CHAPTER 1

INTRODUCTION

1.1 Introduction

Groundwater is probably India’s most valuable and perhaps it’s most vulnerable resource. It is gaining importance as a source to meet the needs of India’s ever increasing population, for domestic, industrial and agricultural uses. The value addition by groundwater irrigation has been significant in the Indian agriculture since 1960s. In several regions it has significantly contributed to food security. It is estimated that groundwater irrigation has contributed 60 percent to the growth in the agricultural productivity (Nagraj and Chandrakanth, 1997). Furthermore, introduction of high yielding varieties, water intensive cropping pattern and technology intensive agricultural pricing policy paved the way for the extensive use of groundwater for irrigation. With time, irrigation by groundwater has surpassed the irrigation by surface water (Debroy and Shah, 2003 and Shah et al, 2003). In 1950, groundwater accounted for less than a fifth of India’s irrigated land and at present it is about 60 percent of India’s irrigated lands receive groundwater irrigation (Shah, 1998 and Shah et al, 2003).

With the spread of groundwater irrigation, the major concern towards further development of groundwater resource has been its equitable and efficient use for sustainability of this valuable resource and consequently the agricultural system dependent on it. As regards groundwater, the rate of extraction has been far above the rate of recharge. As a result, the numbers of over-exploited and dark blocks have increased by nearly 70 percent over the last 14 years (Government of India, Planning Commission, 2000). The issues involved in the groundwater irrigation have far reaching implications. The depleting groundwater resource by way of declining water tables and increasing dark blocks is not only an indicator of an ecological disaster but also emerging socio-economic distress. The future of much of India’s water resources lies in groundwater; a third of its groundwater potential has already been developed and privatized; the remainder will most likely get developed in the next two decades (Shah, 1993). Dhawan (1988), has summarized two most deleterious consequences of groundwater irrigation; (a) the depletion of the water table in tracts witnessing rapid development of groundwater irrigation and (b) the widening of income and wealth disparities between farm classes within an irrigated region. In our national search for social
justice and for ways to reduce rural economic inequalities, land reforms had played an important role. But in the coming decades an equitable distribution of water rights will pose as the major challenge in reducing agrarian inequalities. Professor M. L. Dantwala commented that, “I would urge social scientists concerned with the elimination of poverty and affluence in rural areas to shift their emphasis from redistribution of land to a more equitable access to non land resources....if available water resources are more equitably distributed, it would have a marked impact on the income distribution”.

1.2 Statement of the Problem

Irrigation is the greatest harbinger in the Green Revolution package of technological inputs for agriculture. At an aggregate level, irrigation is complimentary to the use of other inputs, notably fertilizer, and is systematically correlated with greater yields (Bharadwaj 1990, Vaidyanathan 1999). The importance of irrigation to agriculture in India is reflected in the central and state government outlays; “nearly four-fifths of public expenditure allocated to agriculture between 1950 and 1997 was spent on irrigation”\(^1\). Of this amount, nearly 70 percent went to major and medium surface water irrigation projects. Yet groundwater accounts for the largest and ever growing share of irrigation and it has surpassed surface water irrigation.

Since groundwater irrigation is more flexible and reliable than canal irrigation, it stimulates greater investment in complimentary inputs and produces greater yields. Consequently, the contribution of groundwater to the value of agricultural production in India is very high (Dhawan). Disenchanted with the efficiency of public tube-wells, the farmers have resorted to private extraction of groundwater through privately owned pump sets. Since the early 1970s, the number of privately owned pump sets and wells has grown exponentially while investment in public tube-wells has remained flat (World Bank 1998, pp. 10). Groundwater is, thus, becoming critical to the productivity of Indian agriculture and the livelihood of millions.

During the 1980s and 1990s, available data began to show alarming signs of over-exploitation of groundwater. While the rate of groundwater exploitation at the county level remains as low as 31 percent, a few states heavily dependent on groundwater such as

Gujarat, Punjab, Rajasthan, Haryana and Tamil Nadu show more disturbing trends (World Bank 1998). In Punjab, for example, on simultaneous shift to tube-well irrigation increase in acreage of rice cultivation, the number of over-exploited blocks increased from 53 in 1984 to 103 in 2004. At the ground level, it amounts to successive lowering of well depths and capital investments in water technology to lift water which increases the cost of production and lowers net returns. Since the technology needs hefty capital investment, small landholders remain excluded from the benefit of this common pool resource and on account of depletion, many existing tube-well owners who do not have the capital to chase groundwater tables through subsequent deepening of wells are also left out of the beneficial ambit of groundwater irrigation.

Despite the importance of groundwater to agricultural productivity, and despite the signs of degradation of the resource, groundwater has received scant attention from social scientists. Initial studies were preoccupied with the reasons of groundwater development. Its superiority to other sources of irrigation was proved on the basis of the efficacy of groundwater irrigation and its contribution to productive gains in agriculture. Distribution of these productive gains was not discussed an issue. The signs of over-exploitation took a shift in the perspective of the study on groundwater. Focus was laid on condition of the resource (Moench 1995, Bhatia 1992), local institutions for allocation and recharge of groundwater (Moench 1992), link between electricity prices and groundwater use (Shah and Raju 1998, Dubash 2007). In addition there are a few important case studies that focus on unequal access to groundwater and its impact in different parts of the country (Bhatia 1992, Jairath 1985). In this study, the issues on accessibility to groundwater irrigation are studied comparing three different irrigation systems at different levels of groundwater depletion. It shows how contemporary concerns originate in social and institutional arrangement that made possible the rapid private investments in groundwater. While issues of economic accessibility is studied in light of changing profitability and investment to harness groundwater, social accessibility is determined by institutional mechanisms and terms of exchange of groundwater from the resource rich tube-well owners to the resource poor small and marginal farmers.
1.3 An Overview of Literature

Groundwater has played a significant role in maintenance of India’s economy, environment and standard of living. Besides being the primary source of water supply for domestic and many industrial uses, it is the single largest and the most productive source of irrigation water (Chadha, 2001). According to Marcus Moench (1992), “Groundwater is a dry topic unless you happen to have a dry well”. While groundwater development has had important implications for the economy, over-exploitation of the resource is emerging as a major concern both from the sustainability and equity point of view (Shaheen and Shiyani, 2005). Groundwater management involves some of the most complex environmentally and socio-economically challenging sets of issues facing India in the 21st century. So it is important to conceptualize the key aspects of the groundwater resource base and the emerging social, ethical, legal, institutional challenges of sustainable management of groundwater resource and resulting externalities arising out of it.

1.3.1. Conceptualizing Groundwater as a Resource

Groundwater is an indivisible resource. As a result, both the dynamics of the resource base and the services it provides are often poorly understood (Moench, 2000). To study the various aspects of groundwater utilization, it is, thus, very important to conceptualize groundwater as a resource. Though, water resources fall into the category of common pool resources and are public goods, most of these resources do not represent pure forms of open access, community or state property, as they are mixtures of these three idealized types (Berkes and Favar, 1989 and Singh, 1994). A classic example is groundwater in India. A groundwater basin is a common pool resource in the sense that exclusion of multiple users is difficult and costly (Reddy, 2005). By the nature of the resource, groundwater development is largely by private initiative of farmers. Their access to the precious resource is often conditioned by their size of holding, savings and investment capacities (Nagaraj and Chandrakanth, 1997).

1.3.2 Reasons for Development of Groundwater Irrigation

Vaidyanathan (1996) rightly comments that one of the most striking features of irrigation development in India during the past four decades is the rapid growth in the use of groundwater. Several positive externalities associated with groundwater extraction
particularly in agriculture have led to the development of the groundwater resource through spread of tube well technology. The performance of irrigation by wells varies in India from region to region depending upon the availability of groundwater, cropping pattern and other climatic and soil factors (Reddy, 1995). The spread of bio-chemical technology and achievements in agricultural growth have been attributed, in large measure, to the extensive use of groundwater irrigation (Janakarajan, 1993). Dhawan (1990) has recognized four factors namely land consolidation, rural electrification, institutional credit and advent of HYV seeds for the spread of groundwater irrigation in India.

The expansion of groundwater irrigation is the result of several factors. Improvements in the technology of drilling and lifting water have made it possible to tap deeper aquifers, pump larger volumes of water and lower the cost per unit of water extracted. The rural electrification programme, which has been largely funded by the state, together with liberal loan assistance on concessional terms for setting up, deepening and energisation of wells and subsidized supply of electricity have contained the increase in private costs. The advent of new varieties of fertilizers increased the productivity impact of irrigation and the prices of agricultural products have been rising. The productivity per unit of water tapped is much higher in the case of groundwater compared to surface irrigation because groundwater irrigation involves much less waste by way of conveyance and application losses and farmers have much greater flexibility to adjust timings and the quantum of water application to the crop needs (Vaidanathan, 1996; Pant, 2005; Moench, 2000).

