Chapter 16
Political Ecology of Groundwater Depletion in Northwestern India

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Abstract Reduction in the stock of groundwater in terms of quantity and quality by utilization of the groundwater resource by farming communities has been recognized as one of the major environmental problems in northwestern parts of India. The study area as a part of the Indus basin shows clear signs of groundwater depletion in many districts. Pressure on the groundwater resource has become linked to a few major developments in the cropping systems of Punjab, Haryana, and western Uttar Pradesh in recent years. This change in cropping pattern and certain governmental policies has tremendous negative effects on groundwater resources. In the present research, it is inquired how the patterns of groundwater utilization are influenced by the social structure of the farmers, government policies, penetration of market forces in agriculture systems, and surplus extraction of groundwater for irrigation. The chapter argues that the decreasing size of land holdings as a result of disintegration of the joint family system in farming communities under the law of inheritance and governmental policies are the main causative factors of groundwater exploitation in northwestern parts of India. Consequently, a *political ecology approach* has been used in the present research.

Keywords Ground water depletion • North-Western India

16.1 Introduction

Water is a scarce resource for agriculture in India, with a distinctly seasonal climatic regime and spatial variations in groundwater utilization. The study of natural resource utilization can be successfully achieved via the combined efforts of physical and human geographers, each with their established skills (Bell and Roberts 1986, 1991). One of the most robust and profound approaches to analyze

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groundwater utilization in the context of human–environment interaction is political ecology. Political ecology in geography has increasingly sought the incorporation of ecological analysis. This approach provides a framework for human ecologists interested in examining the interrelationships between local patterns of resource and larger political economy (Bassett 1988). Basic to this approach is to understand how political interest, social structure, social institutions, and human–environment interactions act together to cause groundwater depletion (Dhawan 1995; Bhullar and Sidhu 2006).[1] Groundwater depletion ecology is inherently interactive and illustrates the potential for geography to unite the physical (environment), social, and institutional (man-made) worlds. The political ecology concept is employed here in a comparative analysis of regional variations in the nature and intensity of groundwater exploitation in Northwestern India.

Agriculture in India has made amazing progress since the introduction and widespread use of high-yielding varieties of seeds, particularly in areas endowed with assured irrigation. It is beyond doubt that groundwater irrigation, being the stable source of irrigation, has made possible changes in cropping pattern that can contribute to greater increases in productivity (Bharadwaj 1990). The new agriculture technology program, which has been vigorously pushed by government and industry, demands much more water than traditional practices. Strikingly, it is pointed out that the need for agricultural water is going to increase every year as we need more and more food grains to sustain our rapidly growing population, increasing by about 10.7 million per year. Farmers nowadays have easy access to modern water-lifting technology that is capable of rapid groundwater withdrawal.

The area under tube well irrigation, which accounted for less than 1 % of net irrigated area up to 1960, increased to about 37 % by 2006–2007. The development of the rural electrification program and the availability of credit at highly subsidized rates have helped the farmers to increase the area under groundwater irrigation significantly (Shah 1985; Vaidyanathan 1994). The rapid development of groundwater irrigation helped not only the well-owning farmers but also non-well-owning farmers through groundwater markets. The Punjab State Environment Report (2007) indicates that these conditions, which determine access to groundwater, hold the responsibility of overextraction and, hence, decline in the water table (The Tribune 2007).[2] Further, there is debate regarding the efficacy of government subsidies in agricultural production, especially in areas especially where groundwater has been overexploited and agriculture production has become a nonprofitable proposition.[3]

[1] In technical terms the groundwater resource can be deemed to be in depleted state when the groundwater stock of a region diminishes in volume (Dhawan 1995). Generally, such a situation arises if groundwater use or withdrawal in a year exceeds groundwater recharge over the year.

[2] The State of Environment Report (2007) prepared by Punjab State Council for Science and Technology (The Tribune, September, 6, 2007) presents that 103 of 137 blocks in the State are overexploited by tube wells drawing groundwater for paddy cultivation.

