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UNIVERSITY OF SUSSEX

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PH.D. INTERNATIONAL DEVELOPMENT

THE POLITICAL ECOLOGY OF GROUNDWATER GOVERNANCE: THE CASE OF PAKISTAN'S PUNJAB

SUMMARY

This thesis explores the nature of groundwater governance and its role in the global groundwater crisis using a historical case study of Pakistan's Punjab from the nineteenth century to the present. The thesis engages with the problem of groundwater governance on two levels: First, using a critical political ecology framework, I engage with an empirical analysis of the nature of Punjab's groundwater governance across the colonial, post-colonial and contemporary period to suggest how the techniques and mechanisms of groundwater governance over time within the context of the region's broader political economy context have been an active force in the creation of contemporary groundwater crisis. Contrary to existing studies, this thesis suggests that governance, rather than the absence of it has been a decisive factor in the creation of the groundwater crisis in Punjab. The central argument of the thesis rests on an extended definition of "groundwater governance" and the conception of ground water as socio-nature to allow an analysis of the mutually constitutive relationship between state and non-state 'governors' that make up groundwater governance, as well as the relationship between governance, society and groundwater itself. Second, using my empirical findings from Punjab's case, I critically engage with the political ecology of (ground) water literature to emphasize the oft-neglected contribution of groundwater to state developmental goals and forms of state power. In this way, the main theoretical contribution of the thesis lies in extending the concepts of 'colonial hydrology' and 'hydraulic mission' in existing studies that relate social control of water to state power narrowly in the context of surface water. By emphasizing groundwater's strategic importance for the state, the thesis contributes towards the political ecology of

groundwater governance, and how it has a critical role to play in the groundwater crisis both for the case of Punjab and globally.

DECLARATION

- I hereby declare that this thesis has not been and will not be, submitted in whole or in part to another University for the award of any other degree.
- Signature: Fazilda Nabeel

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The intellectual journey that led to the completion of this thesis over the last four years could not have been possible without the support of people who shaped up my experiences, ideas, and arguments, and the resolve to take this through. First and foremost are my supervisors, Jan Selby and Magnus Marsden. Jan was always prompt with providing feedback and insights, and challenging me to deepen my analysis and strengthen my arguments, while Magnus pushed me to broaden my analysis to explore new directions and perspectives. I have been incredibly lucky to be mentored by them during my course of my doctoral research.

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Despite the innumerable challenges in this journey, the love and continuous support provided by my partner Nabeel and daughter Raeyah has kept me going. To them, I dedicate this thesis.

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ABDP:	Agriculture Development Bank of Pakistan
ADB:	Asian Development Bank
AWS:	Alliance for Water Stewardship
BCI:	Better Cotton Initiative
CBM:	Community-based Model
CSIRO:	Commonwealth Scientific and Industrial Research Organisation
DFID:	Department for International Development, UK
EPD:	Environment Protection Department
FO:	Farmer Organisation
GBP:	British Pound Sterling
GDP:	Gross Domestic Product
GW-MATE:	Groundwater Management Advisory Team
GWDO:	Groundwater Development Organisation
IBRD:	International Bank for Reconstruction and Development
IFI:	International Financial Institution
IGRAC:	International Groundwater Resources Assessment Centre
IMF:	International Monetary Fund
IWASRI:	International Waterlogging and Salinity Research Institute
IWMI:	International Water Management Institute
IWT:	Indus Water Treaty of 1960
MDG:	Millennium Development Goals
MNC:	Multinational corporation
MOWP:	Ministry of Water and Power
NDP:	National Drainage Program
NGO:	Non-Government Organisation
PID:	Provincial Irrigation Department
PIDA:	Punjab irrigation and Drainage Authority
RPL:	Rice Partners Limited
SCARP:	Salinity Control and Reclamation Project
SRP:	Sustainable Rice Platform
UK:	United Kingdom
UN:	United Nations
UNECE:	United Nations Economic Commission for Europe
UNESCO:	United Nations Education, Scientific and Cultural Organisation
UP:	Uttar Pradesh
US:	United States
USAID:	United States Agency for International Development
USGS:	United States Geological Survey
WAPDA:	Water and Power Development Authority (West Pakistan)
WWF:	World Wide Fund for Nature

GLOSSARY

arhati:	informal village money lender
barani:	rainfed
chah:	well
chahi:	area irrigated by wells
kanak:	wheat crop
khuwas;	unlined pit for discharging effluents
lambardaar:	head of the village
munji:	rice crop
nahri:	area irrigated by canals
nala:	open drain
naqsha-e-chah:	tree showing time division of time shares for taking turns at well irrigation
peter:	low horse power diesel run tubewell
shamilat:	village commons
shart wajib-ul-arz:	colonial record of land rights at the village level
sifarish	getting work done through political connections
tuccavi:	subsidized loan advanced by pre-colonial and colonial state for well construction
warabandi:	system of distribution of canal water in propertion to farm size as fixed weekly rotations

1. Situating the Research Problem: Groundwater Crisis and Groundwater Governance

1.1 Introduction

This thesis aims to contribute towards understanding the global groundwater crisis. Among the varying perspectives and many ways of framing the problem of unsustainable groundwater use, one of the most oft-cited explanations of the global groundwater crisis relies on framing it as a crisis of governance. This thesis explores the nature of groundwater governance and its role in the groundwater crisis through a historical case study of Pakistan's Punjab from the nineteenth century to the present.

This introductory chapter situates the problem of groundwater governance in relation to the groundwater crisis. The chapter starts by discussing the importance of groundwater as a resource, the extent of the global groundwater crisis, along with an account of the most frequently advanced explanations of the crisis in the literature (Section 1.2). Section 1.3 elaborates on how inadequate groundwater governance explains the crisis. The context of Pakistan's Punjab as a case study of groundwater governance in the groundwater crisis is detailed in Section 1.4. Finally, Section 1.5 summarises the research questions, the thesis structure, and key arguments and provides a brief overview of the theoretical and methodological underpinnings of the chapters that follow.

1.2 The Global Groundwater Crisis

Groundwater is the most abundant source of freshwater in the world, accounting for about 97 per cent of the available non-frozen freshwater (IGRAC 2015). Groundwater contributes to an average of 40 per cent of global food production, with some regions depending on it for 60 per cent of their irrigation water. Groundwater provides 50 per cent of the world's drinking water, serving as a key water source for people located away from surface water sources and/or a piped water grid (IGRAC 2015). Aquifer

systems (underground water tables) provide important ecosystem services as well, especially because of their interactions with surface water systems. Groundwater forms the base flow of river systems and stabilises land in areas with easily compressed soils. It is also an on-demand source of water and protects against dry spells/drought, especially in the winter, when surface water supplies that depend heavily on summer glacial melt decline. The importance of groundwater as a source of freshwater cannot be overstated, especially as current global groundwater extraction is already near maximum sustainable limits (Gleick and Palaniappan 2010) As groundwater over-abstraction becomes a major worry in large basins around the world, concerns about contamination are also growing. To add to the groundwater problems, climate change and variability in rainfall affect the recharge of water stored in aquifers and increase demand for groundwater (Taylor et al. 2013). The improvement in well-drilling techniques and the technology for mining groundwater at little or no marginal cost (e.g. through solar pumps) has also increased demand for groundwater.

Global groundwater use more than doubled between 1960 to 2000, increasing from 312 cubic kilometres to 734 cubic kilometres per year (Wada et al. 2010). Most groundwater abstraction and depletion occurs in arid and semi-arid areas with high population density and a heavy reliance on groundwater because of variable rainfall and surface water supplies, such as Northwest India, Northeast Pakistan, Northeast China, the California Valley in the United States (US), Yemen, Spain, and parts of Iran. Most of these places have recently begun to suffer from rapid groundwater depletion (Fienen and Arshad 2016). The scale and dimensions of the global groundwater crisis, typically measured by volumetric abstraction/ decline in the depth of the water table because of over-abstraction and insufficient abstraction-to-recharge rates, varies across countries. For India, the world's largest user of groundwater, groundwater depletion is estimated to be occurring at a rate of 17.7 cubic kilometres per year, with a third of the aquifers reported to be in overexploited, semi-critical, and critical categories, particularly in the states of Punjab and Rajhastan (Rodell, Velicogna, and Famiglietti 2009). The US depends on groundwater for 60 per cent of its irrigation water and has suffered a cumulative depletion of 700-800 cubic kilometres over the last 100 years (Konikow and Kendy 2005). China's dependence on groundwater increased more than 30 times, from 150,000 tubewells in 1965 to 4.7 million by 2003 (Wang et al. 2007), leading to groundwater levels' falling between 1-10 meters a year in many parts of the country.

Apart from endangering the sustainability of groundwater, this increased use has had adverse consequences for the ecosystem, as groundwater depletion has led to sea water intrusion into the fresh aquifer systems in some coastal cities (e.g. Laizhou City in China) (Changming, Jingjie, and Kendy 2001). Groundwater aquifers in the Middle East and North Africa regions also exemplify the disturbing trend of severe overdraft of and growing dependence on groundwater resources. Countries in the North Africa region, including Algeria, Morocco, and Tunisia, depend on groundwater for 88 per cent, 42 per cent, and 64 per cent, respectively, for irrigation of agriculture. The groundwater crisis in the arid regions of the Middle East is also growing, with annual groundwater extraction-to-recharge ratio as high as 9.54 in Saudi Arabia, 8 in Libya and 3.5 in Egypt (Fienen and Arshad 2016).

Apart from depletion, contamination of groundwater systems has posed environmental hazards and risks to animal, human, and plant lives. Anthropogenic causes of groundwater contamination include agricultural, industrial, and urban sources of pollution. A principle source of groundwater contamination occurs through salinization, a widespread phenomenon in more than a hundred countries that affects more than one billion hectares of land, including in China, India, and the US (Fienen and Arshad 2016). In addition to salinity, waterlogging of soils from poor drainage conditions and high water tables can lead to a loss of cultivatable land. Pakistan's Indus Basin is an example of a region that has been severely affected by problems of waterlogging and salinity. Waterlogging is estimated to affect about 38 per cent of total irrigated land in Pakistan, and about 14 per cent of land has become saline (Kahlown, Akram, and Azam 2002). Agricultural and industrial contamination of groundwater is another a major source of groundwater pollution. Excessive irrigation can drive water from crops' root zones into the groundwater aquifers below, taking with it fertilisers, pesticides, and salts that infiltrate the groundwater table. Foster and Chilton (2003) document the nitrate contamination of groundwater in India and China from agriculture pesticides. Untreated industrial effluent from water-polluting industries like textiles, leather, and others contains heavy metals like cadmium, cobalt, copper, mercury, nickel, lead, tin, and zinc. Arsenic contamination of groundwater can occur because of naturally occurring arsenic or contamination from effluents and is particularly hazardous to human health. Research suggests about 50 million people in the Indus Basin and an estimated 36 million people in the Bengal Delta (covering parts of India and Bangladesh) are at risk of arsenic

poisoning from the high level of arsenic in the soil (Podgorski et al. 2017; Ravenscroft, Brammer, and Richards 2009)

Why is there a global groundwater crisis? The literature – both academic and policy-oriented in nature – has advanced multiple frames with which to explain the contemporary problem of groundwater over-abstraction and pollution. These explanations of the groundwater crisis include that the groundwater crisis is due to the nature of the groundwater as a common pool resource, particular property right regimes for groundwater use, capitalist economic relationships; abstraction technologies, and, most frequently, poor governance of the resource. Among these explanations, the literature frequently attributes the groundwater crisis to the nature of groundwater as typically a common pool resource and contends that the failure of collective action leads to over-abstraction based on the "tragedy of the commons", as advanced by Hardin (1968, 1244): "Ruin is the destination to which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruins to all." However, the status of groundwater as a common pool resource is not unanimously accepted (Langridge and Ansell 2018), as groundwater extraction mechanisms (wells and tubewells) are often privately owned and operated; only the underlying aquifers on which they draw are a part of the commons. Alternatively, discourses on the groundwater crisis that focus on scarcity usually draw on Malthusian perspectives to blame the global groundwater crisis on population pressures. Although the relationship between population growth and groundwater use is complex, an increase in population does reduce the availability of groundwater per capita (Sherbinin et al. 2007). The Global International Waters Assessment lists population growth as a root cause of the global groundwater crisis (United Nations Environment Programme and Global International Waters Assessment 2006). Over-abstraction of groundwater has also been framed as a problem of technology, where the advent of cheaper mechanised drilling techniques and mechanised tubewell pumps has allowed irrigators to use groundwater as an on-demand source whenever there is a shortage of surface water or to expand irrigation to areas that were previously rain-fed (Molle, López-Gunn, and Van Steenbergen 2018). Another dominant explanation for the global groundwater crisis relates to capitalist production, that is, overexploitation and pollution as an outcome of the planned and unplanned processes of economic

production under the dominant global production system of capitalism (Castree 1997; Smith 1998).

One of the oft- cited, and commonly advanced framings of the groundwater crisis is that it is due fundamentally due to the absence or weakness of, or weak governance of the resource, by which it is typically meant the way the resource is formally governed by the state's - institutions, policies, legal entitlements, and rules for the management of groundwater. The Global Water Partnership has declared the groundwater crisis as mainly a "crisis of governance" (Mukherji and Shah 2005). Such perspectives hold groundwater governance to be poor or absent in most parts of the world, and call for "more" or "better" governance as a solution to the groundwater crisis. This thesis goes beyond saying governance should be better to explore its role in the global groundwater crisis by drawing on empirical findings concerning the case of groundwater governance in Punjab, Pakistan. Calls for 'good' groundwater governance in the literature involve both a focus on more regulation by the state and best-practice management, such as decentralised community management of groundwater. This thesis dispels the use of the terms 'good', 'poor', and 'efficient' in describing the problem of groundwater governance because these terms are not as technical and straightforward as the international development literature makes them seem. Categorising groundwater governance in such normative terms undermines the complexity of the problem of groundwater governance and its relationship to the groundwater crisis. In addition, the thesis does not support a particular position about how groundwater governance 'should' be done, so it does not advocate on either side of the spectrum about the role of the state/communities/individuals in the management of groundwater. Rather, the study analyses how the nature of governance, in its various forms and dimensions, is implicated in the making of the groundwater crisis.

1.3. Groundwater Governance as an Explanation for the Global Groundwater Crisis

In the last fifteen years, unsustainable use of groundwater has emerged as a major global issue that has led several international development organisations to research and advocate groundwater sustainability through 'good' governance. These initiatives include the Groundwater-MATE Project, supported by the World Bank; the

Groundwater Governance Project, supported by several international donors; and the International Groundwater Resources Assessment Centre (IGRAC), supported by UNESCO, among others (IGRAC 2015). Most studies on groundwater governance equate good groundwater governance to groundwater management, so they focus on the technical, managerial, legal, and institutional aspects of what groundwater governance entails. Typically, governance for the management of groundwater refers to "the actions taken to control groundwater abstraction and to prevent the degradation of groundwater quality typically with the objective of ensuring sustainable freshwater provision and preserving desired environmental and ecosystem conditions that depend on groundwater" (Rubio 2017). However, such conceptions of groundwater governance mask the complexities of the problem of groundwater governance itself and its contribution to the global groundwater crisis.

As a resource, groundwater is fraught with ecological, economic, political, legal, and cultural complexities, all of which make its governance particularly messy, far from the politically neutral, utopian conceptions of governance advanced by international organisations and most of the policy and academic literature. What makes groundwater governance difficult? What role does the nature of groundwater governance play in the contemporary global groundwater crisis? Is the groundwater crisis caused by an absence of governance, weak governance, or too much governance? What does 'good governance' of groundwater, in relation to 'poor governance', mean? Is it appropriate even to use the terms 'good', 'poor', or 'weak' in describing the problem of groundwater governance? Do good governance frameworks in the literature necessitate a greater role of the state, of the market, or of collective action by the community? To explore these questions and to bring out the complexity of the problem of groundwater governance, the topic must be considered in relation to the materiality of groundwater as an 'invisible' resource and to the nature of its governance in relation to surface water governance.

The groundwater governance problem is distinct because of the resource's invisibility (as an underground resource) and persistent myths about its inexhaustibility, cheapness, and universally high quality (Varady et al. 2012). The underlying problem is that groundwater extraction mechanisms (wells and tubewells) are often privately owned and operated, although the underlying aquifers on which they draw are part of a

common pool resource, where extraction by one user diminishes the quantity and quality of the resource that is available for remaining users. The materiality of groundwater as a sub-surface resource also means that degradation of groundwater does not elicit the same emotional and political response as degradation of rivers, which are much more visible. In addition, the political visibility of the large-scale infrastructure that is associated with harnessing surface water – hydroelectric dams, barrages, and canals – often means that politicians prioritise and allocate higher budgets to the management of surface water.

The patterns and governance of groundwater use are distinct from those of surface water systems, largely because the materiality of groundwater disperses its exploitation widely in space and predominantly in the hands of the private sector, such as irrigation farmers, industrial miners, water supply companies, and owners of domestic wells. Hence, groundwater governance requires influencing and the participation of a large number of dispersed stakeholders – formal and informal, big and small. In contrast to the decentralised nature of groundwater governance, surface water typically necessitates the state to invest in construction of large-scale engineering works to harness and distribute the water (Karar 2017).

Groundwater governance may also involve governance across national boundaries, as most of the world's groundwater systems are transboundary freshwater resources that are shared between countries. The large number of transboundary aquifer systems complicates issues related to groundwater governance. Despite the development of international legal frameworks for groundwater governance, such as the 1997 Law of Non-Navigational Use of International Water Courses, the United Nations Economic Commission for Europe (UNECE) Convention on the Protection and Use of Transboundary Watercourses and International Lakes and the 2008 Draft Articles on the Law of Transboundary Aquifers adopted by the UN International Law Commission, governance of transboundary groundwater has not been taken up by more than a handful of countries. While numerous treaties on surface water use are in place to govern transboundary rivers globally, only six agreements to date are specifically dedicated to transboundary aquifers: the Genevese Aquifer, the Nubian Sandstone Aquifer, the North-Western Sahara Aquifer, the Iullemeden Aquifer, the Guaraní Aquifer, and the Al-Sag/Al-Disi Aquifer (Karar 2017).

Groundwater governance mechanisms range from decentralised, user-managed, neo-liberal types of arrangements to centralised state legislation, metering, and extraction of groundwater. In many parts of the world, especially those with a history of colonial rule, groundwater use and abstraction occurs in a decentralised, atomistic manner. Decentralised, neoliberal types of groundwater extraction with little or no state involvement has historically been practiced in many countries like India, Pakistan, Bangladesh, Spain, and Mexico, while China's groundwater governance has been much more centralised (Mukherji and Shah 2005). Over time, as the groundwater crisis exacerbates, countries have sought to place groundwater abstraction under state control in search of 'better' governance. For example, in Spain, the Spanish Water Code of 1985 placed groundwater resources in the public domain, but because the historic notion of groundwater rights is linked to private property rights over land and because of increased dependence on groundwater, the state's registration and licensing of groundwater pumps have been difficult to achieve. In some cases, where the perception of groundwater users is that the resource is unlimited or God-given, and social norms indicate that resource extraction is acceptable, formal state regulation may have little effect on what is happening 'on the ground' (Khair, Mushtaq, and Reardon-Smith 2015).

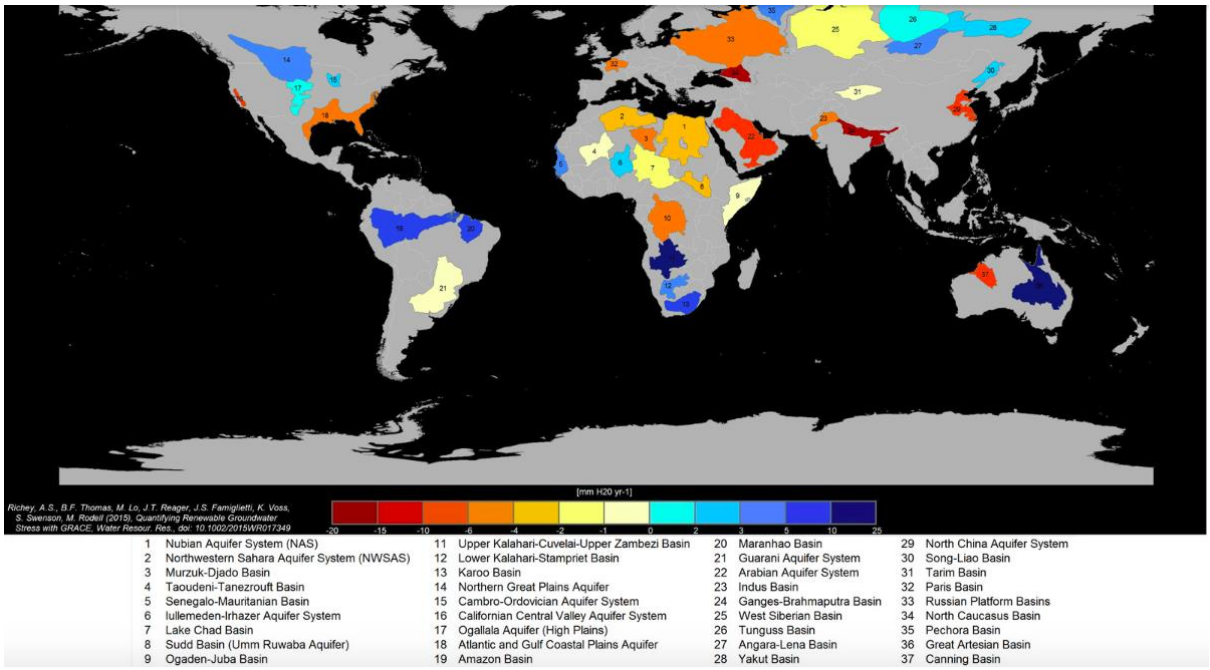
Given the politics and the socioeconomic processes that drive the development and exploitation of groundwater resources in a region and the actors, stakeholders, and socio-technical interactions in the groundwater governance domain, it is not difficult to understand why the groundwater governance problem remains wicked and messy and why it continues to defy statist and neo-liberal solutions around the globe.

1.4 Pakistan's Punjab as a Case for Exploring Groundwater Governance

Punjab, which lies in Pakistan's Indus Basin, presents a useful context for exploring the nature of the groundwater governance problem, as how 'governance' has contributed to the groundwater crisis in Punjab offers insights into the global problem of unsustainable groundwater use. Pakistan is the second-largest economy in the Indus Basin, which it shares with three other riparian countries: India, Afghanistan, and China (FAO Aquastat 2015). Drawing from the Indus Basin Aquifer, which is the second most overstressed groundwater basin in the world (NASA 2015), the country is the fourth-largest

abstractor of groundwater globally (Margat and Gun 2013; see Figure 1.1). Groundwater, which accounts for an average of about 50 to 60 per cent of the irrigation water in the country, serves as a buffer against the variability of the monsoon rains, most of which occur for a short period in the summer (Wattoo and Mughera 2016). In Pakistan, 94 per cent of the groundwater used is used for agriculture, followed by domestic uses (6%), and a 'negligible' use by the industrial sector as per official statistics. In 2015, Pakistan had 1,0496,000 tubewells, most of which were located in Punjab province (Government of Pakistan 2017).

Figure 1.1: Map of Large Groundwater Basins in Distress*



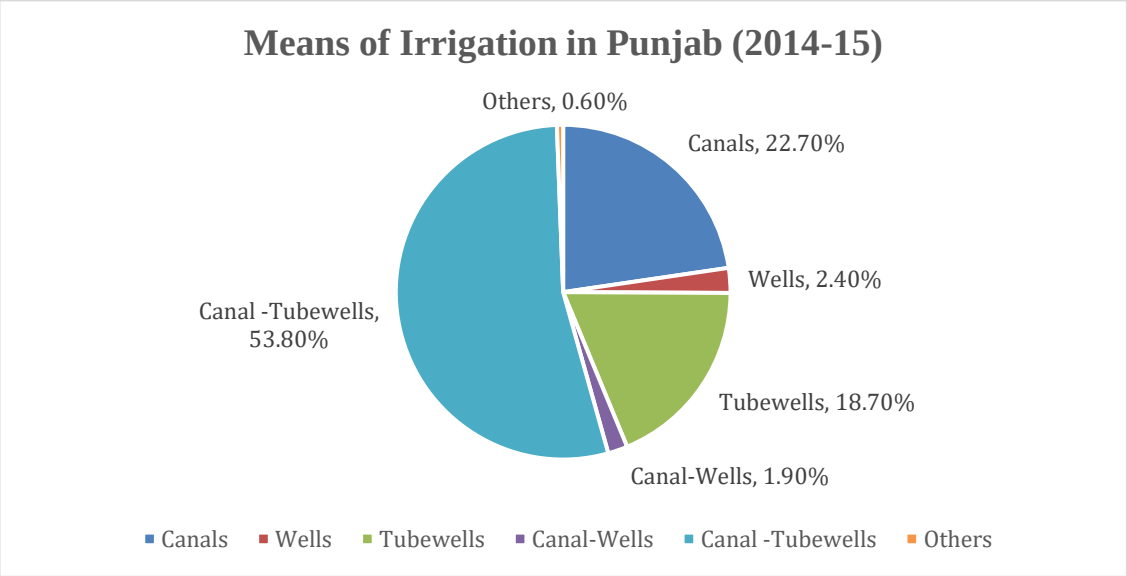
Source: NASA 2015

*Note: Pakistan's Indus Basin is No. 23

1.4.1 Punjab's Growing Dependency on Groundwater

Punjab, the most populous province in Pakistan's Indus Basin, is also the region's breadbasket, as it is the main agricultural contributor to the gross domestic product (GDP) (Government of Pakistan 2017). Punjab contributes 60 per cent of Pakistan's agriculture-based exports. Despite being a land of five rivers (hence, the name *Punj-ab*), the province has come to depend heavily on groundwater sources to support its agrarian-industrial economy. In 2014-15, 76.8 per cent of the irrigated area in Punjab depended on groundwater sources for irrigation, including irrigation exclusively by wells and tubewells and in combination with water from canals (Figure 1.2).

Figure 1.2: Means of Irrigation in Punjab, Pakistan



Source: Bureau of Statistics Punjab 2014-2015; author's illustration

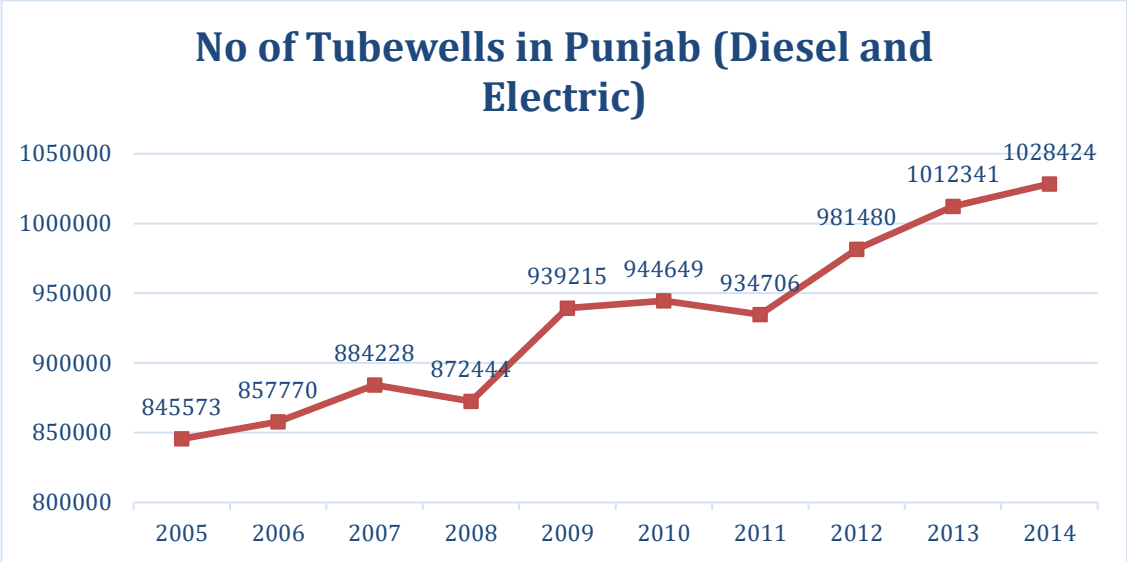
Punjab's growing dependence on groundwater is to some degree a function of surface water availability, as groundwater use has increased recently as surface water flows decline and become more unpredictable in the face of climate change (Watto and Mugera 2016). Having experienced massive investments in large-scale surface irrigation during British rule, as well as in the early post-colonial period, Punjab is home to the largest contiguous surface irrigation system in the world. At the time of its independence, surface water resources dominated the province's water budget, but in recent years the increased variability and decline in surface water supplies because of climate change and population pressures has increased its dependence on groundwater for irrigation needs (Archer et al. 2010). The Indus Basin, of which Punjab is part, is one of the most heavily depleted river basins in the world, having experienced a decline of 15 per cent of available surface water in the last decade alone (Sharma et al. 2010).

Another reason for Punjab's increased dependence on groundwater is that the distribution of surface water is problematic. Canal water is distributed through the *warabandi* system, originally established under colonial rule, which distributes available surface water equitably in proportion to farm size in fixed weekly rotations. In

practice, the rigidity of the *warabandi* system, bureaucratic corruption, and the lack of equity in distribution between head and tail ends of canals means that farmers increasingly rely on groundwater pumped through tubewells for timely access to irrigation water at crucial times in the cropping season (Jacoby and Mansuri 2018; Zardari and Cordery 2009). When the *warabandi* system was set up in the British period, cropping intensities were low at 70 per cent, although they had more than doubled after the Green Revolution of the 1960s, when the introduction of high-yield seeds and fertilisers widened the gap between the demand for crop water and existing allocations from canal water (Shah 2007).

In addition to the inflexibility of the *warabandi* system and the increase in cropping intensities that were due to the Green Revolution, the Indus Waters Treaty of 1960 led to a gradual transition from surface water to groundwater use. The treaty, an agreement on sharing of the Indus River System, was brokered by the World Bank between India and Pakistan in light of the establishment of political boundaries between the newly independent colonies in 1947. Under the treaty, the three western tributaries of the Indus (Indus, Jhelum, Chenab) were given to Pakistan and the three eastern tributaries (Ravi, Bias and Sutlej) to India. At the same time, as the upper riparian, India was given rights of power generation on and non-consumptive use of the three western rivers allotted to Pakistan before they entered Pakistani territory. In the last few decades, intensive hydropower development upstream by India on the western tributaries of the Indus has reduced downstream flow to Pakistan, increasing the country’s dependence on groundwater for supplies (Mustafa 2010).

Figure 1.3: Growth in Tubewell Irrigation in Punjab



Source: Agriculture Census 2015; author's illustration

Punjab is currently highly dependent on groundwater resources for agriculture, industry, and domestic use. Groundwater is the main irrigation source for the major agricultural crops of Punjab, accounting for between two-thirds and three-quarters of the irrigated areas for wheat, rice, cotton, and sugar cane in 2017 (Government of Punjab 2017).[1] Punjab also has a sizeable industrial sector, with more than 48,000 units that contribute 24 per cent of the province's GDP (Punjab Growth Strategy 2015). Several large industrial sectors are water-intensive and water-polluting industries like textiles, leather, pulp, chemicals, and light manufactured goods. Textile manufacturing is an important industry, contributing 54 per cent of Pakistan's overall exports. According to a WWF study on industrial water footprints, Pakistan's textile sector consumes 12,251 million cubic meters of water (Linstead et al. 2015). Groundwater is also the main source of drinking water and domestic water use for most of the province's population. About 87

[1] In 2015-16, out of the 6.2 million irrigated hectares under wheat, 78.4 per cent is irrigated with groundwater sources: 23.6 per cent of the total irrigated area under wheat is cultivated exclusively through tubewells and wells, while 54.78 per cent is cultivated through a mix of canal-tubewells and canal-wells.

Out of the nearly 1.8 million irrigated hectares under rice, 88.7 per cent relies on groundwater: 26.6 per cent relies on groundwater through wells and tubewells exclusively, while 62.07 per cent relies on irrigation through surface and groundwater resources (canal well and canal tubewell).

Out of the 705,000 irrigated hectares under sugarcane, 69 per cent is irrigated through groundwater: 14.4 per cent is irrigated through groundwater sources exclusively, while 54.6 per cent is irrigated through canals and groundwater resources.

Out of the 2.2 million irrigated hectares under cotton, 68.6 per cent is dependent on groundwater resources: 9.5 per cent is irrigated exclusively through groundwater sources, while 59.07 per cent is irrigated with canal water and groundwater.

per cent of the existing water supply programs in Punjab depend on groundwater sources, while 13 per cent obtain their supply from surface water sources. In the districts of Bhakkar, Gujranwala, Gujrat, Hafizabad, Jhang, Kasir, Mandi Bahauddin, Nankana Sahib, Narowal, Okara, Sheikhupura, and Sialkot, the entire population depend on groundwater for drinking water (Pakistan Council of Research in Water Resources 2010).

1.4.2 Extent of the Groundwater Crisis in Punjab

The groundwater crisis in Punjab manifests in the form of persistent decline in the depth of the aquifer because of over-abstraction and groundwater pollution from agricultural and industrial effluents. This section describes the extent of the groundwater crisis based on an extensive review of documentary sources. It also uses insights from fieldwork conducted in District Sheikhupura in Punjab to describe how the crisis' effects are distributed unevenly and affect the livelihoods of the most marginalised users. Chapter 6 provides a more detailed analysis of the local political ecology of the groundwater crisis and the techniques groundwater users employ in face of the deteriorating resource.

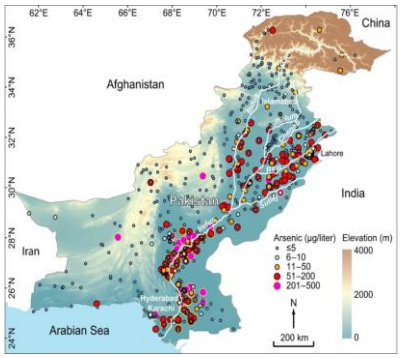
According to a report by IWASRI, groundwater depletion rates across most of Punjab are 16-55 centimetres per year, with some areas, such as the urban area of Lahore, experiencing depletion rates of 40-150 centimetres per year (Basharat, Sultan and Malik 2015). In parts of Punjab with historically good-quality groundwater, such as the Rechna Doab, agricultural and industrial activity and urban growth have caused groundwater levels to fall by 1.5 meters annually (Basharat et. al 2015). Falling groundwater levels from over-abstraction necessitate deeper drilling.

The technical definition of groundwater over-abstraction is largely understood as when abstraction exceeds aquifer recharge, which leads to a decline in the depth of the water in the aquifer. However, this definition is neutral in terms of who bears the costs and gains the benefits of groundwater over-abstraction, the burden of which falls mostly on poorer communities while the benefits accrue to those with economic and political power, who often escape the consequences of falling water tables by digging deeper bores. Fieldwork with rice farmers in Sheikhupura District of Punjab reveals the extent

of the groundwater crisis and its implications for livelihood and equity. The costs of groundwater depletion are born more heavily by poorer farmers, who have a disadvantaged access to surface water irrigation because of the location of their land. Most farmers whose lands are located at the middle and tail ends of the canal reported using an average of 80 per cent groundwater and only 20 per cent canal water, which indicates that farmers' dependence on groundwater for irrigation is often higher than is reflected in government irrigation statistics.

In addition to declining quantity, the degradation of the quality of groundwater means that about 60 million people across Pakistan, with hotspots in Punjab (Figure 1.4) are at risk of arsenic poisoning (Podgorski et al. 2017), given that groundwater is the main source of drinking water for Punjab. While some of the arsenic occurs naturally, a large part of it is the result of agricultural and industrial pollution (Raza et al. 2017).

Figure 1.4: Arsenic Hotspots in Pakistan's Indus Basin Aquifer



Source: Podgorski et al. 2017

Apart from arsenic, seepage from agricultural pesticides and industrial pollution has contaminated shallow groundwater aquifers with hazardous chemicals and metals. Industries routinely discharge untreated effluent, which directly affects the well-being of the local population. One of the methods of discharging effluents is by throwing it in open drains, but not all industries are located on the drainage network, so many have to look for more 'creative' ways of effluent disposal. Local fieldwork in District Sheikhupura of Punjab revealed that it was a standard practice to construct unlined wells, or *khuwas*, to discharge untreated effluent, so it slowly percolate into the groundwater (Chapter 6). This practice, which is common throughout Punjab, has resulted in severe contamination of the shallow aquifer in adjoining areas, making

shallow water unfit for drinking and even for irrigation. Poor farmers at the tail end of canals bear a disproportionate burden of polluted groundwater aquifers compared to wealthier farmers and those at the head end.

1.4.3 Punjab's Groundwater Crisis as a Crisis of Governance

Many researchers explain Pakistan's groundwater crisis as being the result of weak governance, which is typically refers to the regulation, monitoring, and control of groundwater extraction through the formal apparatus of the state (Khair, Mushtaq, and Reardon-Smith 2015; Qureshi et al. 2010; Watto and Mugera 2016). Groundwater governance studies in Punjab and Pakistan point to the absence of or weaknesses in the state's legal, institutional, and regulatory policies and the need to strengthen groundwater governance to achieve resource sustainability. Some studies call for the implementation of international best practices of integrated water resource management for groundwater governance in Pakistan (Basharat et al. 2015). A recent World Bank report equates Pakistan's water crisis to a challenge of governance: "The governance challenges relate to inadequate legal frameworks for water at federal and provincial levels, and the incompleteness of policy frameworks and the inadequacy of policy implementation" (World Bank 2019, xviii). Most of this literature uncritically equates groundwater 'governance' with groundwater 'management' by the state and points to the need for technical and managerial solutions. The focus of 'governance' in most of the institutional and technical literature is on strategies for demand management of groundwater by the state in the form of improved irrigation practices, economic pricing for groundwater, and licensing for tubewells, as well as strategies to improve supply, such as recharge of groundwater through construction of artificial dams and rainwater harvesting.

While institutional and managerial explanations of the problem of groundwater governance are useful, they are necessarily apolitical, and they tend to render both the governance problem and its solutions politically neutral. This thesis departs from these conceptions of the groundwater governance problem in two ways: First, the thesis uses a historical political ecology approach and an extended definition of groundwater governance to explore Punjab's groundwater crisis as a crisis of governance. The

conception of governance (Chapter 2) goes beyond a state-centric understanding of power to emphasise the historical, mutually constitutive relationship between the state apparatus and non-state actors like international financial institutions, NGOs, multinational corporations, and individual users. The study uses the evolution of the groundwater-society relationship as a lens through which to analyse the nature of groundwater governance during the colonial, post-colonial, and contemporary periods. The conception of groundwater as 'socio-nature' and an appreciation of the agency of groundwater as both an object and a subject of governance illustrate the deeply political nature of groundwater governance in Punjab. Second, unlike calls for better governance as a solution to the groundwater crisis, this thesis uses a historical case study of Punjab to show how governance has been an active force in *creating* the groundwater crisis. The nature of the governance, rather than the lack of it, has been a decisive factor in the making of Punjab's contemporary groundwater crisis. I use empirical findings from the case of Punjab to reflect on groundwater governance itself as an explanation for the global groundwater crisis. The theoretical contribution of this thesis, then, is to the political ecology of groundwater governance.

1.5 Overview of the Research: Questions, Method, Concepts

1.5.1 Research Questions and Aims

This thesis explores the sustainability of groundwater use as a problem of groundwater governance. The thesis engages with the problem of groundwater governance on two levels: First, using a historical method rooted in political ecology, an empirical analysis of the nature of Punjab's groundwater governance across the colonial, post-colonial, and contemporary periods suggests how the changing nature of groundwater governance in Punjab has led to the contemporary groundwater crisis. The literature on groundwater governance in Punjab suggests that the groundwater crisis is the result of the weaknesses in or absence of groundwater governance, so it argues for a greater role of the formal apparatus of the state to solve the problem of groundwater over-abstraction and pollution. However, this thesis suggests that governance, rather than its absence, has been a decisive factor in the creation of the groundwater crisis in Punjab. The thesis' central argument rests on an extended definition of groundwater governance and

the conception of groundwater as "socio-nature" to facilitate an analysis of the mutually constitutive relationship between state and non-state 'governors' that make up groundwater governance, as well as the relationships among governance, society, and groundwater itself. The second level on which the thesis engages with the problem of groundwater governance is that of empirical findings from Punjab's case, as the thesis engages critically with the political ecology of the (ground) water literature to make broader arguments about the politics of groundwater governance and the critical role it plays in the groundwater crisis, both for the case of Punjab and globally.

The research addresses the broader question of what caused the global groundwater crisis and how groundwater governance has contributed to the unsustainable exploitation of groundwater globally. More specifically, it explores the nature of the problem of groundwater governance in Punjab and its contribution to Punjab's groundwater crisis. In addressing these central questions, I explore key questions that guide the analyses in each of the empirical chapters:

a) What are the limitations of the extant literature on the groundwater crisis and the problem of groundwater governance, especially in relation to surface water governance? Why have most discussions of water, power, and politics in the literature typically focused on surface water politics while placing insufficient emphasis on the political ecology of groundwater? Is there a relationship between groundwater and state developmental goals?
b) What are the techniques, mechanisms, and patterns of groundwater governance in each of the historical periods (colonial, post-colonial, contemporary) in Punjab's case? How do the techniques of governance and politics and the power associated with them operate across the formal apparatus of the state and the informal non-state 'governors' of groundwater as a decentralised resource?
c) How does groundwater politics work 'on ground'? How does the groundwater crisis interact with the complexity of social relations and power dynamics at the local level? How do the local dynamics of informal groundwater governance relate to more powerful state and non-state governors of groundwater at higher levels?

These questions explore the broader political ecology of socio-economic processes, both chronologically and on a variety of scales, that explain the nature of the groundwater governance problem and its contribution to the groundwater crisis in contemporary Punjab. I consider each of these questions for the case of Punjab and their implications for similar contexts, as well as for the political ecology of groundwater governance.

1.5.2 Theoretical Framework

This research deploys a political ecology framework inspired by Focault and Actor-Network Theory. Political ecology refers to a body of combined theoretical approaches that emphasises the politics and power relationships that are at the heart of social struggles over natural resources (Blaikie and Brookfield 1987; Greenberg and Park 1994; Peet and Watts 1996; Stott and Sullivan 2000). Political ecology-related approaches focus on context and rootedness in history, the social and political construction of nature, and natural resource governance on multiple scales with a central concern for environmental justice. A critical political ecology approach to the study of the problem of groundwater governance necessitates that the politics and power that shape groundwater governance take centre stage. Critical perspectives on environmental governance as an organising concept stress the need to go beyond managerial solutions to environmental problems and focus on the underlying politics so as to ask questions like those related to the governance of what, by whom, and to what end (Bridge and Perreault 2009, 477).

My understanding of groundwater governance is rooted in Focauldian perspectives that entail the state's 'governing at a distance' and involve a decentralised understanding of power. According to this perspective, power is not associated only with the formal state but consists of all of the techniques, technologies, mechanisms, and procedures that are distributed across institutions, agents, individuals, and groups in a society. The governance of groundwater is not just through the institution of the state but is distributed throughout the apparatuses of society, as detailed in Chapter 2. The theoretical framework of governance for this study uses the groundwater-society relationship as a lens through which to explore the problem of groundwater governance. Examining the evolution of the historical groundwater-society relationship in Punjab

emphasises a dialectical understanding of the roles of governance and society with groundwater. The emphasis enables the study to explore how governance across state and non-state actors has shaped and affected the groundwater-society dynamic, but also how the way that groundwater has been developed and used has created patterns of dependence in the society and has affected the techniques of governance.

1.5.3 Methodology

This research was conducted in Punjab over a twelve-month period between the end of August 2016 and beginning of September 2017, followed by a period of archival research at the British Library (London) from October to December 2017. The thesis is based on qualitative case study methodology involving the collection of primary data, intensive archival research, and the analysis of donor and government policy documents. Primary data collection was carried out using a variety of research instruments: semi-structured interviews, institutional ethnography with the Punjab Irrigation Department, and observation of participants at water conferences and workshops in Punjab and focus groups with rice farmers. This research is a multi-sited qualitative study that explores approaches to groundwater governance on multiple scales and across types of governance and actors in diverse settings, including federal ministries that are (or are not) responsible for groundwater; institutions that are responsible for managing groundwater at the provincial, district, and village levels; civil society organisations that engage with groundwater; and studying down to how groundwater is managed by irrigators as 'on the ground' governors of the resource.

As a field of enquiry, political ecology spans multiple disciplines and methods. Methodologies in political ecology range from material to discursive and from empirical evidence about ecology to post-structuralist concerns about power, knowledge, and discourse. Using multiple methodologies allows the researcher to blend individual and institutional, and macro and micro domains to explain the full depth of the groundwater governance problem in Pakistan. In line with the political ecology approach, various research instruments were used to address the overall problem of groundwater governance and answer the research questions. Archival Research at the British Library's India Office of Records, as well as through online resources

(www.hathitrust.org), was used to analyse how seemingly apolitical social relationships around the use of groundwater that have persisted since colonial times were actually embedded in historical political and social relationships and the broader political economy of irrigation finance, agrarian commercialism, and technological advancement. An historical approach rooted in political ecology allowed me to trace the historical contingency of the contemporary problem of groundwater governance and to examine the continuities and changes in governance across historical periods (Chapter 4). Groundwater governance in the post-colonial period in the Cold War context were analysed using a mix of research instruments, including fourteen semi- structured elite interviews, institutional ethnography with the Punjab Irrigation Department, and archival and document research of post-colonial groundwater development projects at the WAPDA Library in Lahore (Chapter 5). A large bank of project documents, primarily from the World Bank, the largest international development lender for Pakistan's water resource sector, were also analysed to clarify the role of international finance and expertise in large-scale groundwater development in Punjab's early post-colonial period. A critical analysis of donor project documents from the 1960s to the 2015, enabled an reflection on the role and power of international financial institutions as significant non-state governors of groundwater. At the same time, government planning documents (including Five Year Development Plans, annual budgets, draft water policy documents, existing legal ordinances for surface and groundwater, Draft Groundwater Act 2017) and data from elite interviews with irrigation bureaucracy was used to reflect on the continuities and changes in techniques of the state for groundwater governance. In order to assess how groundwater is governed 'on ground', a detailed local ethnographic style fieldwork was carried out with rice farmers in three villages District Sheikhupura to analyse the extent of groundwater crisis on ground lending an emic perspective to the study (Chapter 6). In Sheikhupura, water conservation activities carried out by multinational companies sourcing rice from the region were followed and critically analysed to enable discussion of how top down 'conservation as governance' affects users on ground, as well as how local users practice 'adaptation' as a form of governance in the face of the groundwater crisis.

