of technologies that will enhance efficiency, including drip irrigation systems, which would require state intervention to subsidize the technology. The Groundwater Boards are not well positioned to do this. It would require the interventions of NGOs and / or the Irrigation Department, which is now charged only with the oversight of surface water irrigation, to provide the necessary knowledge and technology transfer. And again, as with the spread of the tubewell, the spread of further scarcity-reducing technologies is likely to have uneven and contradictory effects. But the future is bleak as it is and this is one possibility. Research conducted elsewhere in India has shown that water loss through conveyance and evaporation can be reduced by upwards of 60 percent by adopting drip irrigation methods, which today are unheard of in Rajasthan (Narayanamoorthy and Deshpande 2005). Again, incentives for adoption would be required as farmers are generally skeptical of these technologies and the issue of state trust would reemerge.
At a finer scale, however, such as that of this dissertation’s Study Area, there are multiple other pressures, including urbanization, which could further confound the future of agriculture. What are the likely outcomes and changes that will happen in the Study Area as it transitions from a rural area producing subsistence and market crops for surrounding urban areas, to a peri-urban area and finally to an urban area? What form are livelihood strategies likely to take?

The strong possibility of future urbanization throughout the Study Area raises the issue of how the processes described in this dissertation will be altered under the new pressures that urbanization will bring. The form that future regulation and governance strategies will take, though, are paramount in determining the livelihood possibilities for rural people under parallel processes of urbanization. The two will operate in tandem, therefore, pushing and pulling each other. The degree to which the two will be coordinated under state action, which will influence how the processes of tubewell sharing and farmer-state tensions will be altered, remains to be seen. For example, if the state offers incentives to farmers, such as subsidies for drip irrigation technologies, effectively inducing them to remain in agriculture, then farmers will be more likely to resist pressures to urbanize, such as land buyouts from the state for Special Economic Zones, for example. Moreover, government efforts to regulate groundwater or increase the rural electricity tariff to reduce tubewell use are often discarded immediately before elections, the outcomes of which rest on the powerful rural voting constituency. These examples highlight a few instances out of many where government policies are in contradiction among themselves, reflecting the political power of the rural constituency,
which promotes policy incoherence.\textsuperscript{24} Moreover, urbanization is the result of both increased growth and expansion of urban areas from existing urban populations, and rural to urban migration. Therefore, even if farmers resist urbanization, urbanization is likely to encroach upon them, raising land rents and eventually pushing them out.

In sum, this dissertation has accomplished four major goals. First, it has explained how resource scarcity-reducing technologies are not neutrally adopted. Rather they diffuse within previously existing social power relations and inequalities with important implications for the adoption process. Second, it has shown that rather than reducing these inequalities, sometimes the technology has exacerbated them. Third, it would seem that these technologies, once adopted, are recursive in that they have the capacity to transform human-environment relationships. This is in the sense that their use alters and reworks existing political ecological relationships, including the creation of new social institutions and the transformation of ecologies, while sparking off intense struggles over the politics of nature, including those over environmental knowledge. And finally, it has demonstrated that these processes will inevitably condition the creation of future governance strategies not only in India, but globally.

\textsuperscript{24} The power of the farming constituency results in conflicting courses of action, because their vote persuades state policy-makers to form (or not form) policies that increase their chances of reelection rather than promoting the sustainable use of resources or development policies.
APPENDIX – A

SURVEY QUESTIONNAIRE
**1. Household Information:**

<table>
<thead>
<tr>
<th>Member</th>
<th>Name</th>
<th>Age</th>
<th>Sex</th>
<th>Relationship to head of household</th>
<th>Ed.</th>
<th>Main Occupation</th>
<th>Other Occupation</th>
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</table>

Is the house kucha or pucca? ________________

**Interviewer:** __________________________  **Date:** __________________________

**2. Family Income:**

<table>
<thead>
<tr>
<th>Source</th>
<th>Annual Income</th>
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<tbody>
<tr>
<td>Agriculture</td>
<td></td>
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<tr>
<td>Livestock</td>
<td></td>
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<tr>
<td>Daily Wages</td>
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</tr>
</tbody>
</table>

**2a. Household Expenses (not including agricultural expenses):**

<table>
<thead>
<tr>
<th>Details</th>
<th>Annual Expense</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
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<tr>
<td>Medical</td>
<td></td>
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<tr>
<td>Marriages</td>
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</tbody>
</table>
3. **Annual Capital Income and Expenses:**

<table>
<thead>
<tr>
<th>Income</th>
<th>Expense</th>
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<tbody>
<tr>
<td>Source</td>
<td>Year</td>
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(For Example: sale or purchase of land, livestock, irrigation equipment, tractors, etc)