[3] The decline in water productivity growth in the food grains sector of Indian agriculture in the past decade may be attributed partly to the loss of momentum in the development of yield-increasing technologies and partly to the political economy of irrigation from groundwater. The existing regulatory measures in India are totally ineffective or not implemented (Janakarajan 1996). This also

Given this background this chapter focuses upon groundwater irrigation and portrays that the small size of land holdings (social structure and economic conditions) and government policies are responsible for resource degradation. The analysis employs the *regional political ecology* perspective. Through the lenses of this framework, the following analysis provides added insights on how the economic behavior of small farmers is inextricably bound to change the ecology of groundwater depletion, and the politics within which farmers are embedded. The discussion indicates that agricultural practices of small 'progressive' farmers in the study region are accountable for depletion of the water table because of changing cropping patterns.

Small farmers have relatively less access to their own groundwater-lifting technologies such as bore wells, tube wells, and submersible pumps. Therefore, they depend on the farmers having large holdings with irrigational facilities. Consequently, there is a positive correlation between farm size and ownership of irrigation assets; the probability of groundwater purchase can be expected to be inversely related to farm size (Shah 1985). However, even a farmer with a large but highly fragmented farm may go for groundwater purchase to irrigate some of his plots that are located farther from the main plot having the irrigation facilities (Kolavalli and Chicoin 1989; Haque 1996; Saleth 1996). Irrigated land capable of producing two or more crops in a year, using the new agricultural technology, may sustain small and marginal farmers on a viable basis. Small farmers obtain higher yields per hectare because of account of careful culture, intensive cultivation, and easily available irrigation from groundwater from nearby farmers of large holdings. However, the variability and sustainability of farmers should not be considered as a static concept.[4] Moreover, what is found viable today may or may not remain so in future, depending on the population pressure on land. In fact, given the present trend of population pressure on land, most of the small and marginal farmers may join the rank of landless laborers in the future.

16.2 Purpose

The current research investigates the relationship among patterns of groundwater utilization and the influence of social structure of farmers, government policies, and penetration of market forces in the agriculture system and the surplus extraction of groundwater for irrigation. Various dimensions of the problems, such as the economic, institutional, environmental, legal, and political aspects, are addressed to diagnose

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raises a fundamental question: what went wrong with the existing regulatory measure? This warrants a thorough and systematic examination of the socioeconomic and political environment in which they are operating. The logic of groundwater-led agrarian change proceeds in three stages, as in the case of Gujarat State particularly, and is applicable to the entire country by and large; the conditions of access to groundwater; pattern of groundwater use; and conjunction of the two.

[4] It varies because of change in technology, cropping pattern, farming system, population growth, infrastructural facilities, and possibilities of integrations between farm and non-farm activities.

the problem of groundwater depletion. Further, the analysis delves into examining the influence between patterns of groundwater exploitation and social structure of the farming communities. It is hypothesized that this connection has an effect on markets and cropping patterns, leading to surplus extraction of groundwater for irrigation.

16.3 The Study Area

The study area is a part of the Indo-Gangetic plains and the densely populated region of India. It comprises the States of Punjab, Haryana, and Western Uttar Pradesh (the districts of Uttar Pradesh situated adjoining Haryana). This region is one of the largest groundwater repositories of the world. However, rising population and unsustainable agricultural practices have created greater stress on the groundwater resource. The adoption and diffusion of high-yielding varieties of seeds, pesticides, irrigation, and fertilizer intake has changed the entire scenario of this region in achieving food sufficiency. After 1965, emphasis was given to two major crops, wheat and rice. With the increase of irrigation, fertilizers, and high-yielding seeds, the best pulse-growing areas were converted to produce these two crops. Currently, these two crops occupy more than 80 % of gross cultivated area. Paddy cultivation, which requires a large amount of water, has changed the groundwater ecology of this area. Farmers are exploiting groundwater in this area unsystematically and injudiciously. Today, the farming community of this area owns larger land holdings, with their own tractors, combine harvesters, pumping sets, and tube wells. Consequently, an interesting picture has emerged. Small landholders are hiring these facilities from the large farmers to plough, irrigate, and harvest crops. Subsequently, an unhealthy competition has taken place among the small and large farmers to increase agricultural productivity by applying more water and more fertilizers. The sustainability of the groundwater has, therefore, been questioned in this entire tract.