1.6 Thesis Structure

This introductory chapter sets out the primary research puzzle of the global groundwater crisis, groundwater governance's contribution to the groundwater crisis, and the thesis' structure, overall argument, and themes in the empirical chapters. In Chapter 2, I engage critically with the broad literature on the problem of environmental governance and the literature on groundwater governance in relation to surface water governance to highlight the literature's limitations in terms of engaging with the political ecology of groundwater governance, especially in the context of Pakistan's Punjab. Chapter 2 also explicates the theoretical and analytical framework for governance that guides the methodology and analysis in the empirical chapters. Chapter 3 explains the research design and methodology used to answer the overall research question and its sub-questions, as well as ethical considerations and positionality issues connected to the researcher. Chapters 4, 5, and 6 present the main empirical and analytical findings of this research, which relate to the importance of groundwater for state developmental goals, and how this shapes the governance of groundwater: Chapter 4 details how the colonial approach to governance was shaped in response to the importance of groundwater as a buffer against famine in the early twentieth century, for irrigation in areas not served by canals, for winter crops when canal flows decline, and as an additional means of enhancing irrigation and agricultural productivity at little or no cost to the state. Chapter 5 deals with the post-colonial period, when groundwater development played a decisive role in state-building efforts, and the partnership between the developmental state and 'well-meaning' foreign experts, large-scale centralised groundwater development led to the 'green revolution' and associated gains in agricultural productivity. The analysis in Chapter 6 points relates the broad contours of political ecology of groundwater governance to the local dimensions of the groundwater governance challenge by emphasising the power and politics of non-state actors, big and small, and the interaction between actors in the formal and informal governance and groundwater itself as a resource. Chapter 7 concludes the thesis by reflecting on the implications of the thesis' empirical and theoretical contributions for the problem of groundwater governance and its relationship to the global groundwater crisis.

2. Theoretical Framework and Literature Review

2.1. Introduction

This chapter highlights gaps in the literature on groundwater governance and provides the theoretical and interpretive lenses that guide the analysis in the empirical chapters. The chapter's review of the literature on groundwater governance shows how most studies use a narrow definition of governance that focuses on the formal apparatus of the state for managing the resource. In addition, most analytical frameworks for groundwater governance focus on technical, managerial, and institutional approaches to the problem, making the groundwater crisis and its solutions appear politically neutral. By contrast, this thesis explores the problem of how groundwater governance works using an expanded definition of and analytical framework for groundwater governance that leaves room for an emphasis on the politics and power in groundwater governance and the dynamic interaction between state and non-state actors. Using a political ecology approach, the thesis uses the historical relationship between groundwater and society as a lens through which to draw insights into the nature and causes of the problem of groundwater governance for the case of Punjab and its implications for the global groundwater crisis. The point of departure from existing studies is that, rather than calling for more governance as a *solution* to the groundwater problem, the thesis illustrates how governance has played an active role in *creating* the groundwater crisis.

The chapter is organised as follows: After situating the study in the broad literature on environmental governance (Section 2.2), I review the literature on the global and South Asia-specific problems of groundwater governance (Section 2.3). I identify the gaps in the literature on groundwater governance in light of the contrast between surface water governance and groundwater governance to carve an entry point for a political-ecology-based study of groundwater governance through a case study of Punjab. The analytical framework for 'governance' that guides the methodology and the empirical analysis is presented in Section 2.4, along with a discussion of how the analytical framework relates to the thesis' methodology and the empirical analysis in subsequent chapters.

2.2. Approaches to Environmental Governance

Recent years have seen an explosion in the debate on the appropriate model for environmental governance. This section, which reviews, discusses, and critiques existing approaches to environmental governance, is organised roughly in the neoliberal and statist categories to facilitate proposing and defending the value of the political ecology approach to environmental governance broadly, and (ground) water governance specifically.

The broad logic of neoliberal philosophy as it relates to environmental governance is simple: through the privatisation and marketisation of nature, 'common tragedies' can be avoided, pricing the biophysical world through the competitive private sector will lead to the best environmental cost per unit, and moving responsibility for environmental management from the state to civil society actors will empower them and lead to non-bureaucratic approaches to resource governance (Castree 2010). In the last few decades, natural resource management and biodiversity conservation has taken to a neoliberal flavour that is generally focused on the creation of capitalist markets for exchange of natural resources, privatisation and commodification of natural resources, withdrawal of direct government intervention from market transactions, and decentralisation of resource governance to local authorities, self-governing individual and community groups, and non-state actors like NGOs (Castree 2010; Fletcher 2010).

Criticism of neoliberal environmental governance has focused on a number of problems with this approach to governance. Decentralisation of natural resource management to local communities has been found to increase the influence of multinational corporations and international agencies over local interests and local use of resources (Levine 2002). In addition, neoliberal resource governance has equity implications, as marginal communities may become further disenfranchised from their local resources as these resources become privatised and marketized (Brockington, Duffy, and Igoe 2008). It is also not clear whether neoliberal resource governance leads to decreased environmental degradation in some cases or whether reduced degradation in one place is offset by increased exploitation in another, leading only to redistribution of the costs and benefits of environmental degradation (Brockington, Duffy, and Igoe 2008). The overall criticism of the neoliberal mode of governance rests on its inequality as well as

the accumulation of benefits of ‘conservation’ to more powerful entities (Büscher and Fletcher 2015).

The literature on the translation of the neo-liberal worldview into practical applications is both appreciative and critical of its social and environmental benefits. According to the neoliberal resource governance approach, water is an economic good to be managed efficiently by granting private property rights over water and using instruments like tariffs, pricing, metering, and trading through water markets. Bakker’s (2003) study of water privatisation in England and Wales shows both a reduction in leakage rates and a notable increase in the quality of drinking water but acknowledges the social inequities in water service delivery, with a large number of lower-income households subject to water cut-offs during the process. The implementation of neo-liberal environmental policy has also led to civil society activism, as documented in case studies of water and gas privatisation in Bolivia (Nickson and Vargas 2002; Perreault 2006). Studies have also documented the mixed effects of neoliberal environmental policy on the environment itself. For example, Prudham (2004) discusses water poisoning in Ontario in the aftermath of the implementation of neoliberal policies. In the same vein, Heynen and Perkins (2005) discuss how local government rollbacks from maintenance of urban tree cover reduced the number of trees, for which private landowners, left on their own, do not compensate. Extensive literature in this area points to the social and environmental conflicts and adverse effects on equity of access to water after neoliberal reforms. These include case studies of water privatisation in Latin America (Castro 2007; Hailu, Osório, and Tsukada 2009), public private partnerships for water supply in Indonesia (Bakker 2007), neoliberal water sector reforms in Chile (Budds 2004), and the introduction of water pricing in South African cities (Conca 2006).

As opposed to the neoliberal worldview of managing the environment, statist approaches emphasise conservation and maintaining biodiversity through the state’s legal and institutional apparatus. Statist approaches to environmental governance have their roots in ‘fortress conservation’, which originated in the US following the Yellowstone National Park model in 1872 (Spence 1999). Fortress conservation models have been criticised for their exclusionary approach that lead to evictions of local inhabitants and indigenous peoples (Brockington 2002). In addition, demarcation of protected areas for environmental conservation can eliminate existing rights to

resources and transfer the ownership of the commons to the state. The state then controls the allocation of nature's benefits in all of its discursive-material-social manifestations (Perreault, Bridge, and McCarthy 2015), often leading to conflict among a range of actors, including agrarian communities, indigenous peoples, state agencies, and corporations. The creation of a protected area by an external political body (the state) results in redistribution of access to and control of natural resources; such models of conservation have also been linked with state integration and state-making projects, where monopoly over the conservation of nature sustains and provides legitimacy to the state (Vandergeest and Peluso 1995).

A key problem with statist approaches is the capacity of the state and its institutions to regulate natural resources appropriately. The modern state has diverse institutions, such as agricultural ministries and forest departments, to facilitate the definition, regulation, and management of nature (Whitehead, Jones, and Jones 2007), and over time the number, size, and types of institutions involved in nature conservation have increased. Therefore, the concept of 'state' must be unpacked when discussing statist approaches to environmental governance. As Whitehead et al. (2007, 14) explain, "to analyze state-nature relations it is important to unpack both categories so as to understand how their constituent parts are intermixed and connected." Therefore, the interaction between the state and non-state institutions like NGOs, international donors, and private corporations and the legitimacy that the state bestows on these non-state entities for managing the environment require clarification. In this context, Igoe and Brockington (2007) and Neves and Igoe (2010) address how neo-liberal reforms affect state sovereignty in Africa, while Bryant and Bailey (1997) study the role of international donor organisations in the global south and how they invoke their moral and scientific authority in encouraging states to usurp local control and cut off local use of protected areas or conservation territories.

While the discussion above refers to 'neoliberal' and 'statist' forms as two distinct categories, it must be emphasised that such a distinction is not always present in practice. Environmental governance is often represents a spectrum rather than the neat categories of neoliberal or statist described above. The difficulty of examining approaches to environmental governance as separate categories is that often the practical implementation of the approach conflicts with the ideological precepts

characteristic of the approach. Often governance situations that come off as neoliberal involve a considerable role for the state in facilitating the market using incentives, rather than a complete rollback of the state (Knafo 2019). Brockington and Duffy (2010, 480) note that neoliberalism is an uneven project and applied with differential rigour across space. At the same time, statist approaches to environmental governance often involve the state working through or alongside the market mechanism. As Robertson (2015) argues, neoliberalization of nature changes the role of the state in environmental governance. Nuemann (2015) also explains that a seismic shift in the character of statist approaches towards market-based solutions has occurred over time. Practical examples of environmental governance strategies across the global often draw on a range of mechanisms, which involve a combination of the state and market mechanism working together for environmental management.

2.2.1 Value of the Political Ecology Approach to Environmental Governance

Political ecology is a body of theoretical approaches that places politics and power relationships at the heart of analyses of social struggles over natural resource use, governance, and knowledge. It emphasises the context and rootedness in history and the social and political construction of nature and natural resource governance, and the multiplicity and dynamism of scales of environmental governance that are intended to address the inequality of access to natural resources.

Political ecology approaches are used to critique the neoliberal and statist approaches to environmental governance (Perreault, Bridge, and McCarthy 2015, 343). They are concerned with the social arrangements and forms of rule through which people manage environments and resources, and the social, political, and ecological effects to which these arrangements give rise. They are usually rooted in, but not limited to, Marxist, Gramscian, Focauldian, and Science and Technology Studies perspectives, and broadly seek to explain how economic and political power are sustained through socio-ecological arrangements. Political ecology approaches are instrumental in expressing dissatisfaction with and extending the criticism of neoliberal and statist forms of environmental governance as, according to these approaches, neoliberal and statist approaches to environmental governance tend to depoliticise the problem of environmental governance.

Political ecology raises important questions about the neo-liberalisation of nature and its effectiveness as a means of sustainable development, emphasising the character of neo-liberalism as a form of capitalism (Bakker 2015). Political ecology's criticism of neoliberalism is grounded in large part in Harvey's (2005) political economic analysis, which frames neoliberalism as a form of capitalism that furthers "accumulation by dispossession." According to Harvey (2005, 119), neoliberalism hides the grim realities of its reinforcement of class power by providing a "benevolent mask full of wonderful sounding works like freedom, liberty, choice and rights."

Political ecological approaches also problematize and criticise statist approaches to environmental management, often drawing on Foucault to advancing a critical understanding of the state as a totalising institution (Foucault et al. 2007). Political ecology has tried to understand state practices for of environmental conservation as producing, confirming, and extending state sovereignty - even through mundane practices of nature conservation like land surveying, mapping, and measuring and monitoring water table depths (Neumann 2015). The political ecology literature explores the highly contested relationship between states and the environment, seeing the state as a main environmental player where state action is integral to processes of environmental change but is also instrumental in the production of environmental knowledge and in coordination of the access to natural resources. The role of the state in in environmental governance remains highly contested, with one group of theorists perceiving it as an 'environmental guardian', while another camp sees it as "key institutional frameworks in and through which the continued domination and destruction of the natural world is being realized and legitimated" (Whitehead 2008, 415). Competing perceptions about the state as a category of analysis lead to opposing positions on the relationship between the state and the environment: Many theorists identify the state with government institutions, centralised power, and delimited territories (following Mann 1984), but an increasing number of scholars document how the state's activities are manifested through para-state institutions and civic realms and explore how the state's power may not always be centralised or limited to state territory (Whitehead 2008).

The critique of the state with regard to environmental management is also rooted in eco-

anarchist or eco-Marxist traditions. The eco-anarchist-inspired critiques of the relationship between the state and the environment argue that states are too large and insensitive to be able to deal with the local socioecological complexities of the environment. This view is best explicated in Bookchin (2004), who argues that states tend to simplify the local social and ecological complexities of the environment to be able to govern them, and that, in taking collective responsibility for environmental management, states prevent citizens from developing the necessary skills to engage in ecological conservation. Other scholars who emphasise the development of radical ecological and sustainable citizenship include Anderson (2004), Dobson (2003), and Bullen and Whitehead (2005) (For a review, see Whitehead (2008)). The eco-Marxist critique of the state emphasises the relationships among capitalism, the state, and the environment to reveal that the capitalisation of nature involves a considerable dependence on the state, rather than being a neoliberal free-for-all regime. The state facilitates capitalist appropriation of nature not just through provision of heavily subsidised infrastructure (roads, railways, canals), but also through the regulation of property rights, which facilitates large-scale resource exploitation at a global and local level. This view, which is explicated in Swyngedouw (2007) and Whitehead (2007), goes against the Hobbesian view of the state as a guardian of nature, and holds the state complicit in deliberate exploitation of the environment in a capitalist set-up.

2.3. Water Governance Literature

The literature on water governance is vast, covering a range of approaches (institutional, liberal, statist and political ecology), and a range of issues (urban water, water infrastructure, surface water, groundwater, floods, droughts). In line with the scope of this research, I focus on the literature on the politics of water governance, emphasising the dominance of surface water politics in this literature so as to highlight the research gap that this study of groundwater governance fills.

Most of the literature on water governance, particularly studies by international development organisations, position water governance as a technical, institutional, and management issue. In contrast to this simplistic view, critical social science research is increasingly convinced that “water governance at heart is about politics” (Zwarteveen et al. 2017, 8), as it concerns political choices about distribution and directions of water

flows and about who has authority and expertise to make decisions about how water is to be governed. This perspective acknowledges water as a socio-natural resource that shapes "people's lives and livelihoods, development of cultures and political economies" (Mollinga et al. 2008, 11). The literature on the politics of water governance studies the everyday politics of water management (typically how access to water is navigated at the local level); the relationship between water and societal development in relation to state formation, colonisation, or economic growth (c.f. Stone 1984; Wittfogel 1957; Worster 1985); transboundary hydropolitics and hydrohegemony (Zeitoun and Warner 2006), and the global politics of the discourse on water policy. I focus on the relationship between water and societal development/state power to carve out an entry point for this study of groundwater governance.

2.3.1 Surface Water Governance Literature

A large number of studies focus on the hydropolitics of surface water governance in the world's major international transboundary basins. This literature, which is based on realist, Malthusian, institutional and liberal perspectives, focuses on conflict and cooperation between states that share river systems as a key theme in the governance of water (Sadoff and Grey 2005; Starr 1991; Zeitoun and Mirumachi 2008).

An equally large number of studies focus on the relationship between water governance and state power. These studies often draw on Wittfogel's (1957) highly acclaimed (and equally criticised) thesis on the relationship between social organisation and the management of water. Other notions that link water governance and state power are variously referred to as colonial hydrology and hydro imperialism in the context of colonial governance of water (D'Souza 2006; Pritchard 2012); and the concept of hydraulic mission of the state mostly in the context of post-colonial water governance. The concept of colonial hydrology focuses on how large-scale surface irrigation systems led to British control of nature and society and to reorienting ecological relationships between land and water (D'Souza 2006; Gilmartin 2015), as well as on how the "hydraulic interventions of colonialism to simultaneously alter South Asia's fluvial and social worlds" (D'Souza 2006, 625). This thesis takes Wester's (2008) definition of the "hydraulic mission" as its starting point, where the basic idea is for the state to develop the water resource infrastructure as much as possible to maximise its use for national

progress (2). In Wester's definition, this ideology is best expressed by: "every drop of water flowing to the ocean is a waste and the state should develop hydraulic infrastructure to capture as much water as possible for human uses" (Wester 2008, 10). Other authors, such as Worster (1992) and Reisner (1993) in the context of the historical analysis of the hydraulic mission in the US, hold it to be an ideology in which the development of water resources is an emergent and often intentional interest of the state in "controlling space, water, people and [is] recursively constitutive of everyday forms of state formation" (Wester 2008, 9). The hydraulic mission is intended to transform agricultural production and agrarian relationships, resulting in the creation of irrigation constituencies that are keen to increase their access to water. Turton and Meissner (2002) provide a similar definition of the hydraulic mission as an ideology or official policy that seeks to mobilise water and improve supply as a means of achieving social and economic development. The hydraulic mission is a modernist worldview whereby the state, through its hydrocracy (using its technical and scientific knowledge), sets out to "green the desert" and develop water resources for development. The notion of the hydraulic mission implies the state's desire to enhance the state's economic, political, and symbolic power through investment in a 'visible' large-scale irrigation infrastructure.

Other related concepts in the literature, such as the notion of 'water nationalism', also stress how state-making and nation-building processes are inherently related to extensive hydraulic developments by the state (Allouche 2005). Similarly, Meehan (2014, 215) sees hydraulic works as the "wellsprings of state power". The hydraulic mission lends to the state symbolic power to harness natural resources for the benefit of humans, and to develop water resources to their full potential for human use and socioeconomic progress. Large-scale hydraulic works are variously regarded as symbols of state progress and modernity, and are often deployed in discourses promoted by the state elite. For instance, soon after independence from British rule, Indian Prime Minister Nehru described dams as the "temples of modern India." The Marathon Dam in Greece was regarded as a symbol of modernisation and westernisation. It is also not uncommon to see large dams and hydraulic works named after influential national figures, as was the case with the High Aswan Dam in Egypt and Ataturk Dam in Syria (Conker and Hussein 2019).

The literature presents country case studies where large, centralised water works were constructed (e.g. in the US, China, India, Pakistan, Mexico, Egypt, Morocco, and Iran). These studies explain how investment in large-scale irrigation infrastructure projects is linked with state power, especially in the context of post-colonial states that seek to build a coherent imagery of nationhood, development, and modernity in pursuit of internal or external legitimacy (Mohamud and Verhoeven 2016). Whether out of a necessity to achieve national 'self-sufficiency' in food production, to raise rural incomes, to increase economic growth rates, or to earn much-needed foreign trade, post-colonial states have embraced the "hydraulic mission" to strengthen their nation-building and legitimise their power (Molle, Mollinga, and Wester 2009). Such studies of irrigation and state formation emphasise almost exclusively the state's pre-occupation with *surface water infrastructure and harnessing the power of mighty, flowing rivers* as the focus of the 'hydraulic mission'. These studies do not focus on how the development of groundwater by the state can contribute to the state's hydraulic mission. Academic work does not develop conceptually and empirically the importance of large-scale groundwater irrigation in the hydraulic mission of post-colonial states except briefly in the case of Spain (Closas 2018). This is one of the major gaps in the literature that this study of groundwater governance address.

2.3.2 Groundwater Governance Literature – Global and South Asia

Most of the literature on groundwater governance is concerned with the quest for the optimal interaction between state and society for the management of groundwater, that is, whether groundwater should be managed in a state-led top-down manner, a community-based bottom-up manner, privatised, or another combination somewhere along the public-private-community-managed spectrum. The groundwater governance case studies from around the globe do not point to a clear winner as far as the solution to groundwater governance goes, perhaps because of diversity in the legal setting of groundwater use, the number of users, the costs of monitoring groundwater use, and the means available to public-sector organisations for groundwater resource management. Sometimes regulation by the state has little effect on private groundwater use, such as in the case of Spain, where groundwater was declared as a public domain in 1985, so all groundwater developments after 1985 required regulatory permits, but developments before 1985 were unaffected (Llamas and Garrido 2009). Several countries, such as

France, the UK, Spain, Chile, Australia, and the US, have shifted from an open-access regime for groundwater to one with regulated abstraction (Figureau, Montginoul, and Rinaudo 2015).

The regulatory mechanisms for groundwater abstraction range from command-and-control settings to more decentralised water-use associations for management of groundwater. Community-based models (CBMs) for water resource management were promoted in the 1990s as a route to sustainable access and management of water in developing countries, where communities contribute towards, voluntarily manage, and pay for maintenance of shared resources. Van den Broek and Brown (2015) argue that community-based management is a paradoxical combination of the new left and the neoliberal new right. While CBM promotes a roll-back of the state in favour of local control, self-reliance, and collective action with support from both ends of the political spectrum for different reasons: the new left's distrust of the public and private sectors, and the new right's desire to cut state deficits by ensuring that communities cover operations and maintenance costs, thereby promoting commodification of water (van den Broek and Brown 2015). CBM is the prevailing viewpoint of donor agencies, perhaps because it is more acceptable than privatisation of water resources. While several international development institutions uphold CBMs as the preferred model for groundwater management, empirical case studies from around the world do not suggest unequivocal success of decentralised management of groundwater. Van den Broek and Brown's (2015) case study of Uganda finds that, when the state is weak or absent, community-based groundwater governance has unfavourable outcomes. Cleaver (1999) highlights the paradoxes of the participatory approach to environmental management, while Everard (2015) and Shah (2000) discuss the success of local community-based recharge activities in Rajhastan and Gujarat, respectively. In some cases, such as the case of Mexico, which Mukherji and Shah (2005) discuss, farmer communities may be reluctant to participate in groundwater management because the goal of community participation is to limit groundwater abstraction, which in contrary to what farmers usually want.

A range of literature also analyses the economic instruments and institutions that can promote sustainable use of groundwater. This literature documents the use of subsidies as an incentive for groundwater users, such as in the case of Mexico, where well owners

were encouraged to register their wells to access the electricity subsidy. However, subsidies have generally been unsuccessful in promoting conservation of groundwater. Llamas and Garrido (2007) report that the European Union subsidies given to Spain to compensate for decreased groundwater abstractions did not stop the illegal drilling of wells. In the case of India and Pakistan, electricity subsidies for agricultural users have had perverse effects on the use of groundwater and have led to over-abstraction. Other incentives, such as subsidies for water-saving irrigation technologies and subsidies for water-treatment technologies offered to industry and municipalities, can also affect groundwater abstraction.

Scholarship on groundwater resources in South Asia focuses largely on the techno-institutional aspects of groundwater governance. Shah's (2007) *Taming the Anarchy: Groundwater Governance in South Asia* traces the economic, political, and cultural history of groundwater development in South Asia and explores direct and indirect governance solutions for managing an anarchic groundwater economy with millions of small holders. Most of the earlier work on South Asia's groundwater economy focuses on the region's post-colonial groundwater boom—its size, significance, and socio-ecological impacts (Giordano and Villholth 2007; Mukherji and Shah 2005; Shah 2007). Another important strand of research delves into institutions and instruments for groundwater management, including both formal and informal governing solutions. This literature studies the role of informal groundwater markets in South Asia to reveal their implications for equity and efficiency. Meinzen-Dick (2007) discusses how informal water markets and tubewell-sharing improves access to groundwater for small farmers, landless tenants, and younger households in the context of Pakistan. Mukherjee and Biswas (2016) investigate the inter- and intra-generational equity implications of groundwater markets in India in the context of subsidised electricity for tubewell use and find that subsidised energy has a negative effect on intergenerational equity.

In South Asia, recent scholarship on the groundwater governance question highlights the benefits of the participatory approach and community-based groundwater management (Kulkarni, Shah, and Shankar 2015; Rangan 2016; van Steenbergen 2006). Reddy, Reddy, and Rout (2014) discuss the suitability of community-based groundwater governance in the context of three models in Andhra Pradesh India. Studies on community-based groundwater management commissioned by international

development banks or NGOs are particularly supportive of participatory models for groundwater management.

The research around groundwater issues in Pakistan, largely commissioned by international donors (World Bank, USAID) and international research institutes (IWMI, CSIRO), typically advocates best-practice scenarios for data collection and monitoring of groundwater through a network of farmer organisations (Bhatti, Anwar, and Aslam 2017). The literature on groundwater governance in Pakistan focuses on the unregulated and uncontrolled abstraction of groundwater that has led to issues of overdraft, groundwater pollution, and arsenic contamination (MacDonald et al. 2016; Podgorski et al. 2017). Studies also point to the lack of formal government oversight of groundwater use and the historical context for increasing dependence on groundwater in Pakistan's Indus Plains (Watto and Mugera 2016). A range of studies discuss the techno-institutional demand-management and supply-side solutions to the groundwater governance problem in Pakistan (Qureshi et al. 2010).

Most authors who analyse the problem of groundwater governance use using an institutional and/or policy lens. Mukherji and Shah (2005) discuss institutions and policies that affect groundwater governance to replicate successful models of groundwater governance in various countries. The authors favour a shift from groundwater 'management' to groundwater 'governance' and typically advocate instruments like direct and indirect regulation and community participation as solutions to the groundwater governance problem. What is lacking from these and other socio-ecological accounts of the groundwater problem is a discussion of the politics and power that drive groundwater over-exploitation and prevent meaningful implementation of sustainability measures.

As the review of the global and South Asian literature on groundwater suggests, few studies engage with the politics of groundwater governance. While this research makes strides in documenting the factors behind groundwater development, access, informal and formal means of governance, and techno-institutional solutions for management, it does not engage with the politics of groundwater governance and the role of governance in the groundwater crisis. Most studies are technical and apolitical and often treat groundwater as an object of governance. The literature has not engaged with the agency

of groundwater – particularly the dynamics of the relationship between groundwater and society, where groundwater transforms society and is transformed by society – as a useful explanation for the groundwater problem. The literature makes the groundwater crisis and its implications appear politically neutral by focusing primarily on the techno-institutional and managerial aspects of the problem. Such conceptions of groundwater governance hide the political nature of the problem and that water politics can either exacerbate or challenge the unequal distribution of resources and decision-making power in water governance.

2.3.3 Literature on Political Ecology of Groundwater – Global and South Asia

The political ecology approach towards water questions apolitical approaches to the study of water by insisting on "the inseparability of the social and the physical in the production of particular hydro-social configurations" (Swyngedouw 2009, 56). A political ecological examination of a hydro-social process would reveal the social power relationships – material, economic, political and cultural – that mediate access to water. Such an examination would involve an analysis of social actors and the discourses and arguments that defend or legitimate particular water-management strategies (Swyngedouw 2009). Most studies in the political ecology of water focus on the political ecology of water privatisation as an approach to the governance and provision of freshwater with the goal of achieving water justice (and fulfilment of Millennium Development Goals) (Bakker 2004; Budds and McGranahan 2003; Loftus and McDonald 2001). A key theme in the political ecology literature explores the role water plays in shaping the relationships of social power. Swyngedouw (2007) shows that water and social power are mutually constitutive in the Spanish context of dam-building that sought to unite various territorial interests in the country during Franco's regime. As opposed to the environmental determinism associated with Wittfogel (1957), Swyngedouw (2007) highlights that water and power are mutually constitutive. Along with other authors (Gandy 1997; Kaika 2005; Loftus 2005), Swyngedouw (2007) is important in that it considers the role water plays in the production and reproduction of power.

What value does a political ecology perspective add to the study of groundwater governance? Political ecology's accounts of the groundwater governance problem are based on the premise that groundwater (over-) exploitation is the result of a political process. The political ecology approach rests on common assumptions that the "costs and benefits associated with environmental change are for the most part distributed among actors unequally," which either reinforces or reduces existing social and economic inequality and has "political implications in terms of the altered power of actors in relation to other actors" (Bryant and Bailey 1997, 28). Political ecology's accounts of environmental governance (and, therefore, groundwater governance) examine the problem of groundwater over-exploitation on a number of scales, facilitating an exploration of what causes such poor governance of groundwater and who benefits from it. The research is directed at finding "causes rather than symptoms of problems" (Robbins 2011, 21). According to Robbins (2011), political ecology stresses not only that ecological problems are political, but also that our very ideas about them are delimited and directed through a political and economic process.

With the exception of a few case studies (Bhatia 1992; Birkenholtz 2009; Prakash 2005; Taylor 2013; Taylor and Bhasme 2019), all of which focus on Indian states, political ecology's engagement with groundwater in South Asia has been inadequate, and none of the studies on the political ecology of groundwater focus on Pakistan. In the Indian context, Prakash (2005) analyses social differentiation as a result of groundwater overdraft in a village in Gujarat, arguing that decreased water availability exacerbates inequality between rich and poor farmers. When water is scarce, rich farmers stop selling surplus water to poor farmers, who must then turn to working on richer farmers' lands. Under these conditions, subsidising electricity use on tubewells benefits the richer farmers more than it does poorer farmers. Birkenholtz (2009) highlights how adaptation of tubewell technology affects political and ecological processes, altering power relationships and having implications for groundwater governance strategies in Rajhastan, India. Mukherji (2006) compares the cases of water-abundant West Bengal and water-scarce Gujarat in discussing how rural politics – specifically the presence or absence of farmer lobbies – affects the implementation of state groundwater governance policies. The structure and power of farmer organisations and the political history of each state led to no regulation of groundwater use in Gujarat, where the resource was overexploited, while strict regulations were imposed in West Bengal, where only

limited groundwater overdraft had occurred. Taylor (2013) uses a political ecology approach to explain the social and ecological foundations of groundwater overexploitation and agrarian distress in Andhra Pradesh, India. In line with the political ecology approach, Taylor critiques established perspectives on the groundwater crisis in Andhra Pradesh that contend that groundwater overexploitation stems from inadequate regulation or information deficits among rural producers and argues that groundwater overexploitation is a common tragedy of debt-driven households in austere agrarian environments.

The political ecology literature does not examine the relationship between groundwater and society or the agential properties of groundwater. While studies focus on groundwater as the object of analysis, explaining how various actors affect groundwater as a resource is not discussed. Therefore, this dissertation aims to fill this gap in the literature and the gap in understanding the process through which groundwater development and society are mutually constitutive. The study seeks to clarify the concept of ‘colonial hydrology’ and ‘hydraulic mission’ to explain the contribution of groundwater to state developmental goals. Recognition of the critical contribution of groundwater to colonial and post-colonial development will increase appreciation of the agency of groundwater and the political nature of groundwater as a resource, access to which is laden with issues of power. This has implications for groundwater governance and management for Pakistan and other semi-arid economies that overwhelmingly depend on groundwater resources for agriculture production and exports.

2.4. Entry Point and Theoretical Underpinnings

To carve out the entry point for this study of the political ecology of groundwater governance, it is expedient to contrast the problem of groundwater governance with surface water governance. The political ecology of groundwater governance is distinct because of the peculiar materiality of groundwater as an invisible underground resource and because of the greater physical visibility, large-scale infrastructure, and politics associated with governing surface water resources. Such materiality also means that groundwater degradation does not elicit the same emotional and political response as degradation of rivers, which are much more visible. In addition, the political visibility of the large-scale infrastructure that is associated with harnessing surface

water – hydroelectric dams, barrages and canals – means that politicians give higher priority and higher budgets to the management of surface water. The materiality of groundwater as a decentralised resource that is dispersed in space makes it amenable to 'governance' on a variety of levels, formal and informal, public and private, institutional and individual. The dispersion of underground aquifers leaves groundwater exploitation and conservation predominantly in the hands of the private sector, such as irrigation farmers, water supply companies, and domestic well owners. Thus, groundwater governance entails developing a mutually constitutive relationship between state and non-state actors, the latter of which are often more likely to affect local groundwater use. This situation contrasts with the exploitation of surface water, where large engineering infrastructures and the public sector often play a much more prominent role than local users do (Karar 2017).

As access to groundwater requires investment in pump technology, with improved quantity and quality linked to the economic ability to dig deeper boreholes, access to this resource is directly proportional to users' economic power. Individuals and groups with the ability to pump deeper get access to cleaner groundwater as aquifer levels drop and/or become polluted. In contrast, the power and politics of surface water access often rest with the central state apparatus. Even where surface irrigation management is decentralised, getting access to surface water involves payments under the table to local irrigation officials or political representatives who coerce irrigation officials to tweak water shares. The legal plurality associated with the use of groundwater also makes the status of the resource ambiguous and difficult to regulate. In many countries (e.g. India, Pakistan, Bangladesh, Spain) rights to groundwater use have been tied to private property rights of land, but this approach is slowly changing as groundwater resources come under pressure and the state plays a greater role in regulating the use of groundwater resources (e.g. Spanish Water Act of 1985, Establishment of Central Groundwater Board in India). In contrast, the rights to the control and distribution of surface water resources in South Asia lie with the state.

Given the peculiarity of groundwater as a natural resource and the specificities of its governance in relation to other forms of water governance, engagement with the political ecology of groundwater governance is needed. The unsustainable extraction of groundwater is a global phenomenon with worrying consequences for the

environment and people's livelihoods (Molle, López-Gunn, and Van Steenbergen 2018). Despite increased attention to the problem in the last two decades by international development institutions and research institutes, and the stream of global studies on 'groundwater governance', few effective solutions have been offered. Debate on (ground) water governance follows either the liberal or critical perspectives. Recent critical research on water governance highlights the "political nature of hydrosocial territories" (Boelens et al. 2016, 2; Molle, Mollinga, and Wester 2009; Molle and Wester 2009). While this body of work offers an analytical framework that is applicable to the broad problem of water governance, it is its limited engagement with the specific issue of groundwater governance, the dynamics of which differ considerably from other forms of water governance, that must be addressed. In addition, most studies use a narrow definition of governance. The lack of critical analysis in the literature on groundwater governance is a clear research gap, with existing studies making (ground)water problems and their solutions appear "as politically neutral, technical and/or managerial issues which can be 'objectively' solved according to technical knowledge, 'rational use' and 'good governance'" (Boelens et al. 2016, 2). This study fills this gap by engaging with the political ecology of groundwater governance through a case study of Pakistan's Punjab that shows how historical governance processes have contributed to the contemporary groundwater crisis. By elaborating a framework for the political ecology of groundwater governance, conceptualising groundwater as being socio-nature, and using the groundwater-society optic to analyse the problem of groundwater governance, I hope to contribute specifically to filling the identified gap in the literature on the political ecology of water. I locate my research contributions in the wider literature on critical environmental governance and critical water resource governance, with a goal of contributing to a more nuanced understanding of critical perspectives on the problem of groundwater governance.

2.4.1 Framework for the Political Ecology of Groundwater Governance

The concept of "governance" is vague and vulnerable to flexible interpretations based on the disciplinary and ideological context. The governance discourse, necessarily a liberalistic idea that accompanies the political economic restructuring under neoliberal capitalism in the 1980s and 1990s, captures the evolution in the state-society relationship. The discourse has been advanced particularly in the World Bank language

of ‘good governance’, which often conceals political interests and ideological positions and creates the impression that internal mismanagement, rather than global economic structures, is the root of the problem. Therefore, the concept of governance must be unpacked and then applied to elucidate a framework for what “groundwater governance” means for the purposes of this study.

This study follows Selby’s (2003) broad and inclusive definition of “governance” as “complex patterns of coordination between state and non-state actors on a variety of scales” (Cochrane, Duffy, and Selby 2003, 2). Based on Rosenau and Czempiel (1992), this notion of ‘governance’ is distinct from and goes beyond the notion of ‘government’ and explicitly problematises state-centric notions of regulation and administrative power by describing a shift in the institutional geometries of power. Based on this expanded definition of governance, I define environmental governance as being concerned with governing natural resources and environments and as an “ensemble of organizations, institutional frameworks, norms and practices, operating across multiple spatial scales” through which resources are governed (Perreault 2014, 236). Thus, environmental governance refers to the functions of the government that are typically performed by the formal state, but also emphasises the relationships among government, quasi-government, and non-government actors and agencies (Perreault 2014). Most work on environmental governance highlights the obsolescence of inherited analytical categories of public, private, state and/or government and highlights the growing importance of non-traditional actors like non-governmental organisations, multinational corporations, and international development organisations.

In a political-ecology-based study of environmental governance as an organising concept, politics takes centre stage. Critical perspectives on environmental governance stress the need to go beyond managerial solutions to environmental problems by focusing on the underlying politics, that is, to ask questions concerning governance of what, by whom, and to what end (Bridge and Perreault 2009, 477). Frameworks for groundwater governance, most of which are authored by international organisations and their supported ‘good’ global groundwater governance initiatives, have a strongly structural functionalist quality in prioritising coordination and consensus among the actors, rather than the power, domination, inequality, conflict, and justice issues that are at the heart of the political ecology of groundwater governance.

My understanding of groundwater governance is rooted in Focaultian perspectives, which involve a decentralised understanding of power. Focault's concept of "governmentality" is concerned with the *how* of environmental governance: *how* is the environment conceptualised and construed as a domain of the government, *how* is environmental governance accomplished in practical and technical terms, and *how* are agent categories and subjectivities constituted through the practices of environmental governance? (Dean 2010). The "conduct of conduct" is called into question, as it occurs at particular locales or specific institutions of governance (Dean 2010, 7). This approach describes 'green governmentality' or how nature is rendered governable in terms of three elements: a) *episteme of the government*, which consists of the forms of discourse, knowledge, and expertise enlisted to advance programs of conduct; b) *the techne of government*, which involves an analysis of the practices and techniques in the functioning of the government; and c) how the *self* becomes traversed by multiple techniques and discourses that take the subject as their domain of problematisation. This is especially pertinent in the case of 'neoliberal environmentality', which refers to decentralisation, ethical consumption, and community-based management and conservation of natural resources. The community here is understood as an 'invented institution' that is designed to promote self-management and new forms of expertise to address government failures (Valdivia 2015).

From this perspective, power is not associated only with the formal state but consists of all kinds of techniques, technologies, mechanisms, and procedures that are distributed across institutions, agents, individuals, and groups in the society, based on the understanding that "governance" of groundwater not only occurs through the institution of the state but is also distributed throughout the apparatuses of society. This understanding helps in devising some of my central research questions: In what ways has the governance of groundwater been an active force in the creation of the groundwater crisis? What are the techniques/mechanisms of groundwater governance, whether located in the apparatus of the state (institutional, legal, policy incentives, and administrative forms) or in non-state dispersed actors (multinational companies and their growing economic influence and conservation techniques; international financial institutions that advance discourses and finances; both powerful and marginalised individual actors and groups that make adaptations to adjust to deteriorating

groundwater quality and quantity; and the incentives brought in by new technologies of groundwater extraction). The various actors, sites and forces that shape groundwater governance are illustrated in the groundwater governance framework in Figure 2.1.

Within this groundwater governance framework, mapped in Figure 2.1, the state plays an important role in the relationship between nature and society. Social and ecological forces constitute the metabolism, with the state and technology mediators in the metabolic process. States intervene and shape metabolic relationships in a number of ways – by issuing agricultural subsidies to some inputs, by offering a flat subsidy on tubewell electricity that favours rich farmers over poor farmers, by requiring a lengthy bureaucratic procedure for getting an electricity connection for a tubewell (something that only large, well connected farmers are able to do), by requiring licenses for tubewell installations, by environmental legislation – all of which leverage the state's power to influence the metabolic exchange between groundwater and society.

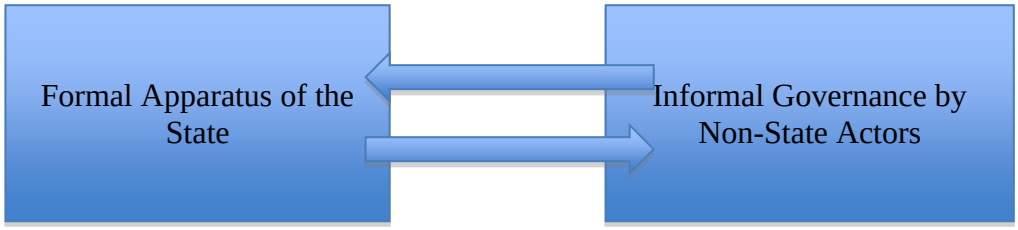
The conception of groundwater governance presented in this study goes beyond a state-centric understanding of power to emphasise the role of non-state actors – (human and non-human), international financial institutions, NGOs, social movements, multinational corporations, individual users, and technology – in the use, distribution, and degradation of groundwater as a resource. Based on Bridge and Perreault's (2009) conception of environmental governance, the thesis explores how the governance of groundwater occurs on a multitude of scales and at a multitude of sites through the complex and continuous interactions among state institutions and actors, non-state actors, and technology that interacts with nature to transform it (Bridge and Perreault 2009, 29). The empirical chapters that follow explore the imperatives for and the power of the state in shaping groundwater governance, mediated by the groundwater-society relationship and technology. Equally significant, the chapters show how the interactions between the state and non-state actors and the power of non-state actors large and small has contributed to creating the groundwater crisis.

In developing the framework for groundwater governance, I emphasise the role of technology as a non-human governor of groundwater and its role in enabling and constricting both state and non-state governors of groundwater. In doing so, I draw on actor-network theory, especially approaches in political ecology that have been used to

analyse water politics and water infrastructure (Bakker 2004; 2010; Birkenholtz 2009; Ekers and Loftus 2008; Swyngedouw 1999; 2004).

Figure 2.1

GROUNDWATER GOVERNANCE FRAMEWORK



Historical Groundwater-Society Relationship as Analytical Lens

What mechanisms and techniques of governance have been used by the formal state across the colonial, post-colonial, and contemporary periods?	**What mechanisms/ techniques/adaptations do non-state actors use to 'govern' groundwater across the colonial, post-colonial, and contemporary periods?**
• What is the role of the formal state in providing expertise on and the exploration, extraction, and conservation of groundwater? • How does the state's legal, administrative, institutional and policy apparatus affect groundwater (ab)use and shape non-state actors' behaviour? • How does the influence of powerful and less powerful non-state actors shape the techniques of groundwater governance by the state? • How does the state's interaction with non-human actants like technology shape the groundwater-society relationship and the groundwater crisis? • What is the role of groundwater in fulfilling state's socioeconomic development objectives? What is groundwater's contribution to colonial hydrology and the hydraulic mission?	• What is the role of society/individual actors in the production of knowledge about and the exploitation, extraction, and conservation of groundwater? • How do powerful and less powerful non-state actors respond to techniques related to groundwater governance by the formal state? • How do global neoliberal discourses on water governance advanced by international financial institutions affect groundwater governance? • How does growing corporate power influence the techniques related to groundwater governance? • How do particular technologies incent and affect the mechanisms of groundwater governance? • How does groundwater governance marginalise less powerful actors in the face of groundwater degradation? How do societal actors use adaptation as a form of governance?

Source: Author

Actor-network theory is one of the theoretical frameworks that focus on the relationship between "technologies and social and ecological systems at particular moments in the economic process" (Birkenholtz 2009). I also draw inspiration from the literature on technonature (Wilbert and White 2009) and approaches that draw on Latour (1993; 2005) to clarify the capacity of non-human nature and technologies to shape socio-ecological change. Based on these approaches, the study examines how the historical evolution of tubewell technology in Punjab and the more recent introduction of water-saving technologies affect both the groundwater-society relationship and the state's approach to groundwater governance. The advancements in technology (or the lack thereof) affect other governors of groundwater in different ways and across time periods. Changes in groundwater extraction technology across Punjab's history may enable or restrict the large-scale use of groundwater, thus contributing to groundwater over-abstraction (Chapters 4 and 5). According to Mitchel (2002) and Birkenholtz (2008), new technologies of extraction do not simply diffuse but become enmeshed in existing social relationships and knowledge, so technological changes and adaptations affect existing-social power relationships, and the way technology is adopted determines both access to groundwater and users' ability to adapt to the groundwater crisis (Chapter 6).

2.4.2 The Groundwater-Society Relationship as a Lens

This study uses the groundwater-society relationship as a lens through which to explore the problem of groundwater governance. The study's key argument, based on the above theoretical framework, is that governance has been an active force in the creation of the groundwater crisis in Punjab. The analytical lens of the groundwater-society relationship helps in advancing this argument for two reasons: First, the conception of governance used in this thesis is broad-based, suggesting that groundwater is being governed not just in relation to the state and its apparatus but also across other social actors. Second, the thesis does not just explore the one-way relationships of governance with groundwater and the society but also the reverse relationships. The study uses a historical method rooted in political ecology, which necessitates the emphasis on a dialectical understanding of governance's and society's relationships to groundwater. It explores how governance by state and non-state actors has shaped the groundwater-

society dynamic and how the way that groundwater itself is developed and used creates patterns of dependence in the society and affects the techniques of governance.

This study holds that nature and society are dialectically linked to each other, as Swyngedouw states, “there is some social in nature, and some natural in society: every modification of one entails modification of the other” (Cornut and Swyngedouw 2000). Using this perspective allows us me to reveal the historical production of groundwater as socio-natural, to help understand explain the groundwater crisis. The relationship between groundwater and society relationship is an historical product that has been constructed by various actors in the broader political economy of local, national, and international power relationships. The groundwater society relationship has been moderated by multiple factors like: natural processes, technology changes, political decisions, nationalistic concerns, and power relationships between lobbies etc.