Groundwater irrigation efficiency is considerably higher than the canal irrigation projects (Shah, 1993). It is known to be as high as 80 percent (Vaidyanathan and Sivasubhramanium, 2004). Dhawan (1988) in his extensive study of inter source differences in productivity of irrigated agriculture has concluded that individually owned means of irrigation, which are mainly dug wells and shallow tube wells, are rated above government and community operated irrigation works like canals, tanks and deep tube wells. A variant of this proposition is that well irrigation is superior to irrigation with surface water in the matter of farm production impact, with private tube wells being the most superior. Studies in villages in Punjab indicate that the flexibility and reliability of the irrigation water source increases the input use increasing the yields and economic returns. Thus tube wells become the most profitable source of irrigation (Sidhu, Chand and Kaul, 1999; Kaul, 1991). Kaul’s study
(1991) further strengthens this point where he reports significant increase in the productivity due to increased use of inputs in farms using electric tube wells as compared to diesel and canal farms. An overwhelming advantage of private ownership of tube wells lies in the matter of maintenance and control of water. At the individual well level private operators is much more efficient even when they operate with ‘low’ technology (Singh, 1991).

Dhawan (1988), in his study has concluded that superiority of groundwater over surface water varies from state to state. Individually owned tube wells in Punjab and Haryana enhance farm output by about 28 quintals/hectares which is almost twice the level of public canal irrigation. Whereas in Tamil Nadu and Andhra Pradesh, there is an additional output of 15 – 21 quintals in case of canals and 34 – 36 quintals in case of wells.

Advent of high yielding variety of seeds is a crucial factor for furthering development of groundwater irrigation bringing about an agricultural transformation ever since the onset of Green Revolution. In fact, innumerable research investigations have highlighted a close relationship between the success of HYV programme in an area and the use of groundwater irrigation- especially individually-owned tube wells and wells fitted with power pumps (Dhawan, 1988; Dhawan, 1990). It is because of the fact that the farmers felt the additional need for water resource particularly after the introduction and spread of high yielding bio chemical package. These additional water requirements could not be met by the traditional irrigation sources like canals and tanks because of their poor maintenance and limited water supply only during a particular time period (Janakrajan, 1993).

Dhawan (1990), while summarizing the positive externalities of groundwater concludes that “being a perennial source of irrigation, tube well encourages crop activity throughout the year. Its dependability during the drought permits crop intensification of a high level as the farmer is insulated substantially against production risk. With the state providing assurance of price stability, owners of tube wells are well placed to a steadily rising standard of living”.

1.3.3. Decline in Groundwater Tables

Over extraction in the specific context of groundwater resource means that withdrawals tend to exceed the annual replenishments via groundwater recharge, the excess being accounted for by a permanent reduction in the volume of groundwater stock underneath – it is in this sense that over-exploitation of groundwater is described as ‘groundwater mining’. Its
unmistakable manifestation is the lowering of groundwater table (Dhawan, 1990). As water is extracted beyond optimum yield level, Groundwater tables go down and may even lead to drying up of the aquifer in the fragile environments (Reddy, 2005). The extent of recession of water table is governed by numerous factors such as density of tube wells; their discharge rates and annual running hours; rainfall and its infiltration rate into the soil, extent of artificial recharge of groundwater through canal/tank seepage; availability of surface irrigation for meeting part of the irrigators demand for water etc (Dhawan, 1990).

According to the central and state groundwater organizations, the intensity of groundwater exploitation has reached, or exceeded, sustainable levels in an increasing proportion of the development blocks all over the country (Vaidanathan, 1996). Although some groundwater experts may brush aside the question of groundwater depletion commenting that there is nothing serious about it and the trend is confined to a few segmented pockets, the fact is that the tube well revolution in Indo-Gangetic plains have reached an optimum stage with respect to groundwater development (Pant, 1987; Bandopadhyay, 1987). Evidences of progressive decline in groundwater tables in several parts of the country like Gujarat, Punjab, Karnataka, Rajasthan, Tamil Nadu and parts of Indo-gangetic plains are accumulating (Shah, 1985; Prihar et al., 1990; Singh, 1991; Bhatia, 1992; Moench, 1992; Singh, 1992; Shah, 1993; Dhawan, 1995; Janakrajan, 1996; Dubash, 2000; Sharma and Sharma, 2004).

1.3.4. Reasons of Depletion of Groundwater

Several studies have been undertaken to understand the reasons for depletion of groundwater. The problem of groundwater depletion has been seen in the wider context of green revolution which has involved a radical shift from traditional agriculture to modern cultivation methods based on an intensive use of new seeds, fertilizers and energized irrigation. The modern technologies of Green Revolution have played a major part in the current crisis of over exploitation (Bhatia, 1992) and the crisis was inevitably built into the political economy of the state from the very inception of the Green Revolution (Sharma, 2003). Ballabh (2003) has argued that the current hype and hysteria about water scarcity as an ‘absolutely natural phenomenon’ and is being created by the privileged minority which is dominant and influential in the water sector.
Dhawan argues that the warning with regard to groundwater mining will become a real concern only when it raises "serious cost implications". But because of a number of reviving circumstances the pinch of the much talked about declining water table is not being felt acutely. Firstly, the new bio chemical farm technology has helped in cushioning the additional expenditure entailed by the decline in the water table. Secondly, the lowering of water table in the canal irrigated tracts has come as a welcome relief to the policy-makers working under the shadow of water logging. Thirdly, massive extension of rural electrification has reduced unit operational cost of pumping water. Fourthly, continued expansion of institutional finance for farm equipment at liberal terms has encouraged adoption of new water extractions machines (1975).

Rapid growth of minor irrigation have led to the over extraction of groundwater resulting in emergence of dark zones which has far reaching implications not only from the users point of view but also from the ecological stand-point (Singh and Joshi, 1989). Jeet (1999) concluded that major factors of groundwater depletion are irrigation development of the area, groundwater quality, cropping intensity, cropping pattern, accessibility to modern water extraction machines, inefficiency of traditional irrigation sources like canals and tanks, high yielding variety of seeds and lack of water recharge due to rainfall below normal.

Notwithstanding the hydro-geological thresholds of groundwater, intensive cultivation of water intensive crops is unabated on an extensive scale ever since the 1970s hastening the groundwater depletion (Nagaraj and Chandrakanth, 1997). Studies have pointed out that the continuously receding groundwater table in the state of Punjab is a phenomenon of 80s. So it is being linked to the main changes in the state, notably to the rise of paddy-wheat crop sequence in the irrigated agriculture in the state (Chand, 1999). Paddy is a much water intensive crop and thus the water requirements are much higher than the other alternative Kharif crops like maize, bajra, pulses which have been replaced by it in the cropping pattern. The phenomenal rise in the paddy cultivation is widely perceived as the main reason behind the fall in the groundwater table in the state (Dhawan, 1993; Singh, 1991). The other factors which have contributed to the lowering of groundwater table include increase in sugarcane cultivation, increase in cropping intensity, increased lining of canal network and bad run of below normal rainfall years in the 80s (Dhawan, 1993). Singh and Sankhayan (1991) opined that shift in cropping pattern to wheat-paddy and wheat-cotton rotation and increase in
sugarcane cultivation has resulted in falling water table in the entire sweet water zone of the state. Joshi and Tyagi, (1991) also concluded that the draft of groundwater is mainly determined by rainfall, rice acreage and number of tube wells. Singh (1992) also concluded that the inadequate rainfall and the extension of area under paddy have been the two principal reasons for the decline in groundwater table in Punjab. According to Surender Singh (1991), increase in gross cropped area, rise in cropping intensity, expansion in area under paddy and emergence of wheat-paddy rotation have impinged upon the groundwater resources of Punjab.

Studies indicated that, owing to the increased demand of water for domestic, industrial and agricultural needs and limited surface water resources, there has been explosive development of groundwater resources (Diwarika and Nagraj, 2003; Moench and Janakarajan, 2006).

The profitability of investments in tube wells and other costly water extraction machines have been greatly enhanced by various government policies including highly subsidised electricity pricing and liberal financial assistance. It has been empirically proved that in particular regions and periods the expansion of water extraction machines has followed the depletion of groundwater, in general these two phenomena are best seen as mutually reinforcing (Bhatia, 1992). But there is evidence that owing to the growing demand for groundwater and substitution of labour intensive water lifting methods by capital intensive electrical irrigation pump sets, there has been large scale exploitation of groundwater leading to a high rate of well failures leading to loss of investment on well irrigation (Nagaraj and Chandrakanth, 1995).