16.4 Methodology

This study draws its inspiration from Blakie and Brookfield's (1987) interpretation of "political *ecology*" with its emphasis on identifying the social and environmental causes of resource depletion. The *regional political ecology approach* employed in this study questions the complex processes of social structure, government policies, institutions, and their combined effects on groundwater depletion ecology. This approach makes two significant arguments responsible for groundwater depletion: first, the decreasing size of land holdings resulting from disintegration of the joint family system in the farming communities under the law of inheritance; and second, government policies, which encourage farmers to grow water-intensive crops, such as rice and sugarcane. Resultantly, to maximize their profit from small-sized land holdings, farmers developed an unhealthy completion to grow more cash and cereal crops from the same piece of land by utilizing more groundwater for irrigation. This practice has given rise to changes in cropping pattern. In short, this reduction in the size of land holdings is viewed as a primary cause of groundwater depletion.

The current study used both secondary and primary sources of data. A combination of quantitative and qualitative methods of data collection was employed. Quantitative data regarding access to and use of groundwater by farmers were obtained with the help of a questionnaire. Similarly, qualitative data concern the experiences and perceptions of farmers involving political, ecological, and economic processes that invaded the use of groundwater resource for irrigation. Such qualitative data are strongly recommended in the regional political approach, which suggests that researchers put farmers at center stage for the explanation of groundwater use (Blaikie and Brookfield 1987; Awanyo 2001).

16.5 Political Ecology: A Research Framework

Reduction in the stock of groundwater resources in terms of quantity and quality in utilization by farming communities has been a traditional theme addressed by geographers. For geographers who have long been interested in human-induced modifications of nature, this amplifies the importance of these themes (Parson 1971; Kates 1987; Turner 1989; Simmons 1981). The human modifications of nature caused curiosity among geographers to develop a new concept of political ecology. But it is only during the past decade that it has both effloresced and, to a degree, coalesced around a set of particular propositions (Page 2003). The idea captures fundamental aspects of human existence as both natural and political beings, which include the energetic and material exchange that occurs between human beings and their natural environment. A political ecological perspective highlights not only the impact of political-economic relationships on the pattern of resource use but also the significance of environmental variables and how their interaction with political-economic forces influences human–environment relationships (Grossman 1984; Watts 2000; Page 2003; Walker 2006; Zimmerer 1991, 1994, 2006). Walker (2006) argued that political ecology has become a firmly established and a dominant field of human–environment research in geography. The term political ecology represents an attempt to develop an integrated understanding of environmental and political forces that interact to mediate social and environmental changes (Bryant 1992), which means considering how relationships of dependence and control between people develop out of and into relationships of dependence and control between people and their natural environment. The common themes that recur in political ecology analysis include the need to set a problem or phenomenon into its broader social and economic context and the need to relate both the phenomenon and its socioeconomic context to a variety of scales ranging from local to global. However, equally important is the setting of political ecology at the local scale. Therefore, what is maintained is that there are connections and influences that rise above any particular scale. The local scale is usually the focus for political ecology, and hence the term *regional political ecology* is applied to appraise the local resource base and its state of utilization, providing insights into the context and process underlying resource depletion.

In a political ecology context, regional political ecology (Blaikie and Brookfield 1987) as conceptual framework provides better understanding for considering regional politico-economic forces alongside the local ecology of resource depletion. The approach has already been used in a variety of studies (Bassett 1988; Mayer 1996). At one point in time, this controversial approach had been applied mainly to the agricultural system and food systems. Its controversy was rooted in the resistance to integration into cultural ecology of the political economy and its associated concepts. Recently, the political ecological framework has been used to understand the patterns and processes of resource utilization.