The concept of socio-nature rejects nature-society dualism and argues that nature and society are inseparable and co-produce each other. This concept draws on political ecology rooted in Marxist historical materialism and the post-structural approach of actor network theory. The concept of socio-nature was first developed by Swyngedouw, who draws on readings in Marx, Lefebvre, Harvey, Haraway and Latour. Socio-nature critiques political economy’s focus on nature as a mere backdrop to society, as well as the shortcoming of post-structuralist research for not emphasising the historical processes of production that underlie the nature-society relationship. While socio-nature is heavily influenced by historical materialism and actor network theory, it does not reconcile the perspectives but is an ongoing critical dialogue between the two perspectives. Research on socio-nature frequently leads to detailed historical empirical research that pays particular attention to power relationships that reconfigure the groundwater-society relationship, such as Swyngedouw’s examination of a reproduction of the Spanish waterscape (Swyngedouw 2015).

All of this work insists that we cannot consider groundwater as apart from the social relationships that produce it and that those social relationships are historically constituted and exist in a context of uneven power. This conception of groundwater as socio-nature acknowledges both the material and historically rooted processes that govern the resource. More important, this conception facilitates an appreciation of the

politics of groundwater within a framework of groundwater governance. The mechanisms and techniques of governance that transformed the groundwater-society relationship illuminate how groundwater's materiality reflects and produces forms of social power. If groundwater were conceived only as natural, ignoring its social and political character, the resulting conception of groundwater governance would necessarily be technical/managerial at best, masking the politics and power involved (Perreault 2014).

3. Research Design and Methodology

3.1. Introduction

In this section I outline the research design, methodology and research instruments used in this thesis. The thesis integrates a variety of qualitative research methods to gain insights into the political, economic, technological and social dimensions of the problem of groundwater governance. This is done at local, provincial and national scales - to consider the implications of the case of Punjab for other countries dependent on groundwater irrigation. First, I describe the methodological approach, which is based on an intensive case study of the Punjab Province of Pakistan (Section 3.2). Next, I describe and justify my approach to data collection focusing on the specific research instruments and data analysis methods (Section 3.3) as well as research participants and sites (Section 3.4). In the last sections 3.5 and 3.6, the chapter will review the ethical considerations and researcher positionality issues connected to the research study.

3.2. Research Design

This thesis aims to understand the global groundwater crisis and the extent to which it is explained by groundwater governance, using a case study of Pakistan's Punjab in the Indus Basin. To answer this overall thesis question, the research design deployed in this study uses a hybrid of methodological approaches and a critical political ecology framework to explore the nature of the groundwater governance through the colonial and postcolonial periods leading up to the current governance challenges, across various levels of governance (local, provincial, national) and a range of state and non-state actors (including donors, NGOs, corporations and individual groundwater users). The research design for the study of groundwater governance in Punjab was based primarily on an intensive case study method. The significance of a research method is closely related to the theoretical problematic within which it is elaborated, hence the choice of a case study method for this study of groundwater governance emanates from the critical theoretical perspective (Morrow and Brown 1994).

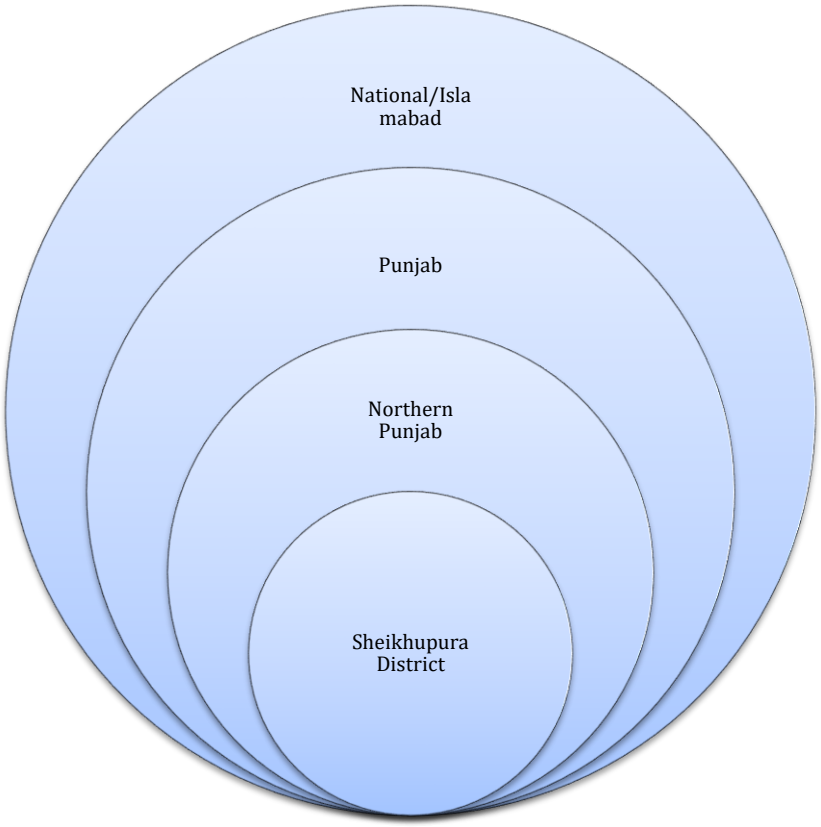
3.2.1 Site Selection: Multisited, Multiscalar Analysis

At a broader level, my research addresses the question of what explains the global groundwater crisis and to what extent is it explained by groundwater governance. At a specific level, it asks how the problem of groundwater governance plays out in the case of Pakistan's Punjab, and using the insights from Punjab's historical case study to make broader arguments about the contribution of groundwater governance to the groundwater crisis.

Site selection is critical to research design. The choice of Punjab, Pakistan as a unit of study for this thesis is justified at length in Chapter 1. Since Punjab is the second most populous province of Pakistan, with roughly the same land area as the United Kingdom, there was a need to further narrow down the research site and focus. The research design for this study was based on a multisited and multiscalar analysis using strategies of "studying up", "studying down" (Nader 1972) as well as "studying through" (Reinhold 1994) to examine the problem of groundwater governance in Punjab. Studying up ensured that I was able to examine the analytics and mechanics of how power operates in the water sector, while studying down and incorporating local fieldwork at the village level allowed me to analyze how groundwater governance operates informally in everyday lives of farmers. In addition, studying through by connecting and chasing narratives across research sites to examine the complex interdependence of multiple sites, actors, institutions and struggles provided a holistic understanding of the groundwater governance problem.

In line with the above research strategy, I demarcated the field into three levels – national (Islamabad), provincial (Punjab) and local (Sheikhupura District in Northern Punjab). Each level and research site chosen within that level provided context for the other where I was able to chase the research puzzle iteratively.

Figure 3.1. Geographical Focus of Fieldwork in Pakistan



During the fieldwork period, my research strategy pendulated between macro and micro and I found it difficult to maintain a balance between national, provincial and local level fieldwork. Water is currently a provincial subject, and while my analysis was focused primarily on the Punjab province, it was important to consider the federal and national level context for groundwater governance. As fieldwork progressed, I consciously traded off federal level interviews with provincial and local district level interviews. This decision was based both on availability of federal level respondents for elite interviews to some extent. To compensate for a smaller number of national level interviews, I conducted a rigorous textual analysis of national policy and strategy documents for water development, agriculture policy, irrigation policy, industrial and trade policies for the postcolonial period. Document analysis was conducted from July to September 2016, accompanied by some scoping elite interviews at the federal and provincial level. From November 2016 to April 2017 I narrowed down the focus of primary data collection to interviews at the local level in Sheikhupura district, and then

came back to provincial level interviews during the final three months of fieldwork from May – September 2017.

3.2.2 Negotiating Access to the Field through Gatekeepers

Prior to starting the Ph.D. program at Sussex, I had the experience of working in the development sector in Pakistan, with a focus on water research since 2013. My previous work experience meant I already had a network of contacts in the water research sector to start off with. In addition, I was familiar with the geographical area, language and the network of key water practitioners, thus mitigating any concerns for accessibility and safety.

Upon starting fieldwork in July 2016, I started making contact with potential interviewees, but met with limited success. I used my existing references to get through to government officials in the Punjab Irrigation Department but perceived as a student from a "foreign university" received only a tepid response. I realized that a local institutional affiliation might open doors for getting due priority and appointments for elite interviews, hence leading to the decision to join the Centre for Water Informatics and Technology at Lahore University of Management Sciences (LUMS) as a Visiting Doctoral Researcher from August 2016- June 2017. LUMS is referred to informally as the 'Harvard' of Pakistan, hence this institutional affiliation helped when making appointments for interviews with current and ex-government officials at federal and provincial level. While working at the Centre for Water Informatics and Technology, I helped to organize two training schools eliciting speakers and participants affiliated with various aspects of water management (surface water, groundwater, floods, hydropower, wastewater). I was also the lead organizer for an international conference on the 'History and Future of the Indus Basin' in January 2017, exposing me to historical perspectives on water use and governance in the Indus Basin, which directly helped me while conducting archival research.

For local fieldwork in Sheikhupura District, access to rice farmers in Sheikhupura was provided by Helvetas Swiss Intercooperation (a contact made at one of the training schools being conducted at LUMS). Helvetas International, in partnership with Swiss

Intercooperation and Rice Partners Limited (RPL, a local NGO in Sheikhupura) were engaged in water conservation initiatives with rice farmers in the region through the WAPRO Project (see Chapter 6). I asked to accompany the project team to the field for one of the WAPRO Project farmer training sessions. The WAPRO Project sought to encourage water use efficiency in rice farming through creating more awareness among farmers and use of "better" (water saving) technology. The project is being conducted and funded in collaboration with MARS Pvt. Limited that imports rice from Pakistan for its sub brand Uncle Ben. Rice Partners Limited, as the local implementing partner, runs the on ground field activities with farmers, and conducts contract, procurement and quality assessment of rice to be exported to MARS Incorporation. The first two visits to Sheikhupura were undertaken as a part of RPL's team as a participant observer to their field activities with rice farmers. The group of farmers enrolled with RPL were large farmers, thus for future visits I made connections with local farmer representatives who were able to arrange interviews and focus groups with a more diversified farmer group.

3.3. Approach to Data Collection and Research Instruments

3.3.1 Case Study of Groundwater Governance in Punjab

This research is based on a qualitative case study approach examining the groundwater crisis and problem of groundwater governance in Pakistan's Punjab and using these findings to inform contributions to the broader literature on political ecology of groundwater governance in other similar contexts. Case study allows an in-depth exploration from multiple perspectives of the complexity and uniqueness of a particular research problem, and can draw on a range of research methods (Leavy and Simons 2014). Thus, studying the case of groundwater governance in Punjab, I drew on a range of sources of information and research instruments: a) archival research; b) document and discourse analysis; c) interviews with a range of stakeholders in the water sector; d) focus groups with rice farmers; and e) participant and non participant observation at national, provincial and local levels. These methods and sources provided insights into different perspectives, experiences, connections, and divergences on the evolution of the groundwater society relationship, as well as the politics underlying groundwater governance and the groundwater crisis in Punjab.

Methodological plurality had its advantages. I started off with accessing and understanding available statistics on groundwater use, development and governance in Punjab through document analysis. At the same time I used interviews and focus groups to explore the contradictions in groundwater use, development and degradation, inequity in access to the resource as well as the differential impact of resource degradation on communities. A political ecology analysis aimed towards promoting progressive social and environmental change cannot happen through "statistical analysis of localities never visited, aggregate quantitative portraits of regions, drive through fieldwork" (McCarthy 2002, 1297). Hence the choice of a qualitative intensive case study using an analysis of actor narratives and discourses was made to understand the underlying social, political and economic structures and processes to the groundwater governance problem. Incorporating archival research helped to develop insights of past events and governance approaches that contributed to present day socio dynamics of groundwater governance. Finally, different forms of data were weaved together to triangulate the findings in order to enhance research quality. According to Denzin and Lincoln (2011), data generated by multiples methods and diverse perspectives when brought together leads to better research validity. Using a range of methods in the case study of groundwater governance in Punjab has enabled a detailed exploration of the problem – through analysis of events, processes, and experiences – and allowed a contextualized understanding of political economy structures and power relations that shapes the techniques and mechanisms of groundwater governance and the groundwater crisis in Punjab.

3.3.2 Archival research: Colonial Approach towards Groundwater Governance

Pre-fieldwork review of existing literature on the colonial approach to groundwater governance showed that existing studies were largely focused on colonial interventions for surface water governance, sidestepping the question of how colonial groundwater policy had evolved (D'Souza 2006; Gilmartin 2015; Whitcombe 1972). Some of the early work in political ecology shows why history matters for conducting a study of political ecology (Blaikie 1985; Peluso 1992; Watts 1983). A critical historical approach to political ecology aims to strengthen the proposed study because "only with a sophisticated and critical understanding of the historical developments of

landscapes/environments, of social relations, and of knowledge and the privilege that attends it, that we can reveal the hidden relations of power" (Davis 2015, 263). A historical political ecology approach is used to highlight how contemporary patterns of groundwater use and governance have their roots in the colonial approach to groundwater development in Chapter 4.

A critical ontological framework for research necessitated an effort to trace the historical context of groundwater governance in the study area through an extensive review of the colonial archives. These were researched from November 2016 to January 2017 using online sources (hathitrust.org and archive.org), as well as visits to the Punjab Public Library in Lahore. Initial archival research was followed up with extensive archival research in the following year from September 2017 to December 2017 at the India Office Records of the British Library's London Office.

I started off with an analysis of official sources such as the Irrigation Commission Reports and Famine Commission Reports to assess groundwater use, importance and development efforts in Colonial Punjab for the earliest years for which records were available. While these reports gave me a snapshot of groundwater use in agriculture in Punjab and its importance as a source of protection against famines, there was a clear need to go beyond these documents to see a) how was the colonial approach to groundwater governance differed from pre-colonial governance of groundwater; b) how colonial approach to groundwater governance evolved over time both absolutely and in relation to surface water infrastructure developments; and c) how did the broader political economy context under colonial rule affect groundwater governance?

Efforts directed at well irrigation, well boring and tube well research and experimentation efforts were located under the purview of the Colonial Department for Agriculture, thus the archival analysis focused on analyzing content from the Punjab Agriculture Department to explore the colonial approach towards development of groundwater and the difficulties that ensued, paying specific attention to the broader socioeconomic context in India, as well as British engagement in significant world events during the colonial period such as the interwar years between World War 1 and World War 2. I laboriously read through the archival records and took photos of relevant sections of colonial reports where data on irrigation sources and well irrigation

was mentioned. The statistics in the available reports from Punjab Agriculture Department were then entered into excel for a quantitative descriptive analysis of trends in well irrigation in colonial Punjab from 1885-1947 (See figures 4.1, 4.2, 4.3, 4.4, 4.5 in Chapter 4). The choice of the time period for analysis of colonial records was largely guided by a) availability of the earliest archival records of colonial administration with statistics on well irrigation; and b) historical events which served as the cut-off year primarily the end of colonial rule in 1947 and the creation of two separate countries in the Indian Subcontinent (India and Pakistan).

The variety of archival materials conveyed the broader socioeconomic context for development of well irrigation and tube well boring and significance (or lack of it) of well irrigation to the colonial administration for India generally and Punjab specifically. These included reports from the Famine Commission (1880, 1898), Punjab Customary Law, Punjab Public Works Department Papers (of which irrigation Department was a part of until 1925), manuals of agricultural engineers discussing tube well developments and experiments, and personal accounts of hurdles in tube well development under colonial rule by colonial irrigation and agriculture officials.

The researcher is conscious of wholesale dependence of archival documents especially published colonial reports, as these are essentially “class products”, hence an effort was made to mitigate the biases wherever possible (Stoler 2009; Watts 2013 p 34). In line with the political ecology approach, this was done by triangulating the information in official reports with unpublished sources. An effort was made to include collections in which unpublished materials predominate. These included records of wells prepared by the British officials, land lease concessions given out to lessees for sinking wells and tubewells, internal feasibilities prepared for tubewell installation and notes of irrigation engineers on the issues in achieving a breakthrough in tubewell irrigation. While the research consulted unpublished correspondence wherever possible, these were extremely few in comparison to almost four decades of annual reports of the department of agriculture. A summary of the key archival documents is given in Table 1 below. The complete list of published reports and unpublished correspondence has been provided in the bibliography.

Table 1: Summary of Archival Analysis Colonial Period

Report on Agricultural Statistics for the Punjab (For the Years 1885, 1886, 1887)
Annual Report of the Department of Land Records and Agriculture (All years between1894-1914)
Statistical Abstract Relating to British India (All years between 1891-1899)
Punjab Department of Agriculture: Report on the operations of the Department of Agriculture. All years between1890-91 to 1940-41
Punjab Department of Agriculture: Report on the season and crops, All Years between 1901/02-1946/47
A Century of Famines and an Inquiry into the best means of providing Against them by F.C Danvers (1776-1877)
Report on irrigation Works in India for the year 1875-76 by F.C Danvers
Punjab Public Works Department Papers (Various Issues)
India Irrigation Commission Report 1901-1903
Report of the Indian Famine Commission 1880
Public Works in India 1837
Punjab Customary Law Tuppers 1881 – Vol.1,2 and 3
Punjab Notes and Queries

Archival research was supplemented by a thorough reading of existing texts on the environmental history of the Indian Subcontinent such as Grove (1995), Gilmartin (2003; 2015) and Ali (1988) and wherever possible exchanging emails and personal conversations with those already working on the environmental history of India. Of particular mention among these are discussions with Dr. Vinita Damodaran (Director Centre for World Environmental History at University of Sussex) and Dr. David Gilmartin (University of California Berkeley). In addition, material from the archives was triangulated with information from elite interviews with senior water administrators in Punjab's Irrigation Department who had some institutional memory of colonial irrigation policies and practices.

3.3.3 Content Analysis and Critical Discourse Analysis: Post Colonial Government and Donor Documents

In the pre-fieldwork period, document analysis on groundwater governance from a range of sources: official government publications and reports authored by NGOs and international donors – was useful in providing a starting point for primary data collection. The difficulty in accessing some government and donor project documents and the labelling of some material as "restricted" also gave me a sense of what questions to follow up in elite interviews with irrigation bureaucracy.

Consistent with the historical approach of this study, a content analysis was performed for the post colonial period reviewing the federal and provincial government policy documents as well as donor and NGO reports related to water sector development in Punjab (Chapter 5). The scope of the content analysis for these reports was not just limited to analysing groundwater related projects, but rather explored the overall government and donor strategy for groundwater development in relation to surface water availability, as well as the prevailing agrarian and economic context at the time the reports were published. Table 2 gives a brief summary of the types of documents surveyed that included both official government sources as well as donor project reports to assess how post colonial groundwater governance was shaped by techniques and mechanisms from both the state and international donors as important non state actors. Documents and Reports collected from visits to the Punjab Irrigation Department, Water and Power Development Authority Library, Department for Land Reclamation, as well as planning and policy documents of federal and provincial governments were used to delineate the complexity of the state's role in large-scale groundwater development in post colonial Punjab. The content analysis for donor project documents focused on primarily on USAID as the initiator of groundwater surveys in postcolonial Pakistan and the World Bank as the largest lender in Pakistan's water sector. To set the context of groundwater development in Pakistan in relation to geopolitical events in the Cold War period, as well as Pakistan's relationship with the United States, the White House Interior Panel Reports were analysed for contextualizing the flow of expertise and bilateral aid for water development extended to Pakistan.

Table 2: Summary of Document Analysis Post Colonial Period

Select World Bank Project Documents for Water and Sanitation Punjab/Pakistan (1960- 2015)
USAID/USGS/White House Interior Panel Reports
WAPDA Feasibility Reports for Punjab Public Groundwater Development projects (SCARP 1-4)
Pakistan 5 Year Development plans (1947-2006)
Government of Pakistan Reports /Punjab Government Documents
Sectoral Reports and National/Provincial Policies for Agriculture, Industry and Trade
NGO Project Reports on Groundwater Use and Development

Reports specific to public sector groundwater development projects were largely retrieved at the WAPDA Library and the Department for Land Reclamation in Lahore. These were analysed from the year 1958 (when the first public sector groundwater development project was initiated) through to the year 1997 (when the government privatized existing public tube wells to cut down on operational costs). To analyse the broader political economy context for private sector groundwater exploitation in the contemporary period, federal and provincial government's energy and agricultural pricing strategies, as well as trade policy incentives we analysed for the period roughly between 1990 – 2017 (Chapter 5). The findings from the breadth of official government sources were triangulated with the primary data collected from elite interviews with senior government officials and former World Bank employees as detailed in Section 3.3.4 below.

To understand the realities of contemporary groundwater governance, critical discourse analysis was employed for both a study of texts produced by government, donor and NGOs, as well as interviews conducted at the federal, provincial and local level. Critical Discourse Analysis (CDA) is the study of the way social power and inequality are "enacted, reproduced, legitimated and resisted by text and talk in the social and political context" (van Dijk 2005, 466). Fairclough (1995) summarizes the key elements of critical discourse analysis to emphasize that CDA addresses social problems, and power

relations that are discursive; it is a method that is historical, interpretive and explanatory and focuses on mediating the relationship between text and society. Fairclough (1995) emphasizes the need to relate discourse structures and discursive practices to social and political structures at the macro level (Gee and Handford 2012). Critical discourse analysis helps to bridge the gap between micro and macro levels of analysis - it helps to connect how discursive interactions and social actions of individual actors are a part of wider social processes.

Discourse analysis was useful in understanding how specific actors construct an argument and how these arguments fit into wider practices of contemporary groundwater governance. In particular, a close reading of donor project reports and strategy papers for the water sector from the 1990s and the contemporary period revealed how powerful donors are able to place the blame on "wasteful farmers" and position agriculture as the bigger user for water hence the need to focus conservation efforts in agriculture primarily, while sidestepping the issue of industrial use of groundwater (Personal Communication, CEO Clean Production Institute 2017). Often a subtle yet powerful alliance of environmental NGOs and multinational companies looking to "green" their operations propagates agriculture as the primary user of water while industrial water use is not highlighted or problematized as evidenced in Chapter 6. Particular attention was paid to voices of marginalized groups when interviewing rice farmers in Sheikhupura. Discourse analysis of print media coverage of recent donor projects for agriculture also equates the use of smartphone technology as being synonymous with "modernization" of the farmers (World Bank 2019).

3.3.4 From Text to Talk: Interviews, Focus Groups and Surveys (2016-2017)

Interviews and focus group discussions enable the observation of forms of agency at multiple levels and sites within the terrain of groundwater governance in Punjab and Pakistan, and also shed light on the divergence between policy rhetoric in government and donor documents and the way techniques of groundwater governance play out on ground (Chapter 6). The use of various data collection methods supports causal analysis based on multiple perspectives of the underlying 'reality' as well as the broader structural and political economy factors shaping groundwater governance historically and presently.

The groundwater problem cuts across scales – both vertical and horizontal, so the issue of interview sampling was a critical one. Based on documentary analysis, elite interviewees were selected purposively based on their experience/involvement/insight for the groundwater problem. In a similar manner, interviews with farmers were also summoned purposefully with special care to include marginalized farmers in tail end villages who were most dependent on groundwater for irrigation. The number of interviews necessary to establish research validity depend on data saturation – which for me was reached around 35 elite interviews and 51 interviews with rice farmers, waterlords and tube well drillers cross three villages in Sheikhupura District (See Section 3.3.5).

Table 3: Summary of Research Participants

Participants	**Level**	**Total**
Current and ex-WAPDA Officials	National	2
Ministry of Water Resources	National	1
Federal Flood Commission	National	1
International NGOs (WWF Pakistan/IWMI/ Oxford Policy Management/ CSIRO/ Helvetas Swiss Intercooperation)	National/Provincial	4
Ex-government Irrigation/Agriculture officials working as World Bank Consultants	National/Provincial	4
Officials from Punjab Irrigation Department	Provincial	4
Current Punjab Department for Agriculture Officials	Provincial	2
Pakistan Council for Research in Water Resources	National	1
Environment Protection Department, Punjab	Provincial	2

Punjab Disaster Management Authority	Provincial	1
Local NGOs	District Level/Local	1
Public Health and Engineering Department Sheikhupura	District Level/Local	2
Irrigation Department Sheikhupura	District Level/Local	3
District Environment Department Sheikhupura	District Level/Local	2
District Industries Department Sheikhupura	District Level/Local	1
Water and Sanitation Department Lahore, Faisalabad	District Level/Local	3
Rice Farmers in Sheikhupura (interviews)	Village Level	51
Informal Tube well Markets Sheikhupura Questionnaire Survey	Village Level	80
Tube well Drillers in Sheikhupura	Village Level	2
TOTAL (not including survey)		87

3.3.5 Local Ethnographic Case Study of Sheikhupura District in Rechna Doab

Archival research, content and discourse analysis, as well as interviews at federal and provincial levels helped to lay out the broad terrains of the groundwater governance problem in Punjab. In order to bridge the macro and micro gap, there was a need to take a closer look at how the lack of formal government oversight for groundwater sustainability plays out at a local level. For thus purpose an ethnographic style approach was used to study rice farmers in the rice-wheat belt in northern Punjab, with an aim to document the breadth of informal mechanisms that exist at a local level to mediate access to groundwater as well as informal (corporate led) initiatives that are being deployed on ground to conserve the resource. An ethnographic style approach was used for studying rice farmers in Sheikhupura District which sought to understand the beliefs, values, attitudes, sociocultural structures that shape groundwater use at the local

level, as well as the coping mechanisms in the face of rapid groundwater degradation taking Sheikhupura district as a unit of analysis.

The socio-economic profile and groundwater dependency of Sheikhupura District justify its choice for detailed local fieldwork in Punjab. The Sheikhupura District is a major rice-wheat producing district of Punjab. In 2013-14, Sheikhupura produced about ten per cent of the Punjab's total rice production, and 3.6 per cent of the province's total wheat production (Directorate of Agriculture, Crop Reporting Service, Punjab, Lahore). [2] Sheikhupura's agriculture economy is almost completely dependent on groundwater The Sheikhupura district of Punjab has 32,251 tube wells, all of which are private, with 86.76% (27,983) being run on diesel, while the remaining being run on electricity (Agriculture Census of Pakistan 2010). [3] All of the cultivated area of 517 thousand hectares in Sheikhupura is irrigated, either through canal, wells, tube wells, canal and wells, or canal and tube wells. About 88.78 per cent of the total area is irrigated through a mix of canal and tube well sources, while 6.5 per cent is irrigated by tube well only. The area irrigated by canal water only is very low, at 0.4 per cent of total cultivated area, while about 4% of the area is cultivated by a mix of canal-well sources. Thus, more than 99% of Sheikhupura's water economy is being supported by groundwater (Government of Punjab 2015).

Alongside being a major agricultural production district, agro commercial enterprises and industry constitute the backbone of Sheikhupura's economy. Sheikhupura is home to 769 industrial units, according to a list obtained from the District Industries Department. These units range from textile, agricultural implements, auto parts, chemical production, dairy, pharmaceutical, steel, glass, leather, paper and packaging, plastic, rice processing, rubber and tanneries. The presence of a range of diversified water intensive and water polluting industries in Sheikhupura district was one of the key reasons for the selection of this district as the study site.

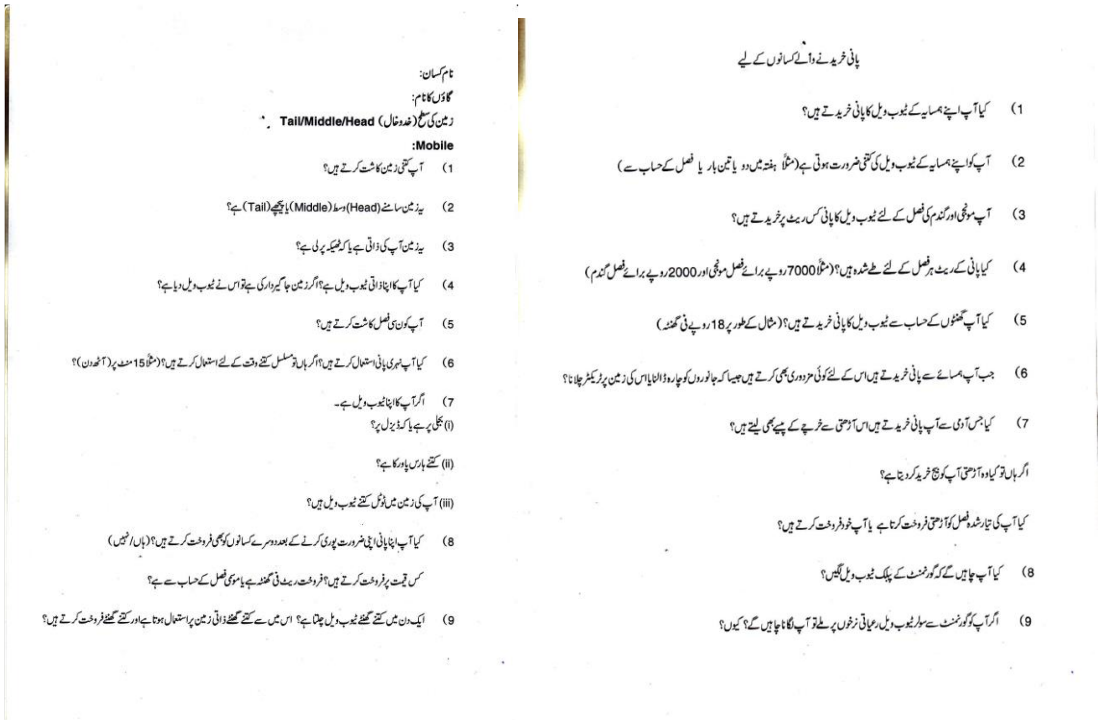
[2] These percentages do not include Nankana Saheb district that is in some statistics considered part of the Sheikhupura district

[3] In 2012-13, Punjab was estimated to have 1012541 tubewells out of which 1011087 were private and 1454 were government tubewells - out of these tubewells 87.79% run on diesel while the remaining 12.2 % are run on electricity (Punjab Development Statistics 2015).

Local fieldwork was conducted in Sheikhupura from November 2016 to May 2017 in three stages. In the first stage, from November-December 2016, three villages were selected along the head, middle and tail ends of the Joyanwala minor canal that runs through Sheikhupura district to conduct three initial focus groups with rice farmers. A total of 21 farmers (7 from each village) were interviewed in order to understand the local cropping patterns, farmer characteristics and irrigation water use proportions. This initial scoping exercise helped to highlight the overwhelming dependency of middle and tail end farmers on groundwater for irrigation.

Image 3.1 Introductory Fieldwork Session with Access through Helvetas Swiss Intercooperation and Rice Partners Limited

In the second stage of fieldwork from January to March 2017, two villages at the tail end of Joyanwala Minor Canal – *Khushhalpura* and *Kathianwala* were selected for detailed analysis of how farmers, big and small, cope with their dependency on ground water, especially in the face of deteriorating quality and quantity of groundwater supplies in the district. Focus groups with groups of irrigators and in-depth interviews with individual farmers and tube well drillers, as well as local irrigation officials were conducted to understand how the 'on ground' implications of the groundwater crisis. A short survey was also administered to determine the extent of prevalence of informal groundwater markets in the selected villages.



نام کسان:
گاؤں کا نام:
زمین کی سطح (خدوخال) Tail/Middle/Head
Mobile:
1) آپ کتنی زمین کاشت کرتے ہیں؟
2) یہ زمین سامنے (Head) وسط (Middle) یا پیچھے (Tail) ہے؟
3) یہ زمین آپ کی ذاتی ہے یا کہ ٹھیکہ پر لی ہے؟
4) کیا آپ کا اپنا ذاتی ٹیوب ویل ہے؟ اگر زمین چاکیرداری ہے تو اس نے ٹیوب ویل دیا ہے؟
5) آپ کون سی فصل کاشت کرتے ہیں؟
6) کیا آپ لمبری پانی استعمال کرتے ہیں؟ اگر ہاں تو مسلسل کتنے وقت کے لئے استعمال کرتے ہیں؟ (مثلاً 15 منٹ پر (آٹھ دن)؟
7) اگر آپ کا اپنا ٹیوب ویل ہے۔
(i) بجلی پر ہے یا کہ ڈیزل پر؟
(ii) کتنے ہارس پاور کا ہے؟
(iii) آپ کی زمین میں نلکی کتنے ٹیوب ویل ہیں؟
8) کیا آپ اپنا پانی اپنی ضرورت پوری کرنے کے بعد دوسرے کسانوں کو بھی فروخت کرتے ہیں؟ (ہاں / نہیں)
کس قیمت پر فروخت کرتے ہیں؟ فروخت ریندی گھنڈ ہے یا موسمی فصل کے حساب سے ہے؟
9) ایک دن میں کتنے گھنٹے ٹیوب ویل چلتا ہے؟ اس میں سے کتنے گھنٹے ذاتی زمین پر استعمال ہوتا ہے اور کتنے گھنٹے فروخت کرتے ہیں؟

پانی خریدنے والے کسانوں کے لیے

1) کیا آپ اپنے ہمسایہ کے ٹیوب ویل کا پانی خریدتے ہیں؟
2) آپ کو اپنے ہمسایہ کے ٹیوب ویل کی کتنی ضرورت ہوتی ہے (مثلاً ہفتہ میں دو یا تین بار یا فصل کے حساب سے)
3) آپ موٹھی اور گندم کی فصل کے لئے ٹیوب ویل کا پانی کس ریٹ پر خریدتے ہیں؟
4) کیا پانی کے ریٹ ہر فصل کے لئے طے شدہ ہیں؟ (مثلاً 7000 روپے برائے فصل موٹھی اور 2000 روپے برائے فصل گندم)
5) کیا آپ گھنٹوں کے حساب سے ٹیوب ویل کا پانی خریدتے ہیں؟ (مثال کے طور پر 18 روپے فی گھنٹہ)
6) جب آپ ہمسائے سے پانی خریدتے ہیں اس کے لئے کوئی حدود ہی بھی کرتے ہیں جیسا کہ جانوروں کو چارہ ڈالنا یا اس کی زمین پر ٹریکٹر چلانا؟
7) کیا جس آدمی سے آپ پانی خریدتے ہیں اس آدمی سے خرچے کے پیسے بھی لیتے ہیں؟
اگر ہاں تو کیا وہ آدمی آپ کو کھاد خرید کر دیتا ہے؟
کیا آپ کی تیار شدہ فصل کو آدمی فروخت کرتا ہے یا آپ خود فروخت کرتے ہیں؟
8) کیا آپ چاہیں گے کہ گورنمنٹ کے پبلک ٹیوب ویل لگیں؟
9) اگر آپ کو گورنمنٹ سے سولر ٹیوب ویل رعایتی نرخوں پر ملے تو آپ لگانا چاہیں گے؟ کیوں؟

Image 3.2: A) Survey for Tubewell Owners (Water Sellers). B) Survey for Tubewell Non Owners (Water Buyers)

Image 3.3: Focus Groups on groundwater use/contamination in Chak Sekham (head end village)

In the third phase of fieldwork from April to June, elite interviews were conducted with a range of stakeholders in Sheikhupura's groundwater economy. These ranged from local irrigation officials entrusted with the task of managing surface water irrigation system (District Irrigation Department), governance for water supply and sanitation (District Public Health and Engineering Department), governance for groundwater pollution (District Environment Protection Department) and governance for local industries (District Industries Department). In order to understand how governance problems at the district level have roots in federal and provincial institutions for governance, interviews at the district level were supplemented by interviews with the provincial government in Punjab, and with the federal government in Islamabad. Interviews with senior officials at the provincial level allowed me to analyze how discourses and practices at the local level match up with responses at the provincial and national levels where water and environment policies were being negotiated.

Image 3.4: Focus Groups on groundwater use/contamination in Khushalpura (tail end village)

Image: 3.5: A Factory in Sheikhupura that has built unlined wells for the disposal of untreated effluent.
*This is a common practice for industrial units without access to drainage. The effluent eventually percolates to the underground aquifer resulting in serious contamination of the shallow aquifers in Sheikhupura.

3.4. Data Analysis and Review

Towards the end of the twelve month long fieldwork in Punjab, I returned to the UK in September 2017 to write up my thesis. Although I was away from the "field", I was still busy collecting archival data at the British Library in order to complete my archival research component. Archival research continued from September to December 2017, alongside interpreting, objectifying and textualising the field data from Punjab. I organized the data into themes and storylines manually. The reason I preferred manual coding over a qualitative analysis software such as Nvivo is that I felt that through automated coding I could have lost the possibility of reading the data in multiple ways. I judged manual coding to be the best means to interpret and analyze the multiple themes during interviews and focus groups.

Of course the analysis interprets a reality, which has been understood and filtered through my own subjective lens. In order to be reflective about my interpretation of data collected in the field, I maintained a written field journal, alongside recording interviews, interactions, conversations (with the permission of respondents). Efforts

were made to record my first impressions, suspicions, biases and frustrations during fieldwork. It also included remarks about what was "said", "what I heard", and the "unsaid" what wasn't said but implied through silence or in context.

3.5. Researcher Positionality and Self Reflexivity

Me: "Please let me know if you prefer some parts of today's discussion to be off the record." (Explaining confidentiality of information and consent before the start of a focus group with rice farmers)
Farmer 1: "*Madam Jee*, we want you to convey each and every thing we say to the Government. We want our voices to get heard."
Farmer 2: (Running over to show me his electricity bill for tube well use). "Here, can you take this to show to the *Wadda Saab (big boss)* in the *Mehekma* (Punjab Irrigation Department)? Last year crop prices were low so the government gave us subsidies in the form of concessions on electricity charges to farmers who had electric tube wells. So we got some relief that year. But this year, they put back all of last year's subsidized bills back on to our electricity bill and sent us escalated amounts to be paid. What choice do we have except pay the bill? If we don't pay the bill, or contest it they will pull away the motors."
Me: (Struggling for the appropriate words in Punjabi) **"**My research is independent and while I may have access to the *Mehekma*, I may not be able to influence government policy to reverse electricity bills..."
Farmer 1: "Madam Jee, we *know* they will listen to you when you speak for us..."

Field Journal,
Khushhalpura Village,
District Sheikhupura,
Punjab.
3 February, 2017

The excerpt above resonates some of the dilemmas regarding researcher positionality and ethics in my interactions with interviewees during fieldwork in Punjab, Pakistan. Fieldwork and analysis meant engaging with the world and constructing abstract understandings about it and within in. In this study I adopt a constructivist approach where both data and analysis are created from shared experiences and relationships with participants (Charmaz 2014). Both researchers and research participants interpret meanings and actions, hence it is essential to become aware of researcher pre-

suppositions and to grapple with how they affect the research. Adopting this approach meant being reflexive about the extent to which the studied experience is embedded in the broader social context and relationships (Charmaz 2006).

Reflexivity involves attention to the effect of how researcher's personal background and identity affect research interactions and interpretations. It involves reflections on personal biases and values. It also involves considering the ideological, ethical, and epistemological assumptions and preconceptions about the research context and the communities studied. The insider/outsider dilemma is an important aspect of self-reflexivity during the research process as the researcher's position in relation to their participants has a direct impact on the knowledge that is co-created between them (Griffiths 1998). During my research in Sheikhupura District in Punjab, I was an insider to the extent that I was of Punjabi origin, could understand the language, and speak a not-so-fluent version of it. Being an insider was advantageous for navigating access to the field, familiarity with village life and customs in Punjab, norms for interaction with males and appropriate dress code while conducting research in villages and institutional settings. Insiders are more aware of the lives of their participants than outsides hence in a stronger position to conduct ethical research that represents marginalized research subjects adequately (Griffiths 1998; Kanuha 2000; LaSala 2003).

While there were considerable advantages to my insider status, I also felt that research participants had high expectations, and sometimes ethical difficulties were presented as the researcher/researched boundaries were challenged. Participating farmers often had high expectations from me as their "*Madam Jee*" who would be their counselor and speak for them in policy circles (Birch and Miller 2000).

While my insider status allowed for a better understanding of context and richer data collection, sharing ethnic and language commonality did not mean that I understood participant's perspectives any better than an outsider - my position as an upper class, female researcher studying at a "foreign" university, being able to roam around freely and talk to men in a village setting without restrictions of *purdah* made the differences between me and my participants outweigh the similarities (Bridges 2001). During fieldwork and analysis I was consciously aware of the aspects of privilege and power that I represented and carried with me through different research contexts- both for elite

interviews with bureaucracy and for farmers in Sheikhupura. Middle and lower tier bureaucrats often exaggerated their roles and the extent of technology they deployed in their work to impress *"Madam Jee"* during the interviews. I was referred to as *Dr. Saab* even though I often clarified that I am not yet a Ph.D.

While I collected the data during semi-structured interviews, I tried to adopt a relatively neutral position, consciously not discussing my own opinion on groundwater governance in Punjab, so as to not taint the perspectives of interviewees. This thesis is a critique of formal government policies and donor policies and programs for groundwater governance. During the analysis, I have tried to represent a broad range of perspectives based on views of the participants and analysis of textual documents, in addition to my own perspective. During the data collection and transcription process, being a part insider, I was acutely conscious of my own response to the research data and experiences.

At the same time I was an outsider as I was also being looked at as a female researcher from an upper class background. This reflected in the majority of my research participants addressing me as *"Madam Jee"*. I was acutely aware of my position as a female researcher amidst the male dominated water bureaucracy in Pakistan, academic networks as well farmer focus group discussions. The word 'farmer' is almost synonymous with being 'male' in the field. My field assistant, Farooq Sahab, who mediated access to farmers in villages in Sheikhupura clarified that rural men will not be comfortable "exposing" their women to you *Madam Jee.* It is against their *izzat* (honour) for someone to interview their wife asking about the work in the rice fields, which was referred to as "insignificant" anyways because "women are only engaged for a few days in the rice transplantation and harvesting stages" (Field Assistant Farooq Sb, 31 January 2017). During the focus group discussions and interviews with farmers, it was interesting to note how the *'baithak'* or parlour in which we were seated only had photographs of the elder males of the family displayed. I was able to convince some farmers to make me meet their families after our focus groups were over. In one such instance I was greeted in English by the woman of the house of a wealthy farmer who wanted me to perceive her as "modern" and "educated" thinking I am a "white person", and when I responded in perfectly fluent Urdu, she asked "*Madam Jee, how can you speak such good Urdu? We thought you are a Gori"(White Woman)*. Dressing up in

traditional *Shalwar Kameez* and *Chaddar* (piece of cloth that covers the head), and speaking Punjabi reduced but clearly did not eliminate the researcher and participant power relationship.

As a part outsider, I found myself constantly addressing the social and psychological distance between myself and my participants in an ethical way to ensure that the research is culturally sensitive and advances a better understanding of how farming communities use groundwater (Bridges 2001). During visits to field sites and interaction with local population, care was exercised to avoid intrusion as well as vulnerability of low-income groups attached to field sites.

In navigating access to and during my interactions with research participants, I felt that being affiliated with a top university in Pakistan gave me a certain degree of authority in dealing with elite interviewees in bureaucracy, NGO, and industrial sector. It also meant that I had several opportunities for non-participant observation, in the form of attendance at conferences and workshops I helped to organize at LUMS. At these events water sector professionals from diverse backgrounds sketched out their perspectives on surface and groundwater issues for Punjab as well as Pakistan at large. Non-participant observation in the first few months of fieldwork gave me an introduction to the research setting and helped in networking with research participants whom I interviewed later (Ostrower 1998). I continued to attend meetings in the bureaucracy, NGO and donor sector whenever I could throughout my fieldwork – hence non-participant observation allowed me to observe my respondents in their interactions with other "powerful players" in the water sector. Such interactions helped to reveal hidden power relations that I followed up on in my later interviews, or while conducting textual analysis of government policy and donor project documents.

3.6. Ethics and Data Protection

Since the study involved human participants and personal data, the research complied with the ERSC Framework for Research Ethics (2015) and approval was sought from the University of Sussex Research Ethics Committee. Ethical considerations in the context of researching the sensitive issue of water include getting prior informed

consent from participants as well as ensuring their confidentiality and anonymity, whenever requested and appropriate. These considerations were valid for all interviews but particularly significant in the case of elite respondents for semi-structured interviews, many of who were still serving as current government officials or involved in consulting positions with donor agencies.

Using the elite interview as a research tool has peculiar ethical issues that I consciously made myself sensitive to. The more commonly discussed ethical issues such as voluntary and informed consent, confidentiality and anonymity apply to elite interviews. However, elites' privileged position and possession of specialist knowledge might mean they want to influence what the researcher writes about them. At some point, the researcher has to deal with the dilemma of "naming of names to give authorial possession to particular comments or pieces of information in order to maintain a critical perspective" at the expense of compromising on the trust and rapport that respondents place in him (Herod 1999, 324). I was acutely aware of such ethical dilemmas and hence consciously asked my respondents for their preference for anonymising names and/or positions. For all elite interviews, a Project Information Sheet (see Annex 3A) was handed out to the respondents prior to the interview. Their consent was sought and recorded in written form through a Consent Form (see Annex 3B). The data collected during fieldwork was stored in a password-protected computer and backed up in a password protected external hard drive periodically.

4. The Place of Groundwater Irrigation in Nineteenth and Twentieth Century British Punjab

4.1. Introduction

The historical case study of groundwater governance in Punjab begins in the colonial period that is the focus of this chapter. The empirical material in this chapter emphasises the changing importance of groundwater for the colonial state and the evolution of the state's approach to groundwater governance in turn. Based on the theoretical framework elucidated in Chapter 2, this chapter posits that the techniques and mechanisms of groundwater governance in the colonial period that arose from the interaction between the formal state apparatus and informal non-state actors played an active role in shaping colonial governance of groundwater as well as in creating the contemporary groundwater crisis in Punjab. The analysis in this chapter, together those in with Chapters 5 and 6, lead to the historical roots of the contemporary problem of groundwater governance as a key finding of the thesis. The empirical analysis in this chapter also illustrates the importance of groundwater to state development goals in the colonial period, thus underscoring the contribution of groundwater to 'colonial hydrology'.