4. **Total Debt:**

<table>
<thead>
<tr>
<th>Amount</th>
<th>Source</th>
<th>Reason</th>
<th>Interest Rate</th>
<th>Repaid?</th>
<th>Mode of Repayment</th>
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</thead>
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5. **Assets:**

- Land Area: _______________ Value: ___________________ Family Inherited: ____________ Purchased: ____________
- Own  Lease-In  Lease-Out  Share-tenancy  Landless  Arrangement/Other: ____________

How many kucha bigha in a pukka bigha? __________

- Tractor ______ Motorbike ______ Jeep _______ Bullock Cart _______ Bicycle: ______ Other: ________________________________
6. Livestock:
- Goats
- Sheep
- Cows
- Bullocks
- Buffalo
- Camels
- Other:

7. Last wet season crop (Kharif)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Bighas</th>
<th>Production Qtl</th>
<th>Home Use %</th>
<th>Market %</th>
<th>Irrigated Area</th>
<th>Irrigation Timings</th>
</tr>
</thead>
<tbody>
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</table>

8. Last dry season crop (Rabi):

<table>
<thead>
<tr>
<th>Crop</th>
<th>Bighas</th>
<th>Production Qtl</th>
<th>Home Use %</th>
<th>Market %</th>
<th>Irrigated Area</th>
<th>Irrigation Timings</th>
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</table>

9. Crop Inputs for Last Year

<table>
<thead>
<tr>
<th>Input</th>
<th>Rabi Cost Total</th>
<th>Kharif Cost Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Lease-In</td>
<td></td>
<td></td>
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<tr>
<td>Seeds</td>
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<tr>
<td>Organic Fertilizer (Manure)</td>
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<tr>
<td>Chemical Fertilizer (Urea)</td>
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<tr>
<td>Pesticides (for bugs or weeds)</td>
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<tr>
<td>Family Labor Hours (preparation, sewing, cultivation, irrigation, harvest. Total = Hours/Day for each x # Days for)</td>
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<td>Description</td>
<td>Details</td>
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<td>Hired Labor Hours</td>
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<td>Owned Bullock Labor Hours</td>
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<td>Hired Bullock Labor Hours</td>
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<tr>
<td>Owned Tractor Hours</td>
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<td>Hired Tractor Hours</td>
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<td>Lease In Irrigation:</td>
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<tr>
<td>Irrigation Equipment and Maintenance</td>
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<tr>
<td>Irrigation Other</td>
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</tbody>
</table>

10. If you leased in or leased out irrigation timings, what was the arrangement (i.e. lease rate, total cost, how and when it was paid for) and how was it settled?

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

11. Well Information: Dug Well, Boring, Tubewell, Dug-Cum-Bore Well

<table>
<thead>
<tr>
<th>Date</th>
<th>Type</th>
<th>Depth</th>
<th>Horse Power</th>
<th>Electric or Diesel</th>
<th>Install Cost</th>
<th>Loan Yes / No</th>
<th>Loan Origin</th>
<th>Loan rate</th>
<th>Paid Off</th>
<th>Working Yes / No</th>
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</table>

Private Tubewell or Boring
12. What is the current depth of groundwater?

13. How did you decide how deep to drill your tubewell?

14. Have you used a state subsidy or program for any of your tubewell constructions? __ YES / NO ___

15. What was it / Amount?

16. How many households depend on your tubewell?

17. Did you consult anybody before digging your last well? __
   _ Engineer _ Pundit _ Sadhu _ Tubewell Drilling Firm _ Other: ___

18. If your current boring goes dry, would you install another one? __ YES / NO ___
   Who would you consult? ____________________________

19. If very little water was coming, would you water your Household or Market crops? __

20. What determines how much land you irrigate (electric, water quality)? ____________

21. Do you coordinate irrigation timings with your neighbor? __ YES / NO __

22. Is groundwater quality worse now than 10 years before? __ YES / NO __ Soil Quality?
   __ YES / NO __
   a. Why or why not? ____________________________

23. Where do you get your drinking water? _ Well _ Tubewell _ Tanker _ Public Well _ PHED Connection _ Other: ___

24. Does someone collect drinking water (who)? ______________ How much time do they spend? ______________

25. What is the drinking water source? ______________
26. How far away is the drinking water source?  

27. Can everyone who needs groundwater get it?  YES / NO 

28. Will the groundwater be gone in the future?  YES / NO  Why?  

29. Should there be rules of groundwater use?  YES / NO  Explain: 

30. Should there be rules that set tubewell construction?  YES / NO  Tubewell/Boring Depth?  YES / NO 

31. Should there be rules that set quantity?  YES / NO 

32. Who should make the rules?  

33. What would improve the groundwater situation?  

BIBLIOGRAPHY


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