Recent attempts to identify the social and environmental causes of resource depletion and environmental degradation are clear in their complexities.[5] Regional political ecology, as led by Blaikie and Brookfield (1987), represents a broad-based approach encompassing a variety of scales, methodologies, and conclusions regarding the causes of land degradation. A variant of this approach has been applied in this study with two distinct aspects: first, the introduction of a small size of farmland is incorporated into the capitalistic mode of production; and second, this in turn may force the farmers to overdraw unsustainable groundwater.

The empirical regional analysis in this study clarifies, elaborates, and extends a number of key propositions of the regional political ecology framework. First, the study demonstrates how the small farmers are in a trap of production and competition. The farmers are trying to produce more agricultural production from small-size holdings by purchasing water from the groundwater markets for irrigation. In examining this phenomenon, the study deepens the *regional political ecology approach* by paying attention to the social relationships of the communities within which the resources are utilized.

When the ecological perspective is applied in the context of irrigation, a number of interesting implications arise (Coward 1980). In agricultural communities, such variables as society, technology, and population characteristics determine the adaptability of irrigation practices. At the microlevel, the political ecological perspective suggests the apparently irrational, unarticulated, and random activities in a particular irrigation system may be unmatched. This phenomenon when examined in relationship to the environment and sociopolitical context of its occurrence can exemplify a deeper understanding in which the events occur.

[5] The significance of recent work by Blaikie (1985), Rees (1985), Blaikie and Brookfield (1987), Redclift (1984, 1987), Emel and Peet (2002) and others is in the development of linkage between resources, economies, institutions, individuals, and societies. These works do not contribute particularly to management-level issues in terms of offering specific approaches. Instead, the major emphasis is on the social, political, and economic origins of environmental problems and the consequences of resource depletion.

Further, the approach adopted in this chapter assumes a concept of social structure that allows decrease in the size of farmers' land holdings that influences groundwater exploitation. The study emphasizes that society-made features reinforce the base for local groundwater markets for small and marginal farmers.[6] Second, the study puts weight upon social relationships within and between the suppliers and users of groundwater. It examines the social behavior of relationships among farmers and inquires how these relationships affect social behavior and human interaction, resulting in groundwater irrigation. The study offers empirically rich insight on how social identities are critical for comprehending the farmers' ability to take advantage of inquiring about irrigation water from a neighboring farmer who has irrigation facilities. A third argument is to examine the rationalization of institutions such as property rights and administrative systems. Broadly, both formal and informal institutions are interesting areas of research in natural resource management.

16.6 Results

16.6.1 Change in Cropping Patterns

The study area includes Punjab, Haryana, and Western Uttar Pradesh located in Northwest India. This region emerged as the most responsive region in the country in terms of agricultural production after the inception of the Green Revolution in the early 1960s. Groundwater irrigation, because of its suitable water quality, has been the most significant factor explaining the success of the revolution. Moreover, farmers to some extent were organized through political parties even in the pre-Independence era.[7] The study area as a part of the Indus Basin shows clear signs of groundwater depletion in many districts. Pressure on groundwater resources has produced a few major developments in the cropping system of Punjab, Haryana, and Western Uttar Pradesh in recent years. The most widely noted development has been the extension of paddy cultivation. In semiarid areas of Punjab, paddy remained a marginal crop of the *kharif*[8] season until about the mid-1960s. Since then, the explosion of tube well irrigation has increased the area under this crop. In addition,

[6] In the northwestern part of India, a mosaic of different shapes and sizes of operational holdings exists; there are, nevertheless, regional characteristics that are of some importance in accounting the regionalization of groundwater irrigation.

[7] The most important factor for the emergence of the farmer's organizations in the *Green Revolution Belt*: a long history of peasant struggle, favorable conditions, and awareness among the farmers. Consequently, the highest level of agricultural development at an all-India level has been recorded in Punjab, Haryana, and western Uttar Pradesh.

[8] In India, generally, three crop seasons are distinguished, namely, *kharif*, *rabi*, and *zaid*. *Kharif* season crops are those crops that are grown during the southwest monsoon period. It is the principal wet season of the country. Its duration is from July to October (the agriculture year begins in July in India). Likewise, *rabi* season pertains to the winter period, beginning in late October and ending in March. Similarly, the *zaid* season is related to crops that are grown between these two seasons.