Research on irrigation in British India does not engage adequately with the history of groundwater development under the broader political-economy context of colonial rule. The literature on irrigation in colonial India focuses on a wide range of themes, but of particular significance in this literature is the discussion on how the introduction of large-scale engineering works for surface water led to British control of nature and society and reoriented ecological relationships between land and water (D'Souza 2006; Gilmartin 2003; 2006). Another key theme in this literature relates to how investments in canal irrigation upset the ecological balance and led to the decline of traditional water-harvesting mechanisms like tanks and wells (Agarwal and Narain 1997; Whitcombe 1972). This literature uses the subject of water primarily to animate the broader aspects of colonial rule and to debate the positive and negative environmental contributions of canal irrigation (Ali 1988; Gilmartin 2015; Stone 1984; Whitcombe

1972). While some of these studies focus on how the "hydraulic interventions of colonialism" worked to alter "South Asia's fluvial and social worlds" (D'Souza 2006, 625), the bulk of this literature focuses on colonial investments in canal irrigation, ignoring the colonial approach to 'minor' or 'private' irrigation works. Of the minor irrigation works, wells and tanks were of the most significant in British India (Agarwal and Narain 1997). The decline of tanks and their restoration has been the subject of considerable inquiry in the context of colonial expansion of the canal network (Agarwal and Narain 1997; Mosse 1999). In the context of British Punjab, the geographic focus of this study, well irrigation was most significant during the period of colonial rule and has remained so in Punjab's contemporary agro-based economy. Well irrigation using subsoil water supplied up to 58 per cent of the total irrigated area in British Punjab in 1886, having been a traditional source of irrigation before the aggressive expansion of the canal network under the colonial government (Report on Agricultural Statistics of Punjab, 1886). The importance of groundwater irrigation has not diminished even in contemporary Punjab, where it supplies between 60 and 80 per cent of the irrigation for major crops in the province (Chapter 1).

The chapter highlights the significance of groundwater irrigation in Punjab during the colonial period. The chapter argues that, during British rule, groundwater resources and promoting the development of subsoil water for irrigation had much more importance than most discussions of 'colonial hydrology' recognise. By tracing the history of groundwater development in colonial Punjab, the chapter analyses when and why the colonial state pushed a rigorous groundwater development agenda. The colonial approach to groundwater was centred on using well irrigation for both its productive and its protective value – productive as well irrigation was a low-cost method (bored at the cultivator's expense) of extending irrigation to areas that were not served by canal irrigation, and protective as well irrigation was seen as a way to provide resilience against famines. In the second half of colonial rule, the promise of mechanisation and advancements in technology for extraction of subsoil water transformed the potential yield from well irrigation, so it brought about a marked changed in the colonial state's approach to this resource.

This chapter reflects on the specific techniques of governance that shape the evolution of the groundwater-society relationship in nineteenth- and twentieth-century Punjab.

The discussion details how colonial policies towards well irrigation changed over the period of British rule in the context of the broader political economy of an expanding colonial empire. It highlights how, in the wake of nineteenth-century famines and the crystallisation of a 'protective irrigation policy', the colonial government renewed efforts to maintain existing wells and encouraged new borings and investigations of the feasibility of tubewells for public programs. The colonial policy towards wells should be understood in the context of the colonial logic of capitalism, especially the expansion of irrigated agriculture through the expansion of the canal system on one hand, and the pressures of famine control and famine relief on the other.

This chapter uses a historical approach central to a study of political ecology to examine the techniques of governance in the context of the broader political and economic forces at play during the colonial period that led to a transformation of the groundwater society relationship in Punjab. The chapter's methodology draws on archival research to assess the significance of groundwater for the colonial state, and in turn the state's approach towards the governance of the resource (See Chapter 3 for detail). While published sources and official records primarily dominate the archival resources that form the basis of the empirical analysis in this chapter, unpublished sources were also consulted; although these were few in comparison to more than five decades of published reports that were used to trace the path of groundwater development in colonial Punjab. In general there was little divergence between published and unpublished sources to assess the colonial state's techniques for groundwater governance.

The chapter starts by exploring the use and importance of groundwater in pre-colonial and early colonial Punjab (Section 4.2), and how the relationship between groundwater and society was reconfigured over the course of colonial rule, highlighting the British interest in promoting well irrigation in the nineteenth century (Section 4.3). The promise of mechanisation for the future of well irrigation in the twentieth century and the ensuing efforts toward well drilling and tubewell installations by the Punjab Agriculture Department from 1908 until end of British Rule are discussed in Section 4.4, along with a record of key impediments in the way of large-scale application of groundwater irrigation. In section 4.5, the colonial approach to groundwater is contrasted against colonial policies towards canal irrigation and in the broader political economy context to highlight the importance of groundwater to the broader colonial

irrigation economy. The analyses in this chapter, reviews the techniques and mechanisms of colonial groundwater governance to provide the historical context for understanding the legacies of the colonial approach and a foundation for understanding the role of state and non-state actors in the development of groundwater in the post-colonial and contemporary periods that is detailed in Chapters 5 and 6.

4.2 Means of Irrigation in Colonial Punjab

4.2.1 The Expansion of the Perennial Canal System

Punjab's irrigation capabilities have been well-known throughout its pre-colonial and colonial history and remain so today. Descriptions of 'Punj-ab' – literally, the land of five rivers – have been historically romanticised based on its network of flowing rivers, canals, and watercourses. As a result, the province's surface waters are the focus of discussion in the early literature. Punjab "is intersected by great rivers; it is bounded on two sides by hills, whence pour down countless rivulets; the general surface of the land slopes downwards with a considerable gradient. These facts at once proclaim it to be a country eminently adapted for canals" (Danvers 1877, 10). Nearly all of the dynasties that ruled Punjab before British rule did something for irrigation, as "nearly every district possesses flowing canals or else the ruins of ancient watercourses" (Danvers 1877, 10). The first recorded canal in Punjab is said to have been the Western Jumuna Canal, which dates from 1351 and was constructed by Feroz Taghlak. The canal was built to supply the gardens and fill the fountains and wells of Feroz's hunting palace in Hissar, but little record of irrigation works along the canal remain, as they fell into disuse upon Feroz Taghlak's death. In 1626, the Feroz canal was restored to supply water to the imperial palace, which was being erected near Old Delhi. The Mughal canals eventually fell into decay and had ceased to flow by the middle of the eighteenth century (Danvers 1877).

In the pre-colonial period, with the exception of a few perennial canals, well irrigation and inundation canals were the primary means of cultivation. Of these, the inundation canals, such as those in the Derajat area of Punjab, supplied water in the summer months (from April to October). During winter, water was not sufficiently high to enter

the canals, but as the rivers rose in the spring from the melting Himalayan snows, the water gradually entered the channels, which obtained their maximum volume in summer (Danvers 1877).[4] However, wells and inundation canals did not support large-scale agriculture, so starting in 1849, after the annexation of Punjab, the colonial government invested in the construction of the perennial canal systems in western Punjab that brought about the largest agricultural expansion in the region. Between 1885 and 1940, canal-irrigated area in British Punjab increased from under 3 million acres to more than 13.5 million acres (Ali 1988, 12). Major works included the Sidhnai canal, Lower Sohag Para, Upper Bari Doab, Lower Chenab Canal, Lower Jhelum, Lower Bari Doab, Upper Chenab, Upper Jhelum, and the Sutlej Valley project. Each canal project had its own colonisation policy on the basis of which land was allotted to selected grantees or was otherwise disposed of for purposes determined by the government (Ali 1988, 13).

4.2.2 The Critical Importance of Well Irrigation under Native Rule and Its Place in an Expanding Canal-Irrigated Colonial Economy

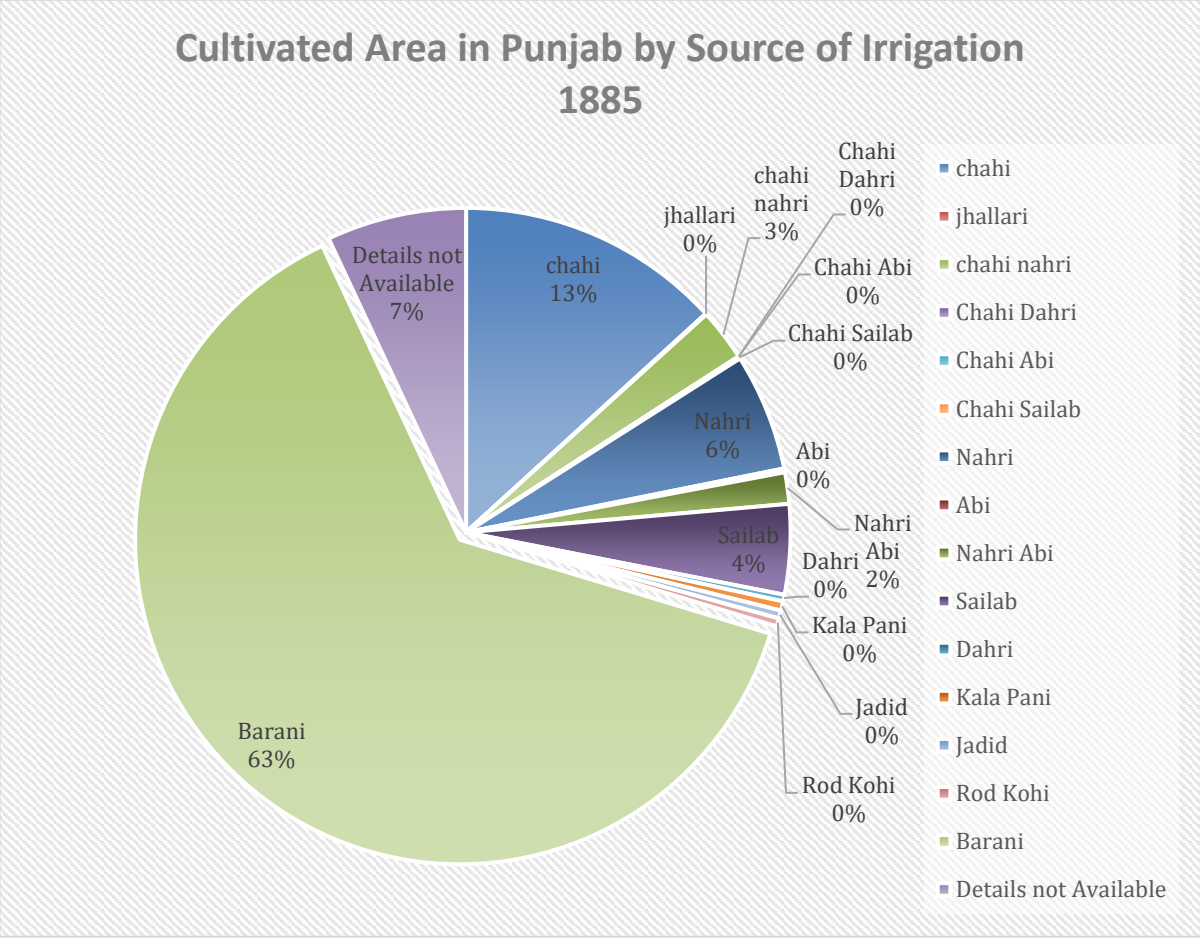
The use of wells for irrigation and domestic purposes was recorded in the Indus Basin as early as the fourteenth century, where the use of subsoil water was made possible through the use of the Persian Wheel. Siddiqui (1986) analyses the construction of artificial irrigation and water works, including lakes, tanks, cisterns, wells, and artificial canals in pre-Mughal India. Well construction in pre-Mughal India consisted mainly of two types of wells: the simple well (*chah*) and the step wells used for man and animals (*bai'n* or *baoli*). Evidence from fourteenth-century texts also suggests that wells, referred to as the *Saqiya* and *Charkh*, were owned both by the state, as well as private cultivators (Siddiqui 1986, 65). Records suggest that the pre-colonial rulers encouraged farmers to build their own wells and harvesting systems. By the turn of the fourteenth century, the Persian wheel seems to have diffused into various territories in North India for irrigation and domestic use. In 1519, Babur, the founder of the Mughal Dynasty, refers to Persian wells being used for irrigation of profitable crops like rice and

[4] Inundation canals in Punjab ran through the Derajat area. The famous Multan canals were considered the property of the government under native rule, but the annual repairs and silt clearances where done by the people. The landholders formed *panchayats*, or committees, to fix the proportion of general burden to be borne by each village, with a scale of fines for defaulters. The systems were worked with *cher*, or statute labour.

sugarcane in Bhera and Khoshab, India, areas that are now part of Punjab in Pakistan (Siddiqui 1986).

Wells constituted one of the dominant forms of irrigation not only in the pre-colonial period, but also in the early years of colonial rule in Punjab until the end of the nineteenth century. In 1885, about 15 per cent of the total cultivated area in Punjab was irrigated either only by wells (*chahi*) or by wells in conjunction with other means (Figure 4.1). In comparison, area irrigated by canals (*nahri*) were between 10 and 14 per cent of the total cultivated area, including area irrigated by inundation canals. Most (63%) of Punjab's agriculture at this point was still rain-fed (*barani*).

Figure 4.1 Cultivated Area in Punjab by Source of Irrigation (1885)



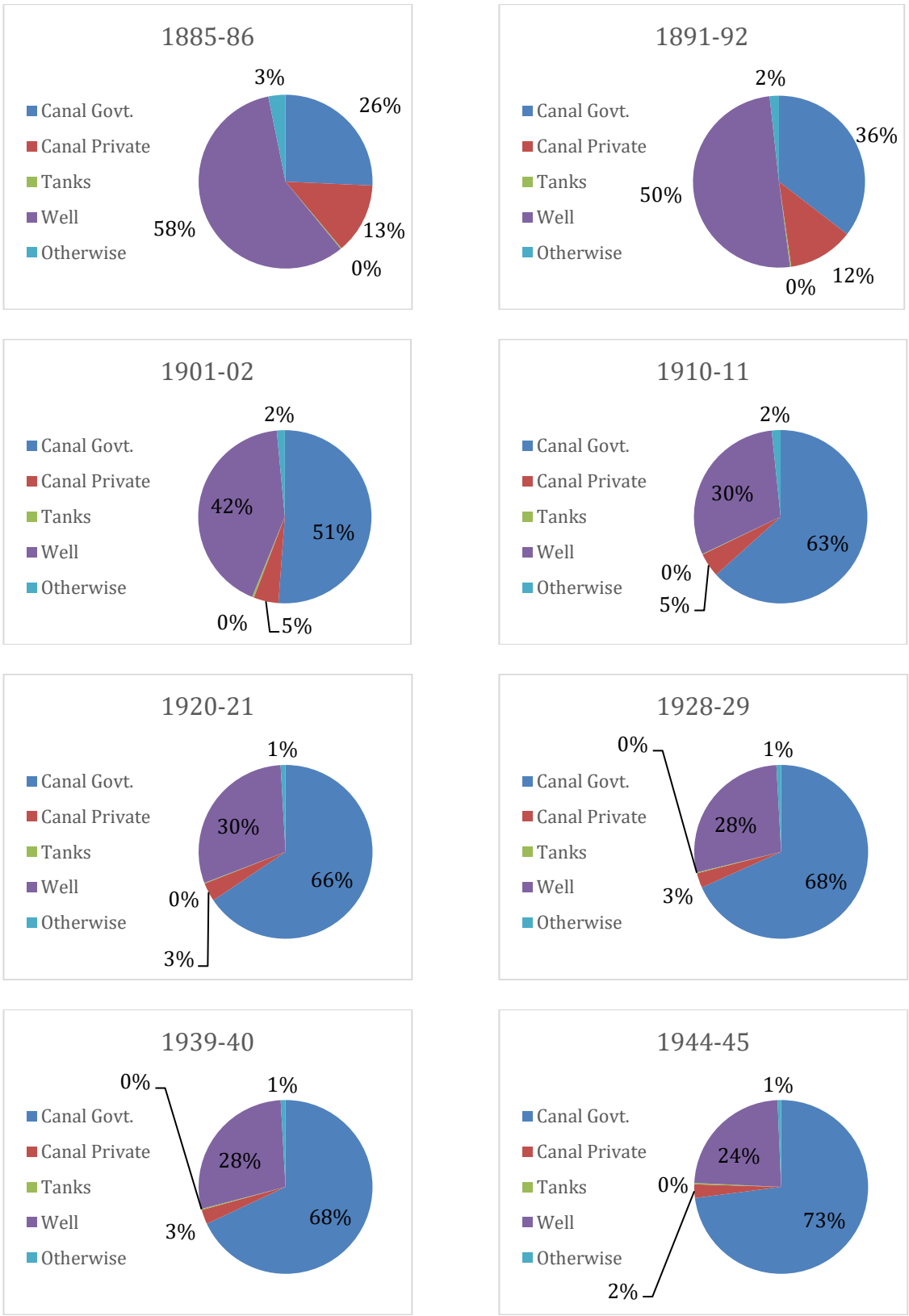
Source: Statistical Abstract Relating to British India, 1885

*Note: Area labeled *barani*= rainfed, *chahi* = well irrigated, *nahri* = canal irrigated

Thirty-nine per cent of the irrigated area in Punjab in 1886 was served by canals, 58 per cent by wells, and 3 per cent by other sources (Report on Agricultural Statistics of Punjab 1886, 11). Colonial Punjab was one of the four provinces (in addition to United Provinces, Bombay, and Madras) in which well irrigation was most extensively practiced in British India (India Irrigation Commission Report 1901-1903). As the *Imperial Gazetteer of India* (1886, 321) reports, "the most favourable conditions for well irrigation are found in the alluvial plains of Northern India, the subsoil of which contains an inexhaustible supply of water. Out of the 13,000,000 acres thus irrigated more than 9,500,000 are in the United Provinces and the Punjab."

For much of the nineteenth century and before, the small-scale nature and yield of well irrigation, coupled with the expense of the animal power needed to work Persian wheels, meant that well irrigation was largely left to individual cultivators. The colonial state continued encouraging well construction through the availability of *tuccavi* loans, a practice that had been encouraged from time to time by pre-colonial rulers as well. The introduction of large-scale canal irrigation works under the British transformed Punjab from dependence on seasonal inundation canals and wells to reliance on the canal network. Not merely avenues for river flow, these canals re-oriented the ecological relationship between land and water (Ali 1988; Stone 1984). As the canal network expanded in British Punjab, the proportion of well irrigation in the Punjab's irrigated area declined from 58 per cent at the end of the nineteenth century to 24 per cent at the end of British rule (Figure 4.2). The absolute area under well irrigation did not decline from the expansion of canal irrigation (Figure 4.3), but well irrigation as a proportion of the total irrigated area in Punjab declined. This decline occurred in the individual districts of Punjab, where an increase in the proportion of area irrigated by government canals was accompanied by a decrease in the proportion of area irrigated by wells (Appendix 4). Part of the explanation for this trend was the high cost of well irrigation, which required animal power to work the Persian wheel, as well as the limited yield from using wells. In comparison, canal irrigation cost the cultivators less and could be used to irrigate large areas of land for water-intensive crops.

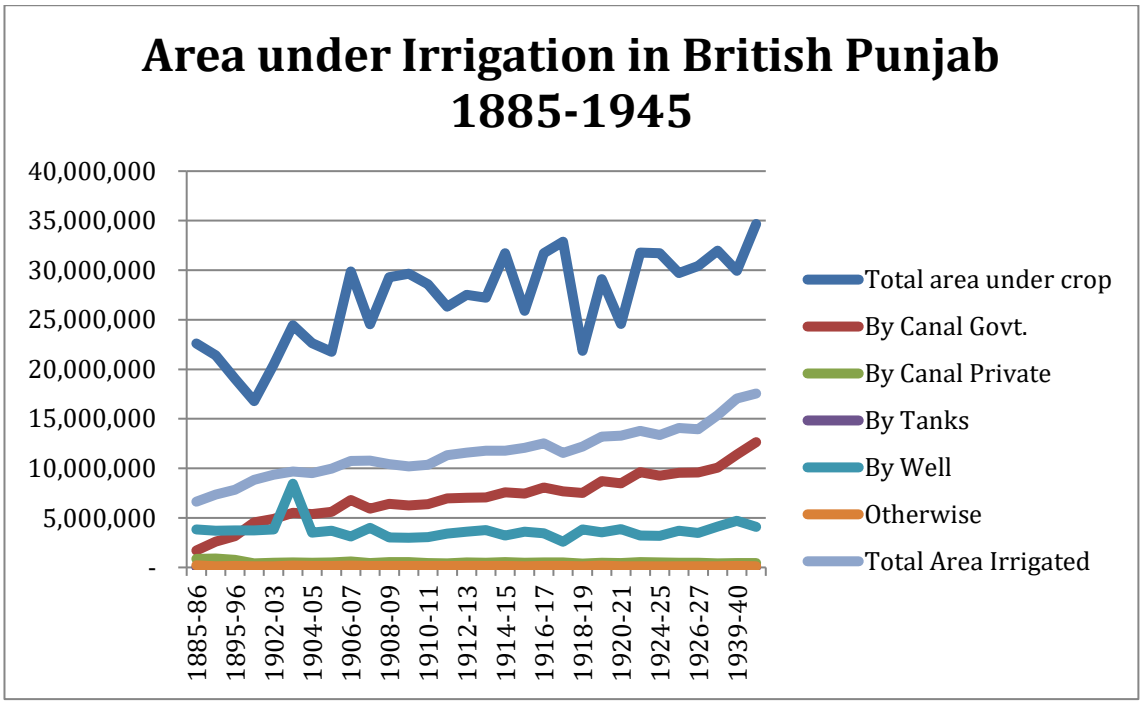
Figure 4.2: Changes in Punjab's Irrigation Mix under British Rule 1885-1945



Source: Report on Seasons and Crops of Punjab, 1885-1945 (various years)

Note: Percentages are based on total irrigated area in Punjab.

Figure 4.3: Area under Irrigation in British Punjab



Source: Report on Seasons and Crops of Punjab, 1885-1945 (various years)

The decline in the proportion of the area irrigated by wells and the colonial fetish for expanding the canal network in nineteenth- and twentieth-century Punjab often leads scholars of South Asian environmental history to disproportionately glorify the role of canal irrigation in furthering the colonial agenda of agricultural expansion in Punjab (c.f. Stone 1984). By contrast, I emphasise the importance of groundwater irrigation through wells and tube wells to the colonial agenda in Punjab, arguing that, far from neglecting groundwater development, the colonial government did much to promote it. The following sections outline the imperatives for colonial interest in groundwater and discuss the efforts made by the government to develop and expand the area irrigated by wells and tubewells. The colonial groundwater policy should be understood in the context of 'productive' versus 'protective' and 'major' versus 'minor' irrigation in the broader political context of an expanding colonial economy. The analysis points to the growing importance of groundwater irrigation to the colonial state, and how it shaped the techniques of groundwater governance by the formal state and informal actors, as well as the groundwater-society relationship.

4.3. Imperatives for Well Irrigation in Nineteenth-Century Punjab

4.3.1 Well irrigation as a Method for Reaching Areas Not Served by Canals

To explain the importance of well irrigation and how the colonial approach to groundwater evolved in Punjab, it is necessary to emphasise the functions served by well irrigation during the nineteenth century. Since more than half of Punjab's agriculture was rain-fed for most of the nineteenth century (Figure 4.1), the variability and lack of rainfall frequently led to distressed crops. The colonial government's grand agenda for extending canal irrigation by constructing large-scale engineered works was ambitiously pursued to reduce the fluctuations in output that were due to *barani* agriculture. While large-scale engineering works for surface water provided a cost-effective method for bringing water to previously barren 'wasteland', the only acres that benefitted from canal irrigation were those that could be served by flow irrigation, since it was a gravity-based system. Canal irrigation was not suitable for upland terrains, areas above canal heads, and other areas inaccessible by canals. The colonial interest in well irrigation stemmed from the use of wells to irrigate uplands and the need for an increased and more flexible allocation of water and cultivation intensity (Ali 1988).

4.3.2 Well Irrigation as a Supplementary Source of Irrigation for *Rabi* Crops

The use of well irrigation was also seen as source of supplementary irrigation in canal command areas for *rabi*, or winter, crops when the canal flows were inadequate or for canals that operated seasonally. For example, a potentially perennial canal irrigated the Sidhnai Colony, but it was used only for the *kharif* harvest. The colony did not obtain a *rabi* supply, as all available water was taken away upstream on the Ravi River by the Upper Bari Doab Canal, which irrigated proprietary lands in the Lahore and Amritsar Districts. Thus, the Sidhnai Canal was a seasonal one in effect, providing only *kharif* irrigation, whilst the *rabi* crop was matured through well irrigation (Ali 1988, 14). In late-nineteenth-century Punjab, the *rabi* crops were an equally important or even more important part of the year's harvest than the *kharif* crop. For instance, in 1886, 42 per cent of the crops grown in Punjab were *kharif*, while 58 per cent were in the *rabi* harvest (Report on Agricultural Statistics of Punjab 1886, 9).

Among the *rabi* crops, well irrigation was particularly critical for the wheat crop, deemed the "most important of all Punjabi crops" and occupying up to a third of the cropped area in the province (Annual Report of the Department of Land Records and Agriculture 1908, 5). The strategic importance of wheat in Britain's global imperial economy also underscores the growing significance of well irrigation for the colonial government. Grown principally as an export crop in nineteenth-century Punjab, wheat accounted for 4 per cent of the value of exports, with the United Kingdom (UK) being the top recipient of wheat exports (Statistical Abstracts Relating to British India 1899-1900). According to the Report on Agricultural Statistics of Punjab (1886, 22), "The majority of agriculturalists eat inferior grain and grow wheat only to sell. As a rule only those who are fairly well off, whether of farmers or of dwellers in towns, eat wheat". Colonial Agricultural Statistics show that well irrigation was an important source of irrigation for the wheat crop, especially before the turn into the twentieth century. In 1886, 25 per cent of the area under wheat was irrigated by wells, as opposed to 13.4 per cent irrigated by canals. However, during this time, about half of the wheat crop was still being sown on dry land that depended on rain. Wheat crop grown on unirrigated *barani* lands was a frequent cause of distress when rains were scarce or unevenly distributed. Such situations led to serious losses in exports for the colonial government, as was the case in 1887-88, when the value of wheat exports dropped from 75 lakhs to 19.5 lakhs of rupees (Report on Agricultural Statistics of Punjab 1886-87, 24). To reduce the uncertainty in wheat yields, irrigation was necessary, and well irrigation was a low-cost method adopted at the cultivator's expense; hence, the colonial government's heightened interest in it.

4.3.3 Well Irrigation and the Evolution of the Colonial Policy of 'Protective Irrigation'

The colonial approach to groundwater development through well irrigation in the late nineteenth century was also influenced by the evolution of colonial irrigation policy and the recognition of wells as a viable form of protective irrigation. Colonial irrigation reports from the nineteenth century indicate that, until 1880, colonial irrigation policy focused on profit, while references to extending irrigation to prevent famine were mentioned as a distant second agenda. Severe famines in Madras in 1877-78 and the

ensuing Famine Commission Report of 1880 established a clear distinction between productive and protective irrigation schemes. According to the Report, profitable schemes with a higher return were labelled productive, while schemes with lower returns for purposes of famine prevention were protective and emphasised to avoid the enormous cost of relief in the aftermath of famines (Famine Commission Report 1880). These "unproductive" schemes were financed by a Famine Fund and labelled "protective irrigation". Despite the emphasis on protective irrigation between 1878 and 1900, the area under protective irrigation registered a meagre increase and measured only 0.14 million hectares by 1900, whereas the area irrigated by productive works increased by 1.9 million hectares during the same period (Indian Irrigation Commission Report 1901-1903). After a series of famines, the Report of the Indian Irrigation Commission in 1903 further emphasised the need for protective irrigation schemes and the need to lower the financial criteria for sanctioning such schemes (Juriens, Mollinga and Wester 1996).

As compared to other sources of irrigation, well irrigation seems to have provided the most resilient form of protective irrigation for famine prevention in times of drought. In British Punjab specifically, more than half of the cultivated area was rain-fed until the end of the nineteenth century, so the fate of agriculture depended heavily on the distribution of rainfall. Most accounts of famines in British India point to "unreasonable rains, unequal distribution or deficient rainfall" (Danvers 1877, 15) as the key reasons for the onset of famine, providing a justification for the colonial agenda of extending irrigation and railways as a means of resilience against famines. Of the various methods of irrigation in Punjab, only perennial canals, which did not depend on rainfall, promised resilience against famines. Inundation canals and canals that depended on the annual monsoon rains did not prove to be resilient during periods of drought. Tanks also did not provide reliable security against the effects of a protracted drought, as documented by many examples of tanks drying up during famines in various parts of India before 1875 (Danvers 1877). Wells, on the other hand were unique in providing resilience to droughts:

> Wells appear to be at all times a suitable means of irrigation wherever water can be obtained at a level not too low to admit of its being raised for the purpose. These works can be constructed where canals could ever be made to reach; on

> several occasions they have been the means of maintaining cultivation when land beyond the reach of their influence has failed to produce anything; on them alone many districts have entirely depended during the recent famine, and although they cost more in proportion to the area they will irrigate than either canals or tanks, they can generally be relied upon to furnish water when tanks are empty and country streams have all run dry. Every effort should be made to increase the number of these important works, as the reservoir to which they lead is practically inexhaustible and beyond the influence of solar evaporation, although like other reservoirs its surface level is liable to be lowered under the combined influences of a heavy drain on its stores, and an absence of fresh supplies from the surface or springs. (Danvers 1877, 15)

While wells were an important source of protective irrigation in the nineteenth century, their large-scale adoption for irrigation was not feasible because of the high expense of working wells using animal power and the uncertainly in various locations about the presence of the aquifer and its yield. As Danvers (1877, 15) writes:

> On account, however, of their first cost and expense in working, it would not be practicable to confine wet cultivation to land watered by wells, neither can they be relied on under all circumstances to maintain their efficiency in every locality during seasons of drought, especially when continued for any great length of time.

The British policy towards groundwater mirrored the evolution of the colonial irrigation policy, the distinction between productive and protective works, and the increased emphasis on the latter by the Famine Commission Report of 1880 and the Indian Irrigation Commission Report of 1901-1903. The emphasis on well irrigation as a form of protective irrigation provided the first impetus for state investment in well-boring in Punjab, manifested in the efforts of the Punjab Department of Agriculture from the beginning of the twentieth century until independence. A more significant impetus for state attention to groundwater irrigation was due to the change in technology brought about by the tubewell, development that in some ways reconfigured the cost of extracting subsoil water and the scale at which groundwater irrigation based on animal power was being used at that time. Section 4.4 details the shifting colonial approach to

well irrigation that was brought about by the promise of mechanisation through tubewells.

4.4. The Promise of Mechanisation in the Twentieth Century and the Shifting Colonial Approach

The promise of mechanisation in the twentieth century through tubewell technology pointed to the immense possibilities of improving the yield from groundwater irrigation so it could be used on a larger scale. This change in scale also enabled the colonial government to look at possibilities for government-sponsored large-scale tubewell schemes, not just for agriculture but also for municipal water supply. Here we see a paradigm shift in the government's approach to groundwater, where the construction and installation of new tubewell infrastructure offered possibilities for the government to charge users for groundwater in a manner similar to the irrigation dues paid for canal irrigation.

While colonial efforts toward building large-scale surface irrigation works is well documented in the literature, somewhat less well known is the extent to which expertise in efficient exploitation of groundwater resources was produced. These efforts were primarily focused on increasing the yield of wells and realising the potential of tubewell irrigation in the first half of the twentieth century. This section provides a comprehensive review of colonial efforts toward well-boring and tubewell installations in the twentieth century and the hurdles that stymied the progress of groundwater development in British Punjab until independence. The analysis in this section is based on a review of reports from the Punjab Agricultural Department (1900-1947) and manuals on well-sinking and tubewell irrigation from the Punjab Public Works Department during the same time. The analysis is accompanied by two summary timelines for groundwater development efforts (Figures 4.4 and 4.5) for well-boring and tubewell irrigation in Punjab. The chapter also documents colonial land-leasing policies that were designed to encourage tubewell installations. The detailed chronological account of the sum of colonial efforts to develop groundwater irrigation in the context of the broader colonial irrigation and economic policy illustrates why, despite an inclination to develop larger-scale schemes for groundwater development, the colonial government achieved only lukewarm success.

4.4.1 Colonial Efforts for Well-Boring in the Twentieth Century

Experiments on wells' potential for irrigation, including technical studies on the yield of ordinary wells in India, were carried out under the British government as early as 1879 (Brownlie 1912). Records of experiments with more cost-effective well-building techniques, yields, and water flows in wells through sandy soils were also written by various engineers in the Punjab Public Works Department (Punjab Public Works Department Papers 1892). Towards the end of the nineteenth century, the Punjab Agriculture Department was exploring variations of the Persian wheel for increasing well yields while reducing the animal power required to raise water from wells.

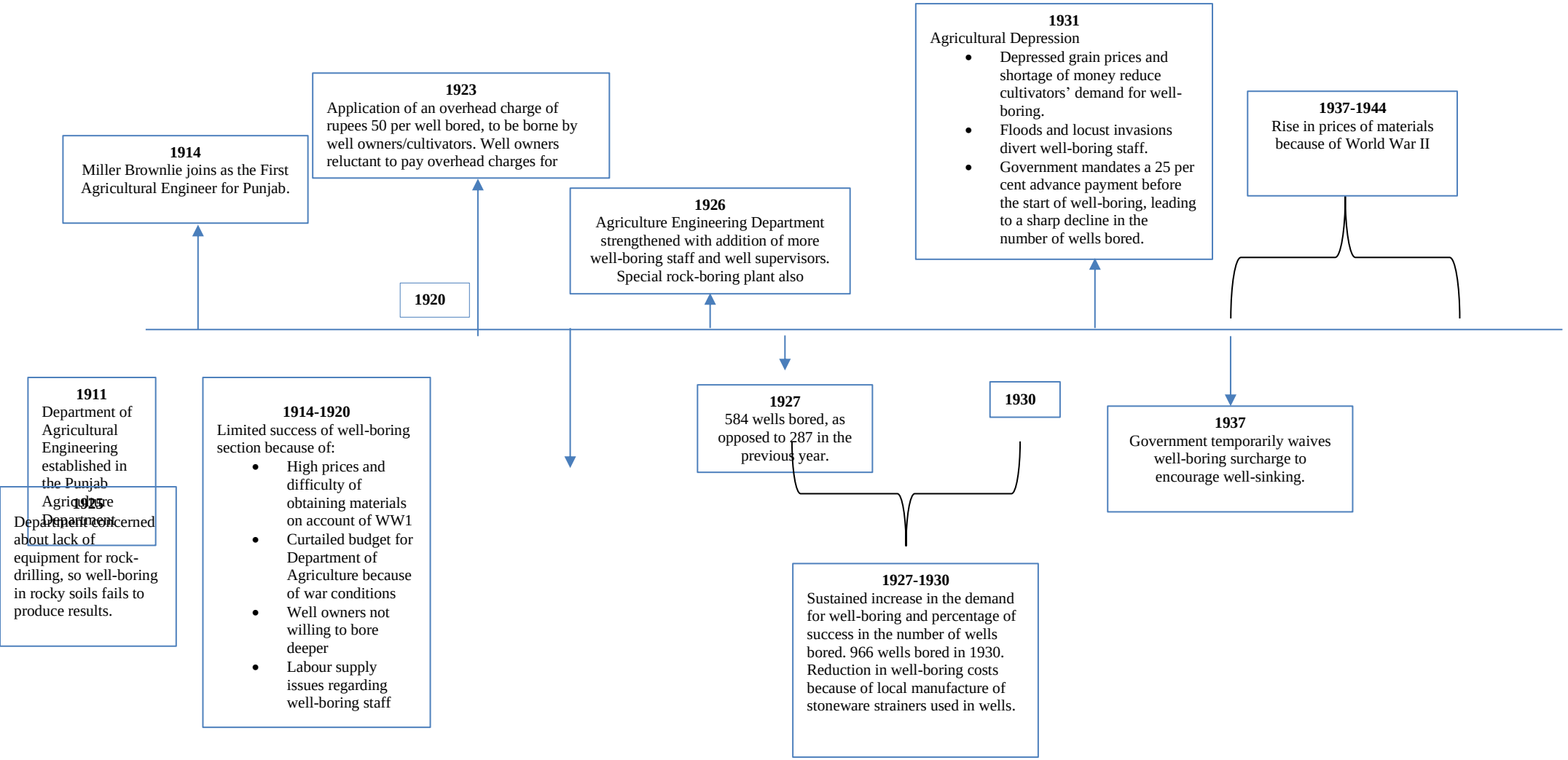
At the turn of the twentieth century, the obligation of the Punjab Department of Agriculture was precise: increase the supply of water in wells and do it economically (Annual Report of the Department of Land Records and Agriculture 1911). A series of consistent efforts over time by the colonial government in Punjab supported their commitment to well irrigation (Figure 4.4). In 1908, investments were made in well gears to increase water yields from ordinary wells up to three times, and the experiments were carried out using ball bearings to reduce the amount of animal power needed to run Persian water lifts (Annual Report of the Department of Land Records and Agriculture 1908). In 1911, a well-boring section was established in the Punjab Agriculture Department with the primary objective of "increasing the water supply in existing wells and conducting of trial borings for new well sites" (Annual Report of the Department of Land Records and Agriculture 1908, 10).

In the first few years of operation, the well-boring section struggled with requests for money for well-boring plants, the need for well-boring supervisors, and the necessity of a "European agricultural engineer" (Annual Report of the Department of Land Records and Agriculture 1911). By 1912, well-boring under the Punjab Agriculture Department had about a 50 per cent success rate in increasing well yields. Since well-boring was an expense incurred by the landlord and there were no mechanisms to test the level and strength of the springs before boring, many landlords were not willing to incur the expense of deep boring. Moreover, the Department did not have boring plants that were suitable for boring a variety of soil types.

The Department of Agriculture attributed the tepid success of the well-boring section before 1914 in large part to the absence of a dedicated agricultural engineer, a gap Miller Brownlie filled in 1914. His dedicated efforts brought the well-boring success rate to 59.5 per cent in 1915, as reported in the Department's Annual Report. Proud of his first year of effort at increasing the area under well irrigation and the revenue collected for British government in turn, Brownlie wrote:

> In each of the 141 successful borings carried out, the irrigated area has been considerably extended, and therefore government benefits on account of increased revenue, while the advantage to the cultivator is very great, representing in some cases the difference between abject poverty and a life of comparative comfort (Report on the Operations of the Department of Agriculture Punjab 1915, Appendix V, xxiv)

Figure 4.4: Timeline of Efforts of the Well-Boring Section, Department of Agriculture, British Punjab



For the most part, the success of well-boring operations and tubewell installations between 1914 and 1920 remained hindered by internal and external constraints. Among the internal constraints, a major hurdle to improving well yields was that owners were reluctant to bear the costs of boring because there was a possibility of failure. According to the Report on the Operations of the Department of Agriculture, Punjab 1915 (Appendix V, xxiv), "Many of these so called failures could be made successful if the work is completed at government expense and the cost recovered gradually from the owners as their income increases due to benefits derived from increased supply of water." The lack of progress in well-boring was also due in part to the difficulty and high price of obtaining the types of boring systems that were suitable for diverse soil types during World War 1. Experiments in treatment systems that were suitable for Punjab's subsoils were hampered during this time due by the difficulty of obtaining the necessary material because of the war (Report on the Operations of the Department of Agriculture, Punjab 1915).

Issues related to the labour supply in the well-boring section of the Punjab Agriculture Department were also problematic for well-boring operations during this time. These issues included low salaries, skill level, and the availability of well-boring labour, especially during harvest season (Report on the Operations of the Department of Agriculture Punjab 1915). In 1917, a light boring plant was ordered to free up boring work from the vagaries of the supply of hand labour, which was particularly hard to source during the harvest period. In years with exceptional rainfall, such as 1917, the number of wells bored plummeted, partly because the abnormal rains reduced the demand for wells and partly because of the difficulty of obtaining materials and the high prices of that which could be obtained because of the war. In 1922, several well-borers were absent for considerably long periods because of illness or the ability to obtain higher pay elsewhere, so the staff strength of well-boring department suffered (Report on the Operations of the Department of Agriculture Punjab 1922, Appendix V, xxv).

The budgets of the small well-boring section within the Department of Agriculture were curtailed between 1910 and 1920, in part because of the war. The limited staff meant that any diversion took away from actual well-boring work. For instance, in 1919, the boring plant was sent to Persia with the military. Similarly, in 1924, the staff spent a

considerable amount of time preparing working models of water lifts and boring equipment for the 'Empire Exhibition' in Wembley (Report on the Operations of the Department of Agriculture, 1924 Appendix V, xxxvi).

Since 1908, well-boring by the Colonial Department of Agriculture had been heavily subsidised , with Rupees 30,000 to 35,000 per annum (in 1908 values) in government subsidies going to paying borers, well supervisors, and office expenses. In addition, the tubes were sold at less than cost during the war years. The well owners were not charged for depreciation or repair expenses, which increased substantially over time. In 1922, in an effort to make the well-boring section self-sustaining, the government levied an overhead charge of Rs. 50 per successful boring, a move that helped raise 7,350 rupees as overhead charges (Report on the Operations of the Department of Agriculture Punjab 1923, Appendix V, xxxvi).[5] In 1929, this overhead charge was replaced by a charge of 0.12 rupee per running foot of boring, as this method of charging appeared to be more popular than the flat rate (Report on the Operations of the Department of Agriculture Punjab 1929, 32). By 1930, the government was able to recover 75 per cent of the total cost of well-boring from well owners (Report on the Operations of the Department of Agriculture Punjab 1930, 65).

The onset of the agricultural depression of the 1930s and the resulting low grain prices meant that farmers were less able to spare funds for well-boring. At the time of the Depression, to safeguard colonial interests, the government mandated an advance of 25 per cent for well-boring services in 1932. This move led to a sharp decline in the demand for well-boring, as only 24 of the 216 well owners who applied for boring could deposit the advance required to have their wells bored in that year (Report on the Operations of the Department of Agriculture Punjab 1932, 30). Faced with a decline in the demand for well-boring[6], the colonial government was obliged to abolish the overhead charge of 0.12 rupees per foot from time to time. However, by this time, prices of iron pipes had increased again following the outbreak of World War II, which served as a major deterrent to demand for boring operations (Report on the Operations of the Department of Agriculture Punjab 1940, 64).

[5] A successful bore is defined as an increase of at least 20 per cent of well yield.
[6] Before the start of the economic depression, up to 1000 bores were being sunk annually, but this number declined to 441 in 1933. For details, see page 40 of Report on the Operations of the Department of Agriculture Punjab 1933.

In summary, as Figure 4.4 shows, the progress of well-boring from 1908 to 1940 was not smooth because of budgetary constraints, the reluctance of landlords, and the availability and high price of materials during the two world wars. Apart from technical problems and the financial feasibility of well-boring, the colonial government's concern that boring operations be financially self-sustaining was a major obstacle to expanding well irrigation compared to the profitability of canal irrigation (Section 4.5.2)

4.4.2 The Feasibility of Mechanised Tubewells for Irrigation – Prospects and Problems

A fundamental shift in the British policy and approach to groundwater irrigation was brought about by the introduction of tubewells, which were "schemes through which subsoil water is obtained from borings only by mechanical power, the supply ordinarily being 6-12 times that obtained by animal power from an excavated well" (Brownlie 1912, 12).

Archival research from the India Office Records show how research and expertise regarding the feasibility of tubewell technology for groundwater irrigation and municipal water supply in Punjab received considerable attention from the Punjab Public Works Department and the Punjab Department of Agriculture. In 1912, Miller Brownlie, the newly appointed agricultural engineer to Punjab, published "Notes on Tubewells", building on the research of his colleagues J. T. Farrant and E.A. Maloney. [7] Brownlie considered tubewells an important source of irrigation in "areas uncommanded by canal irrigation or over areas which have become waterlogged owing to excessive canal irrigation, and in which it is desired to stop or considerably reduce this system of irrigation and pump water from subsoil" (Brownlie 1912, 12). However, despite Brownlie's enthusiasm and efforts, progress in tubewell technology in the first two decades of the twentieth century was slow, largely because of a curtailed budget for the agriculture department, high prices, and difficulty purchasing materials during World War I (Report on the Operations of the Department of Agriculture Punjab 1917).

[7] Brownlie also included detailed calculations on the cost per acre using 'liquid fuel' versus electricity in the manual, as well as the annual recurrent cost to irrigators of using state advances for investment in tubewell systems for irrigation and public water supply services.

In addition, the well-boring department had limited staff, which was also diverted from time to time. For instance, in 1918 two borers, along with their plants, were sent to Persia (Report on the Operations of the Department of Agriculture Punjab 1920).