The most worrisome manifestation of politicization in recent period is the political rent seeking by offering free electricity for pumping water which has led to the over exploitation of groundwater resources (Rao, 2002; Nagaraj and Chandrakanth, 1997; Singh, 1998). There is no doubt that the policy of cheap power, coupled with pernicious flat power tariff, has given rise to two deleterious consequences. First it has enabled the farmers to over-irrigate their crops right up to the point where the marginal value of product of groundwater becomes zero. In a PAU survey it is seen that the farmers of Punjab on an average apply 32 waterings to paddy above the recommended number of 25 waterings. Secondly it has induced the cultivation of water intensive crops like paddy and sugarcane (Dhawan, 1993).
At present even the normal tariff has been waived off and free supply of electricity is declared for agricultural purposes. This leaves no incentives for farmers to economise on water use and encourages indiscriminate and excessive water use.

Rao (2002) has commented that billion tonnes of scarce water resource has been wastefully used over the years in the semi arid plains of India, which could have been saved or diverted to higher productivity uses if the electricity prices and procurement policies were better aligned with the emerging domestic and export demand for foodgrains.

13.5. Externalities Arising out of Groundwater Depletion

Externalities arising out of groundwater depletion could be stock related, cost related and strategic in nature (Provencher, 1998). Stock externalities are also termed as contemporary externalities (Howe, 2002). Stock or contemporary externalities arise when over exploitation of groundwater by some effects others, which is a wide spread phenomenon. Perpetuation of this process could lead to inter-temporal externalities due to drying up of aquifers (Howe, 2002).

Technological externality

Correlated externalities arise when the costs of extraction become uneconomical or costs go beyond the reach of some individuals. A few individuals with access to capital strategically capture all the available groundwater, depriving the others. This is termed as technological externality, which arises due to the fact that access to technology is biased in favour of capital rich farmers. The existing inequality in landholdings, the inequity in access to groundwater widens the skewness in assets and income distribution (Nagaraj and Chandrakanth, 1997). The capital intensity of groundwater extraction makes it easier to exclude rival users especially in fragile resource regions, making the resource privy to a few well-to-do-households (Shah, 1993).

Another reason for virtual dominance of large farmers is perhaps their capacity to absorb the shock due to high failure rate of bore wells due to water table depletion and the associated investment. The higher holding size of large farmers acts as a shock and stress absorbing machine (Nagaraj and Chandrakanth, 1997).
Economic and Social Externalities

Distribution and access to groundwater is uneven and it varies with in a micro environment. Equity in access to groundwater is a concern as groundwater offers considerable potential to enhance land productivity (Nagaraj and Chandrakanth, 1997; Pant, 1984). Access problems or externalities are aggravated in the light of depleting groundwater resources. With over exploitation and depletion of groundwater resources, farmers of small and marginal landholding size, who are not in a position to access the resource, are the first victims of the externalities arising out in the process of resource depletion. Even when they have the financial capacity they are not in a position to compete with the farmers of large holdings in deepening their wells. As a result, the cost of the groundwater depletion is disproportionately borne by these farmers. Not only is the size of the landholding, the quality of land is also an important factor in determining investments in modern water extraction machines. Investments are more attractive on flat, low-lying, fertile and stone free lands. But again such lands are invariably owned by large farmers belonging to the higher castes (Bhatia, 1992). Nagaraj and Chandrakanth rightly commented that, "The race to exploit groundwater resource will continue exponentially by haves, and have-nots will obviously bear the brunt of this negative externality".

The decline in water tables has led to the drying up of open wells and increasing well failures causing higher costs of installing new wells, deepening of existing wells and pumping and other maintenance activities (Moench, 1992 and Shah, 1985). The failure of dug wells, shift to water-high value crops and policy instruments like soft loans to sink wells and zero marginal cost for electrical power to lift groundwater, disturbed the equity in well irrigation, and paved the way for the use of expensive technologies for rapid harnessing of groundwater. As a result, the dug-cum-bore well and bore wells contributed to inter and intra-generational inequity, even though they increased the overall growth of agriculture (Nagaraj and Chandrakanth, 1997).

A declining water table may not only raise the marginal operational cost but also give rise to a situation of diminished water availability, resulting in loss of farm out put of the irrigator (Dhawan, 1975). Further, the magnitude of losses increases as the farm size declines (Reddy, 2005). Farmers who can not afford the extra investments needed for competitive deepening of the tube wells may be forced to give up well irrigation and thereby lose out to the better
endowed farmers (Vaidanathan, 1996). Due to high investment cost and frequency of well failure, marginal and small farmers are fearful of going in for a new bore on an individual basis, thereby limiting their access to the resource (Shaheen and Shiyani, 2005). Studies have also shown that ownership of irrigation assets are dominated by the high caste farmers who are also the better endowed farmers (Bhatia, 1992; Kripa, 1992; Shah and Ballabh, 1997; Singh and Singh, 1998). Thus in the race of competitive deepening of tube wells the distribution of access to groundwater becomes increasingly skewed in favour of large and resource rich farmers leaving the resource poor farmers out of race (Bhatia, 1992; Janakarajan, 1993; Shah, 1993; Saleth, 1996; Moench, 1992; Shaheen and Shiyani, 2005). Small farmers will also not invest in modern water extraction machine because of the risks involved in it like risk of breakdown of collective arrangements and of being cheated by credit institutions and the major risk is that a bore well will fail to strike water (Bhatia, 1992). It is just another example of how in a capitalistic economy, those who are well endowed to start with tend to be the winners in the competition for further accumulation (Bhatia, 1992).

The deepening of wells also implies the consequent drying up of adjacent shallow wells which are served by the same aquifer. Thus, these also need to be deepened in order to have a persistent water yield from them. Shallow wells are largely owned by small and marginal farmers who are unable to invest in the deepening and counter deepening of wells. Moreover it also imposes heavy burdens on new comers who want to install new wells (Janakraj, 1993; Joshi and Tyagi, 1991; Singh, 1991). In a situation of limited supply of groundwater, early control over groundwater by rich farmers can become an irreversible and permanent feature (Singh, 1991). While drought is getting mitigated for the large farmers growing cash crops, energised pump-sets are creating new drought for marginal and poor peasants by drawing down the water table below their reach (Bhatia, 1992).

This has severe equity implications in a situation where farmers have little opportunity to earn their income from sources other than irrigated agriculture (Nagaraj and Chandrakanth, 1997). Reddy, in his study of three villages in Andhra Pradesh has shown that with increasing groundwater depletion and water scarcity, there is a marked decline in irrigated area, cropped area, shifts in cropping pattern and even declining yield rates. Farmers, especially the small and marginal ones are shifting away from more remunerative and water
intensive paddy crop to other less remunerative and less water intensive dry crops as cost of groundwater extraction increases with further depletion (2005). Shaheen and Shiyani (2005), in their study in selected villages in Gujarat have seen that a majority of farmers have changed their cropping pattern from more water intensive crops to those requiring less water. Even in some cases farmers have shifted to other occupations including petty business and working as labourers in nearby urban areas. The study of Nagaraj and Chandrakanth (1997) in selected villages of Karnataka has shown that with increasing depletion of groundwater small farmers, who were earlier well owners, were reduced to the status of buying irrigation water and some were even forced to follow dry land farming and earn wage incomes from labour hiring. Shankar (1992), in his study of villages of Uttar Pradesh reported that small and marginal farmers, who can not afford to invest in deepening of the well due to capital constraints even sell or mortgage their land to install tube wells so that their overall agricultural productivity may rise.

Some studies have also shown that the spread of groundwater irrigation has weakened traditional irrigation systems like tanks, springs and canals (Janakarajan, 1993; Palanisami and Balasubramaniun, 1998; Singh, 1992). The government policies like licensing, sitting rules, and groundwater zones (Shah, 1993) has given a wide spread apprehension that instead of reducing relative inequalities among rural incomes, irrigation development has actually enlarged the relative inequalities already prevalent (Shah, 1993).

1.3.6. Role Groundwater Markets in Reducing Inequality to Access to Groundwater Irrigation

Saleth (1998) estimated that water markets were providing water for about 6 million hectares or 15 percent of the total area irrigated by groundwater in India. The water markets are highly beneficial because it offers irrigation access to all those resource poor farmers who do not own wells and pumps; it enables farmers to irrigate all or most of their parcels of land for better parts of the year; it increases better utilization of the pumping capacity of the well owners; it increases cropping intensity and farm productivity leading to increased demand for labourers and consequently in increased farm incomes (Shah, 1993). Access to groundwater also reduces agricultural risks. Thus, it can enable farmers to begin a gradual process of agricultural intensification and accumulation that allows them to move out of poverty (Moench and Janakarajan, 2006). It has been seen that in relation to operational
area, small and marginal farmers tend to have proportionately more irrigated land than the large farmers. With productivity on irrigated lands being much higher than on non-irrigated tracts, better access to irrigation for small and marginal farmers can significantly reduce poverty (Moench, 2000).