Table 16.1 Shift in cropping patterns in Punjab, 1960–1961 to 2003–2004 (percent of area)

Crop	1960–1961	1970–1971	1980–1981	1990–1991	1999–2000	2003–2004
Rice	4.79	6.88	17.49	26.86	33.29	33.07
Maize	6.91	9.78	5.65	2.51	2.08	1.95
Cotton	9.46	6.99	9.59	9.34	6.07	7.72
Sugarcane	2.82	2.26	1.05	1.35	1.37	1.57
Wheat	29.58	40.48	41.58	43.63	43.18	43.57
Pulses	19.08	7.29	5.05	1.91	0.79	0.55
Oilseeds	3.91	5.19	3.52	1.38	1.26	1.08
Potato	0.19	0.29	0.59	0.31	0.97	0.83
Other	23.26	20.84	15.48	12.71	10.99	11.66
Total	100	100	100	100	100	100
Total cropped area (in thousands of hectares)	4,732	5,678	6,763	7,502	7,847	7,905

Source: Bhullar and Sidhu 2006 (*Economic and Political Weekly*)

the area under sugarcane also shows an increasing trend over time (Table 16.1). The area under rice, a crop with high water consumption, which was 4.79 % of the total cropped area in 1960–1961 increased to 17.49 % in 1980–1981 and further to 33.07 % during 2003–2004. Similarly, the area under wheat increased from 29.58 % of the gross cropped area in 1960–1961 to 41.58 % in 1980–1981 and 43.57 % in 2003–2004. Because the water requirements of these crops are relatively higher, total water requirements therefore increased (Singh 1992). The changing cropping pattern has a negative effect on groundwater resources. In fact, as fertilizer consumption increased and the irrigated area expanded, the growth rate of yield has slowed down and depletion of groundwater has been pervasive. Similarly, in Haryana and Western Uttar Pradesh (Meerut, Moradabad, Bulandshahar, Aligarh, Agra, Madhura, and Roorkee) during the past two decades, overexploitation of groundwater for rice and wheat along with sugarcane has adversely affected groundwater storage. The area under cultivation for wheat, paddy, and sugarcane has increased many fold. The fact is that the area under sugarcane increased without any impact of the Green Revolution because of price incentives. Therefore, production and acreage are largely determined by price and profitability.

During 1960–1961, Punjab State had only three sugar mills operating, with a daily sugarcane crushing capacity ranging between 2,950 and 3,200 tons. By 2001, the number of sugar mills increased to 19 with the per day crushing capacity increasing eightfold. Consequently, the area under sugarcane also shows increasing trends over time. The changing cropping pattern has a tremendous negative effect on groundwater storage. The latest assessment of water utilization compared to its availability shows that of 118 administrative blocks in Punjab, 73 are ranked as excessively depleted. Similarly, in Haryana more than 40 administrative blocks have been declared highly depleted in terms of overexploitation.

The states of Punjab and Haryana have practiced multiple cropping from one field during one cropping year. By converting these crops into areas, one can arrive at gross or sown areas in 1 year. Hence, these areas are directly proportional to the water consumed by the crops grown. In 1992, the gross irrigated area stood at 72 million ha served equally by surface and groundwater resources. This figure rose to 81 million ha in 1997. Disaggregated data are not available; however, it is reasonable to suppose that new water came from wells (Kochhar 2000). Continuous exploitative agriculture by adopting cereal-based (rice–wheat) crop rotation and application of heavy irrigation has caused an adverse impact on groundwater resources. In Haryana and Punjab States, production of cotton has sharply declined in both States. It is one of the several crops grown during *kharif* that was replaced by rice. Because rice is a more profitable crop than cotton, farmers preferred its cultivation.