The potential of tubewells for extending large-scale use of subsoil water was clear, but the challenge was to bring the cost of tubewell irrigation to a level at which it could feasibly be comparable to the amount cultivators paid for canal irrigation. As mentioned in the Punjab Agriculture Department's report:

> In 1922, a single tubewell cost twenty five to thirty thousand rupees, according to subsoil conditions and with fuel prices still high, the maintenance charges including interest on capital and depreciation amounts to thirty five rupees per acre per crop. Even with good markets rates for farm produce the landowner hesitates in sinking a comparatively large capital and having to pay about six times the average canal rates for irrigation. (Report on the Operations of the Department of Agriculture Punjab 1922, Appendix V, xxvii)

Public tubewell schemes that planned to bring large areas of government wasteland into cultivation were prepared in the 1920s and 1930s but did not materialise because of high prices and budgetary constraints (Report on the Operations of the Department of Agriculture Punjab 1924, 4). Records show various feasible public tubewell schemes, but they did not reach fruition. For instance, in 1929, the possibility of bringing 16,000 acres of government *barani* and wasteland under lift irrigation[8] at Minarwala was being considered by obtaining electric power from two waterfalls on the Bhawana Branch of the lower Chenab Canal. Specifications and proposals for hydroelectric schemes were also being considered. Another scheme for 10,000 acres of *barani* and wasteland near Chiniot was being considered for lift irrigation, as was 46,000 acres in the Chach circle of Attock District by installing hydroelectric power on the Harro River. In the Chach circle, the cost of well irrigation was 79 rupees per acre, while lift irrigation at the time was estimated to be 15 rupees per acre (Report on the Operations of the Department of Agriculture Punjab 1929).[9]

[8] Lift irrigation entails lifting water from the subsoil by means of electric/diesel pumps.

[9] In 1930 a separate Lift Irrigation Division was created within the Agriculture Engineering Department to deal with "Investigation of the possibilities of irrigating areas uncommanded by canal irrigation and with the preparation of schemes for lifting water from the subsoil by tubewells, etc., wherever that may an advantage" (Report on the Operations of the Department of Agriculture 1930, 66).

Tubewells brought the promise of using subsoil water for irrigation and municipal supply on a larger scale, but they were also being investigated as a way to treat waterlogging in irrigated tracts. Mechanised pumping of water through tubewells from waterlogged soils would help to lower the water table and resolve the growing problem of waterlogging at the time. The Punjab Agriculture Department was considering using battery-operated tubewells in Hafizabad Tehsil of Gujranwal District to cure waterlogging. [10]

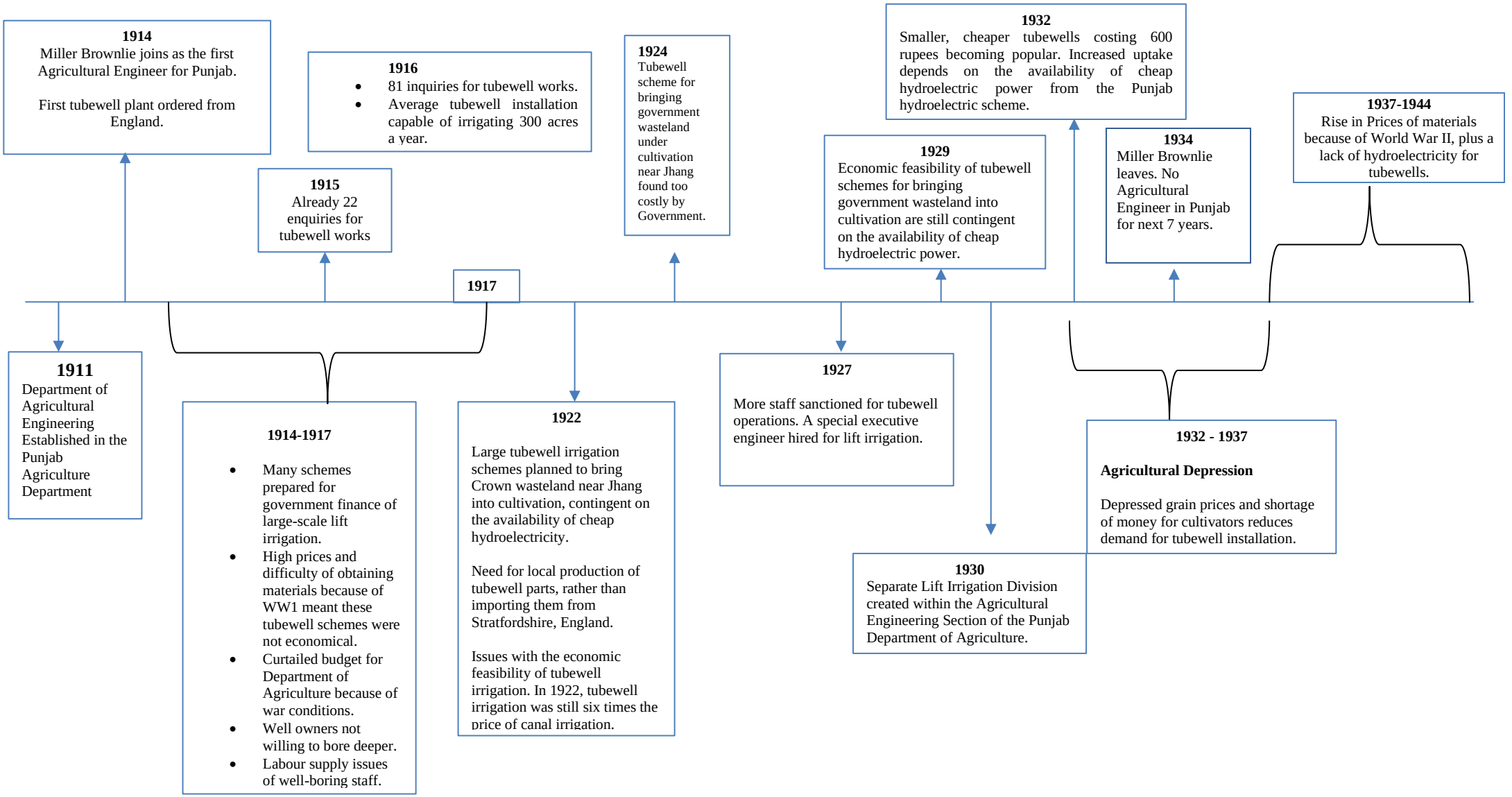
The success of the colonial state's efforts in establishing the economic feasibility of lift irrigation hinged on the ability to generate cheap hydroelectric power to drive planned tubewell schemes. According to 1930 estimates, if tubewell technology was run by generation of electric power through internal combustion engines, the costs were 19-25 rupees per acre for large lift-irrigation schemes. For the same electricity to be generated through hydropower, the costs were only 11-13 rupees per acre, depending on the scale. Inquiries revealed that farmers were willing to pay up to 12 rupees per acre for lift irrigation because well irrigation was more expensive than the cost of tubewells powered by hydroelectricity at that time (Report on the Operations of the Department of Agriculture Punjab 1930). By the end of the 1930s, as the colonial state worked towards realising large-scale hydroelectric power schemes, the popularity of tubewells increased, especially in areas where cheap hydroelectricity was available and when "canal irrigation [was] not available and where the subsoil water [was] suitable for irrigation" (Report on the Operations of the Department of Agriculture Punjab 1941, 64). However, the progress of tubewells was once again stymied by the onset of World War II, and the prices of pipes and strainers increased. According to the Report on the Operations of the Department of Agriculture (1941, 89), "Although tubewell irrigation continues to be popular in localities in which cheap hydroelectric electricity is available, the present high cost of pipes and strainers owing to war conditions stands in the way of extending this form of irrigation…."

[10] The scheme to cure waterlogging entailed "pumping of water from the subsoil to maintain a balance of spring level, and the lining of main canals to reduce the enormous losses of water from these by seepage, are the two main means of curing or averting the evils of waterlogging…." (Report on the Operations of the Department of Agriculture 1929, 35).

4.4.3 The Fate of Colonial Land Lease Policies to Encourage Groundwater Irrigation in Punjab

In Punjab, the colonial government's efforts at supporting technical improvements in well-boring and tubewell installations were also accompanied by land leasing policies that favoured groundwater development. In the nineteenth century, to encourage well irrigation as a supplementary form of irrigation, the colonial government made well-sinking a condition for obtaining leased land in some parts of Punjab. For instance, in the Sidhnai Colony of the Multan District, which was colonised between 1886 and 1888, canal irrigation flows were seasonal, so the colonial government made well construction an obligation for the tenants of large land grants. Grantees had to possess 'a certain amount of capital', as Ali (1988, 16) documents: "To attract such men, the minimum size of the land grant was fixed at 50 acres, up to 4 times as large as the smallest grant in the later, perennially irrigated colonies." Such practices continued under colonial rule such that, even in the early twentieth century, when attempts were made to experiment and further the feasibility of tubewells, the grants of land were tied to the commitment to drill tubewells. In the 1920s and 1930s, while exploring the feasibility of bringing large tracts of government wasteland into cultivation by installing state-owned tubewell irrigation, the colonial government was also giving private cultivators incentives for using tubewells through the enterprise of agricultural intermediaries and individual cultivators. Of these intermediaries, Sir Ganga Ram, an executive engineer, deserves special mention for his experiments with tubewells that explored the promise of using canal flows to provide power for pumping wells (Board of Revenue 1920).

Figure 4.5. The Colonial State's Efforts to Install Tubewells



Following these efforts, the colonial administration made tubewell installation a pre-condition for granting of tenure, such that lessees were required to construct tubewells as a part of their lease obligations. Despite these state policies, tubewell irrigation had not taken hold by 1920, primarily because of the difficulty of installing hydroelectric power plants at the canal falls, high maintenance expenses for tubewells, and some tubewells turning out to be of inferior quality (Punjab Public Works Department 1938).

Ali (1988) captures the difficulties in successful realisation of colonial land lease policy:

> In the Upper Chenab Colony in 1920, two leases were given to Gurdit Singh and Gajinder Singh, who belonged to a landlord family of Jharauli in Karnal District. Gurdit's lease, over an area of 592 acres, was regarded by officials as an abject failure. The few tubewells constructed proved defective and of inferior quality. By 1927 only 41 acres were cultivated, instead of the 335 acres required under the lease. Gurdit died in 1930, and his lease was terminated by the government. Gajinder Singh, who was leased 180 acres, was called upon to construct only one tubewell. He made efforts over the years to work his tubewell properly, though he continued to cultivate through subtenants. Another tubewell lessee in the same colony was I. J. Engles, a retired Inspector of Police. Engles obtained 533 acres in 1924 on a 10 year lease, with an obligation to cultivate through at least two tubewells. Only in 1927 was the first tubewell constructed; but Engles died in the same year and the lease was terminated. Two other tubewell ventures, situated in the Chunian Colony, also came to grief. In 1927 the government leased 1,000 acres to Hari Kishen Kaul, on condition that he cultivate 400 acres a year from tubewells. Kaul did construct tubewells, but he incurred heavy losses, as he found their operation to be uneconomic. The lease was terminated in 1937 on grounds of failure. The other case was a 1,094 acre lease given in 1928 to a syndicate which included Sardar Habibullah Mokal, a member of the Punjab Legislative Council. This lease, too, was terminated after 10 years, for the lessees were unable to achieve any success. (Ali 1988, 399)

The colonial approach to groundwater development by tubewells was by no means uniform across the officials. For instance, the terms and conditions of the grant of land

to intermediaries for tubewell construction changed for Sir Ganga Ram as an intermediary became sterner when Dwyer replaced Dane as the Governor General of India (Board of Revenue 1914). Moreover, government encouraged private enterprise through intermediaries for promoting tubewells, only where it suited the government's revenue goals. Many a times, land was leased to politically influential families over intermediaries like Sir Ganga Ram who had a demonstrated record of success in lift irrigation Ali (1988). Many a times there were disagreements between Punjab Government and the central Government of India, especially when projects deemed feasible by the Punjab Government, were shelved on account of lack of approval of funds by the central government (Brownlie 1912).

4.5. Making Sense of the Colonial Approach to Groundwater Development in Punjab

The colonial approach to groundwater should be understood in the context of an expansive economic policy, relative profitability and large-scale potential of canal irrigation, the opportunities afforded by mechanisation of groundwater irrigation, and the evolution of colonial irrigation policy in the context of 'productive' versus 'protective' irrigation. As the empirical analysis in this chapter shows, the crystallising of the importance of groundwater irrigation within the bounds of the overall colonial irrigation policy can be seen in the last quarter of the nineteenth century and the first half of the twentieth century. However, colonial accomplishments in groundwater development in Punjab are less well-known in historical accounts than accomplishments in large-scale canal irrigation. The colonial state's efforts to develop and manage groundwater paled in comparison to its investment in large-scale engineering works and bureaucratic machinery for canal irrigation. This section provides an overview of the factors that underlay the disparity in the treatment of groundwater irrigation compared to canal irrigation and an appreciation of the strategic importance of well irrigation during colonial rule.

4.5.1 Materiality of Groundwater as '"Small-scale", "Minor", and "Protective"

Through much of the nineteenth century, the colonial state's attention to groundwater

irrigation was limited to maintaining meticulous records of the area under well irrigation while leaving the extension of well irrigation largely to individual cultivators, occasionally encouraged and subsidised by *tuccavi* loans from the state. Groundwater irrigation was largely a private form of irrigation at the time, with well construction undertaken at the cultivator's own expense. The Indian Irrigation Commission Report (1901-1903, 32) sums up the state's rationale for its limited support of well irrigation during much of the nineteenth century: "The profits of well cultivation in these districts have hitherto formed a sufficient inducement to landowners to construct wells, and the rate of recent progress indicates that private enterprise requires little assistance in the matter from the State." The state's confidence in private enterprise for groundwater irrigation translated into limited support of well irrigation except in "insecure" districts, where well construction was more difficult (India Irrigation Commission Report 1901-1903, 33).

Colonial records refer to the materiality of groundwater as "small scale", "minor", and "protective" irrigation, which puts groundwater in sharp contrast with the "major", "productive", and "large-scale" canal irrigation system developed by the state. In pre-colonial India, the scale of irrigation traditionally determined who the sponsor would be. For example, well-to-do peasant cultivators would dig wells, the chiefs would build tanks, and the kings would build larger canals or dams. Since wells were a low-cost means of irrigation that required comparatively small capital outlays, they were usually built by villagers, individually or in groups, with little assistance from the state. Thus, we see the colonial approach to groundwater development in the nineteenth century as a continuation of pre-colonial ways, where the state facilitates well construction only through loans and by offering technical expertise. This approach begins to change in the twentieth century, possibly because of the advent of tubewells that offered the possibility of increasing the yield from groundwater-harvesting systems significantly. Thus, we see state investment in large-scale application of tubewells for bringing government wasteland into cultivation in the twentieth century (Section 4.4). In contrast to the small-scale nature of well irrigation in the nineteenth century, canal construction required considerable investment and coordination spread out over a large number of beneficiaries, which would have been difficult to coordinate without the state's involvement.

4.5.2 Profitability of Canal Irrigation

That the perennial canal system in Punjab was a commercial proposition aimed at yielding profit for the colonial state has been well documented in the literature (Ali 1988, 280). For each of the canal projects initiated by the British, assurances regarding the project's profitability were a prerequisite for its sanction by the government. Canals were classified as 'public' and 'productive' irrigation works, as opposed to the classification given to wells as 'private', 'minor', or 'protective' works. Most state-owned canal projects in the nineteenth and twentieth centuries yielded a lucrative profitability of 50 per cent, with the ratio of working expenses to gross receipts[11] between 20 to 30 per cent (Ali 1988, 280). On the other and, well-sinking, as a decentralised and small-scale resource, was traditionally at the cultivator's expense and, as its yield was limited, did not generate profitability at a scale similar to that of canal irrigation. Of course, well irrigation improved agricultural productivity (and, as a result, higher land revenue assessments for the state) compared to *barani* (rainfed) lands and for *rabi* crops. However, well-boring was a heavily subsidised activity, with the Punjab government's paying between 30,000 and 35,000 rupees per annum towards the "pay of borers and their mates, the pay of the well supervisors, travelling and office expenses of these men and head office expenses all paid for by the government" between 1915 and 1923, in addition to subsidising material costs during war years (Report on the Department of Agriculture Punjab 1923, xxxv). As documented in Section 4.4, the introduction of an overhead charge for well-boring was aimed at reducing the government's burden of providing subsidies but ended up dampening the demand for well-sinking. Public investment in well-boring was also influenced by wells' low profitability relative to the high returns from canal irrigation. This difference changed in the twentieth century, when tubewell technology could promise large-scale groundwater irrigation and government-run tubewell schemes that could offer a return on the state's investment.

4.5.3 Legal Treatment of Groundwater in Relation to Surface Water

[11] The ratio of working expenses to gross receipts is a measure of the profitability of canals used by the Punjab Punjab Works Department. The lower the ratio, the higher the profitability (Ali 1988).

In the pre-colonial period, the rights to sub-soil water were also largely left to the custom that arose from local social relationship, kinship, and "tradition", in large part determined by the share of investment in jointly owned wells in communities. When the British settled Punjab, they found that most wells were held as share-based systems of timed water turns. The colonial administration studied this system of customary rules governing groundwater rights, along with social and economic relationships at the village level, and recorded the system in village administration papers called *shart wajib-ul-arz*.[12] The *shart wajib ul arz* regulated the management of the village commons, or *shamilat*, in the villages, ranging from cultivation of *shamilat* by proprietors and tenants to grazing rights by proprietors and non-proprietors of the village, the use of wells, and the right to plant and cut trees in the *shamilat*. The shares of investment in jointly constructed wells determined the times of day when each shareholder's bullocks had to be yoked and unyoked to allow the cattle to drink or for another shareholder to draw water for irrigation (Gilmartin 2015). The tree of each well or *naqsha-e-chah*, was drawn out to determine the original division of water when the well was sunk and subsequent time shares for using well water for irrigation (Kaul 1991). While these rights were initially recorded in the *shart wajib ul arz* initially as customary rules, the *wajib-ul-arz* was incorporated under formal statutory law in 1872, after the passage of the Punjab Laws Act. Groundwater rights were formally tied to private property rights over land in 1882, after passage of the Indian Easements Act based on common law principles of England (Gilmartin, 2015, 109). According to the Easements Act, owners of land had the right to "collect and dispose within his own limits of all water under the land which does not pass in a defined channel and all water on its surface which does not pass in a defined channel" (Indian Easements Act 1882, Section 7).

While rights over groundwater were tied to private property under colonial rule, ownership and rights over the extensive canal network rested with the state. Investment in and control of the newly built surface water systems in colonial India came to be guided by a formal statutory framework of law that was heavily influenced by principles of Roman law that hold 'flowing waters' to be the domain of the public (Van Koppen et

[12] The compilation of Punjab Customary Law by Sir Charles Tuppers and other settlement officers relied on the local knowledge of the leading men of the tribe at the village level. The village customs were recorded by posing questions regarding tribal customs to local men and recording the answers and any discussion.

al. 2017). The Northern India Canal and Drainage Act of 1873 gave control to the state to “use and control for public purposes, the water of all rivers and streams flowing in natural channels, and of all lakes, and other natural collections of still water”. Perhaps the scale of investment in canal irrigation necessitated public ownership and control over surface water, whereas the small-scale investment and decentralised nature of well irrigation meant that control and usage rights could be vested with individual cultivators.

4.5.4 Placing Groundwater Development in Punjab in Relation to Groundwater Development in Other Provinces

The preceding sections describe the significance of groundwater irrigation to the colonial agenda for agricultural productivity and famine resilience, as well as its promise for resolving the waterlogging of soils in Punjab. An attempt to characterise the importance of groundwater to the ‘colonial hydrology’ at a provincial level in Punjab is incomplete without reference to the larger context of the policy priorities for groundwater in the central British government’s agenda.

The efforts of the Punjab Department for Agriculture toward groundwater development in the early twentieth century, as well as budgetary allocations and subsidies allotted for well-sinking and tubewell experiments in the province, were embedded in the larger policy context of the central government’s perceived utility of groundwater irrigation in British India. Subramanian (2015) argues that the ability of tubewells to expand the irrigated area quickly led the colonial government to invest in state-funded expansion of tubewell irrigation to expand food production in the interwar years. In this regard, the province of Uttar Pradesh (UP) was the global pioneer in the first large-scale use of motorised tubewells (Subramanian 2015).

Tubewells was the subject of experimentation in certain provinces since the beginning of the twentieth century, as the case of Punjab shows. However, the financial viability of tubewells in comparison with canal irrigation hinged on the availability of cheap hydroelectric power. In 1927, under the leadership of Provincial Irrigation Engineer Sir William Stampe, the province of UP made a breakthrough in harnessing the falls of the Upper Ganges Canal to support the first public tubewell irrigation program in India,

which became the largest public tubewell program in the world. During World War II, Sir William Stampe was appointed as the Irrigation Advisor to the Government of India, which gave him opportunities to push for tubewell irrigation in the central government's agenda (Subramanian 2015). One explanation for the breakthrough in public tubewell technology in UP in the late 1920s is that, while Punjab was still struggling with public tubewell irrigation schemes, UP had already exhausted its potential for expansion of surface water resources and needed to exploit groundwater resources to expand agriculture (Subramanian 2015). Tubewell construction in UP was heavily subsidised by the provincial government, which provided loans and grants, and well-boring was also free for cultivators, with well owners paying only for the cost of pipes and strainers used to sink wells. Despite heavy government support, tubewells were economical only for land holdings larger than 500 acres (Subramanian 2015). Even in Punjab, the government gave out large land grants contingent on tubewell installation, but private enterprise in Punjab did not realise the economic feasibility of tubewell irrigation (Section 4.4). The experience of UP in bringing about a breakthrough in tubewell irrigation in India and the resulting increase in priority given to tubewell development in the central government suggests that the progress in Punjab was restrained by the delay in completing the Punjab Hydroelectric Power Scheme.

4.6. Conclusion

The analysis in this chapter shows how complex patterns of interaction between the state and non state actors shapes the political ecology of groundwater governance, drawing on the theoretical framework of groundwater governance in Chapter 2. The analysis in the colonial period shows how state has an important role to play in shaping groundwater's use as a resource for the society, through its institutional, legal and policy functions. It emphasizes the role of the state in shaping the groundwater-society relationship in the colonial period through state interventions such linking groundwater rights to private property rights, by extending *tuccavi* loans for well construction and by making land grants and lease contingent upon sinking tubewells. In line with the extended conception of governance defined in Chapter 2, this chapter goes beyond a state centric understanding of power in shaping groundwater governance, by highlighting the critical role of 'private enterprise' in the development (or the lack thereof) of groundwater irrigation in the colonial period. As this chapter illustrated, well

sinking and tubewell installations depended critically on the cultivator who in large part bore the costs of groundwater irrigation. Technological advancements in groundwater extraction mechanisms in the colonial shaped groundwater governance in critical ways and helped to explore the possibility of using groundwater for large-scale irrigation. Together, the complex patterns of interactions between state and non-state governors of groundwater in the colonial period shape the political ecology of groundwater governance, and has a significant repercussions for contemporary groundwater crisis.

The empirical analysis in this chapter is central to the thesis' overall argument. The chapter shows how the strategic importance of groundwater irrigation for colonial Punjab increased over time, increasing the emphasis on research on and experimentation with publicly supported schemes for well-boring and tubewell installation. The efforts of the colonial state to implement groundwater irrigation that are documented at length in this chapter testify to the significance of groundwater for 'colonial hydrology' and the state's developmental goals, whether for expansion of irrigation for winter crops, famine prevention, or relieving waterlogging through vertical drainage.

The empirical material presented in this chapter extends the existing understanding of colonial hydrology by explaining the contribution of groundwater to the colonial state's developmental goals. The analysis shows how groundwater fulfilled the developmental goals of the state, extending irrigation and expanding agriculture, and hence revenue generation in an extractive colonial economy. Groundwater irrigation through wells and tubewells fulfilled various imperatives of the colonial state, hence the increased attention given to it in colonial irrigation policy over the course of the twentieth century. The contribution of groundwater to colonial hydrology, brings to light the specific materiality of groundwater as a decentralized resource. The techniques to capture groundwater as a resource and availability of groundwater extraction technology have been decisive in shaping the state's approach towards groundwater and groundwater's contribution to colonial hydrology as the chapter illustrates. In contrast to the original conception of the term colonial hydrology that was understood as the centralized management of large-scale canal irrigation, groundwater's contribution to colonial hydrology was largely navigated by the state facilitating groundwater development indirectly through enabling private enterprise.

The analysis also points to the historical roots of the contemporary problem of groundwater governance in Punjab. The colonial approach to groundwater irrigation evolved slowly over the course of the nineteenth and twentieth centuries in British Punjab. The legal and policy changes for groundwater irrigation the colonial government initiated led to profound changes in the groundwater-society relationship, sowing the seeds for the explosive growth in the post-colonial use of groundwater and the contemporary problem of groundwater governance. Based on the theoretical framework for groundwater governance set out in Chapter 2, the colonial state's techniques for groundwater governance, such as land lease policies for tubewells, shaped both the behaviour of non-state actors and the groundwater-society relationship. The chapter also demonstrates how advancements in groundwater-extraction technology (or the lack thereof) meshed with existing social relationships and how state and non-state actors' adaptations of new technology changed social relationships. This change had repercussions not just in the colonial period but led to lasting changes in the early post-colonial and contemporary periods,

Despite the colonial state's efforts at groundwater development, by the end of British rule, groundwater irrigation had not escalated to the proportions observed in Punjab's contemporary irrigation landscape. Two world wars and associated difficulties with and high prices of obtaining imported materials for tubewell-boring and installation were partly to blame. In addition, because cultivators bore the costs of well installation and tubewells, high prices and lack of availability deterred demand for groundwater irrigation. As the next chapter describes, it was only after India's independence in 1947 and the creation of Pakistan that schemes sponsored by USAID and IBRD, along with the strategic input from the Revelle Commission, facilitated successful installation of large-scale state-owned tubewell schemes in Punjab. These 'public tubewells' were initially installed with the intention of alleviating the problem of waterlogging and salinity, but within a decade, installation of private tubewells by individual cultivators rose quickly as tubewell technology became commonplace and tubewells came to be manufactured locally. The explosive growth of tubewell irrigation, accompanied by the availability of high-yielding varieties of seeds and fertilisers, along with the mechanisation of agriculture, led to the post-colonial 'green revolution' (Chapter 5). Cutting across the colonial/post-colonial divide, we find significant continuity in the

approach to groundwater governance in the two periods. The post-colonial state in Pakistan merely scaled up British efforts toward using groundwater, aided by the availability of international finance, technical expertise from the United States, and freer movement of technology in the Cold War setting.

5. Groundwater Development in the Early Post-Colonial Period: 1947-1990

5.1. Introduction

The purpose of this chapter is to explain the role of the postcolonial state in achieving a breakthrough in large-scale groundwater development and the importance of groundwater in the post-colonial state's hydraulic mission. The analysis stresses the role of the early post-colonial state supported by foreign aid and expertise in reconfiguring the groundwater-society dynamic in the broader Cold War geopolitical context. Punjab's experience in the early post-colonial period illustrates the role of post colonial state, aided by international donors as powerful non state actors, in furthering the contribution of groundwater to the hydraulic mission. The chapter also contributes to the main argument of the thesis by illustrating how the mechanisms of groundwater governance in the early post colonial period have led to the contemporary groundwater crisis.

As mentioned in Chapter 2, the literature on the Indus Basin of Pakistan focuses on the state's attempt to control the natural environment through development of a large-scale irrigation infrastructure and its relationship with colonial and post-colonial state building (Akhter 2015; Ali 1988; Gilmartin 1994; Haines 2013; Michel 1967; Mustafa 2002). This literature analyses the complex evolution of state power, social inequality, and economic development in the context of irrigation and agriculture in Pakistan's Indus Basin, but it focuses on the development of hydraulic politics and hydraulic mission with surface water infrastructure, that is, dams and canals, while discussions that link irrigation and Pakistani statecraft ignore the importance of groundwater in the Pakistani state's hydraulic mission and the historic role of the state in transforming the groundwater-society relationship. This literature often alludes to groundwater development in Punjab as a 'silent' revolution led by the individualistic behaviour of farmers but provides little or no discussion on the role of the post-colonial state in groundwater's development and exploitation (Watto and Mugera 2016). By contrast, this chapter argues that the transformation of the groundwater-society relationship did not happen as a 'silent revolution' but was led by the state as an integral part of its post-colonial 'hydraulic mission'. Thus, this study fills an important gap by exploring the Pakistani state's prominent role in developing groundwater irrigation in the Indus Basin

and by teasing out the importance of groundwater for the newly independent state's hydraulic mission. No other study examines the contribution of groundwater to the hydraulic mission of the post-colonial Pakistani state. In the Indian context, a number of studies highlight how groundwater irrigation through tubewells (rather than mighty dams) have served as 'temples of modern India' by contributing the much-needed increase in water availability to mobilise the Green Revolution (Kulkarni and Aslekar 2018; Subramanian 2015).

The chapter's methodology draws on a content analysis of federal and provincial government policy documents as well as international donor project reports related to water sector development in Punjab from 1950 to 2017, with particular attention to the prevailing agrarian, economic and geopolitical context at the time the reports were published. Drawing on the political ecology of groundwater governance framework presented in Chapter 2, this chapter explores the imperatives of the early post colonial state, and the relative power of state and non-state actors in bringing about large scale centralised development of groundwater in Punjab in the context of incoming international aid and expertise in a Cold war environment. Two main ideas underpin this chapter. First, the chapter proposes that the early post-colonial state played a pivotal role in achieving a breakthrough in large-scale development of groundwater for irrigation, thereby transforming the extant groundwater-society dynamic. Second, it highlights groundwater's decisive contribution to the post-colonial state's 'hydraulic mission' and the broader development processes in Punjab. The chapter starts with a discussion of groundwater's importance in Punjab's post-colonial hydraulic mission (Section 5.2), tracing the post-colonial state's interest in groundwater development and the ensuing trajectory of large-scale, centralised groundwater development in the region. The analysis points to the specific mechanisms of formal governance, aided by foreign expertise, in bringing about a massive increase in groundwater irrigation initially through centralised development, but eventually through atomistic private tubewells (Section 5.3), leading to the groundwater 'revolution' that has made the resource an integral part of the post-colonial "hydraulic mission" and the contemporary hydro-social order in Punjab (Section 5.4). The chapter contributes to the overall thesis by analysing how large-scale public groundwater development in the early post-colonial period altered the groundwater-society dynamic, sowing the seeds for the current groundwater crisis in Punjab. The chapter also highlights how interactions between the

post-colonial state and non-state actors shaped the nature of post-colonial groundwater governance and Punjab's groundwater crisis.

5.2. Trajectory of Post-Colonial Groundwater Development in Pakistan (1947-1990)

This section charts the history of how a combination of factors led to state development of groundwater in the first three decades after independence. It argues that the fragile and newly independent post-colonial Pakistani state looked towards public groundwater resource development to achieve three goals: a) as a quick method of increasing water availability to ensure food self-sufficiency and reduce foreign exchange spent on imported grains; b) vertical drainage through groundwater pumping to relieve the waterlogged and saline soils that had rendered about a quarter of West Pakistan's area unsuitable for cultivation at the time; and c) growth of the agriculture sector through increased groundwater availability for irrigation. The discussion highlights the role of the state and non-state actors in transforming the groundwater-society dynamic and the contribution of groundwater to the post-colonial state's hydraulic mission.

5.2.1 Problems of Partition and the Imperatives for Post-Colonial Groundwater Development

The partition of the subcontinent in 1947 and the creation of Pakistan involved separating both land and water resources in the Indus Basin, with the latter made possible through a series of diplomatic efforts brokered by the World Bank that culminated in the Indus Water Treaty (IWT) of 1960. The IWT assigned to India the three eastern tributaries of the Indus, the Ravi, Beas, and Sutlej Rivers, and to Pakistan the three western tributaries, the Indus, Jhelum, and Chenab Rivers. In the aftermath of the IWT of 1960, which divided the surface waters of the Indus, the immediate concern of the Pakistani state was to make up for the water 'lost' to India by constructing massive replacement works for diverting water from the Western tributaries to the fields that the Eastern tributaries of the Indus had previously irrigated. The Indus Basin Development Fund made this possible through a financial agreement among Pakistan, the World Bank, and a group of capitalist states, including Australia, Canada, New

Zealand, the UK and the US (Akhter 2015, 70). The Indus Basin Project was the largest integrated irrigation project in the world at the time, with a funding of about $1.2 billion (Michel 1967).

Pakistan's first decade after independence was politically and economically unstable. In the early 1950s, during the Korean War, the economy saw a temporary boom because of the increased demand for jute products from East Pakistan (now Bangladesh). After the end of the Korean War boom, the decline in foreign exchange earnings in Pakistan did not work favourably for the country, and a shortage of food, medicine, and essential consumer goods resulted from unfavourable monsoons. This problem was resolved with the help of foreign aid that brought in food grains and aid for development programs. In the period of the country's first five-year national development plan, Pakistan had to import extensive amounts of food grains, which consumed $700 million in foreign exchange in addition to freight charges paid on food grains received as aid. According the country's second five-year plan, "the stubborn problem of agricultural production" and the inability of the country to become food self-sufficient continued into the end of the 1950s (Government of Pakistan, Second Five Year Plan, 1960-65, 2).

At the time of independence, surface water resources contributed most of Punjab's water, but increased variability and decline in surface water supplies that were due to climate change and population pressures over the decades has increased dependence on groundwater for irrigation needs. The Indus Basin is one of the most depleted river basins in the world in terms of surface water supplies, with a decline of 15 per cent in the last decade alone (Archer et al. 2010; Sharma et al. 2010). At the same time, the adoption of high-yielding varieties of seeds during the Green Revolution enhanced crop yields but lead to a three-fold increase in crop water requirement (Shiva 1991). A part of the increased water demand for the Green Revolution was met by expanding the surface water infrastructure as part of the extensive Indus Basin Plan signed in the aftermath of the IWT. However, the increase in the amount of water needed for the Green Revolution was supplied in large part through public and private groundwater development. For instance, in 1967, groundwater's contribution to irrigating the wheat crop was only 36 per cent of the total water requirement, but by 1986, groundwater irrigation for wheat had increased to 59 per cent of the total irrigation requirement (Byerlee and Siddiq 1990). Moreover, the state was promoting the cultivation and

export of water-intensive agricultural crops like rice to achieve rapid agricultural growth. In 1960, groundwater contributed 8 per cent of total water supplies at the farm gate in the Punjab Province, but this share had gone up to 40 per cent by 1985. Currently, more than 60 per cent of the water for irrigation comes from groundwater sources, so the resource is critical for agriculture (Gilmartin 2015).

5.2.2. Centralised Groundwater Development

Failure of Initial Public Groundwater Schemes

In the first decade after independence, Pakistan struggled to secure her share of the Indus' surface waters while at the same time the growing problem of waterlogging and salinity also presented a sizeable constraint for agricultural growth and food security. Groundwater levels and the loss of land to waterlogging and salinity had been recognised as a growing problem as early as 1908 (Chapter 4), when the first comprehensive survey of the water table in Chenab colony was conducted. However, even though the colonial government sought to ameliorate the problem by promoting the value of tubewells as a vertical drainage solution, there was little progress on the issue of waterlogging by the eve of independence in 1946 (Gilmartin 2015).

After independence, the Pakistani government initiated a series of programs to control waterlogging via vertical tubewell drainage but saw inconclusive results, perhaps because of the limited scope of these scattered projects (Johnson 1989, 2). The Rasul Scheme, originally proposed as a tubewell irrigation and tubewell drainage scheme in 1927 but delayed for several reasons, was finally sanctioned in 1944.[13] Partition of the subcontinent and the ensuing chaos meant that the implementation of the Rasul scheme was further delayed, and even when the project became functional, it was deemed a 'failure' (Michel 1967, 460), as the 495 tubewells installed in the Chaj Doab were so close to the canal that they accelerated seepage into the soil, rather than relieving waterlogging. Similarly, most of the 762 tubewells installed in the Rechna Doab failed or declined in yield because of blockage of strainers and incrustation of tubes when

[13] The scheme proposed installation 1,700 tubewells of 1 cusec capacity each in the waterlogged areas of Rechna and Chaj Doabs in Punjab, using power from a planned hydroelectric power plant near Pabbi, in Rasul. The scheme was delayed first because of jurisdictional issues about where the power supply would come from, and then because of financial stringency during World War II.

deposits of carbonates built up on the well strainers. The Punjab Irrigation Department also began work on two additional tubewell schemes in the late 1950s – the Pindi Bhattian Scheme and the Chichokimalian scheme – both of which were later incorporated into the World Bank-sponsored SCARP project (Michel 1967).

International Expertise and Aid for Large-Scale Public Groundwater Development through SCARPs

After a series of lukewarm efforts at ameliorating waterlogging and analysing prospects for groundwater development by the newly independent Pakistani state, international expertise and financial assistance came to the rescue and initiated large-scale groundwater development in Pakistan. In 1953, the Pakistani government reached an agreement with the predecessor of USAID for "technical assistance in soil and water resources investigation", initiating the "West Pakistan Groundwater Survey", nicknamed "Project 035". The immediate objective of Project 035 centred on the "the provision of soils and water data essential for agricultural development, improved irrigation, salinity control, and land reclamation in West Pakistan" (United States Department of the Interior, 87)[14]. As a result of Project 035, a Pakistani counterpart of Project 035 for managing project activities was established as the Groundwater Development Organisation (GWDO) within the West Pakistan Department of Irrigation. GWDO was transferred to West Pakistan Water and Power Development Authority (WAPDA) in 1960, where it was reorganised in the form of Water and Soils Investigation Division.

The production of knowledge from Project 035 in the form of soil data and maps, water-table maps and hydrographs, exploratory well logs, water quality analysis and maps, and technical reports eventually fed into the design and construction of the first Salinity Control and Reclamation Program (SCARP 1) in 1961, a pilot project in the Chenab colony that was funded by a low-interest American loan (USAID 1984). The SCARP's solution, which had also been advocated even in the colonial period, was simple: install

[14] "The long-range objective of Project 035 was to build within the West Pakistan government an organization to train Pakistani personnel to carry out independently comprehensive and continuing soils and water-resources investigations required for effective management of these resources and increased agricultural production" (United States Department of the Interior 1976, 88).

public tubewells for vertical drainage that would lower the water table while providing additional water for irrigation. The WAPDA, an institution created to meet the preferences of the World Bank to manage the construction of surface infrastructure under the Indus Basin Plan, was also given charge of designing, monitoring, and implementing the public tubewell programs in consultation with the glut of foreign consultants assigned to the project (Michel 1967).

This was a time, immediately after the signing of the IWT of 1960, when foreign donors committed huge sums of money for the necessary infrastructure under the Indus Basin Plan, which involved the construction of multiple dams and barrages on the western rivers allocated to Pakistan to compensate for the loss of water from the eastern rivers allocated to India under the IWT. The post-treaty Cold War environment provided the perfect opportunity for then-President Ayub Khan of Pakistan to visit the US to lobby for more funding, highlighting his "concern with waterlogging and salinization which threatened the future of Pakistan's agriculture" (United States Department of Interior 1965, 89). US President Kennedy responded by appointing a special scientific presidential panel headed by Richard Revelle, who was then the Science Advisor to the US Secretary of Interior. The final report on the study, titled "Land and Water Development in the Indus Plain" but popularly known as "the Revelle Report", was published by the White House in 1964. The report emphasised approaches to lift agriculture in the Indus Plain above the subsistence level and set the area on the road to substantial productivity. The knowledge products from the Revelle Report led to the massive expansion of SCARP programs in the 1960s and 1970s and as many as 15,000 state-owned and -managed tubewells and the most comprehensive response to the issue of waterlogging and salinity in Punjab ever (White House-Department of the Interior Panel on Waterlogging and Salinity in West Pakistan 1964). These public tubewells were usually installed at the heads of tertiary water channels to supplement and compensate for irregular canal water supplies to village watercourses (Gilmartin 2015).

Ayub Khan's regime was particularly instrumental in facilitating both Pakistan's tube well revolution and the ensuing Green Revolution. Ayub's model of development attempted to base a "revolutionary Pakistani developmental nationalism on technocrat led development" in an effort to legitimise the seizure of power by the military regime (Akhter 2015, 71). Securing funding for the colossal Indus Basin Plan and achieving a

"breakthrough" in agricultural production through the Green Revolution were featured prominently in this period's development rhetoric. Indirectly, Ayub's 'decade of development' hinged on augmentation of water course availability from surface water resources (through the series of infrastructure works under the Indus Basin Plan), along with an increase in groundwater supplies through public investment in tubewells. The literature mentions time and again the massive infrastructure of the Indus Basin Plan as critical to cultivation of Pakistan's nationhood (Kirmani 1968). The role of groundwater development through tubewells in the success of the 'decade of development' and beyond is less discussed, but it deserves a closer look. The next section charts the trajectory of the public tubewell program, its recurrent operation and maintenance issues, and eventual privatisation. It also provides context for donor emphasis on and state facilitation of private tubewell development.

Trajectory of SCARP Program, Problems and Transition to Private sector

Public investment in tubewells for drainage was spent in the period between the 1960s and the 1990s. By 1985, WAPDA, with the help of its (mostly) foreign consultants, had completed 32 reclamation projects entailing the construction of 12,819 public tubewells and 2,131 miles of surface drains at the considerable cost of 4,955 million Pakistani rupees (Bhatti 1987). The literature does not analyse comprehensively whether the large-scale public investment in SCARP tubewells exclusively and decisively led to relief for the country's waterlogging and salinity woes. An evaluation report by the Overseas Development Authority UK, which provided 3.9 million GBPs' worth of tubewell linings for the program from 1976 to 1979, found the benefits of the SCARP program as a whole to be compromised: "The benefits from the SCARP programme as a whole were below potential. There was some reduction in waterlogging and soil salinity but there were signs that these gains might be reversed in future. Although agricultural production had increased the targeted improvement in yields had not been achieved" (DFID Evaluation Report 2004).

Textual and content analysis of World Bank Project Reports from the SCARP program and reports from the WAPDA Library in Lahore highlight considerable design, operation, and maintenance issues with the project. Institutional coordination among the federal government, WAPDA, foreign consultants, and provincial governments during

the project's life did not play out well. WAPDA, together with consultants, was responsible for planning, design, and construction of SCARP tubewells, after which these were handed over to the Provincial Irrigation Departments for maintenance. The Provincial Irrigation Departments were ill-equipped to handle the maintenance of public tubewells from either the expertise or the budgetary perspective (Directorate of Land Reclamation 1979; WAPDA 1981; 1988). The SCARP also suffered from persistent problems because of the design, maintenance, high operating costs of the tubewells, as well as the absenteeism of public tubewell operators in the late 1960s (Bhatti 1987). In addition, discussions with former WAPDA officials who had institutional memory of SCARP implementation highlighted that the foreign consultants hired for SCARP were largely divested from the "reality of farming communities and the on ground operational issues of public tubewells" (Personal Communication, Former Member Water WAPDA 2017).

The problems of SCARP tubewells came to the surface in the latter half of the 1960s and the 1970s, nudging the government into another World Bank program for disinvestment in public tubewells. It was ironic that while the Bank had funded the investment in the public tubewell program in the 1960s, the Bank also suggested and led the privatization and transition of ownership to communities of the same only two decades later. This transition took place in a series of 'public tubewell disinvestment' projects in the 1990s: SCARP Transition I, SCARP Transition 2 and the 'Punjab Private Groundwater Development Project' (World Bank 1996). In the late 1980s, a pilot project for the transition of SCARP tubewells was launched. The aim of the project was to replace high cost SCARP tubewells with shallow private sector tubewells that could pump for irrigation in fresh groundwater areas to achieve the drainage objective and keep water tables low for productive agriculture. Under the SCARP Transition Pilot Project, 213 SCARP tubewells were transferred and replaced by 2100 private tubewells, by providing necessary incentive and technical guidance to farmers. This was followed by the Second SCARP Transition project where a further 1353 SCARP tubewells were closed and replaced by 4700 private/community tubewells (WAPDA 1988; Jahangir, Qureshi, and Ali 2002). These projects were followed by Punjab Private Sector Groundwater Development Project launched by the Government of Punjab as the executing agency for the World Bank in 1997. The project aimed to achieve disinvestment of 4230 SCARP tubewells in fresh and saline groundwater areas and the

establishment of 6360 private tubewells owned by individuals/communities of farmers. The project sought to “redefine Government's role in groundwater development” and “achieved” its aims by disinvesting 4250 SCARP tubewells and replacing them with community tubewells (WAPDA 1984; Chaudhry and Young 1989). In addition, the project sought to develop a monitoring program and regulatory framework to ensure sustainable use of the groundwater resources, through the use of the newly created farmer organisations in maintaining the groundwater irrigation systems (as one component of decentralized water management reforms initiated by the Bank). However, this objective could not be materialized, and even though the Punjab Irrigation and Drainage Authority Act of 1997 lists groundwater management as a function of the FOs, in practice there was no community ownership of groundwater (Punjab Irrigation and Drainage Authority Act 1997). Evidence from detailed interviews with senior irrigation officials with institutional memory of the reforms indicate that the Bank tried to “create” a sense of local ownership for tubewells handed over to farmer community groups. Community ownership groups for takeover of public tubewells were often reported to have been hastily put together for the purpose of utilizing the government’s monetary subsidy for tubewell installation under the project and abandoned soon after the project ended: “Some of the community group of farmers made for takeover of state tubewells were bogus. If the World bank required a group of 10 farmers to take over the tubewell, in reality the group consisted of only 2-3 farmers who would take and submit identity cards of other farmers just to become eligible for ownership transfer” (Personal Communication with Director Social Enterprise and Management Unit Punjab Irrigation Department, 2016).

The change in World Bank’s vision for Pakistan’s groundwater governance from centralized development to decentralized development and management was in line with dominant global ideas for water governance. Earlier in the 1960s, the Bank had financed and led large-scale centralised investment in public tubewells in Punjab at a time when ideas of state planning and centralised management of irrigation were eminent in discourses of global irrigation development. However, this vision radically changed in the 1980s and 1990s as public institutions came to be seen as ‘inefficient’ and ‘profligate’ and ideas of decentralisation, community management and participation propagated by the Bank shaped the ideas for water governance globally (World Bank 1995). In the postcolonial period, the Bank has served as the conduit for the transfer of

dominant global ideas for water governance. The power of the Bank with respect to affecting the nature and problem of groundwater governance in post colonial and contemporary Punjab and its influence on formal state policy has been consistent, in large part due to its ability to offer loans for the much needed capacity building in the institutional apparatus of the state for 'improved' groundwater governance (Personal Communication, Former Chairman Planning and Development Department, Government of Punjab 2017).