The key factors that promoted the development of water markets include natural and physical factors including soil fertility, topography, hydrology, climatic conditions especially the untimely or delayed rainfall, land and water quality, reliability of groundwater sources, percentage of farm area under canal irrigation, well density, profitability from water selling, risks associated with agriculture mostly crop failures, untimely availability of labourers, extent of land fragmentation, farm size, subsidized electricity and access to modern technology for deeper wells and pumping (Diwarika and Nagraj, 2003; Singh, 2002; Shah, 1991; Saleth, 1991; Dubash, 2000). Studies have shown water markets in the eastern regions of the country like Orissa, Bihar and Bengal to be least developed, and those in Punjab, Haryana, Western Uttar Pradesh, Maharashtra, Gujarat and parts of Tamil Nadu to be highly developed (Shah, 1991).

It is observed that groundwater markets will take care of the equity issues in accessibility to groundwater (Shah, 1993; Satyasai, 1987; Shah and Raju 1988; Shankar, 1991; Singh, 2002; Shah and Ballabh, 1997). In other parts of the world, water markets are increasingly being used as a machine for efficiently redistributing water to the highest value uses – particularly during times of scarcity (Moench, 1991).

Since the possibility of performance of the buyers is better than the farmers using other sources of irrigation, groundwater markets have a tendency to improve the equity in sharing the groundwater as well as the income generated thereof (Singh and Tewari, 1998). Shah and Ballabh, (1997) in a village level study in north Bihar have come to a conclusion that water buyers achieve marginally higher cropping intensity compared to water extraction machine owners. Studies have shown that groundwater markets lead to higher and risk free income realization and employment generation by increasing crop yield and cropping intensity and changing cropping pattern in favour of high value crops (Singh and Singh, 2003). Thus groundwater markets have a tendency to improve the equity in sharing the groundwater as well as the income generated thereof (Satyasai, Kumar and Mruthyunjaya, 1997).
Saleth (1991) in an extensive study of groundwater markets in five Indo-gangetic states, viz., Bihar, Haryana, Punjab, Uttar Pradesh and West Bengal concluded that groundwater markets benefit mostly the small and marginal farmers with low or no share in canal irrigation especially under unfavorable climatic conditions. Since the reduction of crop damage through groundwater purchase occurs largely in smaller farms, water markets have powerful welfare effects in terms of both increasing and stabilizing small farms' farm income.

To understand the equity effects of groundwater markets, it is important to know who sells water and who buys water. Academic debate persists regarding this issue. Some scholars are of the opinion that sellers of water are the farmers with larger holdings who have the financial capacity to install their own water extraction machines and sell surplus water after meeting their own requirements while the buyers were the farmers with smaller holdings who do not have the financial capacity to install modern water extraction machines and thus, buy water from the large farmers. Such a situation is evident in regions where water levels are deep and construction of tube wells are very costly which can only be afforded by the rich farmers with larger land holding size who can also chase the water table due to their sound economic condition which is beyond the reach of the poor farmers (Singh, 2000; Moench, 1992; Shah, 1985). However, another set of studies have indicated that well owners with small land holdings have a higher extent of participation in water selling than those with larger holdings because the former tend to have surplus water even after irrigating their own fields (Meizen and Dick, 1996; Narayanamoorthy, 1994; Shah and Raju, 1988). However, a farmer with large but highly fragmented farms may go for groundwater purchase to irrigate some of his plots located farther from the main plot having irrigation facility (Shah, 1993; Saleth, 1991).

While all these studies look at the water exchange primarily through determinants of price, Wood (1995) recognizes the role of the water buyers' structural location in the social networks. Thus while there is a myth of a single universal price of water within a village, an ability to pay the price does not guarantee access to water. Moreover real prices are lowered for favoured clients. Access is decided on the basis of “moral circles of proximity”. Dubash (2000) also in his study concludes that social norms in the villages are price signals in the
water markets rather than the economic competition. Thus groundwater markets are ecologically and socially embedded.

If one has to compare the economic benefits of buyers and sellers in groundwater markets with regards to yield impact, it gives a very mixed result. The average yield was reported to be greater in case of water extraction machine owners than the water buyers (Singh, 1998; Gupta, 1995; Shah and Raju, 1986; Pathak et al., 1985). On the other hand some studies reported that the buyers obtained significantly higher yield in comparison to water extraction machine owners (Shah and Ballabh, 1997; Shah and Raju, 1986 and Singh and Singh, 2003). Some studies also indicate the difference in yields realised by the buyers and the sellers were non-significant (Strosser and Kuper, 1994 and Shankar, 1992).

While it has been mentioned that groundwater markets lead to a more egalitarian distribution of gains from groundwater development; certain group of scholars question the very premise on which the equity angle of water markets rests (Dubash, 2002). Studies have shown that the terms of groundwater transactions might tend to be rather exploitative especially in regions of groundwater water scarcity where the water sellers gain significant power to dictate terms to the water purchasers (Janakarajan, 1993).

Cost of water extraction and selling price may be regarded as the indicators of efficiency of water markets. If the cost of water extraction is equal to the selling price, water markets can be considered as efficient. If it is greater than selling price, then water markets are inefficient one and if selling price of water is greater than cost of water extraction then water markets can be considered as exploitative (Sharma and Sharma, 2004; Shah and Ballabh, 1997).

Studies have shown that, such exploitative water markets although make groundwater accessible to both resource rich and resource poor farmers, it leads to greater disparity in their incomes as buyers of water receive lower net returns from cultivation of crops on account of higher charges paid by them for purchased irrigation water; thus widening the gap between the resource rich and resource poor farmers. It has failed to protect the interests of the small and marginal farmers and other weaker sections of the society (Satyasaii, Kumar Praduman and Mruthyunjaya, 1997; Prasad, 2002; Bhatia, 1992). Still in the wake of failure of traditional irrigation system the farmers may opt for purchase of water at high cost.
rather than going without it (Sharma and Sharma, 2004; Janakarajan, 1993; Reddy et al., 1993).

Terms of transaction in water markets depend on the availability of groundwater in the region, nature of crop, level of education, farm size category, preference of the sellers for leisure or farm work, power pricing policy of the state and the stage of market development in that area (Janakarajan, 1993). Kind based contracts are reported when the water prices are high. It is mostly seen in areas with water scarcity with well developed water markets (Janakarajan, 1993; Satyasai et al., 1997; shah, 1993). Whereas in areas where water scarcity is less prevalent; hourly mode of transaction may become prevalent (Satyasaii, Kumar and Mruthyunjaya, 1997). Studies have also shown cash-based hourly terms of contract in the semi arid regions and kind based crop output sharing contract in arid regions (Sharma and Sharma, 2004). The water rates also depend on the quality of the water and the type of energy used. Janakarajan (1993) in a village level study in Tamil Nadu has reported that poor quality of water is charged low; if diesel pump is used for lifting water, rates are high irrespective of the quality of water. It has also been proved that education and awareness among the farmers decrease the extent of exploitative nature of water markets (Satyasai, Kumar and Mruthyunjaya, 1997).

Power pricing affects groundwater markets. Shah and Ballabh, (1997) in their study in villages in north Bihar have shown that changes in water prices occur with the changes in diesel prices. Every time the diesel prices rose, water cost rose by three times the rise in the diesel cost. Studies have shown that groundwater markets have proved to be a boon and it relates to economic and efficient use of electricity (Pant, 2005). A group of scholars argue that flat rate of power tariff encourages the farmers to over use their pump sets because they do not pay by the quantity or time of electricity use. Whereas the meter of variable power tariff basis would strengthen the inducement to save on electricity bill by economizing on electricity use (Sharma and Sharma, 2004). The bulk of power subsidies go to the well off water extraction machine owners as more poor depend on purchase of water than use their own water extraction machines. So to enable poor to gain access to groundwater it is enough to switch to flat rates (Shah, 1991). The best pricing system seems to be the progressive flat rate. In this rate per horse power raises as the capacity of the water extraction machines increases. Thus it not only encourages small holders to own water extraction machines but
also enables small water extraction machine owners to assume leadership in the market since they have distinct cost advantage; in addition, in water scarce areas, they discourage large capacity motors (Shah, 1991). In contrary to this argument, Dubash (2000) opines that electricity tariffs only become relevant to the decision of pumping when price rather than quantity becomes the constraining factor. Moreover, fixed rate electricity pricing has led to inefficiently high and wasteful use of water over time.

But it has to be taken into consideration that evolution of water markets is possible only in the regions where enough groundwater is available for trading. Markets do not evolve where there is not enough water to share or sell (Reddy, 2001). Studies have shown in regions of groundwater depletion and water scarcity, groundwater markets do not operate as the available water is not even enough to irrigate the well owner's land (Reddy, 2005).