16.6.2 Government Policies

More than other parts of India, the three States of Punjab, Haryana, and Western Uttar Pradesh have been responsible for overexploitation of groundwater. The expansion in groundwater irrigation in this area is the result of several factors such as improvement in technology of drilling and raising water, rural electrification program funded by the State, liberal loan facilities, and subsidized supply of electricity. On all these grounds, the government's policies of supporting and encouraging private groundwater development has been until recently widely acclaimed. There is now growing apprehension that these policies are leading to overexploitation of the groundwater. Evidence of progressive decline in the groundwater table is accentuating many socioeconomic and environmental problems (Bilas 1980; Pant 1987; Janakarajan 1996; Jeet 2001).

India faced the problem of chronic food shortage up to the end of the 1960s, which forced the government to identify high productivity regions to increase the production of food grains. Punjab State was identified as the potential food grain basket of India as it was endowed with fertile land and sufficient irrigation sources. Government intervention in the market led to remunerative price and assured marketing of the produce through a minimum support price policy backed by public stocking of food grains. Sufficient funds were invested in agricultural research to increase the productivity of wheat and rice (Sidhu et al. 2005). The area under wheat and rice increased at a very sharp rate (Table 16.1). Assured procurement of rice and wheat acted as a strong catalyst to shift the area toward these crops. The Food Corporation of India purchased whatever quantity was offered for sale and ensured market clearance. The minimum support price (MSP) (although is declared for 24 crops) is effective only for these 2 crops. In this way, the farmers were induced to divert their land from other crops to wheat and rice (Sidhu and Johl 2002).

The rice and sugarcane crops are in need of more water from sowing to harvesting periods. Such a high intensity of irrigation cannot be met with canal water alone even if it is available. So, the demand is met through pumping groundwater with electricity-operated tube wells. Further, the agriculture sector was supplied electricity at a subsidized rate or even free of cost for several years. The government had followed a distorted price policy. In the 1990s, the average annual electricity subsidy to the agriculture sector was rupees 10,470 million. Rice and wheat together consumed 66 % of the total irrigation water used in the agricultural sector of Punjab State (Hira et al. 2004). In Haryana, rice has been cultivated even in those areas where the soils are not suitable. A recent study conducted in Haryana has shown that until a few years ago the Rohtak District did not have any land under rice cultivation because the soils were not suitable for rice cultivation. Because of the remunerative price policy of the government, however, farmers have started growing paddy in this district (Jeet 2009).

16.6.3 Decrease in the Size of Land Holdings

The term agricultural holding or land holding refers to the amount of land held by one farmer. The average size of a holding in India is about 2 ha (or about 6.2 acres). The vast majority of farmers in India have very small and uneconomic holdings; only a small majority of farmers have large farms. Decrease in the size of land holdings is another significant factor in groundwater depletion of the three states in Northwestern India. Following disintegration of the joint family system, land holdings are equally divided among all the male members. In this process of division, the size of land holdings decreases from one generation to another. Table 16.3 provides information regarding land ownership patterns in the three states. Nearly 57 % of families in villages of these states own tiny land holdings, only up to 1 ha. Another 18 % of families own farms between 1 and 2 ha. In other words, 75 % of farmers own small land holdings consisting of up to 2 ha or about 5 acres, and they own only 26 % of the total area of the land of India. These patterns are for marginal and small farmers only.

Much the same is true of farmers of Haryana, Punjab, and Western Uttar Pradesh (Table 16.2). The size of land holdings decreases very quickly, which is an indication of the division of the joint family system of the farmers (Table 16.3). The plains of Northwest India were pioneers in the adoption of the new technology of the

Table 16.2 Land holdings in Punjab, Haryana, and Uttar Pradesh

		1990–1991	2000–2001
Size	Class	Percent	Percent
Marginal	Less than 1 ha	57	69
Small	1–2 ha	18	23
Medium	2–10 ha	23	07
Large	More than 10 ha	02	01

Source: Directorate of Economics and Statistics (2004)

Table 16.3 Average size of land holdings in Punjab, Haryana, and Uttar Pradesh

State	Average size of land holdings (ha)		Percent decrease
	1990–1991	2000–2001	
Punjab	3.79	3.11	21.86
Haryana	2.13	2.01	5.59
Uttar Pradesh	0.86	0.84	2.3

Source: Statistical Abstract of Haryana, Department of Economic and Statistical Analysis, 2003–2004

Green Revolution in India. Consequently, the highest level of agricultural development has been recorded in Punjab, Haryana (except for the districts of Hisar, Sirsa, Mahendragarh, and Dadri and Loharu Tehsil of Bhiwani District), and many districts of Western Uttar Pradesh.