5.3. Private Tubewell Development

In 1950, the Department of Agriculture reported only 177 private tubewells, all of which had been installed with assistance from the state since 1939 (Johnson 1989, 1). In subsequent decades, private tubewells played a greater role than public ones in increasing the share of groundwater in the overall irrigation mix. By 1996, Pakistan had about 300,000 private tubewells, most of them in Punjab. Groundwater had accounted for only 8 per cent of the total irrigation water in 1960 but went to 40 per cent in 1996 and 60 per cent in 2006 (Gilmartin 2015). As Gilmartin (2015, 240) comments, "the explosion of private tubewells seemed to suggest a new source of dynamism rooted in independent actions of individual irrigators themselves. And this was all the more critical, because this was a question that inevitably intersected…. with larger concerns not only of irrigation management but Pakistani statecraft as well."

While the state planned the investment in public tubewells through SCARP projects, the parallel growth of private tubewells mushroomed almost unnoticed until a survey was done in 1964. Most accounts of private tubewell development in Punjab document it as a "silent revolution" and attribute its phenomenal growth to the individual incentives of the farmers. I argue, contrary to the view that growth in private tubewells was not due entirely to tubewells' economic feasibility and profitability; instead, private groundwater development took place in the context of state facilitation through a mix of agricultural subsidies.

The Punjab government offered subsidies for private tubewell construction, power connection, drilling, and electricity tariffs during the Green Revolution in the 1960s and

1970s as an incentive for farmers to increase cropping intensity to meet the targets for agricultural growth that would stabilise the newly independent country (Pakistan Agricultural Research Council 1972). A tubewell construction subsidy of 16,000 rupees was given to small and marginal farmers at the tail ends of canals and rain-fed areas. A subsidy of 15,000 rupees was also provided for connection to the electricity grid, along with a subsidy for drilling costs extended by the Punjab Agriculture Engineering Department. In addition, a subsidy scheme introduced in 1972 was available to farmers, giving them a subsidy of 20 per cent on the cost of diesel used in diesel-operated tubewells. By April 1979, the diesel subsidy scheme had supported 11,500 tubewells at a cost of 132 million rupees (Anson 1984, 34). Agricultural tubewells were extended a subsidised electricity rate of 0.35 per kilowatt-hour, while non-agricultural customers paid 66 per cent more than the subsidised rate. In addition to direct subsidies, the Agriculture Development Bank of Pakistan (ADBP) provided institutional credit for private tubewell development. Between 1964 and 1981, the number of tubewells increased from 23,000 to 186,000, with an average increase of 9,500 tubewells each year. ABDP's loans contributed to approximately 20 per cent of the tubewell units installed each year (Anson 1984, 135).

Whether government subsidies had a causal effect on the explosive growth of private tubewells is not certain. One study finds that most of the farmers surveyed, especially those in canal-irrigated areas, stated that they would have invested in private tubewells even without the subsidy (Anson 1984). However, the state's subsidies for private groundwater development signalled the state's intent to harness groundwater resources for agricultural production and economic growth, keeping in mind groundwater's critical importance to the post-colonial hydraulic mission. Government policy for boosting the agricultural sector in the 1960s increased incentives for agricultural production, increased loans for tubewells and other farm inputs, and improved rural electrification – all of which increased demand for tubewells in Pakistan. Table 5.1 shows that the number of private tubewells increased more than eightfold during the five years from 1960 to 1965.

Table 5.1: Growth in Private Tubewells in the Early Post-Colonial Period

Private Tubewells Installed in West Pakistan 1948-1975/75	
Period	**Tubewells Installed**
1948/49-53/54	330
1954/55-59/60	975
1960/61-64/65	8,000
1965/66-69/70	12,050
1970/71-74/75	14,700
Total Installed in West Pakistan (1948-80)	**175,125**
Total Installed in Punjab (1948-80)	**154,468**

Source: Aftab and Rahim (2007)

The explosive growth of private tubewells was also greatly facilitated by the local manufacture and availability of diesel pumps and tubewells that occurred with the birth of a small-scale tubewell industry in Daska, Punjab (Aftab and Rahim 1986). Burgeoning private sector demand and demand from the public sector for pipes, pumps, and electric motors for providing municipal water supply gave rise to a local tubewell manufacturing industry in Daska. In 1949, BECO Pakistan obtained from a British firm designs for slow-speed diesel engines and imported the equipment needed for manufacturing. From 1952 to 1959, a partnership was set up with KSB AG, a West German firm that specialised in producing pumps and turbines. In the second half of the 1950s, BECO collaborated with American, British, and German firms to gain the technical knowledge needed for tubewell design and construction.

Part of the reason why the state extended subsidized private tubewells and other incentives as key mechanisms of governance lay in the high operational and maintenance costs of the public tubewell SCARP program. As early as 1965, only five

years after the start of the SCARP program, the government of Pakistan encouraged private tubewell development in its official development plan:

> Construction of private tube wells has been accelerating rapidly and is now estimated to be running at 6500 per year, of which two thirds are diesel operated. The rapid development of private tubewells now requires a new tactic – a strategy of public-private development. It is proposed to give private tubewells every assistance in the form of imports, credit and electrical connections. With such assistance, some 40,000 new tubewells can be expected during the plan period. (Government of Pakistan, Third Five Year Plan, 294)

At times of low flows of foreign aid, such as during the 1965 Indo-Pakistan war, the government was forced to reduce allocations for the public tubewell program and rely on private tubewells (Government of Pakistan, Fifth Five Year Plan, 324). Of the 32,000 private tubewells installed in the Fifth Plan period (1978-83), 5,800 were installed under the tubewell subsidy program. While SCARP tubewells had many operating and maintenance issues, government-assisted private tubewell development programs were doing well. Up to 1982-83, a subsidy of 211.6 million rupees had been given to farmers, with which 19,433 private tubewells were installed. In the Sixth Five Year Plan, an additional 102 million rupees were to be allocated as private tubewell subsidies for installation of 8,195 additional private tubewells, most of which were to be located in Punjab (Government of Pakistan, Sixth Five Year Plan). The Eighth Five Year Plan initiated no new public tubewell program in the Fresh Groundwater zones but that the program would be tackled exclusively through private sector. From then on, SCARP tubewells to alleviate waterlogging and salinity would be installed only in saline groundwater zones (Government of Pakistan, Eighth Five Year Plan 1993-98).

Notwithstanding the operation, maintenance and budgetary issues of SCARP that propelled the government towards privatisation of public tubewells, a major push for privatisation of state tubewells and to push groundwater development through private tubewells came from the World Bank. As Section 5.2.2 explains, in the 1980s the World Bank ‘advised’ the government to hand public tubewells over to willing farmers in the private sector under the SCARP Transition Project. The privatisation of SCARP tubewells and the emphasis on facilitating private tubewell development happened in the context of sector-wide irrigation management decentralisation institutional reforms

that were being implemented through Bank financing in the 1980s and 1990s in line with the Bank's overall policy of structural adjustment for Pakistan's economy (World Bank 1997; 2007). In this period, the language of most World Bank authored irrigation sector reports and country assessment strategy reports on Pakistan repeatedly identify 'low irrigation efficiency' and 'high water losses' as problems with the irrigation bureaucracy in Pakistan (World Bank 1984; 1995). The decentralisation reforms were aimed at "radical restructuring of the public sector institutions in favor of a decentralized, commercially oriented and participatory institutional framework for managing the irrigation and drainage system" (World Bank 1999, 21). The role of the Bank as the largest lender in the water resources development sector for Pakistan, and through the technical scientific expertise it offered, was thus critical in shaping the techniques and mechanisms of formal groundwater governance by the state (Qamar 2006). As this chapter documents, foreign aid and expertise most notably from the United States and through Bretton Woods institutions such as the Bank, was critical in initiating large-scale public groundwater development in the 1960s, and equally critical in shaping the transition to private sector led groundwater development over time in Punjab.

5.4. The State, Aid, Expertise, and Groundwater in the Post-Colonial Hydraulic Mission

The confluence of state-directed investment, foreign aid and expertise, and local lower-cost pumps in the early post-colonial period transformed the groundwater-society relationship in a way that had decisive consequences for the contemporary problem of groundwater governance in Punjab. Since independence, Pakistan has played a crucial role in the geopolitics of large dams because of the country's arid climate and long history of water resource development. Coordination among the US State Department, the World Bank, and US-based engineering firms played a key role in executing the Indus Basin Plan from the 1950s to the 1970s. The US often held out large infrastructure projects in Pakistan as bargaining chips to convince Pakistan's political leaders to reverse growing Chinese influence in the region. As US Attorney General Robert Kennedy remarked in 1963, "The US has so many problems with Pakistan that

holding out a *Tarbela* [dam] as a possible consolation prize may serve our political interests" (Kennedy 1963).

The high point in Pakistan's pursuit of the post-colonial hydraulic mission came about at when negotiations for the IWT were underway. The state emphasised ensuring food self-sufficiency, leveraging agriculture as a driver of economic growth, and increasing water availability to make up for the eastern rivers that would be lost to India under the IWT. A large part of the cultivatable area was affected by waterlogging and salinity, a menace that the Pakistani state had launched a series of efforts to solve, but without success. Pakistan's President Ayub Khan's request to President Kennedy was granted in the form of a dedicated panel of experts, headed by Richard Revelle, that designed a comprehensive solution to waterlogging woes in the form of public investment in tubewells.

The years between 1950 and 1975 were the heyday of national planning in South Asia. All South Asian countries, including Pakistan, wrote their national plans, stressing food self-sufficiency and addressing problems of national economic growth, poverty, and inequality. National economic planning for many of these post-colonial states faced serious financial, infrastructural, administrative, political, and intellectual constraints. These gaps were filled by external finance and expertise distributed strategically in the Cold War setting. External funding came in the form of grants and loans directly from countries that sought to wield influence on formal imperial territories, and indirectly from the richest countries (most notably the US) through the Bretton Woods institutions of the World Bank and the International Monetary Fund (IMF) (Ludden 2005). Realistically, national development regimes in South Asia were officially, but not operationally, independent territories in a global development regime during this time.

In the 1960s, a wave of agricultural intensification was launched that favoured investors and industry by increasing demand for inputs like fertilizer, high-yielding seeds, tractors, and tubewells, which increased rice and wheat yields and improved food security for national populations in South Asia. In a way, encouraging national governments to increase national wealth and food security by spreading a mix of new production technologies pushed by lavish state subsidies gave them the Green Revolution a strategic blueprint for development (Ludden 2005). This strategic

blueprint led most states to adopt development plans that called for expensive investment in improving agricultural inputs, including water availability. These extensive development and infrastructural projects demanded external financing in the form of aid and loans. Around the same time, lending to developing countries increased under Robert McNamara, president of the World Bank (Ludden 2005), but Pakistan's particularly sensitive geopolitical position meant that aid to the country, especially from the US, fluctuated with changing global political circumstances, as well as the nature of the political regime in Pakistan. Foreign aid and loans have played important roles in the pattern of growth, especially because of their influence on the development strategy (Lele and Nabi, 1991). While aid was important for overall growth, it was particularly critical for the development of water resources in Pakistan. The water resources sector led the country in aid and loan flows from independence to 2002 (Qamar 2006).

The first half of the 1960s was a period of high aid flows for both surface and groundwater resources. Pakistani politicians had been shy with aid in the first decade after independence, but Ayub Khan's military coup in 1958 led to an alliance between the military and the bureaucracy that made the aid partnership blossom (Lele and Nabi 1991). During this period, Pakistan enacted policies that emphasised growth without concern for equity, which the government planned to address in the latter half of the 1960s. Under Ayub, massive capital flows were channelled to the water and power sectors. The US government took the lead in developing a comprehensive strategy for agricultural development in the form of the Revelle Report, which was commissioned by President Kennedy.

The Indo-Pak war in 1965 and a slash in external resources meant some of plans had to be shelved and financial stringency imposed for many of the ongoing programs in the water resource sector. Pakistan remained in the US's political disfavour for the next fifteen years after 1965. Perhaps this disfavour synchronised with the shift in emphasis from state-owned tubewells to private tubewells. The 1970s saw the election of a populist government under Zulfiqar Ali Bhutto and the start of a difficult decade that included the separation of East Pakistan in 1971, oil price shocks in 1973, and nationalisation of industrial and financial sectors, leading to a decline in growth rate to 3.9 per cent. In 1979, the Soviet invasion of Afghanistan and Ayatollah Khomeini's ousting of the Shah of Iran put Pakistan back in the market for foreign aid. Under

President Zia ul Haq, Pakistan adopted a liberal economic strategy that encouraged privatisation and restored investors' confidence after the nationalisation of the 1970s. In the 1980s, the country's growth rate was restored to 6.6 per cent.

Pakistan was not unique in receiving aid flows and expertise for water resource development after independence. In the context of imperial disintegration and the emergence of US economic and technological predominance, the US State Department planned a developmental regime for South Asia's historical transition. The focal point of this regime, as Truman's Four Point Agenda suggested, made 'modernisation' an instrument of Cold War strategy (Cullather 2010). Cullather (2010) discusses the river valley projects in this wave of modernisation were the highlight of US efforts to shape Asia's transition. River valley projects proliferated across Asia in combination with national economic planning and planning ideology. By the end of the 1950s, Pakistan, India, Afghanistan, Sri Lanka, the Philippines, Burma, and Thailand each had its multi-year development plan and a river development project underway. Dams occupied a special place in these development plans (Cullather 2015, 110). For political leaders in America and Asia, the connection between big dams and state formation was straightforward, as "the panoramic wall of a dam was a screen on which they would project the future" (Cullather 2010, 110).

The transformational aspect of this 'concrete revolution' as referred to by Sneddon (2015) was deeply implicated in global geopolitics and the US foreign policy apparatus' efforts to exert influence over newly emerging nation states by providing technical and economic assistance (Sneddon 2015, 3). For most developing countries, technical assistance by the US focused on extensive river valley projects and dams, as was the case for Pakistan. However, Pakistan's productivity issue was not simply related to building more dams; it was equally and more gravely concerned with reclaiming almost a quarter of the country's cultivatable land that had been lost to waterlogging and salinity. This is where international aid contributed decisively to large-scale groundwater development not only in Punjab, but also in other parts of South Asia.

The transfer of technological knowledge regarding water resource development played a central role in solidifying geopolitical alliances between the American State and newly independent post-colonial regimes like Pakistan. Pakistan's case demonstrates

the flow of technical expertise from the US and the UK for water infrastructure projects under the Indus Basin Plan. Industrialised countries' companies had a vital role in the design, construction, and supervision of these large-scale irrigation schemes, with financing provided by international development banks. The same was true for the expertise provided under SCARP Projects. A textual review of SCARP project documents from the WAPDA Library archives shows that foreign consulting firms were engaged in preparing feasibility reports for, designing, and supervising construction for the SCARP public tube well program (SCARP 1 Annual Report 1965; Punjab, Land and Water Development Board 1971; Chaudhry and Young 1989). Most of the firms engaged in water projects in Pakistan were UK or US in origin. Notable among these are Timpton and Klambach (Denver, US), Hunting Technical Services and Sir Murdock MacDonalds (UK), Mott MacDonalds (UK), and Harza Engineering (Chicago, US). Harza Engineering was appointed by the US government to construct the surface water infrastructure post-IWT as a part of the Indus Basin Plan and was responsible for the design and construction of Mangla, one of Pakistan's two largest dams. These studies were sometimes a consequence of the grand strategic reports like the White House-Department of the Interior Panel on Waterlogging and Salinity in West Pakistan (1964), Harvard Water Resources Group Report (1965), and Leftinck Report (1967) that spelled out the direction for developing groundwater and tackling the issue of waterlogging.

5.5. Conclusion

The chapter highlights the role of the early post colonial state in achieving a breakthrough in large scale centralised groundwater development in Punjab. As conceptualised in the governance framework in Chapter 2, the state was supported in critical ways by foreign aid and expertise most notably from important non state actors such as the United States and international organisations such as USAID and World Bank. The interactions between state and non-state actors and the dynamics of aid, expertise and finances embedded in dominant global discourses for environmental governance were critical in pushing the initiation of large scale public groundwater development as well as the move towards predominantly private sector led groundwater development a few decades later. The hydraulic mission around groundwater was thus steered by the state, and shaped by non-state actors in important ways.

The hydraulic mission of the twentieth century was an extension of colonial governments' nineteenth-century drive for state-led irrigation development (Chapter 4). The British, French, and Dutch took up large-scale surface water irrigation development as a part of their colonial hydrology and hydro-imperialism (D'Souza 2006; Pritchard 2012). As Chapter 4 articulated, the British colonial government realised the value of experimenting with state-sponsored groundwater irrigation projects and encouraging private ones. Perhaps the seeds for postcolonial hydraulic mission around groundwater in India and Pakistan had already been sown by the Colonial Department of Agriculture's efforts as detailed in Chapter 4.

The analysis in this chapter provides a basis from which to contend with the treatment of the term 'hydraulic mission' in the literature, which is limited to studies of large-scale surface water infrastructure. The literature typically relegates groundwater to the status of a small-scale irrigation resource to be developed by individual farmers. However, we see examples of large-scale public development of groundwater by post-colonial states in countries like Pakistan, India, Bangladesh, and Spain. The argument for linking groundwater development to the hydraulic mission in Punjab also hinges on the critical role of groundwater in bringing about the Green Revolution. A growing body of work on the history of the Green Revolution in South Asia asserts that it is more a "tubewell revolution" than a wheat revolution (Repetto 1994; Shah 2007; Subramanian 2015). While investment in dams and canals have been central to the existing understanding of water and modernity in the literature, Subramanian (2015) shows how twentieth century irrigation (and associated agricultural productivity) is largely based on a move to small scale groundwater irrigation for the case of UP province of India. India and Pakistan have currently emerged as the largest groundwater users in the world, with the latter also as the worlds top groundwater exporter (Podgorski et al. 2017).

The pattern of post-colonial groundwater development experienced in Pakistan was not driven by a unique Pakistani experience; rather we see similar patterns of centralised groundwater development in other post-colonial newly independent states. As in the case of Punjab, there is evidence of the strong role of international finance and expertise by the World Bank in bringing about a breakthrough in large-scale groundwater development, as well as shaping the character of postcolonial groundwater governance

as a significant non-state actor. Like Punjab, post-colonial states in other parts of South Asia were also supported by international finance and expertise for centralised public groundwater development in the context of the Cold War. In the 1950s, the USGS came into India to offer technical expertise for groundwater development, enabled by President Truman's Point Four Program of 1948, as well as the Indo-US Technical Cooperation of 1952, both of which were part of the United State's overall strategy to use technical aid for Cold War diplomacy. As a result of US diplomatic efforts and the signing of the Indo-US Technical Cooperation, the All India Groundwater Exploration Project came into being in 1953, targeting fifteen soft-rock regions of India for groundwater exploration and development (Subramanian 2015). In the Indian province of UP, the largest public tubewell program had already been pioneered under colonial rule, and by 1946 the province had 1,800 government-owned tubewells, each serving 250-500 acres and managed centrally. In the post-colonial context, UP's groundwater development trajectory benefitted from the finance and expertise offered by the World Bank. In the 1960s, support from the World Bank came for expansion and improvement of the public tubewells in the province. From the 1970s on, financial support from the World Bank was geared towards both supporting private tubewell credit schemes geared to small farmers and rehabilitating and improving tubewells. By 1990, about 30,000 large public tubewells across UP had been constructed with support from the Dutch and the World Bank. Shah (2001) documents how the World Bank-financed public tubewells in the UP deteriorated a few years after beginning operations, which provided the impetus for development of private tubewells. Bangladesh (East Pakistan before 1971) also received assistance for its public tubewell development program from West Germany in the 1960s. During the 1970s and 1980s, the World Bank played a key role in groundwater development through its support of organisations like the Bangladesh Agricultural Development Corporation in the construction of deep public tubewells. Most of the deep tubewells in Bangladesh faced operational and capacity issues, so a range of institutional management solutions, such as farmer cooperatives and water usage associations, were explored to ensure their efficient use and sustainability, but these solutions were largely ineffective (Subramanian 2015).

How, then, does our understanding of the hydraulic mission change when we consider groundwater? How did the techniques of postcolonial groundwater governance transform the relationship between groundwater and society? By taking up large-scale

development of publicly owned and operated tubewells, the post-colonial state in Punjab altered the meaning of the groundwater-society relationship in three major ways. First, groundwater through public tubewells was being supplied by the state in a manner similar to the provision of surface water. However, farmers paid no dues for groundwater, whereas they had to pay *abiana* for the surface water. Second, the working of SCARP tubewells and the on-demand nature of groundwater encouraged farmers to adopt private pumps once the technology was locally available and feasible economically. Third, despite the privatisation of public SCARP tubewells, the state continued to support and facilitate farmers to use groundwater irrigation by 'governing at a distance' through a range of subsidies for private tubewell installation and operation and through agricultural subsidies, as detailed in this chapter. Perhaps the most profound effect of the state's intervention in the development of centralised groundwater schemes was the demonstration effect to the farmers. By the late 1960s, private tubewells outnumbered public tubewells, but public tubewells had already transformed how society valued groundwater. Technological advancement was also critical in transforming the groundwater-society relationship in the post-colonial period. Unlike in the colonial period, when land grantees found private tubewell development to be economically unfeasible, in the post-colonial period technological improvements and the availability of locally made pumps transformed the relationship between groundwater and society.

Many of the techniques of groundwater governance in the colonial period contributed to the boom in atomistic tubewell development in the post-colonial period. The legal rights to groundwater defined in the colonial period held that legal access to groundwater was linked to rights to private properly over land, so treating groundwater in this way, with little or no state oversight, effectively meant that the only cost of using groundwater was that of pumping it from the ground. While the cost of pumping groundwater was higher than the fixed *abiana* farmers paid for their allocation of canal water, they did not have to wait their turn to get water to irrigate their crops. The lack of flexibility in surface water supplies and the on-demand nature of private groundwater pumps made farmers willing to invest in the pumps, which led to the private pump boom.

This chapter showed how a decisive change in the history of groundwater development in the Indus Basin materialised because of the availability of international finance and

foreign expertise in the geopolitical context of the Cold War. Around the world, post-colonial third-world governments were pressed to deliver the fruits of development to their constituencies and to strengthen nation-building and legitimise their power (Molle et al. 2009). For many of these countries, including Pakistan, investment in irrigation and storage for surface water structures provided a path to agrarian and economic progress and the consequent fulfilment of their "hydraulic mission". Their mission was supported by states in the front line of the Cold War that had economic and geopolitical interests in fuelling this post-colonial hydraulic mission. As this chapter demonstrates, groundwater played a significant role in increasing the available water for irrigation and providing necessary inputs for the exponential increase in agricultural production brought during the Green Revolution in Punjab.

The consideration of groundwater as a part of the hydraulic mission of states has a number of implications for our current theoretical and empirical understanding of the term in the political ecology literature. In fact, one can argue that there are analogies to be drawn between the tubewell revolution and the 'concrete revolution'. Tubewells bring together political, economic, financial, ecological, hydrologic, and cultural processes, just as large dams and other mighty surface water structures do. The hydraulic mission around groundwater also entailed the use of subtle forms of power in a way that differs from that used in the hydraulic mission around dams and surface water infrastructure. Publicly owned and operated SCARP tubewells may not have been overt symbols of state power, but by providing a substantial increase in water availability through an on-demand source, pumps were a critical factor in increasing agricultural productivity during the Green Revolution and helping the newly independent state to establish its legitimacy through improved food self-sufficiency and economic progress. The implications of groundwater's contribution to the hydraulic mission for the existing theoretical understanding of the concept have been further taken up in Chapter 6 and 7.

6. Realities of Contemporary Groundwater Governance

6.1. Introduction

This chapter builds on the (hi)story of the groundwater-society relationship's transformation, as explained in Chapters 4 and 5, to relate it to the realities of contemporary groundwater governance. While the earlier chapters lay out the broad terrains of the political ecology of groundwater governance in Punjab, this chapter zooms in to gain an emic perspective of how groundwater governance plays out "on the ground." Based on extensive fieldwork conducted with farmers in the rice-wheat belt in District Sheikhupura of Punjab, the chapter reflects on the local dynamics of groundwater management and how these dynamics relate to the formal and informal governance structures at the local and higher levels of governance. The analysis explores the local political ecology of groundwater governance, focusing on questions of access to the resource and the distributive aspects of its governance by studying the power relationships between irrigators, between irrigators and the state, and between irrigators ad other informal "governors" of groundwater. By exploring the practice of governance on ground and linking it to governance at higher levels, the analysis reaffirms the thesis' main argument, which implicates the techniques of contemporary governance in the making of Punjab's groundwater crisis.

As detailed in Chapter 2, studies of groundwater in Pakistan are technical and discuss aggregate dimensions of the groundwater problem. This literature has variously explored the "drivers of groundwater use" (Mekonnen et al. 2016) or issues of groundwater governance, management, and over-exploitation mostly at a macro level (Basharat et al. 2014; Qureshi 2010; 2015; Shah 2007; Wattoo and Mughera 2016). Only a few studies analyse the groundwater governance problem at a local level to highlight how resource degradation impacts farmers' livelihoods. Of these, Khair, Mushtaq and Smith (2014) use a survey of tubewell owners and non-owners to reveal farmers' perceptions of the groundwater governance problem in the context of a depleting aquifer in Baluchistan province of Pakistan. Meinzein-Dick (1994; 1996)

analyses Pakistan's informal groundwater markets using district-level and micro-level data to examine the prevalence of and farmers' participation in informal groundwater water markets as a means of access to water. These studies use a quantitative methodology to explore the institutional and farm-level factors that affect groundwater access and development. However, there are few qualitative case studies that use a political ecology approach to reflect how groundwater is critical for farming communities and reflect on the power dynamics involved in accessing the resource, or the dimensions of marginalisation from resource degradation. Moreover, the literature sidesteps the question concerning how the local governance of groundwater—shaped across a multitude of actors, big and small, state and non-state—affects the degradation of groundwater resources, and how such degradation affects livelihoods in the context of the existing power dynamics, and how informal conservation initiatives, championed by commercial agribusinesses and multinational corporations, affect local communities. While some studies address these issues in a global or other geographic context (Boelens and Vos 2012; GRAIN 2012), studies of the Indus Basin do not explore how corporate conservation initiatives play out. This chapter follows the activities of one such water-efficiency initiative, run by the Mars, Inc., which sources rice from the Sheikhupura region for its Uncle Ben's sub-brand. The chapter's analysis undertakes to determine how these informal conservation activities, led by powerful non-state actors, interact with other groundwater users and with the formal state apparatus. The analysis draws attention to the role of MNCs, as non-state actors, in shaping the groundwater crisis and their contribution to the contemporary hydraulic mission.

This chapter draws on fieldwork in District Sheikhupura of Punjab with a range of groundwater "governors" (See Chapter 3 for a detailed methodology). A mix of research tools is used to delve into the breadth of the groundwater governance problem as it plays out on ground. Initially, I accessed rice farmers in Sheikhupura by following a water conservation project, WAPRO, run in the district by Helvetas Swiss International and Mars, Inc.. The WAPRO Project team accompanied me on my first two field visits, after which I was able to approach a more diverse group of farmers more independently through a local farmers' representative. Interviews and focus groups with farmers in the rice-wheat belt were conducted in two tail-end villages (Khushhalpura and Kathianwala) with a view to understanding how farmers cope with their dependence on groundwater in the face of deteriorating quality and quantity. I

conducted a short survey of 80 respondents to highlight the prevalence of informal groundwater markets as a means of access, especially in the face of resource degradation. In addition, interviews with local, provincial, and federal government officials helped to explain how problems at the district level are linked to policies (or the lack thereof) at the provincial and federal levels.

This chapter is structured in relation to three central themes. First, to clarify the local political ecology of groundwater governance, the chapter explores how the power relationships among groups of farmers influence their dependence on groundwater and their eventual adaptation to groundwater degradation (Section 6.2). Second, based on the theoretical framework set out in Chapter 2, this chapter analyses how the link between the local political ecology of groundwater and the techniques of governance deployed across multiple sites, scales, forces and "governors" of groundwater affects the contemporary groundwater crisis (Section 6.3). Third, the chapter substantiates the thesis' main argument by analysing how contemporary techniques of groundwater governance by state and non-state actors are implicated in the making of the current groundwater crisis. The chapter also delves into how the mix of techniques in the contemporary period further the state's hydraulic mission and reflects on how the character of the hydraulic mission around groundwater has evolved over time to encompass a larger role for non-state actors in contemporary Punjab (Section 6.4).

6.2 Groundwater Governance on the Ground

Fieldwork with irrigators in Sheikhupura revealed how groundwater is governed by a myriad of non-state actors as end users, how these irrigators as the on ground "governors" of groundwater relate to and interact with other more powerful non-state governors of groundwater, and how they are affected by the institutional and legal mechanisms of formal groundwater governance by the state at multiple levels. This section uses the primary data collected during fieldwork in Sheikhupura to ascertain the character of the local political ecology of groundwater, with a focus on questions about access to the resource and how its degradation is embedded in existing power dynamics.

6.2.1 Access to Groundwater

Interviews and focus group discussions with rice farmers on the extent of their groundwater use for irrigation revealed that the power relationships among groups of farmers influence their dependence on groundwater and their eventual adaptation to groundwater degradation. As conceptualised in the theoretical framework (Chapter 2), power is a social relationship built on the asymmetric distribution of resources and risks that manifests here in the interactions between groups of farmers, between farmers and the state, and between farmers and other non-state "governors" of groundwater. Local fieldwork was performed to tease out the social power relationships that mediate how groundwater is governed on the ground.

In Sheikhupura, as well as in Punjab at large, the level of dependence on groundwater for irrigation is a function of the availability of surface water supplies in canals. Canal water is distributed according to a system of *warabandi* (fixed turns), which distributes water using fixed weekly rotations to each cultivator in proportion to his cultivated area. In practice, the system of distribution of canal water does not guarantee equity for farmers, particularly those at the middle and tail ends of the canal (Jacoby and Mansuri 2018). It is common for farmers whose land is located at the upper ends of the canal to enlarge their outlets to increase the water discharge delivered to their fields. These head-end farmers often bribe the irrigation officials to avoid having to repair the outlet or bring it back to its original dimensions and to avoid being taken to court (Mustafa 2002; Rinaudo 2002). Influential farmers at the head end are often connected to higher-level irrigation officials or local politicians who can ensure a continued supply of more than a fair share of canal water. In return, local politicians rely on these influential farmers to garner votes from the rural population during elections (Personal Communication, Farmer Representative Sheikhupura). Most medium and small farmers feel powerless to contest their surface water allocation, which is routinely usurped because of tampering by head-end farmers. A small farmer in Khushhalpura village of Sheikhupura explained, "If we go and complain, no one listens to us. There is no point in getting into a fight. Better to use your own tubewell; one should help oneself rather than relying on these government officials."

As Chapter 1 explained, the unpredictability of canal water supplies and disproportional appropriation by head-end farmers translate into middle and tail-end farmers' dependence on groundwater in Sheikhupura to ensure timely and sufficient irrigation

supplies. Focus group discussions and interviews with farmers who cultivate lands at the middle and tail ends revealed that farmers use an average of 80 per cent groundwater and 20 per cent canal water. These results for groundwater's contribution to irrigation surpass official government statistics in Punjab, which estimate groundwater's contribution to irrigation at 60 per cent of total irrigation (Government of Pakistan 2015).

The mechanisms of access to groundwater for irrigation were similar in all three villages in Sheikhupura where the fieldwork took place. (See Chapter 3 for detailed methodology.) Farmers used two primary mechanisms of groundwater extraction: tubewells run on electricity, which the farmers referred to as "motors," and tubewells run on diesel, which they referred to as "*peter*". Each technology had its pros and cons: an electric tubewell was more expensive to install, costing USD $3,500 to $4,500 (in 2017 prices), along with hefty bribes to state departments to acquire electricity connections. In contrast, diesel-run tubewells were cheaper to install, requiring about USD $1,500 (in 2017 prices) in initial expenses. High initial investment costs and the difficulty of getting an electricity connection from the state authority explain why more than 86 per cent of farmers in Sheikhupura use diesel tubewells (Punjab Development Statistics 2016). While electric-powered tubewells had higher initial investment costs, their running costs were cheaper than diesel-powered tubewells, in part due to the state's electricity subsidy extended for agricultural groundwater users.

Groundwater irrigation through tubewells is critical for small farmers in tail-end villages like Khushhalpura, but groundwater is more expensive than canal irrigation in terms of initial installation expenses and running costs. Most farmers in Sheikhupura reported borrowing from local money-lenders or banks and even selling off household assets, such as livestock and jewellery to pay for the initial expenses of tubewell installation. To make matters worse, small farmers without a *sifarish* (political connection) had to bribe bank managers to approve their loans for tubewells. As a farmer in Kathianwala village remarked, "For every 100,000 rupees in a loan, you have to bribe the manager 10,000 rupees in cash" (Personal Communication 2017).

While private tubewells safeguard irrigators from the unpredictability of the amount of water available from canals, private groundwater irrigation through tubewells is

financially burdensome. In contrast to the contemporary period, where all of Sheikhupura's 31,015 tubewells are privately owned, state-owned SCARP tubewells were popular with the farmers in the 1960s, 1970s, and 1980s (Punjab Development Statistics 2016). A small farmer whose land was located at the middle of the canal expressed his nostalgia about the SCARP era, when tubewell water was *free*:

> "Before SCARP tubewells, the entire area was barren. SCARP brought prosperity to the farmers. We were very prosperous until the year 2000, when SCARP tubewells were taken out. During SCARP years, even smaller farmers were doing well. They did not have to bear diesel expenses for *peter* engines. After SCARP ended, some small farmers could not afford to install electric motors. Most of them use *peters* and have to bear heavy diesel expenses. In addition, we have to pay *maamla* (*abiana*) for canal water, which we don't even get a trickle of! *Abiana* is 200 rupees an acre every six months, so a farmer with 25 acres has to pay 5,000 rupees every six months in canal water charges, despite not getting any water!" (Personal Communication, 2017)

For small, cash-starved tail-end farmers who are heavily dependent on groundwater for irrigation, the high costs of tubewell installation and prohibitive maintenance expenses gave rise to other forms of tubewell use, sharing, and ownership patterns, many of which are not reflected in official statistics. Many small farmers who own less than twelve acres jointly own *peter* tubewells to save part of the initial investment costs. In such tubewell-sharing, farmers whose lands are located in close proximity to each other jointly pay for the installation of a diesel tubewell. The *peter* is the preferred technology for joint ownership, as it makes accounting easier; farmers use their own diesel during the time they irrigate and also contribute a proportionate share of any repair and maintenance expenses for the tubewell. Some large farmers also shared tubewells with their neighbours in areas where their holdings were fragmented such that, instead of incurring boring expenses for a small land holding of five acres, they 'ask' their neighbours for groundwater access.

While the discussion in chapter 5 highlighted the operational issues and inefficiencies of the SCARP tubewell program, the farmers with memory of SCARP tubewells remembered them fondly. Results from the field indicate that access to groundwater in practice is heavily contingent on groups of irrigators' economic power. In the same

vein, the response to groundwater degradation and the extent to which depleting groundwater levels and polluted aquifers marginalise farmers is embedded in power dynamics. The next section discusses the implications of the groundwater crisis for irrigators in the context of local power relationships.

6.2.2 Groundwater Degradation and Marginalisation

To add further complexity to how access to groundwater is affected by differences in power between irrigators, this study explores how irrigators adapted to groundwater degradation in terms of depleted groundwater levels and deteriorating quality. The relationship between surface water and groundwater irrigation and existing power relationships between head-end and tail-end farmers affect the latter's dependence on groundwater. Groundwater degradation and marginalisation are also related, as fieldwork in Sheikhupura showed that groundwater degradation is both the result of and the cause of some irrigators' marginalisation. As explained in section 6.2.1, when middle and tail-end farmers are marginalised by head-end farmers in their efforts to acquire their fair share of canal water, it increases their dependence on groundwater, leading to localised over-abstraction. Further, in the group of farmers who depend on groundwater irrigation, the smaller, cash-starved farmers are harder hit by falling groundwater levels than are more powerful groundwater users, such as multinational companies and large agribusinesses that have the economic power to drill deeper to access declining aquifer levels and better water quality. Smaller farmers, who typically own less than five acres, either make do with shallow, polluted groundwater or, if their tubewells fail to deliver, buy groundwater from water lords informally. Survey results with 80 farmers on the prevalence of informal groundwater markets indicate that 43 per cent of the respondents in tail-end villages reported to be engaged in water-buying or water-selling. Of those participating in informal water markets, a majority of water buyers (80 per cent) were small and medium sized farmers mostly with land up to 15 acres. Some large farmers sold tubewell water to as many as fifteen smaller farmers whose lands were close by to his landholding. Interviews in Kathianwala village in District Sheikhupura revealed that the standard payment for tubewell water for rice is 7000 rupees (approximately USD $70 in 2017 exchange rates), and that for wheat is 2000 rupees (USD $20 in 2017 exchange rates) per year (typically paid after the harvest season). The difference in the price of water between rice and wheat crops reflects the

rough difference in the amount of water that is needed to irrigate the crops. Water to the purchaser is released only after the bigger landlord fulfils his own irrigation requirement. The alternative to purchasing water from a waterlord is to borrow money from the local informal moneylenders, or *arhatis*, to pay for installation of own tubewell. Small farmers are hesitant to borrow from *arhatis*, as they charge a high interest rate and it does not make economic sense for many of them. As a small farmer who owned 2.5 acres of farmland in Kathianwala, explained "*Peter* installation costs are roughly 150,000 rupees (USD $1500) and will require diesel, etc. The value of crops from 2.5 acres will be a total of 150,000 to 200,000 rupees (USD $1500-2000) at most, so it is not feasible to borrow from *arhati* to get your own *peter* installed. Better to buy water" (Personal Communication, 2017)

Sustaining the expenses of buying groundwater from waterlords becomes more pronounced for cash starved small farmers who frequently need the support of *arhatis* (money lenders) to make payments for groundwater along with other farm inputs. As groundwater levels have been persistently, recent years have seen an increase in groundwater sale rates in these informal groundwater markets in line with the increase in energy prices from the government. As one water lord commented: "As the electricity prices go up, we have to increase water rates. Five years ago, water rates were Rs. 5000 for *munji* (rice) and 2000 rupees for *kanak* (wheat). Now we must increase water rates yearly" (Personal Communication, 2017). Dependence on buying groundwater in informal markets also tends to tie the buyer and seller together in a relationship that goes beyond cash sales. The direct out-of-pocket expenses for groundwater purchase in Sheikhupura must usually be supplemented by in-kind payments by water purchasers, which can include, but may not be limited to, performing farm activities free of charge, such as ploughing the water-seller's land and feeding his livestock. As one marginal farmer dependent on his neighbouring waterlord for groundwater explained, *"*We cannot say no to the person who supplies us with water for our crops"(Personal Communication, 2017).

The problem of declining groundwater levels and associated issues of access is one part of the groundwater crisis in Punjab that affects irrigators. Groundwater quality across Punjab is also deteriorating. Groundwater quality in the Sheikhupura area has rapidly declined because increased agricultural and industrial pollution. Chemical fertilizers and

pesticides used for cultivation percolate into the groundwater, contaminating the shallow aquifer. Industries routinely discharge untreated effluent, which directly affects the well-being of the local population. One of the ways of discharging effluents is to throw it in open drains. However, this method is usually feasible only for industries that are located closer to the drainage network; it is standard practice for most industrial units to construct unlined wells, or *khuwas*, in which to discharge their untreated effluent so it slowly percolates into the ground. This approach has resulted in severe contamination of the shallow aquifer in adjoining areas, making shallow water unfit for drinking and often even for irrigation. Interviews with farmers in Sheikhupura suggested that they were cognizant that water quality from depths of 50-100 feet is not suitable for crops because of the chemicals in the water. Larger farmers are able to overcome this issue by drilling deeper, with most large farmers boring tubewells up to 400 feet, while smaller farmers must usually make do with shallow, lower-quality groundwater for both irrigation and drinking to limit the costs of drilling and pumping. The local Public Health and Engineering Department charges 5000 rupees ($50) for groundwater quality testing to determine the depth at which water quality will be suitable for crops, but not all farmers can afford it, and even if they can, they cannot afford to drill deeper if the test says they must to find good-quality water. Some farmers rely on “tasting” the water themselves to determine the quality of groundwater and the required depth of their bore, but this method is hardly accurate. Interviews with leading tubewell drillers in the Sheikhupura area suggest that both local and multinational industries drill bores as deep as 900 feet to pump good-quality groundwater. The industry does not require a permit form the state to dig deep bores, and the amount of water pumped by an industry is not metered or recorded by any formal government institution (Personal Communication with City District Officer Public Health and Engineering Department Sheikhupura, 2017).

The case study of Sheikhupura shows that it is these power geometries and the social actors that are part of them that decide who will have access to and control over groundwater, and who is shielded from the ill effects of groundwater degradation and who is marginalised by the groundwater crisis. The discussion in this section highlights how the political ecology of groundwater governance is mediated by power differences between irrigators and is shaped by the relationship between irrigators and the state. It

also signals how in practice groundwater governance happens across a range of sites and is shaped by a range of forces, as the next section illustrates.

6.3. Multiples Sites, Forces, and "Governors" of Groundwater

Groundwater governance occurs on many levels across state and non-state actors, big and small, whose interactions are often bound in relationships that are not linear and are mostly multidirectional. This set-up is illustrated in the thesis' theoretical framework (Chapter 2) and is demonstrated in the case study of Sheikhupura. On one hand, groundwater is a decentralised resource where abstraction and pollution is governed by individuals. On the other hand, techniques of governance by powerful state and non-state actors actively shape how these groundwater users perceive and use the resource. This section links the local political ecology of groundwater access and degradation to the techniques of governance that occur at multiple levels and scales through both state and non-state actors by focusing on two types of governance: a) how techniques of governance by more powerful and visible non-state actors, particularly MNCs and international development organisations, shape the behaviour of irrigators as it relates to groundwater and work to affect the state's approach to groundwater; and b) how the formal state's mechanisms of governance in the form of legal, institutional, and policy functions (at various levels and scales of governance) shape the behaviour of a range of non-state actors. By examining these multiple sites, forces, and governors of groundwater, the analysis reflects the complexity of contemporary groundwater governance in Punjab. In this way, the chapter highlights the specificity of the groundwater governance problem (in relation to surface water) and contributes to the analytical framework for the political ecology of groundwater governance.

6.3.1. Irrigators and Other Non-State Actors

Apart from irrigators as "on-the-ground" local non-state governors of groundwater, other, sometimes more powerful, non-state actors seek to shape groundwater governance in Punjab. Of critical significance among these are multinational companies and international financial institutions that work to shape groundwater governance through their interactions with local irrigators and by influencing formal state policies that govern the resource. While the role of IFIs was discussed in Chapter 5, this section

delves into the techniques of governance that are advanced by multinational corporations. This is done by following a water conservation project initiated by Mars, Incorporated as a corporate social responsibility project for making their rice supply chain in Sheikhupura more sustainable, The project, named "Water Productivity" (WAPRO), was steered by Helvetas Swiss Intercooperation, a Swiss development agency, in partnership with Mars, Inc., owner of the world's largest global rice brand, "Uncle Ben's." For Mars, the goal of the project was to reduce the environmental footprint of its rice, which is sourced from farmers in Sheikhupura, under the standards of the Sustainable Rice Platform, which is the first-ever global standard for sustainable rice. The WAPRO Project encourages efficient water use in rice farming by increasing farmers' awareness of the need, and the use of better technology. As a local implementing partner in Sheikhupura, Rice Partners Limited (RPL) works with farmers on the field level. RPL runs field training and education activities with farmers and manages the contracting, procurement, and quality assessment of rice to be exported to Mars, Inc.

The WAPRO project typically involved conducting a series of training sessions with contracted rice farmers to educate them on techniques for water efficiency. Rice farmers contracted by Mars were encouraged to use water-saving techniques like direct seeding of rice (DSR), alternative wed drying (AWD) and laser land levelling. By accompanying RPL staff on initial training rounds for its contracted farmers, I was a non-participant observer in these sessions. The typical training session included distribution of brochures advocating water productivity in the local language of Urdu, speeches made by Helvetas, Inc., and RPL staff taking photos for the project's annual report, ending with serving *biryani*, a local rice and meat dish. Follow-up interviews with RPL staff and focus group discussions with farmers revealed the efficiency and equity implications of the field activities under WAPRO. The contracted farmers enter into a contract to supply Mars with rice for the upcoming year, a preferred option for farmers not least because it feels "important" when "white people" come to a meeting of which they are a part (Personal Communication with Large Farmer in Chak Sekham, 2017). Farmers get a higher rate (roughly a dollar per *maund*) from RPL when they sell their rice to Mars, as opposed to selling in the open market. However, to reduce transaction costs of sourcing the rice, RPL deals mostly with large farmers. In the sample of rice farmers that supplied RPL over the 2016-2017 period, only a handful of

farmers farmed less than twelve acres. Large farmers have more resources with which to access the desired inputs for production of premium rice, as well as better ability to cope with droughts or pest attacks, hence ensuring a smoother supply of rice for Mars. In addition, large farmers have more resources to engage in modern irrigation systems, such as laser land levelling and drip irrigation for efficient water use, thus checking the boxes for making rice production "sustainable."