The literature does not provide a clear consensus on the impact of groundwater markets on equity and sustainability of groundwater resources. Although some studies show that the groundwater markets help in correcting inequalities in the accessibility to groundwater between rich and the poor farmers, making its use sustainable, some scholars are of the view that development of water markets leads to increase in groundwater withdrawal which further raises the questions related to sustainability aspects (Singh, 1998).

1.3.7. Issues on Property Rights of Groundwater

Uneven spatial distribution of groundwater coupled with the intertwining of land and water rights result in further externalities, which can be termed as legislative externalities. Legislative externalities arise when there is no clear-cut legislation demarcating and protecting different property regime (Bell, 1990). At present the owner of a piece of land has also the right to exploit water under it. But rarely do the boundaries of a block of land owned by an individual coincide with the boundaries of the aquifer from which it draws groundwater. Consequently, several people already have the legal right to tap a common aquifer. But under these conditions it is difficult rather impossible to define an unambiguous way the property right in groundwater on individual basis (Vaidanathan, 1996).

In India, rights in groundwater belong to the land ownership. The consequence of such a legal framework is that only the land owners can own groundwater. As the demand for irrigation has increased with the spread of modern crop production technology, existing
owners of tube wells have enjoyed unchallenged *de facto* ownership right on the community's groundwater resources. In effect, thus, ownership rights on water are given or denied through the rights to establish modern water extraction machines (Shah, 1991). It also implies that rich landlords can be rich water lords (Singh, 2002). It is argued that the present *de facto* water rights system not only distorts resource allocation but also leads to negative equity and ecological effects (Saleth, 1996). Dhawan (1975) has commented that the accentuation of external diseconomies that are invariably encountered in the unregulated exploitation of an “ill-defined-ownership” resource like groundwater has been totally neglected while appraising the superiority of “new groundwater water extraction technology”.

Legislative externalities further reinforce technological externalities. Farmers make private investments assuming that they have absolute rights to the groundwater water aquifer beneath their land. These situations arise not only due to the nature of the resource but also due to the existing institutional arrangements and policy frameworks (Vaidanathan, 1996).

Studies have shown that differential capacity of horse powerage of installed tube-wells situated close to one another is a major cause of drying up of shallow wells which are majorly owned by small farmers in areas of fast receding groundwater table. These resource poor farmers who fail in the race of competitive well deepening can not access the groundwater resources lying under their own land. The ill defined property rights of groundwater act against these resource poor farmers who can not resist the resource rich farmers from extracting water from their aquifers since the large farmers deepen the bores on their own land with their own money (Bhatia, 1992).

Another notable fact in this regard is that there is no legislation either to control over exploitation of the resource or to prohibit the selling of water by well owners. The legal proposition has impact on prices of water. In case of surface water markets, buyers are in a better position to bargain for lower prices, since there is a provision which bans the lifting of water from the canal for unauthorized purposes. On the other hand in the groundwater markets, the sellers can fix higher prices since there is no legislation which prohibits sale of groundwater (Prasad, 2002).
As a result of this lack of appropriate legal framework, any management system attempting to directly regulate groundwater extraction would be open to legal challenge. On a practical level this means that there is no legal basis for taking action against individuals or groups who damage groundwater availability for others or violate management agreements. For example, groups investing in recharge structures would have no legal means of preventing overlaying land owners from exploiting the newly created resource. Thus, lack of clear cut property rights over groundwater will greatly complicate any management groups (Moench, 1992). This situation also has heavy negative implications for future users and adds tremendously to the costs faced by the current users (Moench and Janakarajan, 2006).

Legislation to provide a framework for addressing emerging groundwater problems is essential in India. In addition, where scarcity is a major issue, rights are likely to come in conflict. Some machine for ranking rights is, therefore, essential (Moench, 1994). Scholars are also of the view that a more radical departure from existing legal provisions would be to define some kind of collective property rights over groundwater (Bhatia, 1992).

1.3.8. Farmers' Perceptions and Policy Implications of Depleting Groundwater

Dhawan (1990) points out that there are two inherent problems of groundwater management. First is the over exploitation leading to a permanent lowering of the water table and second is the mutual discord among the users of this common property resource.

While private costs arise mainly due to use values or user costs, social costs arise due to stock-related externalities that include use and non-use values such as protecting the resource for future generations, existence values etc. It is seen that farmers are more concerned about present crisis and thus will keep drilling deeper and get as much out of this resource as possible because to them “here and now” is more important rather than thinking about the fact that 20 years hence their land will turn into a desert. Since it seems impossible to devise any incentive schemes by which the current generation can be made to care for the next generation, the only way is to forcefully and continuously din into the public ears the emerging trends and their consequences (Vaidanathan, 1996).

Studies on relative economics of output price support versus input subsidization show that input subsidies are better. The relative economics of fertilizer and irrigation subsidies show
that investment in irrigation infrastructure is more productive in the long run as compared to fertilizer subsidies (Singh and Joshi, 1989).

A question that arises in the groundwater management is whether privatization of irrigation can provide the necessary correctives (Rao, 2002). State intervention becomes essential where externalities in the form of excessive drafts threaten to increase the new investment cost, marginal pumping costs, or damage the quality of water. Thus, the state has a major role to play in correcting the imbalances arising out of groundwater depletion (Singh, 1991).

Bhatia (1992) in her study strongly argues the necessity of public owned bores as it can address to the multifaceted problems arising out of groundwater over exploitation. First, it would help to prevent over exploitation since public control could be exercised on the number and depth of bores in a particular area. Second, it would facilitate a rational location of bores through coordinated planning reducing the problems of well interference. Third, it would ensure a more equitable distribution of groundwater since large farmers no longer will have the virtual monopoly to access to this resource. Fourth, it would also ensure much better spreading of the risks involved in drilling the bores by transferring the risks from private individuals to the community or the government. Lastly, the social ownership of bores would also facilitate the emergence of various forms of community management to regulate groundwater extraction.

Palanisami and Balasubramaniun (1998) have also strongly recommended the role of community wells in terms of cost of irrigation and equity in groundwater supplies. According to them the economic inequality increases due to the existence of local monopoly in the water markets, which yields "super-normal" profits to the well owners, indicating that the benefits of the common property resource are more or less captured by the private investments and the common property is highly mismanaged.

Crop diversification is encouraged through shift to comparatively less water intensive crops to economize on water use especially in areas where water table is fast receding (Johl, 1985; Chahal and Chahal, 1989, Chand, 1993). The main objective of the policy should be to direct the farmers to grow whatever they want to grow with less water and get the maximum productivity per unit of water (Iyer, 2004).
The availability of rural credits is one of the policies through which resource poor farmers can afford investments of modern water extraction machines. But studies have shown such credit policies act in favour of large farmers due to certain reasons like need for minimum assets for applying for a loan, preference of rich farmers for quick recovery of loans and caste based favouritism (Bhatia, 1992).

Government has attempted to implement policies for greater management of groundwater. But these policies are debatable as they have not given any positive outcome. According to Moench (1992, 2000), the that traditional centralized management alternatives- the import of new supplies, governmental regulation, limitations on credit and electricity connections, and pricing machines make little impact on resource condition or have proven so far impossible to implement.

Low cost and low quality electricity for agriculture contributes to erosion of electricity distribution systems and encourages wasteful consumption, even as farmers are increasingly deprived of adequate and good quality power (Dubash, 2007). Electricity subsidy provided by the government does not reflect the private cost of irrigation as the marginal cost of extracting groundwater is zero (Dhawan, 1986). But social cost rises with progressive pumping. So with such a policy, society will bear the burden of additional cost of decline of groundwater (Joshi and Tyagi, 1991). The huge funds saved by the state by removal of electricity subsidy can be redeployed for meeting sprinkler and drip irrigation subsidies (Dhawan, 1993). According to Singh (1994) flat rate system of revenue assessment on the consumption of electricity by tube wells must be replaced by volumetric assessment in order to rationalize the use of groundwater resources. Flat rate system resorts to wasteful expenditure on this resource. If the farmer has to pay for actual amount of electricity used he will operate his tube well optimally. On contrary to this subsidization of electricity supply it is necessary for keeping agricultural production competitive in a liberalized economic environment but the scope of subsidization should be made more targeted through proper metering and granting electricity subsidies through non-transferable tickets (Jain, 2004).

It has been argued that community based investments in replenishment as well as extraction of groundwater would make better economic as well as ecological sense (Reddy, 2001; Rao. 2002). Excluding a few scattered instances, possibilities for community management of groundwater resources remain theoretical. In many areas communities have developed
organizations for managing groundwater like *Pani Panchayats* in Maharashtra (Sathi, 1989) and some cooperatives in Gujarat (Moench, 1993); actual management of the resource to control depletion is, at best, rare.