The success of the Green Revolution in this region was itself made possible by assured and constant irrigation, which was provided initially by water obtained from a canal system harnessed from the river network and, subsequently, by water obtained as a result of the installation of electric tube wells and pump sets. With the disintegration of the joint family system, every individual farmer wants to get more yield from the small operation holdings. In doing so, small and marginal farmers install their individual tube wells and pump sets, although the efficacy of these water-extracting machines is questionable. Presently, a large number of tube wells extract groundwater in an unsystematic, uncontrolled, and injudicious manner. Interestingly, during 1966–1967 in Haryana State, one tube well used to supply water to nearly 2 ha (1.76 ha) of agricultural land, but this supply decreased to 0.07 ha in 2001–2002. Consequently, the geographic density of tube wells/hectare has increased tremendously. As a result, the interfering cone of each individual tube well has created a cone of depression leading to excessive groundwater depletion.

Second, in areas where operation holdings are too small and farmers are not in a position to install individual tube wells, groundwater markets are in operation. In this case, small farmers purchase water from the nearby tube well owner. As a result, widespread groundwater markets have arisen in this area. As a result, there exists a positive correlation between farm size and ownership of irrigation assets. Moreover, groundwater purchase can be expected to be inversely related to the farm size.

The nexus of agriculture and groundwater irrigation in the Northwest region of India has brought benefits but it is also characterized by problems and weaknesses: (1) there has been overexploitation of groundwater, leading to depletion, (2) water markets tend to emerge in the context of groundwater extraction through tube wells, and (3) there is danger of unsustainable extraction and inequitable relationship between sellers and buyers. Free and highly subsidized pricing of electricity has become the major reason for groundwater overdepletion, and (4) the response to the aforementioned three problems resides in groundwater regulation, but this has so far not been found feasible because of political and legal constraints.

16.7 Conclusions

In Northwestern India, the cropping pattern has changed drastically since the inception of the Green Revolution. Farmers grow more water-consuming crops such as rice and sugarcane. Hence, they are very enthusiastic about installing shallow tube wells. The advantage of a tube well relative to the canal supply lies in the fact that the source of water is owned by the individual farmer. Moreover, small farmers are in competition with each other for obtaining greater yield from a small piece of land in terms of growing more crops from the same field. It requires more water to practice multi-cropping from the same field. Therefore, because of the wholesale exploitation of groundwater, a tendency of falling water level leading to competitive deepening and larger financial losses has taken place. In many areas, shallow tube wells have gone dry and farmers now drill multiple bores alongside or within existing structures, and even this system of shallow tube wells had shown failure in terms of sufficient yields of water. Consequently, big farmers in this region install submersible pumps to tap the deeper aquifer beyond 200 m depth. This phase of water extraction has created various political, social, economic, and environmental problems among the farming communities and governmental organizations. However, challenges arise in three interrelated contexts:

1. This part of the country has witnessed changes in social structure, emerging from the split in landholdings caused by the increase in population. Consequently, large-sized landholdings are being converted into small pieces of land. This change in social structure encourages small farmers to grow cash crops such as wheat, paddy, and sugarcane for maximum profit and economic standards. This change in society is perennial and unmanageable.
2. The nexus among groundwater suppliers (big farmers) and users (small farmers) has led to the development of exploitation in groundwater markets. This nexus is strong and irrevocable so long as the ownership of the resource remains in the hands of landholders.
3. Present laws and regulations are not efficient enough to control overexploitation. Even political will is lacking in the execution of these regulatory measures. This concept raises a fundamental question: What went wrong with the existing regulatory mechanism?

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