Image 6.1 and 6.2: Educating Farmers about Water Conservation under WAPRO

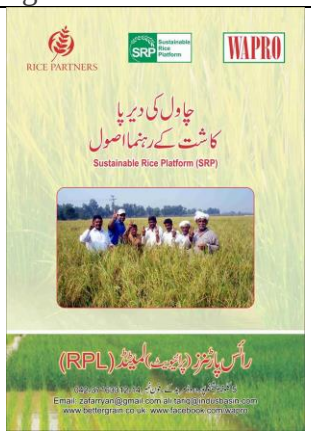


Image 6.1: Farmers posing with "V" hand sign after receiving the WAPRO Project's information leaflet

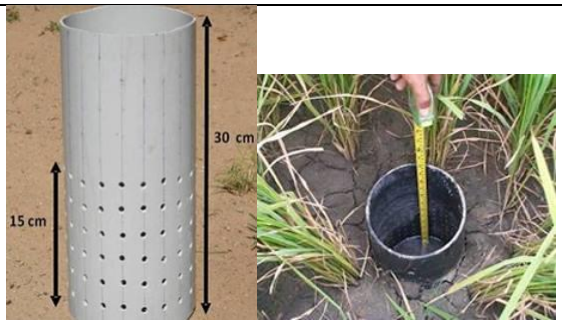


Image 6.2: Water Saving Tubes that indicate soil moisture and water levels, distributed by RPL

The distributive effects of the water-saving technology advocated under the WAPRO Project also tended to work against the poor farmers. RPL recommended laser land levelling before cultivation to ensure water efficiency, but most small farmers cannot spare the cash to rent a laser land leveller for their fields. The smaller farmers enrolled with RPL were also unable to take advantage of the water-saving technology supplied to them. Perforated water mark tubes, referred to as AW tubes, were given out to farmers to help them determine when to irrigate their rice crop (Figure 6.2). When obliged to use the AW tubes to reduce unnecessary use of water, contracted farmers, whether large or small, did not find them useful. Large farmers with plentiful water supplies found it inconvenient to check water levels in the AW tubes every day, preferring just to give plentiful water to the crop, while smaller farmers were too involved with menial tasks to take full advantage of the AW tubes. Moreover, despite rounds of training on water efficiency, local knowledge and conventional wisdom among rice farmers holds that

"one should not let the fields dry even for a day while cultivating rice," so they over-irrigate as a precaution (Farmer, Kathianwala, 2017).

How do such local (ground)water conservation initiatives championed by multinational corporations relate to the governance of groundwater at higher levels of formal governance? How do multinational companies position themselves as advocating for water conservation in their interactions with provincial and federal institutions and other non-state actors, such as international development institutions and international NGOs? Multinational corporations, in partnership with development agencies, are trying to change how groundwater is governed on the ground, mostly as a part of their corporate social responsibility efforts towards branding their products as "sustainable." The techniques of governance corporations use are aimed towards educating local irrigators about water use and affecting perceptions of water use at the top levels of governance. These goals became evident when I attended a water stewardship stakeholder meeting chaired by the Director of WWF Pakistan, sponsored by Nestle Pakistan and in honour of representatives visiting from the Alliance for Water Stewardship Standard headquarters. Those in attendance discussed Punjab's groundwater exploitation problem and put forth prescriptive solutions. The participants in the meeting fulfilled the participation criteria typical of development agencies and checked all the relevant stakeholder boxes – industry, academia, a local government representative, research organisations, international NGOs — and also included farmer to get a grassroots perspective. The meeting frequently referred to the agricultural sector as responsible for 93 per cent of all groundwater use in Punjab, followed by the need to educate farmers about the efficient water practices embedded in processes like those endorsed by the Sustainable Rice Platform and the WAPRO Project. However, water-intensive use of groundwater by corporations and the resulting pollution was not mentioned, and the issue of industrial water (ab)use was almost masked behind the list of water stewardship standards to which multinational like Mars and Nestle increasingly subscribe. The farmer representative in the meeting was asked to speak to the group about how the WAPRO Project has benefitted him and, of course, his speech about the WAPRO project had transformed the lives of farmers like him contained all the praise his audience was expecting to hear. In a follow-up conversation with the farmer, I found out that he is one of the large well-to-do farmers who doubles as a water lord.

Other multinational companies with extensive groundwater use, such as Nestle, Coca-Cola, and Pepsi Co. International have also jumped on the sustainable production bandwagon, and many have come up with their own plans for reducing the water footprint of their operations (Coca Cola 2018; Pepsico Pakistan 2018). This is partly to mitigate the growing concerns around industrial groundwater use. The rise of multinational corporations as significant "governors" of groundwater has complicated the policy space in Punjab. Multinational companies like Nestle and Mars that are engaged in virtual water exports are increasingly seen as important stakeholders in Pakistan's economy, which frequently gives them leverage to shape ideas in the formal governance policymaking space. For instance, during my year of fieldwork, Nestle Pakistan frequently collaborated with the Government of Punjab in holding seminars to engage with and discuss plans for sustainable water use in the country. These meetings often showcase the water stewardship standards that Nestle follows, strongly suggesting that Nestle is the industry leader in championing sustainable water use and that other sectors should implement similar reforms. Knowledge creation, advocacy, and engagement with important stakeholders is one of Nestle's key strategies to be seen as a conservation activist. As the company's Head of Corporate Social Responsibility (CSR) remarked, "Nestle's global introduction of bottled water products were initiated with the Sheikhupura factory. Because this was the birthplace of bottled water, it stirred a lot of negative propaganda in international media. That is why we thought we should come out and tell the *truth* through our research and advocacy activities" (Personal Communication with Nestle Pakistan CSR Head, 2017.

Multinational companies are central to Pakistan's economic growth and job creation process, so their voices are heard in policy circles. Therefore, it is common for them to push for national policies that favour agricultural exports and promote water markets in the name of efficient water use. As the case of Sheikhupura illustrates, the efficacy of such policies is questionable. Existing literature drawing on other case studies also suggests that MNC activities for water development and conservation can further marginalise and disempower local communities (c.f. Boelens and Vos 2012; Vos and Boelens 2014; Vos and Hinojosa 2016).

6.2.2. Irrigators and the State

How does the reality of groundwater use on the ground connect with the mechanisms of formal governance and state policies for groundwater abstraction at the local, provincial, and national levels? Through what techniques and mechanisms does the state affect other "governors" of groundwater? What are the existing institutional, legal, and policy apparatuses for formal governance of groundwater? Local fieldwork in Sheikhupura followed up on the irrigators' responses about their interactions with the state by interviewing government authorities at various levels (local, provincial and federal) to relate the reality of how groundwater is "governed" in practice to the mechanisms of formal governance that exist to manage the resource in the contemporary period.

In Sheikhupura, as well in Punjab at large, groundwater access, use, and management are primarily the responsibility of the end user. The only point of contact between the irrigators and the state in the contemporary governance setting is that which takes place in acquiring an electricity connection. Since more than 86 per cent of tubewells in Sheikhupura are based on diesel, only a small percentage of the farmers interact with the state on the question of groundwater (Punjab Development Statistics 2016). Many farmers reported that government subsidies for electric tubewells and for diesel have been phased out over the years. Moreover, whenever electricity subsidies in recent years, they were implemented inconsistently. As the *lambardaar* (head) of Kathianwala village, who owns an electric tubewell, explained:

> "Government policies are extremely haphazard. Last year crop prices were low, so the government gave subsidies in the form of concessions on electricity charges to farmers who had electric tubewells, and we got some relief that year. But this year, they put all of last year's subsidised bills back onto our electricity bills and sent us escalated amounts to be paid. What choice do we have except to pay the bill? If we don't pay the bill or contest it, they will take away the motors."

Various district-level government departments in Sheikhupura district, including the Irrigation Department, the Environment Department, the Public Health and Engineering Department (PHED), and the Agriculture Department, are supposed to deal with the question of groundwater management. The District Irrigation Department is entrusted with the task of managing water supply rotations for surface water at the watercourse

level and for collecting canal water dues, but it does not address the issues of groundwater over-abstraction or pollution. The PHED is the local government body that is responsible for the construction and maintenance of water supply schemes and monitoring of water quality and groundwater levels in rural areas. In interviews with the PHED staff, when I inquired about the interaction of groundwater users with the state, particularly the need for a license before the installation of a tubewell, the chief district officer said there was "no need to get any permission from PHED, of course; it is their private matter" (Personal Communication, City District Officer PHED Sheikhupura, 2017). Despite managing municipal water supply schemes based on groundwater, the PHED staff clearly regarded groundwater governance to be beyond their purview: "There is no policy even at the provincial level, so how can we manage groundwater? We don't have the capacity to undertake comprehensive management of groundwater. We are only mandated to install water supply schemes in rural areas" (Sub District Officer, PHED Sheikhupura 2017)

Staff at two other district-level government offices, the District Industries Department and the District Environment Protection Department, also affirmed that either groundwater issues were beyond their responsibility or they did not have the capacity to monitor it. As a sub-inspector at the District Environment Protection Department of Sheikhupura emphasised:

> "There are 769 industrial units in Sheikhupura alone and only two environment inspectors to monitor compliance. What can just two people do? We visit factories only when we get a complaint from either the top (provincial government) or from the local residents or neighbouring factories. We report a violation to the Punjab Environment Tribunal, which then holds a trial to decide the case, but that is no good because there are hundreds of thousands of cases already pending in the Environment Tribunal."

State institutions at the district level consider groundwater to be beyond their purview and mostly a "private matter" of irrigators, and interviews at the provincial and federal level revealed a similar story. Most of the elaborate state irrigation bureaucracy at the provincial and federal levels manages and distributes surface water, not the aquifer. Some monitoring and management still happens in silos with considerable institutional overlap and confusion about where the responsibility for groundwater conservation lies.

At the provincial level, groundwater is the responsibility of the Punjab Irrigation Department and the Punjab Agriculture Department. The Irrigation Research Institute, which lies within the Punjab Irrigation Department, does extensive research on groundwater hydrology, pollution, and over-abstraction, but in practice these government departments at the provincial level do not consider groundwater management as falling into their sets of responsibilities. Similarly, while the pollution of water bodies like lakes, rivers, oceans, and aquifers is generally considered to be within the purview of the Punjab Environment Protection Department (EPD), in practice the EPD has little to do with groundwater. As its former Secretary remarked, "We don't have the capacity to regularly monitor industry's compliance with effluent treatment standards" (Personal Communication, Secretary Environment Government of Punjab, 2017). Following up on the question of industrial groundwater pollution with the Punjab Industries Department revealed that most of the staff perceived groundwater use to be outside their purview. As the Secretary of Industries explained during an interview, "The Industries Department is concerned with the development of the industrial sector, while pollution control and management are a task that should be handled by the Environment Protection Department" (Personal Communication, Secretary Industries Government of Punjab, 2017). Interviews with senior officials in the Punjab Irrigation Department and the Punjab Environment Protection Department reveal that the state's functions with respect to groundwater rely largely on funds from international donor projects. In the post-colonial period, state institutions for the development and conservation of groundwater have usually been created in existing government departments to manage a groundwater-related component of a donor-funded project and become dysfunctional as soon as the project money dries up (Personal interview with the Director of the Social Enterprise and Management Unit, Punjab Irrigation Department, 2016). In effect, the state apparatus at the district and provincial levels does not currently shoulder a permanent institutional responsibility for managing groundwater.

Notwithstanding the lack of clearly defined institutional responsibility for formal groundwater governance by the state, its legal apparatus for groundwater governance is also in disarray. Contemporary legislation on groundwater rights and entitlements is based on colonial law and a jumble of post-colonial amendments to it. The most decisive change in legal entitlements to groundwater in Punjab was brought about by

the colonial state, which still de facto defines groundwater use in the province. In pre-colonial times, customary law in various forms governed groundwater water use based largely on community, rather than individual, rights to water. This approach changed with the introduction of the Indian Easements Act in 1882, which tied groundwater rights to private property rights over land, effectively treating groundwater as the landowner's private matter. During the post-independence period, the state passed a number of laws for groundwater management. The Punjab Soil Reclamation Act of 1952 set up a Soil Reclamation Board, which was established to control the problems of waterlogging and salinity that affected fertile lands in the newly independent country. The key responsibilities of the Soil Reclamation Board included issuing licenses to landowners to install private tubewells for pre-determined land reclamation areas, but the Board was suspended after a few years, and the responsibilities shifted to the Provincial Irrigation Departments. After the establishment of the Water and Power Development Authority (WAPDA) under the Pakistan and Power Development Authority Act in 1958, the responsibility for groundwater development and monitoring rested with WAPDA under the World Bank-sponsored SCARP programs (Chapter 5). Further, in 1997 the Provincial Irrigation and Drainage Authority Act, which was passed as a prerequisite to decentralising irrigation management, placed groundwater management with communities of farmer organisations. However, as with other post-colonial legislation that addressed groundwater, the 1997 PIDA Act was largely lip service to the community management and ownership of groundwater, and it saw little follow-up or implementation (Personal interview with Muhammad Javaid, Director of the Social Enterprise and Management Unit, Punjab Irrigation Department 2016). Despite a series of legal provisions and amendments to the constitution, none of the post-independence legislation around groundwater has been implemented (Steenbergen and Gohar 2005).

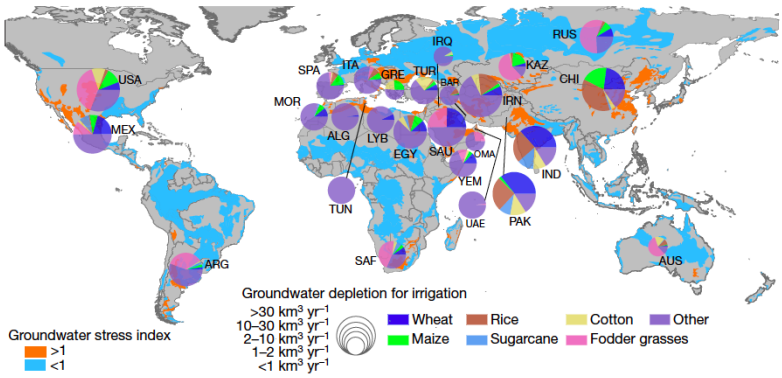
A blend of colonial and post-colonial legislation on groundwater has also generated confusion among state authorities regarding the division of the federal, provincial, and local responsibilities for groundwater governance in the contemporary period. Water is a provincial subject in Pakistan, although it can be developed and regulated by two federal bodies - the Council of Common Interests and WAPDA. The Water and Power Development Authority Act of 1958 gave the federal body a mandate to develop water resources in Pakistan with consent from the provinces. In the provinces, the control over

groundwater, pollution, and over-exploitation lies with the respective Provincial Irrigation Departments, granted by a 2006 Amendment to the Canal and Drainage Act of 1873. A senior irrigation officer at the Punjab Irrigation Department reported that, although provincial governments theoretically have the mandate to intervene in cases of groundwater over-exploitation, in practice this mandate has rarely been invoked. At the district level, local governments in rural and municipal areas have the right to regulate the use of private water sources and tubewells for drinking water (Local Government Ordinance 2001). However, this mandate of the local government impinges on the rights of property granted by the Indian Easements Act of 1882, which effectively grants unchecked private ownership of the common pool of groundwater resources that flow under the land to its owner.

The institutional and legal apparatus of the state in the contemporary period facilitates non-state actors in their private exploitation of groundwater. In addition, state policies that are intended to stimulate Pakistan's agriculture sector have created perverse incentives for groundwater over-abstraction through the mix of agricultural subsidies historically (as detailed in Chapter 5) and in the contemporary period. The agricultural sector has strategic importance for Pakistan and Punjab's economy, as the sector currently contributes about 21 per cent of the country's GDP while employing 45 per cent of the labour force and contributes 80 per cent of Pakistan's export earnings (including forward links to agriculture-based industries like the textile industry) (Economic Survey of Pakistan 2018). Since the early post-colonial period, the government has extended heavy subsidies to the use of agricultural inputs like fertilizers, pesticides, tubewells, tractors, and improved seeds in an effort to boost growth in the agriculture sector. Although these subsidies were phased out under the IMF's structural adjustment program in the 1990s, important exceptions are in place for wheat, sugar, and fertilizers in the contemporary period (Dorosh and Salam 2007; Pursell, Khan, and Gulzar 2011). In 2016-17, the government gave out 25,098 million rupees in fertilizer subsidies, which amounted to about 15 per cent of total subsidy budget for that year (Federal Budget 2017-18: Budget in Brief 2017). The fertilizer subsidy is the largest subsidy in the subsidy budget, with wheat and sugar subsidies falling into the second position (Federal Budget 2017-18: Budget in Brief 2017).

The techniques of formal governance for groundwater are layered with politics and power dynamics, enabling powerful non-state actors and multinational corporations to benefit disproportionately from groundwater over-exploitation. Favourable wheat and sugar subsidies, often established to benefit the capitalist interests of the ruling political elites, as well as attractive export subsidies for rice, have distorted economic incentives to cultivate these crops. Rice is Pakistan's second-largest export commodity, yielding the government about $2 billion annually in foreign exchange (*The Express Tribune* 2017). Rice exporters have continually lobbied the government for subsidies on seed, water, diesel, and electricity so the "cost of paddy will be reduced and exporters can compete in the world market" (*Business Recorder* 2017). The cropping patterns of cotton-growing districts in Punjab, such as Rahim Yar Khan, Bahawalpur, and Multan, have shifted towards growing sugar cane because of the artificially inflated support price of sugar, despite the heavy water requirement of the crop (Personal interview with the Former Secretary for Agriculture Punjab, 2017). The government also supports the key water-intensive agriculture-based export sectors of textiles, leather, sports goods, surgical goods, and carpets through its "zero rated regime" (*The News* 2017). Pakistan's government is also trying to increase exports of highly water-intensive halal meat to Gulf countries and China (*Dawn Newspaper* 2018). In summary, the agriculture and economic policy places considerable emphasis on water-intensive agribusiness production and export, facilitating allocation of precious groundwater resources based on users' ability to extract.

Figure 6.1: Groundwater Depletion by Major Agricultural Crops



Source: Dalin et al. 2017

Formal governance in the contemporary period is largely a mix of state subsidies and trade policy incentives that encourage cultivation and export of water-intensive

products. The nature of such governance has led to Pakistan's emergence as the top groundwater exporter in the world, ahead of the United States and India (Dalin et al. 2017). About 11 per cent of the use of non-renewable groundwater for irrigation is by the international food trade, of which two-thirds is exported by Pakistan, the United States, and India (Dalin et al. 2017). Figure 6.1 shows the fractions of groundwater depletion that are attributed to irrigation of major crops by country. For Pakistan, the cultivation of rice, wheat, sugarcane, and cotton accounts for a major share of the use of non-renewable groundwater.

6.4. Conclusion: Contemporary Groundwater Governance and the Hydraulic Mission

Examining the dynamics of local groundwater governance in Sheikhupura and studying the multiple levels and sites where governance of this resource takes place reveals the complexity of groundwater governance, as reflected theoretically in the framework described in Chapter 2 and practically in this chapter. The chapter shows how myriad state and non-state actors and the interactions between them across levels and sites within Punjab's broader political and economic context shape the character and complexity of groundwater governance in the contemporary period. By exploring the power dynamics involved in access to groundwater and its degradation, the analysis teases out questions that are central to the political ecology of groundwater governance. In addition, the analysis delves into how corporate conservation initiatives affect irrigators on the ground and how corporations affect the rhetoric and policy around water conservation and productivity in their interactions with higher levels of the government.

The chapter augments the political ecology study of groundwater governance by investigating the local power dynamics involved in access to, degradation of, and conservation of groundwater and how they relate to the mechanisms of formal and informal groundwater governance across levels and scales. Thus, the chapter is the thread that stitches the macro analyses in chapters 4 and 5 to the realities of contemporary groundwater governance to address the questions that are central to a study of political ecology. The analysis in the chapter reaffirms the overall argument of the thesis about the nature of governance playing an active role in the creation of the

contemporary groundwater crisis by illustrating how various aspects of formal and informal groundwater governance in Punjab practically work towards facilitating groundwater overexploitation – through the myriad of techniques - formal state policies, institutional and legal apparatus of the state at federal, provincial and local levels, corporate social responsibility initiatives for sustainable groundwater use by corporations often in partnership with international NGOs and international development institutions. The chapter also reaffirms the key argument of the thesis by corroborating the role of groundwater in the contemporary hydraulic mission. Groundwater helped to fulfil the state's hydraulic mission in relation to the goal of maximising water resource development for national social and economic development through water intensive exports. However, the nature of the hydraulic mission using groundwater has changed over time when compared to the colonial and early postcolonial period. In the contemporary period, the location of who drives hydraulic mission has changed with an increasing role for non-state actors, including IFIs and MNCs, in shaping good governance for groundwater.

The literature defines the concept of the hydraulic mission as typically concerned with investment in large-scale surface water infrastructure, led by the state's hydraulic bureaucracy. The notion of the hydraulic mission in the literature is almost synchronous with direct state involvement in harnessing water resources for national progress (Molle et al 2009). The case of groundwater development in Punjab shows how the nature of the hydraulic mission around groundwater was initially led by centralised, large-scale public tubewell development through SCARPS but eventually gave the reins of groundwater development to non-state actors (Chapter 5). In the early post-colonial and contemporary periods, the formal state's institutional, legal, and policy techniques of governance have consistently facilitated private groundwater development through non-state actors. By delving into the character of Punjab's contemporary groundwater governance and the increased importance of non-state actors, this chapter extends the hydraulic mission concept away from fixation on the state as the key driver of the hydraulic mission. The case of contemporary governance of groundwater in Punjab, as discussed in this chapter, shows how the hydraulic mission is increasingly steered by non-state actors in a capitalist economy.

This chapter also highlights how the concept of the hydraulic mission in the literature and the mission's obsession with "not a single drop of water should reach the sea without being put to work for the benefit of Man" (Molle et al. 2009, 332) masks the power inequities inherent in working towards the mission. The chapter shows how power differences between state and non-state and between non-state actors themselves have disparate benefits for groups in the pursuit of the hydraulic mission. As conceptualised in the theoretical chapter, power is a social relationship built on the asymmetric distribution of resources and risks that manifests in the interactions between groups of farmers, between farmers and the state, and between farmers and other non-state "governors" of groundwater. The implications of the empirical analysis in this chapter, together with the analysis from the colonial and early postcolonial period, for the existing conception of hydraulic mission have been further taken up in the concluding chapter (Chapter 7).

7. Conclusion, Theoretical and Policy Implications

7.1. Review of Empirical Findings

This thesis contributes towards understanding the global groundwater crisis, through an exploration of the role of groundwater governance. While the thesis does not refute other alternative explanations of the global groundwater crisis – such as the nature of groundwater as a common pool resource; property right regimes for groundwater use; or the groundwater crisis being a product of capitalist economic relations and technologies of abstraction – the main argument of the thesis is about the role of governance, particularly through the role of the state and state projects of economic development, in the making of the groundwater crisis. The study deployed a historical case study approach and a consideration of the broader political economy processes to analyze the ways in which the techniques of groundwater governance have contributed to the groundwater crisis across the colonial, postcolonial and contemporary periods in Pakistan's Punjab. This thesis departs from existing technical and managerial accounts of governance that simply allude to the need for "good governance" as the "solution" to the groundwater crisis in Punjab as well as globally. Rather, the central argument of the thesis is that the techniques and mechanisms of governance over time – arising from the interaction between formal state apparatus and informal non-state governors - have played an active role in the creation of the contemporary groundwater crisis. In this way, using insights from the empirical analysis conducted for the case of Punjab, the thesis contributes to an understanding of how processes of governance affect the global groundwater crisis.

As highlighted in Chapter 2, existing research on water governance has extensively focused on the relationship between the social control of water and forms of state power/legitimacy in the context of centralized development of surface water infrastructure, but does not pay attention to the power and politics associated with groundwater governance. The major theoretical contribution of the thesis, based on the theoretical framework proposed (Chapter 2) is the emphasis on the mutually constitutive relationship between groundwater and the state's developmental goals. The empirical

analysis and methodology used for each historical period substantiates the main argument in important ways. For the colonial period, the study analyses the strategic importance of groundwater in contributing to the 'colonial hydrology' in Punjab under British rule until 1947. For the postcolonial period, the study examines groundwater's role in the newly independent Pakistani state's post-colonial 'hydraulic mission' after 1947. For the contemporary period, the thesis highlights how the location of the state's hydraulic mission around groundwater has changed in favour of private groundwater development in the context of Punjab's water intensive export economy, and the increased importance of non-state actors and private enterprise in shaping groundwater's contribution to the hydraulic mission. For each of the historical periods the thesis has contributed to an understanding of how groundwater affects governance, by fulfilling various imperatives of the state (hence emphasizing the agency of groundwater itself) – and in turn how techniques of governance affect groundwater as a resource.

The empirical analysis in each chapter analyzes the strategic importance of groundwater for the state in each of the historical periods, and how this in turn shapes the response of the state and the techniques of groundwater governance. Chapter 4 explores how the colonial approach to governance was shaped in response to the increasing importance of groundwater for the colonial state– groundwater served as a buffer against prevention of famines in the early twentieth century, for irrigating areas not served by canals and for winter crops when canal flows decline, for relieving the problem of waterlogging and salinity that affected agricultural productivity at the time, and as an additional means of enhancing irrigation by private enterprise at little or no cost to the state. Chapter 5 delves into the postcolonial period where groundwater development again plays a decisive role in contributing to postcolonial state-building efforts - through the partnership between the developmental state and 'well-meaning' foreign experts, large scale centralised groundwater development led to the 'green revolution' and associated gains in agricultural productivity. Comparison between colonial and postcolonial period- highlight the role of technology in enhancing groundwater exploitation, as well as the role of international geopolitical conditions, and powerful non-state actors such as IFIs in making groundwater a ubiquitous means of irrigation in the postcolonial era. Chapter 6 relates the realities of contemporary groundwater governance as experienced by on ground governors of groundwater to present the breadth of sites, forces,

institutions and actors across which groundwater governance takes place. In each of the empirical chapters, the analysis brings to light how the groundwater-society relationship evolves in the light of changes in the formal governance of groundwater, and how informal 'governors' and broader political economy shape the formal governance of groundwater processes.

Overall the key theoretical contribution of the thesis is to advance how the strategic importance of groundwater for the 'hydraulic mission' and state's developmental goals shapes the techniques of governance by the state across historical periods. State interventions for groundwater development and use in Punjab have been decisive in shaping and reshaping the groundwater-society relationship. The state is a particular aspect of the hydrosocial cycle that is constructive and reconstructive of the groundwater-society relationship through flows of power across various historical periods. Recognising groundwater as a small scale, decentralized "protective resource", the colonial state's interest in groundwater extraction for agricultural commercialization intensified as tubewells showed the promise of changing the feasibility of using groundwater for on a larger scale (Chapter 4). The early postcolonial state's groundwater policies and programs in Punjab have been geared towards commercialization of agriculture to further the national agenda of "food security" and "economic growth" (Chapter 5). As detailed in chapter 6 even in the contemporary period, the state is dependent on the commodification and export of groundwater embedded products to boost foreign exchange earnings in the context of a capitalist economy. In the case of a "groundwater exporting" society such as Punjab, Pakistan, commodification of groundwater embedded products such as wheat, rice, sugarcane and cotton, produces forms of power that can be used to "modernize" the society through alteration of groundwater-society dynamic. The problem of groundwater over abstraction results from government policies that enact specific forms of decentralized legal groundwater regimes that tie groundwater extraction to private properly rights over land. In addition, a range of government policies over the years have facilitated and stimulated groundwater based economic growth and groundwater exports, making Pakistan the largest exporter of groundwater in the world, ahead of the United States and India.

The thesis has illustrated the many ways in which the current groundwater crisis in Punjab is historically contingent on the colonial approach to groundwater governance. The techniques of groundwater governance used in the colonial period – particularly the legal, administrative and institutional changes - have left behind strong legacies for postcolonial and contemporary governance approaches. Part of it had to do with the change administration for agriculture and irrigation brought about in the colonial period as has been documented in existing literature on minor irrigation polices in the colonial period. Other studies have corroborated the legacy of changes brought about by colonial rule. According to Uma Shankari and Esha Shah, land tax matters were settled collectively by the village community in the pre-colonial period (Hardiman 1998). During colonial rule, the British made villages individually responsible for paying taxes. Village communities were also no longer able to raise finances for upkeep and maintenance of water resource systems, or compel villagers to contribute labour for maintenance of water channels and wells. The move from collective to individual management of water for irrigation, meant more and more farmers invested in individual wells and later tubewells, as opposed to jointly owned and operated groundwater systems of the pre-colonial era (Hardiman 1998). At the same time, an important legal change brought about in the colonial period that has implications for the current groundwater crisis was the entitlement to groundwater based on principles of English Common law. In pre-colonial times, customary law in its various forms governed water usage, based largely on community rather than individual rights to water. The change in legal entitlement to water as tied to property rights over land was brought about by the colonial administration (Singh 1991).

The findings of the thesis highlight that there are important continuities in the imperative of the state's engagement in groundwater governance across historical periods. The colonial and early postcolonial state's interest in groundwater development was also geared towards agricultural expansion and commercialization for economic growth. Groundwater had helped fulfill the hydraulic mission of the state in relation to the goal of maximizing water resource development for national social and economic development. Perhaps in the contemporary period, the location of who drives hydraulic mission has changed with an increasing role for IFIs, MNCs, NGOs for shaping "good governance" for groundwater (Chapter 5 and 6). The findings also underscore the importance of changes in the techniques of groundwater governance in Punjab from

pre-colonial through postcolonial and contemporary times – changing from a small scale individually managed resource in the pre and early colonial period to publicly developed schemes for groundwater development in the late colonial and early postcolonial period, to being a completely decentralized, laisseiz faire, individually managed resource in the contemporary period. The implications of this transformation of the groundwater-society relationship have been profound. On the one hand, agricultural and agro-based industrial output in the Punjab has dramatically improved due to increased reliance on this "on demand" water resource compared to unreliable surface water supplies. On the other hand, increased dependence on groundwater has had water justice implications – spatial, temporal, sectoral, provincial, regional and most importantly between individual groundwater users.

How does the case of Pakistan's Punjab illustrate an important dimension of the groundwater crisis of governance? Punjab is an arid and densely populated province of Pakistan, overwhelmingly dependent on groundwater for its economy and livelihoods. Existing discussions of the groundwater "crisis" of Punjab that focus on shallow institutionalism or environmental managerialism - are unreflexively about relations of power and political economic processes that drive the crisis. This thesis engages in historical analysis that reveals how groundwater - in the broader political economy contexts associated with colonialism, postcolonialism and contemporary period - has become an object of governance as well as a subject of governance. The thesis shows how in the colonial and early postcolonial phase the state's concern for the reclamation of land affected by waterlogging and salinity, concerns for food security and agriculture self sufficiency and irrigation, furthered processes through which *groundwater emerged as an object of governance.* (Chapter 4 and 5). Groundwater has also served *as a subject of governance,* having shaped society and governance in many important ways. Groundwater has held various meanings and served different uses for the society at different points in Punjab's history – its use as an underground store of water furthered its use as a means of protective irrigation to guard against 19th century famines. In the early 20th century, groundwater levels closer to the soil surface were perceived as a problem rendering agriculture unproductive. In the context of a post-colonial developmental state locked in strategic Cold war Alliances, groundwater was looked upon as a low hanging fruit, which could quickly increase the water budget needed for agricultural expansion, food self sufficiency and economic growth. In the contemporary

period groundwater in Punjab serves to fulfil demands for agricultural production and agro-based exports, earning the country much needed foreign exchange but also making it stand out as a water scarce country that has emerged as the world's largest exporter of groundwater.

Punjab's case allows exploration of colonial approach towards groundwater development as well historical path dependence for groundwater governance due to its experience with colonisation, hence can be used to make useful comparisons with other countries with experiences of colonisation such as Egypt, Kenya and Sudan where groundwater is a critical resource. Punjab's case also seeks to illustrate the challenges of an early postcolonial developmental state critically dependent on development of water resources to expand a primarily agrarian economy. The role of international expertise and finance for ground water development in the early postcolonial period and increasingly in the later decades, and Pakistan's geopolitical position in the Cold War further enhance the complexity of postcolonial groundwater development in Punjab. Similar to other developing regions, Punjab has been subject to participatory reforms in the water sector that have aimed to decentralise water management (both surface and groundwater). Punjab's experience with the participatory reforms shows the resilience of local groundwater management mechanisms in the face of top down imposition of community based groundwater management structures. Local fieldwork in Punjab also illustrated how groundwater overexploitation, pollution and contamination has water justice implications, and how these relate to the techniques of governance practiced by state and non-state actors. Punjab's history demonstrates the power of international financial institutions in promoting groundwater development in the region, and also the current power of large water intensive multinational corporations who are increasing getting more visibility as important "stakeholders" of Punjab's groundwater.

The analysis in the empirical chapters demonstrates how the techniques of groundwater governance and the groundwater-society dynamic in Punjab have evolved through contestation between different imaginaries of various actors about how groundwater should be managed. State, water user groups, non- government groups, donors, corporate interests - all have their own diverging perceptions about how groundwater should be "governed". In addition, what each stakeholder takes from groundwater and

gives to groundwater (eg. pollution) constantly reshapes groundwater as socio-nature and has justice implications for other users/actors.

7.2. Research Limitations and Questions of Generalizability

Before exploring the implications of my research for the political ecology of water literature specifically, and the wider literature on environmental governance, I address the theoretical, methodological and data limitations of my research study, as well as questions of generalizability. One limitation of the thesis is the use of "groundwater-society dynamic" as the lens of analysis. Using this optic as a way to analyse the political ecology of the groundwater crisis in Punjab had a number of advantages – it allowed for the perception of groundwater as "socionature", giving it agency and making it a subject of analysis, rather than a mere object of analysis. A consideration of other optics could have opened up aspects of the groundwater crisis that this thesis could not address. I considered other optics, such as state-nature-society triad for examining the problem of groundwater governance in Punjab, but the scope of my field research did not allow for an in-depth examination of the nature Pakistani state in the interest of maintaining focus and brevity. This thesis has engaged with the way the state affects the groundwater-society dynamic to the extent of the state performing its formal and informal functions of groundwater governance (legal, economic, policy functions). This thesis has not engaged deeply with the political character of the Pakistani state and how it has changed over various democratic and military regimes.

Another limitation is with regards to the sites and sources of data, some of which were inevitable. For archival research on the colonial approach and treatment of groundwater, data sources heavily draw on the British Library India Office Records, for the simple reason of ease of researching these archives as compared to the archives researched in Punjab. I also consulted the Punjab Public Library, the WAPDA Library, the Punjab Archives as well as libraries in the Punjab Irrigation Department in order to diversify the archival data sources for this research. While effort was made to include unpublished sources wherever possible, the thesis relies primarily on published reports from the colonial period to trace the evolution of the colonial state's policy towards groundwater development (See Chapter 3). In addition, I consulted the existing

environmental histories of South Asia broadly, and the Indus specifically including Whitcombe (1972), Stone (1984), Gilmartin (2015), Gadgil and Guha (1992), Stig Toft Madsen (1999) and Mosse (2003).

The thesis finds that international financial institutions and development banks such as the World Bank and Asian Development Bank are powerful non-state actors shaping the techniques of groundwater governance by the state and for the society at large. Despite having approached international donor representatives in Punjab and in the Washington DC Headquarters, interviews with them could not be arranged possibly because of the non-disclosure agreements that the current employees in these institutions were bound to. Thus, the analysis for the role of international expertise and finance in shaping groundwater development draws on reflections on the role of donors in interviews with Punjab government officials who had institutional memory of the reforms, and attending conferences/workshops/report launches with participation from international donors. In addition, a thorough content analysis of donor project documents in the water sector from 1960- 2017 was carried out to understand the trajectory of donor reforms and how it transformed according to dominant global ideas for development and water governance. It must also be pointed out that the analysis has mainly focused on the role of the World Bank because of its historical position as the major and major lender in the water sector. However, other international agencies such as DFID, ADB and USAID have also contributed significantly to water sector projects and to knowledge production for groundwater governance and management in Pakistan.

In terms of the geographical focus of the research, Pakistani Punjab has been selected. However, the Punjab province has an area as large as the United Kingdom, with a great diversity in groundwater availability and quality between Northern and Southern regions of the province. Since the groundwater crisis is a crisis of space and time depending in part on the hydrological characteristics of the aquifers across Punjab, it is hard to generalise the findings from the study area (mostly focused on Northern Punjab) to the entire province. Groundwater depletion and deterioration in quality, along with problems of salinity are much more acute in Southern Punjab Districts of Multan, Khanewal, Vehari, Lodhran and Pakpattan, as compared to Northern parts of Punjab studied in this research (World Bank 2019). Even within parts of Punjab, which do not get groundwater recharge because of being distant from canal seepage, the groundwater

crisis manifests itself in the form of higher levels causing water logging and salinity. This limits the generalizability of my findings even within the Province of Punjab. Similarly, the groundwater crises in other provinces of Pakistan - Baluchistan, Sindh and Khyber Pakhtun Khwah have their own unique political ecologies. More than one half of the aquifers in the Indus Basin of Pakistan are saline and of limited value, with most of them located in Sindh.

The generalizability of the theoretical and empirical findings from the case of Punjab for the political ecology of groundwater governance in other country contexts, as well as the contribution of the role of groundwater governance to the groundwater crisis depend upon the nature of the groundwater problem and the specific political-economy context in each country. However, the key contribution of the thesis in highlighting the contribution of groundwater to developmental goals of the state is generalizable to other similar contexts where groundwater forms an important part of the irrigation mix. Recent scholarship on the hydraulic mission corroborates the contribution of groundwater. Wester (2009) documents how groundwater irrigation becomes increasingly important for the hydraulic mission of the state in Lerma Chapala Basin of Mexico. Similarly Closas (2018) has examined the role of groundwater within the hydraulic mission of the state during the 1950s Franco's regime in La Mancha, Spain. Further exploration of the historical role of groundwater in fulfilling the developmental goals of the state, and the relationship between groundwater and state formation/state power/ legitimacy is an important area of research for countries where groundwater abstraction is high such as China, India, Bangladesh, Saudi Arabia, Iran, Mexico and Spain.

The theoretical framework for groundwater governance presented in this thesis intensively engages with the problem of groundwater governance and its political ecology. This framework provides a basis for analysing the politics of groundwater governance, and the mutually constitutive relationship between groundwater and society on one hand, as well as the state and non-state actors of governance on the other. While this framework is easily generalizable to other country contexts, as well as to explaining the global groundwater crisis, it is not an all-inclusive framework. Rather, the framework, just like the rest of the thesis, is an attempt to engage with the political ecology of groundwater governance in its own right, as distinct from the political

ecology of water governance because of the myriad ways that groundwater is different from surface water.

7.3. Theoretical Implications

7.3.1. Connection between Theory and Empirical Findings

The thesis has deployed a political ecology framework for groundwater governance inspired by a Foucaultian perception of governance and power as set out in the theoretical chapter 2 (Fig. 2.1). The groundwater governance framework draws on Swyngedouw's conception of groundwater as socionature, in order to appreciate how groundwater and society have been co-constitutive of each other throughout Punjab's history. The framework for groundwater governance is also inspired by Actor-Network Theory, especially with respect to the agency of tubewells as non-human 'governors' of groundwater and the role of this technology in enabling and constricting both state and non-state governors of groundwater. How do the empirical findings of the thesis reflect on the theoretical framework used in Chapter 2? How do the theoretical underpinnings of the thesis inform the empirical findings? How has each chapter found out something about governance happening across state and non-state actors, about dispersed power from above and from below and about the agency of technology and socionature? To answer these questions, this section summarises the link between the theoretical framework deployed for the thesis and the empirical findings across chapter 4, 5 and 6.

Foucaultian inspired political ecologies recognise that environmental truths are not ahistorical, and are produced across a variety of sites and by both state and non-state actors (Valdivia 2015). Based on these theoretical underpinnings, the thesis set out to explore how the governance of groundwater happens across dispersed institutions, agents, individuals and groups in the society. It also set out to examine how relationships of power shaping groundwater as a resource manifest from above and also from below in line with the Foucaultian approach. The findings from the empirical chapters reflect how the state has enacted techniques and mechanisms of governance for groundwater that entail "governing from a distance". The colonial state while engaging in efforts for improving the yield of wells and facilitating tubewell sinking, maintained confidence in the "private enterprise" for the proliferation of tubewells. This is manifest in the legal, institutional and policy dimensions of formal governance of groundwater

during the colonial period as detailed in chapter 4. The techniques of colonial governance of groundwater encouraged groundwater development from a distance by incentivising land lessees to sink tubewells through attractive land lease policies, while at the same time making legal changes through the Easements Act to support individualised extraction of groundwater. The activities of the Department of Agricultural Engineering in 'supporting' well boring and tubewell installation in Punjab detailed in Chapter 4 reaffirm the state's commitment to groundwater development and governance, albeit from a distance. In the postcolonial period (Chapter 5), the state pursues its hydraulic mission around groundwater by investment in large scale centralised SCARP tubewells, while facilitating private tubewell development through subsidies. In line with the Foucaultian approach, the post colonial and contemporary governance of groundwater (Chapters 5 and 6) shows how power is dispersed and it is a question of from below as much as it is from above. Governance by working through regimes of practice, rules, plans of actions and "programs of conduct" works to manage social life. Each of the chapters show how groundwater governance and the crisis are shaped from 'above' through the techniques and mechanisms of the state for governing groundwater in terms of its legal institutional and policy dimensions (Focault and Ewald 2003). In response to these, individuals shape their own behavior, disciplining the actions and capacities of the self and others to act as significant non-state governors of groundwater. Drawing on the Foucaultian approach, chapters 5 and 6 specifically show how the power to shape groundwater governance does not rest exclusively with the state, or with other social bodies and locations – rather power designates actions and relationships between state and non-state actors that induce individuals to act in particular ways with regards to their resource use. The case of Punjab shows how the state does not directly control groundwater, but uses indirect techniques of governance to promote particular types of behaviour among non-state actors. Chapter 6 further delineates the relationships of power within groups of non-state actors, and between state and non-state actors, to narrate how contemporary groundwater governance is shaped across multiple sites, forces and governors of groundwater.

The empirical chapters also point to how the techniques of governing at a distance for groundwater stand in sharp contrast to centralised development, control and distribution of surface water in the colonial and early post colonial period. The hydraulic mission around groundwater is subtle and enrols a more invisible form of politics – whereby the

state is not directly building dams to control water resource development, but is rather incentivising groundwater development through indirect mechanisms and techniques such as land lease policies, tubewell installation, energy and agricultural subsidies.

The analysis in the empirical chapters also corroborate the role of technology as a non-human 'governor' of groundwater in line with the Actor-Network theory. The empirical material in each historical period illustrates the capacity of technology in shaping groundwater use, dependency and overabstraction. The empirical chapters show how water extraction technology and its interaction with the existing social relations can serve as a limiting or enabling factor for groundwater development and the groundwater crisis. Whereas lack of economic feasibility of tubewell technology in colonial Punjab limited the large scale development of groundwater during the colonial period (Chapter 4), the availability of low cost tubewells (and hydroelectricity) during the post colonial period helped the state to realize the its postcolonial hydraulic mission through private tubewell development (Chapter 5). In the contemporary period, technological advancements in pumping technology are embedded within the broader political economy of an agro-based water intensive export economy as detailed in Chapter 6. Chapter 6 also shows how technologies of extraction and of conservation do not simply diffuse, but rather become enmeshed and work through existing social power relationships (Mitchel 2002). Farmers without enough capital are only able to afford installation of lower cost diesel pumps, but have to face higher operational costs for refuelling. As opposed to this, farmers with the economic might and political influence to afford the higher priced electricity tubewells, benefit disproportionately from any electricity subsidies for tubewells. In the contemporary scenario, the prospects of installation of solar tubewells, with higher installation costs but no running costs, will tend to exacerbate the groundwater injustices as only farmers with enough capital will be able to install these. The way technology gets adopted affects the way groundwater users adapt to the groundwater crisis – with larger farmers having the ability to install deeper turbines when groundwater levels fall or shallow layers become polluted, and smaller farmers losing access or having to rely on water lords for access to groundwater. Furthermore, the type of technology, whether water-extracting or water-saving, gets differential responses in adoption by different 'governors' of groundwater. As chapter 6 illustrates, incorporating water-saving technology is an essential part of 'greening' their

business operations for large multinational corporations, but for smaller farmers the adaptation of water-saving technology may be more difficult.

The empirical analysis for each historical period also documents the techniques of governance that lead to transformation of the groundwater-society relationship in that period. This analysis draws on conception of groundwater as 'socio-nature', following Cornut and Swyngedouw (2000) and Swyngedouw (2015) to focus on the social and political character of groundwater in addition to its materiality. In each empirical chapter, a consideration of how groundwater affects society, and how society and governance in turn affect groundwater as a resource serves to reveal how groundwater reflects and produces forms of social power.

7.3.2 Implications for Political Ecology Literature

The theoretical framework that guides the empirical analysis in this thesis contributes to an understanding of the political ecology of groundwater governance. In existing literature, many authors have elucidated various aspects of the political ecology of water (Loftus and McDonald 2001; Bakker 2004; Budds and McGranahan 2003; Swyngedouw 2009; Loftus 2015). However, the literature has treated the political ecology of water as a whole, without emphasizing the specific political ecology of groundwater. Why does the political ecology approach need to specifically engage with the problem of groundwater governance, as distinct from the broader political ecology of water? First, the significance of groundwater as an irrigation resource, as well as a source of drinking water warrants a deeper analysis of the political ecology of this resource. In regions such as Indian and Pakistani Punjab, at least 60 per cent of the water at the farm gate for irrigation purposes comes from groundwater. Second, the political ecology of groundwater access is peculiar, often being tied to properly rights to the land, and only requiring the appropriate water extraction mechanism (diesel or electric pump) to extract unlimited quantities, in the absence of formal monitoring. Third, as groundwater access requires investment in technology, with improved quantity and quality linked to the economic ability to dig deeper boreholes, access to this resource is directly proportional to the power differential between users. In contrast to this, power and politics of surface water access are distinct as they often involve

underhand payments to local irrigation officials or political ties with local politicians who coerce irrigation officials to tweak water shares (Rinaudo 2002; Personal Communication with Farmer Representative Kathianwala, 2017). Fourth, the materiality of groundwater, particularly its invisibility as an underground resource, means that groundwater degradation does not elicit the same emotional and political response as degradation of rivers. Additionally, the visibility of large-scale infrastructure associated with harnessing surface water such as dams mean that politicians allocate more priority and budgets to the management of surface water.