Bhatia (1992), in her study came up with an interesting conclusion. According to her, collective ownership of water extraction machines was very common among rich farmers. By contrast, in the same villages small farmers were unable to enter into collective arrangements even among brothers. She has asserted that poor farmers find it more difficult to contribute their share of expense on a timely basis. They are less able to bear the risks involved in collective arrangements. And perhaps they are sharply divided by the competitive struggle for survival.

"A management system with full user participation and control requires a radical departure from present arrangements. Although it will take time to accomplish, such a system should be the ultimate goal" (Vaidyanathan, 1991). Although there is intense debate between those who favour Vaidyanathan’s proposition and those who are more skeptical of the management capabilities, legislative structures need to provide avenues for participation and local management (Moench, 1994).

1.3.9. Emerging Issues

From the review of the literature some important issues have come up, which need further considerations.

- The literature highlights the major transformation of Indian agriculture after the advent of groundwater irrigation especially after Green Revolution. Scholars have recognized several factors namely land consolidation, rural electrification, institutional credit and advent of HYV seeds for the spread of groundwater irrigation in India. Several studies have proved that tube wells are the most profitable and efficient source of irrigation because of its flexibility and reliability of the irrigation water source which increases the input use increasing the yields and economic returns. This has further led to the shift to groundwater irrigation in many areas (Dhawan, 1988, 1990; Kaul, 1991; Janakarajan, 1993; Vaidyanathan, 1996; Sidhu, Chand and Kaul, 1999; Pant, 2005).
• The literature summaries the major factors of groundwater depletion like irrigation development of the area, groundwater quality, cropping intensity, introduction of water intensive cropping pattern, accessibility to modern water extraction machines, inefficiency of traditional irrigation sources like canals and tanks and advent of high yielding variety of seeds. The profitability of investments in tube wells and other costly water extraction machines have been greatly enhanced by various government policies including highly subsidised and free electricity pricing and liberal financial assistance which has led to the over exploitation of groundwater resources (Bhatia, 1992; Dhawan, 1993; Nagaraj and Chandrakanth, 1997; Singh, 1998; Rao, 2002).

• It has been argued that there is an inherent inequality attached to the accessibility of groundwater irrigation as it requires capital investments for groundwater extraction technology. Consequently initial benefits from groundwater development tend to disproportionately favour those who are already economically well off such as the large farmers as the tube well installation is capital intensive and small farmers do not have investible surplus (Dhawan, 1993; Nagaraj and Chandrakanth, 1997; Reddy, 2005).

• This differential with regard to the accessibility of groundwater is increased as the cost of accessing groundwater resource increases as the water table declines. Better endowed farmers who can afford efficient water extracting pumps win the competitive deepening of wells further increasing the differentiation and competition over scarce resource leading to conflict. In this situation any policy regulation will only make the situation worse as it will affect the small and marginal farmers who are often the late comers in groundwater irrigation (Nagaraj and Chandrakanth, 1997; Moench, 1992; Shah, 1985; Vaidanathan, 1996; Bhatia, 1992; Janakarajan, 1993; Shah, 1993; Saleth, 1996; Shaheen and Shiyan, 2005).

• An important point debated by scholars is, whether groundwater markets will take care of the equity issues in accessibility to groundwater. While some scholars mentioned that groundwater markets lead to a more egalitarian distribution of gains from groundwater development (Shah, 1993; Satyasai, 1987; Shah and Raju 1988; Shankar, 1991; Singh, 2002; Shah and Ballabh, 1997), certain group of scholars question the very premise on which equity angle of water markets rests as the terms of groundwater transactions might tend to be rather exploitative especially in regions of groundwater scarcity where the
water sellers gain significant power to dictate terms to the water purchasers (Bhatia, 1992; Janakarajan, 1993; Shah and Ballabh, 1997; Satyasaii, Kumar Praduman and Mruthyunjaya, 1997; Dubash, 2002; Prasad, 2002; Sharma and Sharma, 2004).

- Another debatable issue is what kind of electricity pricing should be followed to correct imbalances in groundwater accessibility for sustainable development of groundwater (Shah, 1991; Shah, 1993; Dubash, 2002; Sharma and Sharma, 2004; Pant, 2005).

- The issue of ill defined ownership rights of groundwater further reinforces inequality in groundwater accessibility and management of this common property resource becomes a major challenge as it lacks a proper legal framework (Shah, 1991; Bhatia, 1992; Moench, 1992; Vaidyanathan, 1996; Saleth, 1996).

- The available literature also portrays the appropriateness and evaluation of several corrective measures undertaken for sustainable development of groundwater irrigation both by the state and by community participation (Joshi and Tyagi, 1991; Vaidyanathan, 1991; Bhatia, 1992; Moench, 1992, 2000; Reddy, 2001; Palanisami and Balasubramaniun, 1998; Rao, 2002).

1.4 Objectives of the Study and Research Questions

**Objective 1.** To analyse the trend of irrigation structure in Punjab and to assess the relationship between cropping pattern changes and water demand in the agricultural sector of the state.

**Research Questions**

1. Whether the state of Punjab has undergone or has been undergoing a structural change in terms of sources of irrigation and if so how and when has the shift taken place. (District level).

2. What are the environmental consequences of expanding groundwater irrigation in Punjab, more specifically the significant difference in the water requirements of emerging cropping patterns in groundwater and canal irrigated systems?
Objective 2. To analyse the effect of depleting groundwater resources on the changing cropping pattern and the cost of cultivation.

Research Questions

1. Whether the depletion of groundwater has led to significant increase in cost of cultivation and corresponding lowering of net returns in spite of support policies like high procurement price and free electricity?

2. Whether there is any significant difference in the profit levels among the different irrigation systems, different cropping patterns and across different land holding size classes?

Objective 3. To analyse the implications of depleting groundwater resources on access to groundwater irrigation across different land holding size classes.

Research Questions

1. In what way does the groundwater depletion affect its accessibility for irrigation across different land holding size classes?

2. Whether the groundwater markets take care of the equity issues in accessibility to groundwater and what are the implications of free power tariffs with regard to this?

Objective 4. To study farmers' response in relation to groundwater scarcity with regard to cropping pattern change, increase in cost of cultivation and state's policy of procurement prices and power tariffs.

Research Questions

1. How have the procurement price policy and electricity pricing policy affected their decision making in the selection of crops and in absence of these support policies what crops would they have selected?

2. How has or how will Groundwater depletion affect the livelihood of farmers? What are the coping machines that the farmers have devised or would devise as a result of continuous groundwater depletion?
1.6.1 Time Frame and Aggregation of Spatial Units

The temporal frame chosen under study for showing the cropping pattern shifts and structural change in irrigation is taken for four points of time, i.e., 1980-81, 1990-91, 2000-2001 and 2005-06. The triennium averages of all the chosen variables have been taken in the analysis. The reason for the choice of such a time period is validated by the literature which stresses upon the fact that the agricultural crisis in Punjab has started in the eighties when not only the productivity had stagnated but the natural resource base was also under threat of unsustainable exploitation.

The districts are taken as individual spatial units which means it is a district level analysis for the second and third chapter. Presently Punjab state has 19 districts as five new districts were demarcated in the state during the period 1991-92 to 2007-08. To make the comparison feasible, these districts were merged with the parent districts to form 12 original districts of 1980-81. As some of the districts were formed by extracting area from more than one parent districts, the data relating to different variables related to these districts were merged into parent districts according to the ratio of net sown area extracted as given in the table 1.1.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Districts Original Districts</th>
<th>Proportion of the different variables of the new district merged with the original district</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nawan Shahar Jalandhar Hoshiarpur</td>
<td>0.60 0.40</td>
</tr>
<tr>
<td>2</td>
<td>Mukatsar Faridkot</td>
<td>1.00</td>
</tr>
<tr>
<td>3</td>
<td>Moga Faridkot</td>
<td>1.00</td>
</tr>
<tr>
<td>4</td>
<td>Mansa Bhatinda</td>
<td>1.00</td>
</tr>
<tr>
<td>5</td>
<td>Fatehgarh Sahib Patiala Ludhiana</td>
<td>0.83 0.17</td>
</tr>
<tr>
<td>6</td>
<td>Taran Taran Amritsar</td>
<td>1.00</td>
</tr>
<tr>
<td>7</td>
<td>S.A.S. Nagar Rupnagar</td>
<td>1.0</td>
</tr>
<tr>
<td>8</td>
<td>Barnala Sangrur</td>
<td>1.0</td>
</tr>
</tbody>
</table>

1.6.2. Primary Surveys and Sample Design

In order to select the sample district of the study, percentage of area irrigated in the districts and the changing structure of irrigation in different districts is taken into consideration. More than half of the districts have more than 98% of their gross cropped area under irrigation. Four districts of Kapurthala, Sangrur, Amritsar, Ferozpur and Ludhiana show 100% irrigation of all cropped area (Index – 2.2). The net irrigated area by different sources has been studied at the district level (Table -2.2) show that only two sources of irrigation are there in all the districts, that is, canals and tube wells. It has also been seen that the districts like the state are undergoing a structural change in terms of irrigation sources where a shift is noticed from canal irrigation to tube well irrigation. Among all the districts in Punjab, Amritsar district has been chosen for generating primary data base for the study as in this district 100 percent of cultivated area is under irrigation and the two major modes of irrigation are canal and tube well coexist only in this particular district (39% by canals and 61 % by tube wells, 2005 – 2007 triennium average figure).