Existing literature on South Asia has briefly engaged with various aspects of the political ecology of groundwater (Bhatia 1992; Prakash 2005; Birkenholtz 2007; Taylor, 2013; Taylor and Bhasme 2018). This literature has served to highlight disparate elements of the political ecology of groundwater presented through the case study method. However, the treatment of the political ecology of groundwater in existing literature lacks analytical specificity. The empirical findings of this thesis seek to elucidate such a framework, in order to build a generalized understanding of the political ecology of groundwater governance. Using a historical approach and the groundwater-society relationship as the optic for analysing the problem of groundwater governance in Punjab, the empirical findings of this thesis offer insights for the broader theoretical literature on the political ecology of groundwater governance.

The key contribution of this thesis to political ecology literature lies in the recognition of the state's interest in groundwater as an important contributor to the 'colonial hydrology' as well as to the postcolonial 'hydraulic mission'. Existing discussions of colonial hydrology and hydraulic mission have focused on how investment in large-scale centralized irrigation infrastructure projects are linked with consolidation of state power (D'Souza 2006; Molle et al. 2009; Woster 1985; Wester 2008). While existing analysis has mostly focused on the relationship between investment in mighty surface irrigation projects and state power, this thesis has illustrated the role of the colonial and postcolonial state in development of groundwater irrigation systems, and the importance of groundwater as a resource to the colonial hydrology and the postcolonial hydraulic mission in Punjab. In this way, one of the main contributions of the thesis to the literature on political ecology is highlighting the agency of groundwater, as well as the subtle forms of power and politics associated with groundwater governance.

The colonial hydrology of the British period extrapolated into the hydraulic mission of the postcolonial state inspired by development and modernization theories of the second half of the twentieth century. This promoted western model of development and application of western science through investment massive surface irrigation infrastructure projects to solve the problem of underdevelopment in traditional societies like Punjab. However the approach to water resource governance in the case of Punjab's colonial hydrology and the postcolonial hydraulic mission was also defined by a significant focus on groundwater resources as detailed in Chapter 4 and 5. The empirical chapters highlight groundwater's contribution to Punjab's colonial hydrology and hydraulic mission by outlining the techniques and mechanisms of governance for developing groundwater by both state and non-state actors during this period.

Does the addition of groundwater to colonial hydrology and hydraulic mission fundamentally question these concepts? The original conception of colonial hydrology by D'Souza (2006) was framed as a case of state led top down centralized water development in the context of British investment in and control of surface water. However, the specific materiality of groundwater as a decentralised resource necessitated that the colonial state supports 'private enterprise' for well construction and tubewell installation. Thus, while the Punjab Department of Agriculture made sustained efforts for groundwater development, these efforts relied on encouraging private enterprise. Just as private water lords (to the likes of Khakwanis of Multan and Tiwanas of Shahpur) had been deployed as proxies of the state in expanding the agricultural system through canal irrigation, the colonial state engaged agricultural intermediaries and incentivized individuals by making large grants of government wasteland contingent on the sinking of tubewells in the 1920s and 1930s (Gilmartin 2015, 137; Ali 1988). It was these intermediaries and large land lessees who were selected on a precondition of possessing a minimum amount of capital who invested in propagation of tubewells for irrigation as Chapter 4 details. The state's interest in expanding the agricultural (and hence land revenue) system in a decentralized manner in the case of groundwater warrants a revisit to the original conception of colonial hydrology in existing literature. As Punjab's case demonstrates, hydraulic development around groundwater was not centralized in the colonial period, even though the colonial government explored feasibilities of larger scale public tubewell schemes from time to

time. The decentralized pattern of hydraulic development for groundwater in the colonial period as seen in the case of Punjab stood in sharp contrast to D'souza (2006)'s original conception of colonial hydrology as centralized development and control of surface water.

Existing literature on the hydraulic mission has focused on the use and mobilization of large-scale surface water projects as a part of the state driven modernization mission. In this literature, the hydraulic mission is driven by the state's hydraulic bureaucracy, the likes of the US Bureau of Reclamation in the United States, National Irrigation Commission in Mexico and the Water and Power Development Authority in Pakistan (Molle et al 2009). The central theme running through these postcolonial hydraulic mission case studies was the role of the state as the large-scale developer of (surface) water resources, as well as the importance of the latter for state building and development. The consideration of groundwater's contribution to colonial hydrology and hydraulic mission in Punjab compels us to reconsider the existing understanding of these concepts. First, as evidenced from Punjab's case, the state was not the sole developer of groundwater resources. The colonial state had recognized the decentralized nature of groundwater as a resource, and the importance of the individual as a 'governor' of groundwater, hence sought to encourage groundwater development by incentivizing individual cultivators through *tuccavi* loans, or facilitating well sinking and tubewell installations. The postcolonial state initiated the large-scale centralized development of groundwater, but did not restrain private development of tubewells. Rather, as chapter 5 documents, the postcolonial state used techniques and mechanisms of governance at a distance to indirectly stimulate the proliferation of private groundwater development. The contribution of groundwater to the hydraulic mission allows a rethinking of the role of the state and hydraulic bureaucracy in driving the hydraulic mission. As Punjab's case has demonstrated, the state had a critical role to play in achieving a breakthrough in groundwater irrigation in the colonial and early postcolonial periods but was facilitated by non-state actors in important ways. In the contemporary period, non-state actors have a greater role for operationalizing the hydraulic development of groundwater and shaping the techniques and mechanisms of groundwater governance through their interaction with the state. At the same time, the state through its techniques of governance (legal, institutional, policy) facilitates

groundwater development by non-state actors, giving the latter an enhanced role in taking the hydraulic mission forward.

The increasing importance of non-state actors in facilitating the hydraulic mission, in turn then raises the question of who is the owner of the hydraulic mission. Chapter 6 documents the range of state and non-state actors and forces that drive the hydraulic mission in contemporary Punjab. Driving the hydraulic mission through a decentralized irrigation resource like groundwater compels one to ask "whose" hydraulic mission is being pursued? In the case of ancient grand empires like Chinese, Mesopotamian or Egyptian, the control of river systems supported and sustained their power; hence the owner of the hydraulic mission was the state (Wittfogel 1957). The investments in large-scale engineering works for irrigation development during 19th century colonialism also reflected the state's imperative to pursue the hydraulic mission for commercial expansion of agriculture. The early postcolonial state's imperative to pursue the hydraulic mission through large-scale centralized groundwater development also belonged to the state albiet facilitated and steered by international donors as non state actors. In the contemporary context, where the techniques of governance by the state condone and even facilitate extraction by non-state actors, would it be appropriate to refer to the hydraulic mission as the hydraulic mission of the *state*?

The consideration of groundwater's contribution to the hydraulic mission also compels us to explore the end goal of the hydraulic mission. In the colonial period, large-scale investments were aimed at the productive control of nature for increasing revenue and expanding commercial agriculture (Gilmartin 1994). These investments in canal irrigation not only represented commercial and revenue calculations for colonialism, but the intended colonial control of society and nature ended up altering "South Asia's fluvial and social worlds" (Gilmartin 2003; D'Souza, 625). In the 20th century the professed goal of the hydraulic mission of the state has been centered on national progress often defined as "not a single drop of water should reach the sea without being put to work for the *benefit of Man*" (Wester 2009; Molle 2009, 332). In Pakistan and other newly independent third world countries, the urgency of the hydraulic mission to deliver agricultural growth and food security for a fragile economy was obvious, influenced by ideas of modernity and development symbolized by large scale TVA- like irrigation schemes and dams in the Cold War context at the time. This inspired a

multitude massive irrigation projects across the third world as well as in post independent Pakistan where the largest contiguous irrigation system was planned with the help of the World Bank. Hydraulic mission pursuing large-scale irrigation infrastructure as a symbol of "modernity" and development helped newly independent countries in the third world to improve nation building and legitimation of their power. The physical and political visibility of state's investment in dams and other surface water infrastructure has suggested that the hydraulic mission of the state is intended to pursue development for performative reasons. If hydraulic development of surface water was driven by performative reasons, then what explains the sustained pattern of groundwater development? Were patterns of hydraulic development around groundwater economically driven or politically driven? The lack of physical visibility associated with groundwater development signals that the hydraulic development around groundwater offers few opportunities for political visibility of the status of the regime. Punjab's case offers insights to support the non-performative aspect of state's support of hydraulic development around groundwater both in the colonial and post colonial period. In the colonial period, the state's support of groundwater irrigation as a form of 'protective irrigation' and a means for famine prevention is an example of groundwater development for non-performative reasons as documented in Chapter 4. Similarly, in the post colonial period, while the development of groundwater for the hydraulic mission was aimed towards 'national progress' as professed by Pakistan's policy and planning documents of the time, it was primarily pursued as a means to solve the problem of waterlogging which was hampering agricultural productivity as Chapter 5 details. Even in the contemporary period, the state facilitates sustained groundwater exploitation through a mix of techniques in the legal, institutional and policy dimensions of formal governance. The state's continued emphasis on groundwater development in Punjab, despite the lack of political symbolism attached to tubewells, perhaps signals that the end goal of hydraulic development around groundwater is for economic development, and not for performative reasons.

7.3.2. Implications for Literature on Environmental Governance

The findings of this thesis have implications for existing approaches to environmental governance. The thesis, by illustration of Punjab's historical experience with groundwater governance, contributes to expand the existing theoretical and empirical

findings for both statist and neoliberal approaches in environmental governance literature. The thesis for the most part explored the nature and role of governance in the making of the groundwater crisis, while not siding with any particular form of governance advocated in existing literature. The findings of the thesis re-iterate the need to dispel notions of "good" governance in order to appreciate the complex, messy nature of groundwater governance. In the same vein, the analysis in this study does not emphasize a particular approach to groundwater governance over another. Rather, illustrates how various ways of managing groundwater – centralized, community based and individualised – all generate inequitable socioeconomic outcomes and are amenable to manipulation by the more powerful social actors.

The thesis has highlighted how groundwater governance in Punjab has evolved from being managed jointly as a common resource by indigenous communities in the pre-colonial period, to being developed and managed by the state in the colonial and early postcolonial period, and finally evolving to neoliberal, individualised management in contemporary times. Punjab's experience shows that in contemporary times, the dominant neoliberal logic does not just dictate the extraction of groundwater based on the ability to pay for costs of pumping, but has also come to dominate ideas of conservation of groundwater. Conservation initiatives are increasingly being championed by extractive industrial interests in groundwater and the promotion of global standards for water productivity such as the Alliance for Water Stewardship, Sustainable Rice Partnership and the Better Cotton Initiative (Chapter 6). The local Sheikhupura case study demonstrates how neoliberal modes of access to groundwater as well as its management and conservation excludes the marginalised and exacerbates groundwater injustices.

The thesis illustrated how role of the state is central to the mutually constitutive and dynamic relationship between groundwater and society. Thus, the historical evolution of the relationship between the state-nature-society is central to the problem of groundwater governance. Changing conceptions of the state and how it acts upon the groundwater-society dynamic play a critical role in producing and re-producing new forms of groundwater governance. State action and inaction can both have transformative effects on the groundwater crisis. While the thesis has illustrated examples of how colonial and postcolonial state have actively developed groundwater

resources, state inaction on legal entitlement to groundwater often serves to contribute to the crisis, or at the very least condone it. As chapter 6 demonstrates, environmental legislation and legal pluralism for groundwater facilitate extractive agricultural and industrial interests in national and transnational context (for example, through the virtual export of groundwater embedded products).

The relationship of the state with the global (neoliberal) economy is a decisive factor in determining the groundwater-society dynamic. Since the 1980s, developing countries like Pakistan, Chile, India have experienced water governance reforms as a part of broader capitalist transformations under globalisation and structural adjustment programs. Dominant water governance language and logic emphasizing the 'economic value' of groundwater is so infused with neoliberal ideology. For many developing countries, the journey towards economic growth (through agricultural expansion), has often been driven by an equally rapid capitalisation and commodification of water resources. For countries like India and Pakistan, where groundwater is a significant contributor to the overall irrigation requirement, groundwater commodification and export have contributed to and often led capitalist accumulation and national economic growth. Of course, this growth is not evenly distributed, especially when it banks on groundwater extraction, the water justice implications of which are profound.

The thesis findings also point towards the agency of the state and how historically state imperatives for intervening in the management of natural resources transform the resource as well as its relationship with the state and society. It also raises an important question of whether the state is a neutral actor in groundwater governance. As seen in the case of Punjab, the relationship between capital, international aid and decentralised users all interact to affect state policy towards groundwater. In the early postcolonial period, international expertise and aid are seen to influence state policies towards groundwater. In the contemporary period, owners of capital and large agro-industrial interests are able to exercise structural power over state managers to shape the context in which the state makes decisions.

The thesis highlights the role of international financial agencies and development banks in shaping dominant ideas for water governance for developing countries. Punjab's post-colonial trajectory for centralised large scale public tubewell development and

management advocated and supported by international expertise of the USGS and the World Bank in the 1960s, is similar to the path advised for Indian Punjab and UP as well as Bangladesh. In the 1970s and 1980s, the shift in global development rhetoric against public management of natural resources and the move towards decentralised, privatised or community based forms of management was championed by the World Bank in its water resource projects across the developing world. In particular, the idealised form of community management of groundwater as the "ideal" type governance for groundwater has seen to fail to work in indigenous settings. My findings illustrate how global ideas of community based natural resource management are taken up by federal governments through donor programs and ultimately travel to local contexts, where they are often not accepted. It is ironic how community management and joint ownership of wells worked in pre-colonial period, but donor experimentation with community management in the contemporary period has shown that it cannot be imposed from the 'outside'. The communities of farmers 'created' for the taking over and management of public tubewells in the 1990s in Punjab were quickly dismantled after the life of the project (Chapter 5).

7.4. Implications for Water Policy and Governance – in Pakistan, South Asia and Similar Contexts

Most accounts in the existing literature on South Asia, uncritically locate the groundwater governance problem variously in ineffective regulatory structures, market distortions created by the provision of subsidized energy or lack of an institutional framework for groundwater management. While these explanations of the problem of groundwater governance are important, they are necessarily incomplete as they do not take into account the broader political economy context in which groundwater (ab)use has been embedded historically. Existing accounts of groundwater governance offer a technical, depoliticized overview of the groundwater governance problem, undermining the political nature of the governance challenge.

The empirical findings of this thesis suggest that by considering the historical importance of groundwater to the state's development goals in Punjab, there is reason to

improve the policy priority for groundwater conservation. In the contemporary scenario, the water resources policy debates in Punjab are dominated disproportionately by the need to increase storage by the construction of dams on western tributaries of the Indus in a race against upstream India and development pressures. The securitization of the transboundary surface waters shared with India and the use of the rivers as issues of 'national security' has placed an overwhelming pressure on successive governments to build dams. A historical analysis of the importance of groundwater for the region's development, and an emphasis on its current role as the major contributor to agro-industrial and domestic needs in Punjab can make space for effective groundwater policies.

Incorporating historical analysis into groundwater policy will bring attention to the legacies of colonialism and the contribution of postcolonial policies and programs by the state embedded in specific political economy issues of each era. This challenges existing ahistorical and apolitical perspectives focusing merely on the technical/managerial aspects of the groundwater crisis in Punjab. An appreciation of the history of groundwater development and the role of state and beyond the state entities in shaping the groundwater-society relationship, will also lead to an appreciation of the blend of old and new institutions created by colonial and postcolonial state and donor programs for the management of groundwater. This will bring attention to the need to clearly demarcate responsibilities for groundwater between various levels in the state – federal, provincial, local – as well between institutions at the same level. For example, as local fieldwork in Sheikhupura illustrates, the issue of institutional responsibility for groundwater pollution at the local level is unclear, leading both the local irrigation departments and local environment departments to neglect the monitoring of groundwater quality deterioration.

There is a need for reviewing and engaging with the production of knowledge around groundwater. Most of the existing knowledge production about groundwater use and overexploitation has either been funded by international financial institutions and aid agencies such as the World Bank and DFID, or increasingly by multinational corporations sourcing water intensive inputs from Punjab. The dominant rhetoric in the reports is to blame agriculture sector, the main user of groundwater, as "inefficient" and highlight multinational company efforts to conform to international standards of water

efficiency such as the AWS and SRP. The thesis presents compelling evidence to engage in critical knowledge production to review and measure industrial water use, as well as the need to reassess the growing visibility of the industrial sector in the water policy space.

Finally, one of the most decisive elements for groundwater policy is rethinking the legal entitlement to groundwater as being tied to private property rights over land. The process for redefining groundwater entitlement based on a criteria other than economic ability, is of course riddled with politics, as the consultant responsible for drafting Punjab's Groundwater Act explained, "This law is a very politically sensitive matter, that is why it has never been made" (Personal Communication with Consultant for Draft Punjab Groundwater Act 2017). The findings outlined in this thesis have attempted to illustrate the historical and political complexity of the groundwater-society dynamic in Punjab in order to appreciate how legacies of colonialism and postcolonial policies continue to feed into the contemporary crisis. This presents valuable insights for the literature on water governance specifically and environmental governance broadly.

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Appendix 3A: Consent Form for Research Participants

University of Sussex

CONSENT FORM FOR PROJECT PARTICIPANTS

PROJECT TITLE: **GROUNDWATER GOVERNANCE IN THE INDUS BASIN OF PAKISTAN**

Project Approval Reference: _____

1. I agree to take part in the above University of Sussex research project. I have had the project explained to me and I have read and understood the Information Sheet, which I may keep for records. I understand that agreeing to take part means that I am willing to:

- Be interviewed by the researcher YES/NO
- Allow the interview to be audio taped YES/NO
- Make myself available for a further interview should that be required YES/NO

2. Please choose which option you are comfortable with regarding disclosure of information and identity:

A. I understand that any information I provide is confidential, and that no information that I disclose will lead to the identification of any individual in the reports on the project, either by the researcher or by any other party.

OR

B. I understand that (*outline steps to be taken)* will be done to prevent my identity from being made public.

AND / OR

C. I understand that I will be given a transcript of data concerning me for my approval before being included in the write up of the research

OR

D. I understand that I have given my approval for my name and/or the name of my town/community, and / or the name of my workplace to be used in the final report of the project, and in further publications.

I understand that my participation is voluntary, that I can choose not to participate in part or all of the project, and that I can withdraw at any stage of the project without being penalised or disadvantaged in any way. YES/NO
I consent to the processing of my personal information for the purposes of this research study. I understand that such information will be treated as strictly confidential and handled in accordance with the Data Protection Act 1998. YES/NO

3. Do you agree that the information provided can be used in further research projects which have research governance approval as long as your name and contact information is removed before it is passed on? YES/NO

Name: _____

Signature _____

Date: _____

Appendix 3 B: Project Information Sheet

University of Sussex

PARTICIPANT INFORMATION SHEET

You are being invited to take part in a research study. Before you decide whether or not to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully.

STUDY TITLE
Groundwater Governance in Indus Basin of Pakistan

PURPOSE OF THE STUDY
This research aims to understand the nature and underlying causes of problem of groundwater governance, particularly the neglect of groundwater management, in the context of the Indus Basin of Pakistan.

Guided by this main research question, this research will engage with a number of sub-questions: How does the production of knowledge and expertise on groundwater affect the nature of its (non) governance? How do state and non-state actors (including donors, NGOs, groundwater users), shape and affect groundwater (non) governance? What is the nature of interaction between state, non-state actors and groundwater as a resource?

WHY HAVE I BEEN INVITED TO PARTICIPATE?
Your experience as knowledge as an experienced water professional in Pakistan will be extremely valuable for gaining insights into the groundwater governance issue in Pakistan.

DO I HAVE TO TAKE PART?
It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

WHAT WILL HAPPEN TO ME IF I TAKE PART?
You will be asked to participate in a series of semi structured interviews that will help in collection information on the nature of groundwater governance in the Indus Basin of Pakistan. Each interview will last for about one hour. The total time commitment expected from you for the entire study will be no more than 3 hours over the entire period of fieldwork.

WHAT ARE THE POSSIBLE DISADVANTAGES AND RISKS OF TAKING PART? (WHERE APPROPRIATE)
Taking part in the study will require some time commitment.

WHAT ARE THE POSSIBLE BENEFITS OF TAKING PART?
Your participation in the study will contribute towards understanding the problems in groundwater governance in Pakistan and help in pointing towards policy solutions.

WILL MY INFORMATION IN THIS STUDY BE KEPT CONFIDENTIAL?
All information collected about the individual will be kept strictly confidential (subject to legal limitations) and confidentiality, privacy and anonymity will be ensured in the collection, storage and publication of research material. In cases where you agree to speak on record, it will be possible to link information to your identity. You have the right to withdraw participation at any stage of the research process (Please see informed consent form for details).

WHAT SHOULD I DO IF I WANT TO TAKE PART?
In order to take part in the study, please read and understand this Information sheet as well as the Informed Consent Form. You will have to sign the provided copy of the Informed Consent Form (which will also be explained to you in person before the start of the interview) in order to become a research participant.

WHAT WILL HAPPEN TO THE RESULTS OF THE RESEARCH STUDY?
The results of the research and any information you agree to share will used towards my doctoral dissertation thesis. They will be published in the online repository of Sussex Research Online. The researcher will also disseminate research findings in journal papers and a monograph publication after completion of doctorate. Participants will be able to request a copy of the research findings from Sussex Research Online Repository.

WHO IS ORGANISING AND FUNDING THE RESEARCH?
I am conducting the research as a student at the Department of International Development, School of Global Studies, University of Sussex. The study is being funded by Economic and Social Research Council.

WHO HAS APPROVED THIS STUDY?
The research has been approved by the Cross-Schools Research Ethics Committee (C-REC) ethical review process at the University of Sussex.

CONTACT FOR FURTHER INFORMATION
For further information or any concerns regarding the research process, please contact:

RESEARCH SUPERVISOR
Dr. Jan Selby
Professor of International Relations
University of Sussex
Email: J.Selby@sussex.ac.uk

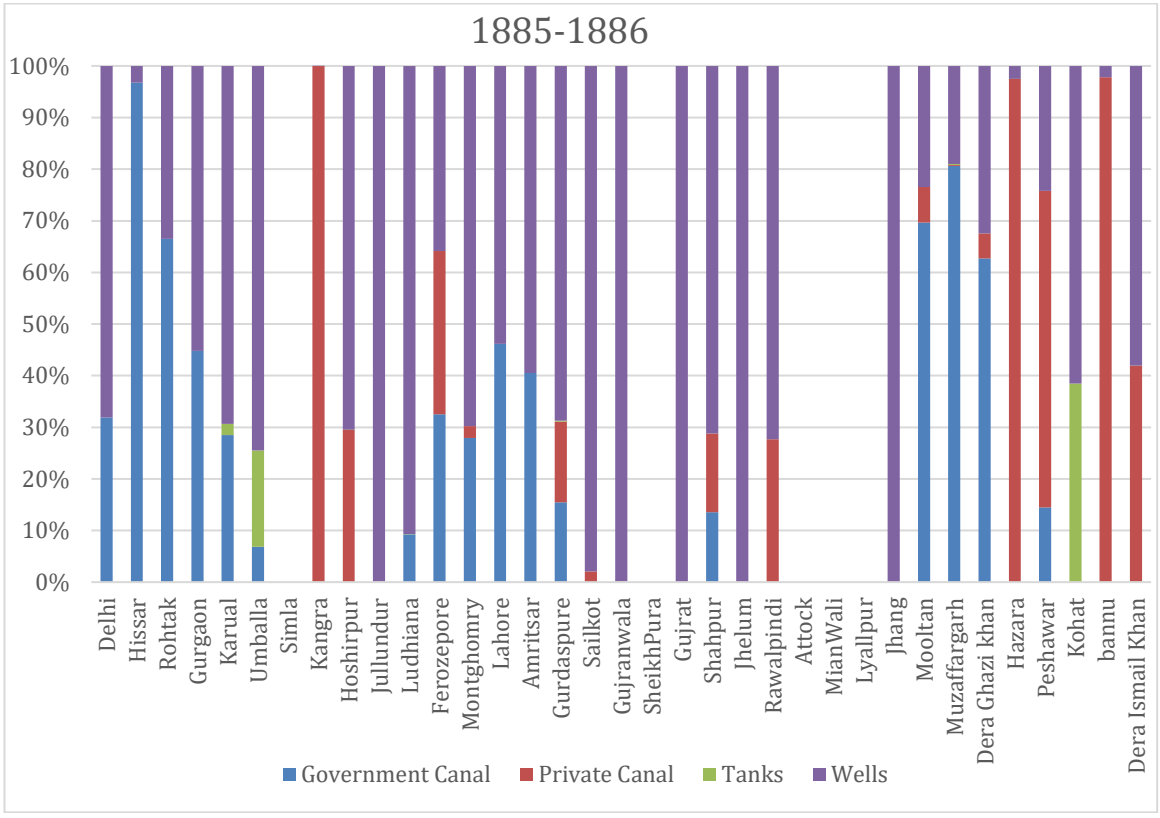
CHAIR OF CROSS SCHOOLS RESEARCH ETHICS COMMITTEE
Prof Janet Boddy
Email: J.M.Boddy@sussex.ac.uk

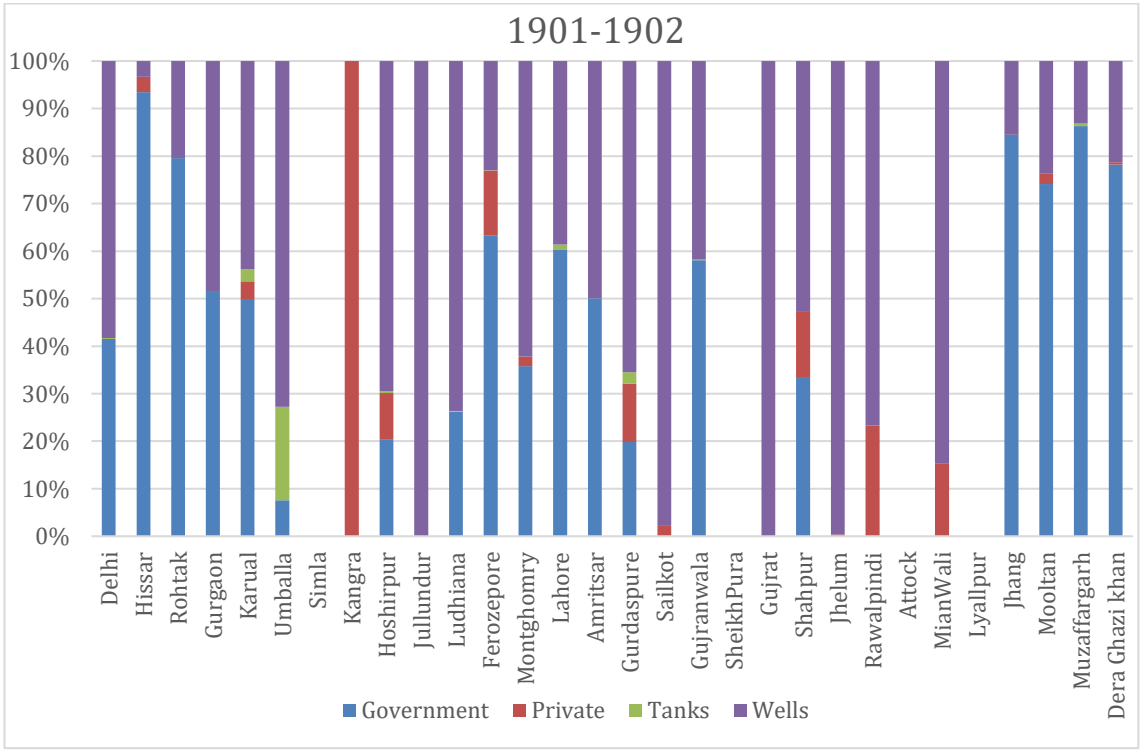
"University of Sussex has insurance in place to cover its legal liabilities in respect of this study."**

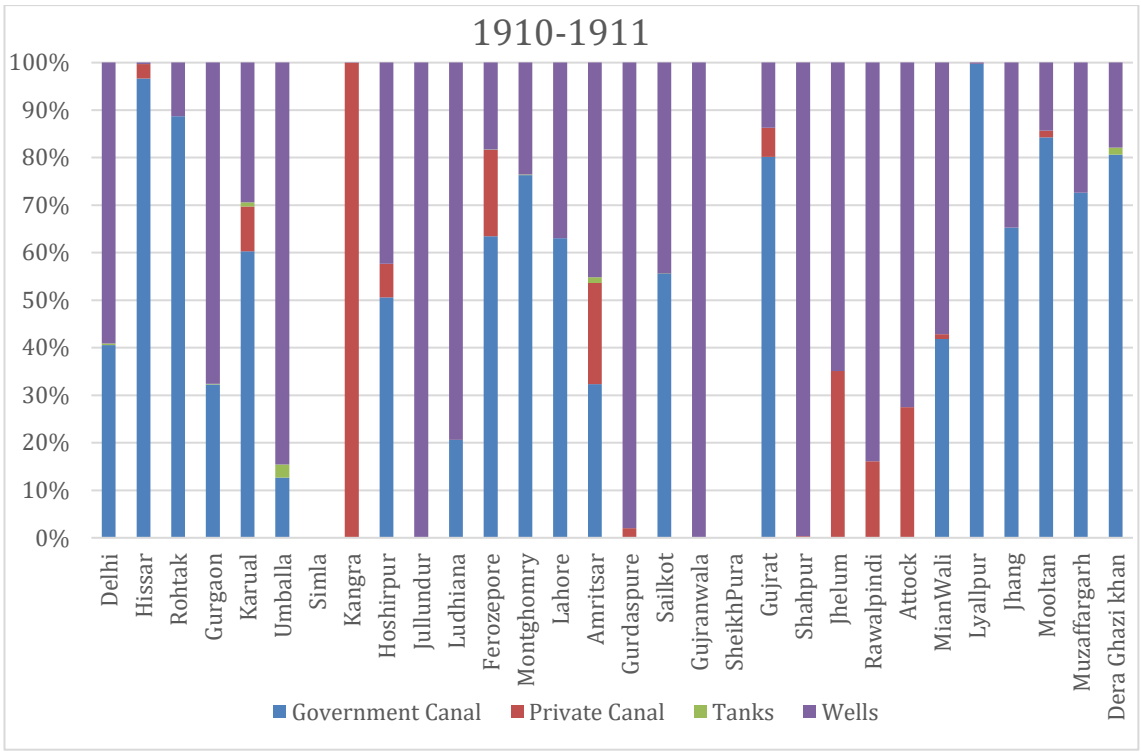
Thankyou for taking time to read the information sheet.

Date:

Appendix 4: District Wise Changes in Irrigation Mix in Punjab (1885-1945)*






1910-1911
100%
90%
80%
70%
60%
50%
40%
30%
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Delhi
Hissar
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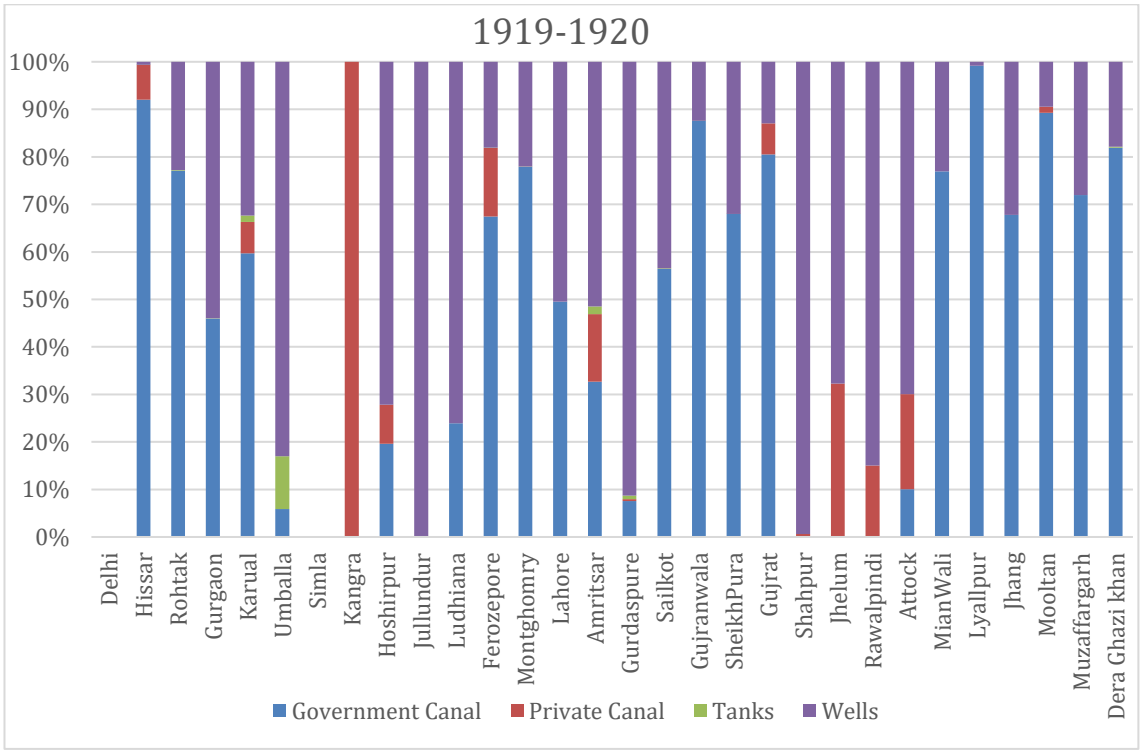
Gurgaon
Karual
Umballa
Simla
Kangra
Hoshirpur
Jullundur
Ludhiana
Ferozepore
Montghomry
Lahore
Amritsar
Gurdaspure
Sailkot
Gujranwala
SheikhPura
Gujrat
Shahpur
Jhelum
Rawalpindi
Attock
MianWali
Lyallpur
Jhang
Mooltan
Muzaffargarh
Dera Ghazi khan
Government Canal
Private Canal
Tanks
Wells


1919-1920
100%
90%
80%
70%
60%
50%
40%
30%
20%
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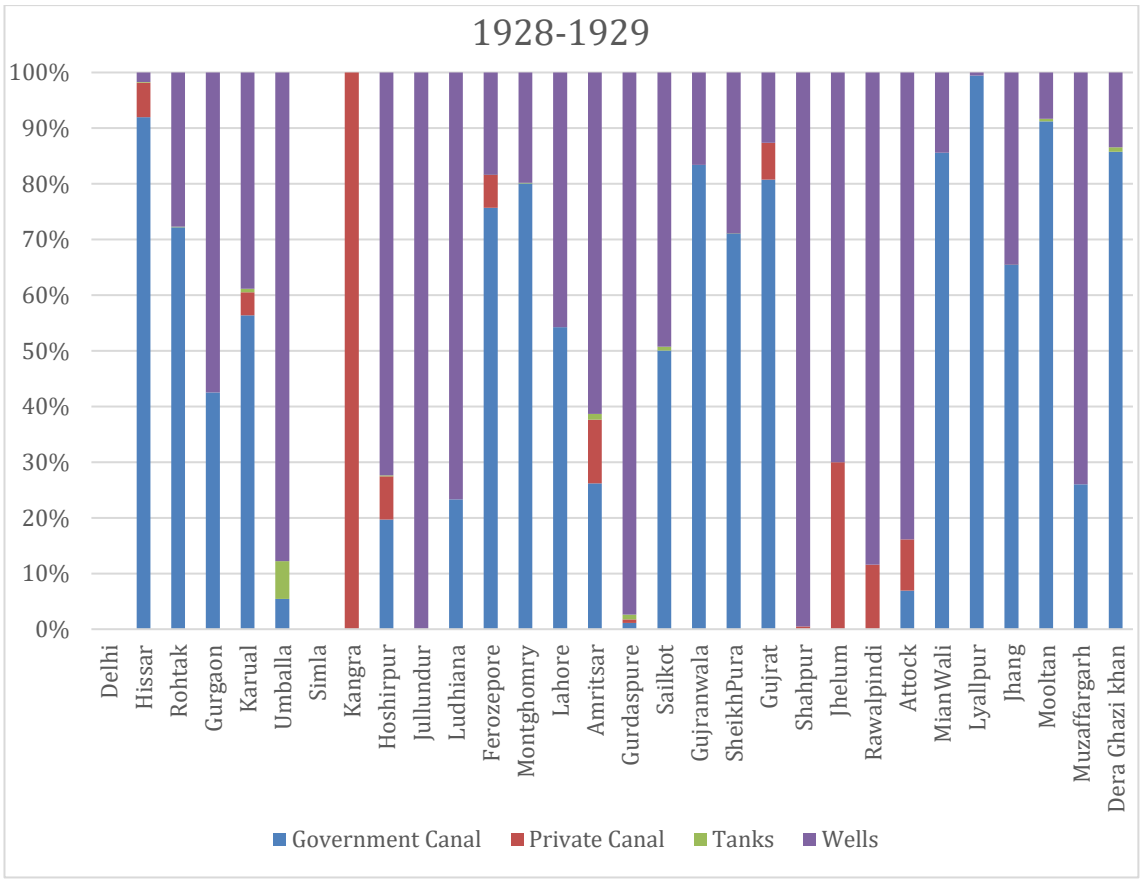
Delhi
Hissar
Rohtak
Gurgaon
Karual
Umballa
Simla
Kangra
Hoshirpur
Jullundur
Ludhiana
Ferozepore
Montghomry
Lahore
Amritsar
Gurdaspure
Sailkot
Gujranwala
SheikhPura
Gujrat
Shahpur
Jhelum
Rawalpindi
Attock
MianWali
Lyallpur
Jhang
Mooltan
Muzaffargarh
Dera Ghazi khan
Government Canal
Private Canal
Tanks
Wells


1928-1929
100%
90%
80%
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Delhi
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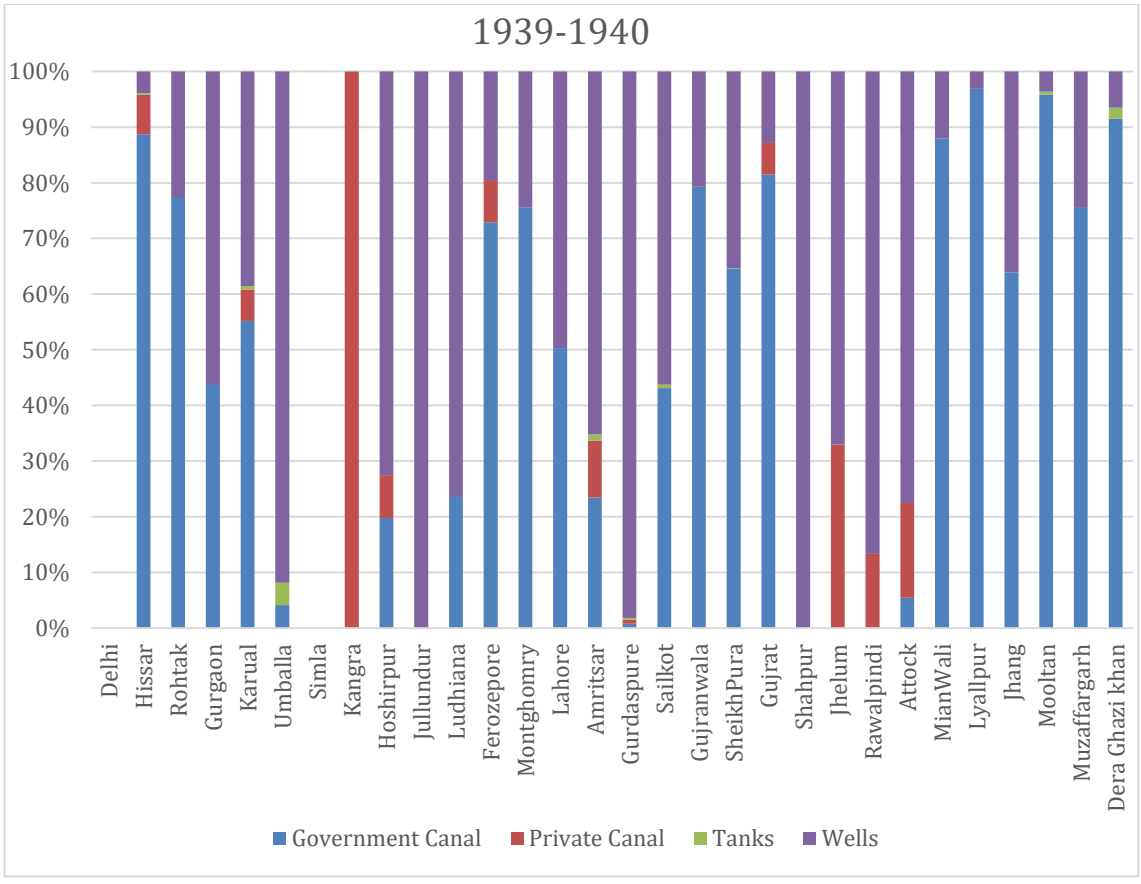
Gurgaon
Karual
Umballa
Simla
Kangra
Hoshirpur
Jullundur
Ludhiana
Ferozepore
Montghomry
Lahore
Amritsar
Gurdaspure
Sailkot
Gujranwala
SheikhPura
Gujrat
Shahpur
Jhelum
Rawalpindi
Attock
MianWali
Lyallpur
Jhang
Mooltan
Muzaffargarh
Dera Ghazi khan
Government Canal
Private Canal
Tanks
Wells


1939-1940
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Delhi
Hissar
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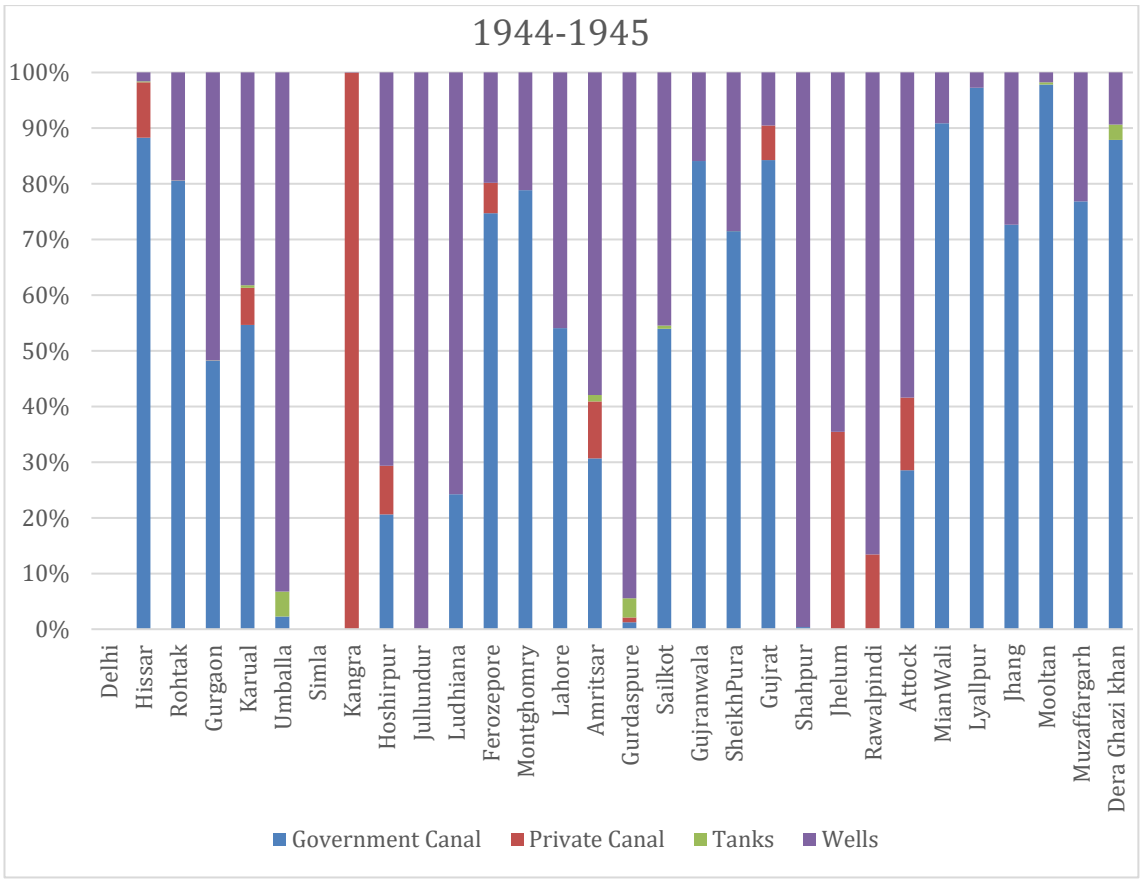
Gurgaon
Karual
Umballa
Simla
Kangra
Hoshirpur
Jullundur
Ludhiana
Ferozepore
Montghomry
Lahore
Amritsar
Gurdaspure
Sailkot
Gujranwala
SheikhPura
Gujrat
Shahpur
Jhelum
Rawalpindi
Attock
MianWali
Lyallpur
Jhang
Mooltan
Muzaffargarh
Dera Ghazi khan
Government Canal
Private Canal
Tanks
Wells



Source: Statistical Abstract Relating to British India 1885-86; Reports on Seasons and Crops (Various Years)

*Note: These graphs show changes in irrigation mix in colonial Punjab between 1885-1945. The choice of districts included in each year have been based on districts included in Punjab's administrative boundaries. Data on some districts missing in various Reports.