The sample villages have been chosen taking into consideration the different modes of irrigation and Amritsar being a district with almost 60 percent of area under well irrigation and 40 percent under canal irrigation, there is a greater possibility of finding out such categories of villages in the same district. Moreover Amritsar has a dominant rice-wheat cropping pattern with 100 percent of its blocks in the over-exploited category. The sample villages have been drawn from only one district as they all will fall under the same agro climatic zone with similar physical characteristics like soil and climate as it is difficult to incorporate important associated phenomenon such as rainfall and soil at the household level and such a sample design will minimize the effect of these variables on agriculture at the village level.

Although Amritsar is an agricultural district, it has the highest percentage of urban population after Ludhiana. Since the study broadly looks into the impact of irrigation, out of 16 blocks, only those blocks of the district are chosen as the universe of the sampling where the percentage of cultivable area to total area is 90 percent. Out of these blocks, villages are selected where 99 percent of gross cropped area is under irrigation. The selected villages are further categorized into mixed irrigated village where at least 40 percent of the net irrigated area is under canal irrigation and dominantly tube well and well irrigation (both wells and
tube wells with electricity and without electricity) where 100 percent of irrigation is dependent on groundwater. The dominantly well and tube well irrigated villages are categorized into two types - villages with major problem of groundwater depletion and villages with comparatively less serious problem of groundwater depletion on the basis of primary information from key informants regarding the depth of the water table.

From each of this selected category of villages one village has been selected on the basis of disproportionate random sampling. The households from the universe of cultivating households are chosen through proportionate random sampling from sub-strata of marginal (1 - 2 acres), small (2 - 4 acres), medium (4 - 10 acres) and large (more than 10 acres) households. The number of households taken from each village is 100 approximately, that is total of 300 households have been surveyed.
FIGURE - 1.2
SAMPLE DESIGN FOR EACH STRATUM

Stratification scheme for households
Ranges (in acres)
1. Marginal (1 to 2 acres)
2. Small (2 to 4 acres)
3. Medium (4 to 10 acres)
4. Large (more than 10 acres)

PROFILE OF VILLAGES

Geographical Characteristics

<table>
<thead>
<tr>
<th>Name of the Village</th>
<th>Tohi Kalan</th>
<th>Gharinda</th>
<th>Ballab-e-Darya</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>Verka</td>
<td>Gandiwind</td>
<td>Ajnala</td>
</tr>
<tr>
<td>Geographical Area (sq km)</td>
<td>378</td>
<td>486</td>
<td>555</td>
</tr>
<tr>
<td>Slope</td>
<td>Gentle</td>
<td>Gentle</td>
<td>Gentle</td>
</tr>
<tr>
<td>Prevalent Soil Type</td>
<td>Alluvial</td>
<td>Alluvial</td>
<td>Alluvial</td>
</tr>
</tbody>
</table>

Demographic & Social Characteristics

| Total number of Households | 344 | 319 | 98 |
| Population of the Village  | 2189| 1820| 636|
| Male Population of the Village | 1171| 981 | 335|
| Female Population of the Village | 1018| 839 | 301|
| SC population (percentage)  | 58  | 53  | 14 |
| Literates (percentage)      | 44  | 49  | 50 |

Agricultural Characteristics

<table>
<thead>
<tr>
<th>Type of irrigation</th>
<th>Mixed</th>
<th>Groundwater</th>
<th>Groundwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivated Area (NSA)</td>
<td>326</td>
<td>355</td>
<td>509</td>
</tr>
<tr>
<td>Gross Cropped Area (GCA)</td>
<td>664</td>
<td>771</td>
<td>908</td>
</tr>
<tr>
<td>Cropping Intensity (percentage)</td>
<td>204</td>
<td>217</td>
<td>178</td>
</tr>
<tr>
<td>Sources of Irrigation</td>
<td>Canals and tube-wells</td>
<td>tube-wells</td>
<td>tube-wells</td>
</tr>
<tr>
<td>Irrigated Area by source</td>
<td>canals - 43 %</td>
<td>tube-wells - 57 %</td>
<td>tube-wells - 100 %</td>
</tr>
<tr>
<td>Average depth of water table below</td>
<td>40 feet</td>
<td>60 feet</td>
<td>150 feet</td>
</tr>
</tbody>
</table>

Area under crops (percentage to gross cropped area)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Tohi Kalan</th>
<th>Gharinda</th>
<th>Ballab-e-Darya</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>33</td>
<td>44</td>
<td>52</td>
</tr>
<tr>
<td>Rice</td>
<td>41</td>
<td>43</td>
<td>36</td>
</tr>
<tr>
<td>Cane</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Maize</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Vegetables</td>
<td>7</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Fodder</td>
<td>19</td>
<td>12</td>
<td>6</td>
</tr>
</tbody>
</table>
Based on the above sample design, three villages of Tohl Kalan, Gharinda and Ballab-e-Darya have been selected for the study. Tohl Kalan represents a mixed irrigation system with 43 percent of the net sown area under the canal irrigation and 57 percent under tube-well irrigation. Gharinda and Ballab-e-Darya are villages totally dependent on groundwater irrigation but Gharinda does not have problems of groundwater depletion whereas Ballab-e-Darya faces major problems of groundwater depletion. The characteristic profiles of the three villages have been presented in the tabular form.

1.6.3. Focus Group Discussions

Besides the primary survey at the household levels, focus group discussions were also organized to extract information. Focus group discussions have been held taking into consideration the homogeneity of the groups with regard to the social and economic class. For this purpose small homogenous groups were selected based on the criteria of water selling and buying. Large farmers in most of the cases are expected to be water sellers as they can afford the high cost of installing the water extraction machines and are also able to deepen wells at intervals as water table recedes at a very fast rate. Moreover, when there is free agricultural electricity running cost is marginal and they can pump out as much water possible. Thus, they are likely to have surplus water which they can sell to farmers who do not have their own water extraction machines to earn additional profit.

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3 It must be noted here that all the area under canal irrigation is also irrigated by tube-wells as water in the canals are not sufficient for irrigation. Thus area under the canals in real sense is the area under conjunctive irrigation.
Thus, under these circumstances the major water buyers are small farmers and the major water sellers are the large farmers. But when the large farmers have fragmented landholdings they are likely to buy water also as it is not possible to have water extraction machines in all the fragmented fields. Studies have also shown that small farmers also sell water as they have less land and often after irrigating their own land, they are left with surplus water. But in case of depleting groundwater table, the small farmers are left behind in the race of competitive deepening of wells. Thus, in areas of scarcity of groundwater, it is very unlikely to find any small farmer selling water. So such a categorization has been done in the focus group to take into consideration the view point of both large and small farmers with respect to the perception of groundwater depletion, effect of water markets in bringing about equity of groundwater accessibility and also the policy implications.

1.6.4. Statistical Techniques:

A number of statistical tools have been used at different stages of the analysis in this study. Some of these techniques have been explained within the chapters where they have been applied. The statistical methods used are as follows:

1. Growth rate has been calculated in two ways.

   The annual compound growth rates have been computed in each district with the help of the following formula:-

   \[ R = \text{Antilog} (\log X_2 - \log X_1) - \frac{1}{n} \]

   Where R is annual compound growth rate of a chosen variable, \( X_1 \) is the value of the variable during earlier period, \( X_2 \) is the value of the variable during the later period and \( n \) is the interval between two periods.

   The average annual growth rate has been computed by computing the simple growth rate by the formula:-

   \[ R = \frac{X_2 - X_1}{X_1} \]

   Where R is annual growth rate of a chosen variable, \( X_1 \) is the value of the variable during earlier period, \( X_2 \) is the value of the variable during the later period. Then the respective growth rates of each year of the time period are averaged to derive the average annual growth rate.
To see the disparity in income inequity, measures like Gini’s concentration ratio (GCR), Theil Entropy index, Standard deviation of logarithmic income and coefficient of variation have been calculated by using the formula:-

\[ CV = \frac{\sigma}{X} \times 100 \]

Where CV is Coefficient of Variation, \(\sigma\) is standard deviation and \(X\) is simple mean.

\[ GCR = \sum_{i=1}^{N} P_i (Q_i + Q_{i-1}) \]

Where GCR = Gini concentration ratio, \(P_i\) = Proportion of number of farmers, \(Q_i\) = cumulative proportion of income and \(Q_{i-1}\) = proceeding cumulative proportion of income.

\[ TE = \frac{1}{N} \sum_{i=1}^{N} Y_i \ln \left( \frac{Y_i}{\mu} \right) \]

Where TE = Theil Entropy index, \(\ln\) = natural Logarithm, \(Y_i\) = Average income in that group in Rs, \(N\) = number of income groups and \(\mu\) = overall mean income in Rs.

The Gini’s coefficient has been calculated from the Lorenz curve and has been defined as the area between the Lorenz curve and the diagonal line divided by the area of the whole triangle. The value of Gini’s coefficient ranges between 0 to 1. 0 means no concentration and equitable distribution but 1 means high concentration.

For measuring the levels of the different indicators like production, acreages, cost of cultivation and net returns of different irrigation system in different landholding categories arithmetic mean has been used. Student’s ‘t’ test has been applied to test the statistical significance of the differences between means of each of the irrigation system.

The method used to derive the crop combination regions is J.C. Weaver’s Method (Weaver, 1954). In this method the actual percentage area under different crops in a region are compared with the different theoretical base curves. The formula used is to calculate the index (\(\sigma\)) is given below. The minimum of \(\sigma\) gives the best fit.

\[ \sigma^2 = \frac{\sum (x_i - X)^2}{N} \]

Where \(X\) is the theoretical percentage, \(x_i\) is actual percentage and \(N\) is the number of crops.
(5) Crop specialization has been measured by Entropy Index (EI). The formula used for calculating their values is given below:

\[ EI = \sum_{i=1}^{N} P_i \log P_i \]

Where EI is Entropy Index, N is total number of crops and \( P_i \) is the acreage proportion of the \( i \)th crop in the total cropped area. The increase in the value of Entropy Index indicates decrease in specialization.

(6) Other statistical tools used are correlation, simple percentages and cross tabulations. The cartographic techniques used for the visual representation of the data are restricted to bar diagrams, line graphs and choropleth.

1.7. Data Base

The present research work is primarily an empirical one and is based on field survey data at the primary level. However, the analytical background of the study is (primarily in the second and the third chapter) is based on secondary data sources. The following table summarizes the secondary data sources collected from multiple sources.

<table>
<thead>
<tr>
<th>S. N</th>
<th>SOURCES</th>
<th>VARIABLES</th>
<th>LEVEL</th>
<th>YEARS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Statistical Abstract of Punjab, various issues</td>
<td>Area, Production, Yield of each crops, Gross and Net irrigated area, Irrigated area by sources, number of diesel and electrically operated tube wells.</td>
<td>Districts</td>
<td>1970 to 2006</td>
</tr>
</tbody>
</table>

For detailed analytical study, primary data was generated from field survey. A survey of three villages of Amritsar district was completed with the help of the questionnaires at the household level (appendix 1.1). The primary data was collected though a household survey of 300 households in three villages during a number of visits in 2008.
1.8. Geographical Personality of the Study Area

The present study basically pertains, in general, to the state of Punjab and specifically to the district of Amritsar. The state of Punjab is located in western India and is drained by the tributaries of Indus, viz. Ravi, Beas and Sutlej. Punjab has a vast expanse of flat alluvial land while the Shiwalik hills in the north have fluvial deposits of the three rivers, namely, the Ravi, Beas and Sutlej, which flow through central Punjab, and the sand dunes in the southwest. Among the Indian States, Punjab holds place of pride for its outstanding performance in agricultural and rural development. Because of its outstanding contribution to the agricultural economy of India, the state has earned the status of “Food Basket of the Country” and “Granary of India”.

Amritsar is one of the border districts of Punjab situated in the north western part of the state in the Bari Doab between Beas and Ravi rivers. It is located in the majha tract surrounded by Pakistan in the north-west and west, Gurdaspur in the north east, Kapurthala in the east and Tarn Taran in the south. The district shares its name with the district headquarters and derives its name from the tank surrounding the Golden Temple in the city. It literally means “The tank of nectar or the tank of immortality”.

The flat topography of Amritsar district is the product of alleviation by the Beas and the Ravi rivers. The soil is light reddish yellow loam known to the people as maira, but it stiffens into rohi or clay. The climate of the district is characterised by general dryness, except during the brief south west monsoon, a hot summer and a very cold winter.

Amritsar is mainly an agricultural district with majority of its population living in the rural areas and agriculture provides the single largest source of employment and livelihood to the population. There are two main crop harvests in a year, Kharif and rabi and a short ziad period where farmers grow vegetables and fodder. The principal Kharif crops are paddy, cotton, maize and sugarcane and the rabi crops are wheat, gram, barley, barseem and winter vegetables. The area under paddy has increased from 29 percent in 1980-81 to 39 percent in 2006-07 replacing maize and gram. Acreage of wheat also showed an increase from 43 percent to 49 percent in the last twenty five years. It is a two crop combination region with wheat – rice as the dominant cropping pattern.
FIGURE 1.4
LOCATION OF STUDY AREA

Location of Punjab in India

Location of Amritsar in Punjab

Location of Sample Villages in Ajnala, Verka and Gandiwind

Location of Ajnala, Verka and Gandiwind in Amritsar

Location of Punjab in India

Location of Amritsar in Punjab

Location of Sample Villages in Ajnala, Verka and Gandiwind

Location of Ajnala, Verka and Gandiwind in Amritsar

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The district has 100 percent of its cropped area under irrigation and major sources of irrigation in the district are government canals and tube-wells. Although the district is undergoing a shift towards groundwater irrigation, still 39 percent of net irrigated area is under canals and the rest 61 percent under groundwater irrigation. The canal irrigation started in the district in 1860 when upper Bari Doab canal got completed in 1859. The four branches of this canal running through this district are Sabraon branch, Kasur branch, Main branch and Lahore branch. The various branches of the upper Bari Doab provided irrigation to the district which mainly depended on canals for the irrigation, especially in Tarn Taran and Patti Tehsil where sub soil water is brackish and is not fit for irrigation. The dependence on canals declined over the last few decades due to the popularity of tube-wells which supply adequate water whenever required. The area under tube-well irrigation has increased at a rate of 2.14 percent and in the last 25 years the area under tube-wells has increased form 40 percent to 60 percent. With increasing groundwater draft with the expansion of tube-well irrigation, Amritsar like the other states of Punjab is showing signs of over-exploitation. According to the Central Groundwater Board, North Western Region, all the sixteen blocks of the district are over-exploited. On account of lowering of groundwater depths, the farmers have resorted to pumping water through electricity driven submersible pumps. As cost escalates with receding groundwater tables, many small and marginal farmers have leased out their land and have shifted to other occupations.

1.9 Organization of the Study

The study has been divided into eight chapters. The first chapter is introductory in nature which deals with the statement of the problem, literature review, objectives, research questions, data base, methodology and geographical personality of the study area. The second chapter provides a background of development of irrigation in the state of Punjab and the consequent transformation in the relations of productions in agriculture from 1980 to 2007. The discussions in this chapter demonstrate how the extent of groundwater use and its productive capacity shaped the agrarian change in Punjab with particular emphasis on the change in irrigation structure and shifts in cropping pattern drawing the interrelationships between these two important aspects of agriculture. The third chapter has been devoted to study the changing status of groundwater resource in order to analyse and understand the availability, utilization and over exploitation of groundwater resources in different regions.
of the country and the state of Punjab in particular. The fourth chapter deals with the analyses of the costs and returns to agriculture with respect to different irrigation systems, different land holding classes and across major crops. The fifth chapter reappraises the externality of groundwater irrigation and analyses the external diseconomies in groundwater utilization in terms of its accessibility to groundwater irrigation to large farmers vis-à-vis the small and marginal farmers. How small and marginal farmers face dire threat to their very existence in agriculture is brought out by analysing externalities as a dynamic concept of groundwater depletion. The sixth chapter pertains to the development of understanding of the aspects of emergence, structure, operations and expansion of groundwater markets. Appropriate empirical basis is applied to analyse the impacts and outcomes of groundwater markets in terms of productivity, equity and efficiency. In the seventh chapter farmers' response are analysed and examined regarding factors taken into account while deciding the cropping pattern and the effect of MSP and free electricity on their cropping decisions. It also studies the farmers' perceptions with regard to groundwater regulation and coping strategies adopted and will be adopted by them in face of water depletion. The last chapter provides the summary, conclusions and policy implications.