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1

Equity in Access to Irrigation Water: A Comparative Analysis of Tube-Well Irrigation System and Conjunctive Irrigation System

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1. Introduction

Access to irrigation water is one of the most important factors in modern agricultural production. It offers opportunities for improving livelihoods particularly in rural areas as access to reliable good quality irrigation reduces the cost and increases the quantum of production by reducing the risks faced by the rain fed agriculture. In agricultural water distribution, equity is limited to allocation and receipt of irrigation water. Equity means fairness in creating fair access to water for all, both within and between communities and within and between regions. Since more than 60% of the irrigated area is under groundwater and is fast increasing with time, the equity in access to groundwater is of great concern. It is noteworthy to mention that in the Indian context water allocation principles refer to 'proportionate equality' and 'prior appropriation'. The former operates in the existing inequality of land ownership and the later generates inequality through uses (Pant 1984).

By the very nature of the resource, groundwater development is largely by private initiative of farmers which is conditioned by their size of land holding, savings and investment capacities. Because of this reason in the first phase of groundwater exploitation, the poor invariably got left out in the race for groundwater irrigation and decades later when they began to enter groundwater economy a set of new rules and regulations like licensing, sitting rules and groundwater zones made their entry difficult in most areas and impossible in those areas where groundwater overdraft was high (Shah 1993). With intensive groundwater exploitation, declining water tables have further reduced access to groundwater irrigation to a large number of small and marginal farmers who can neither use traditional techniques nor are able to use 'lumpy' new technology so as to pump water at an economic price. Moreover, chasing water table is beyond the reach of resource poor farmers. In such conditions they have to depend on the other well owners for groundwater irrigation. This has severe equity implications especially in a situation where farmers have little opportunity to earn their income from sources other than irrigated agriculture (Dhawan 1982). Thus in the process, the race to exploit groundwater resource is exponentially continued by the haves and the have-nots continue to bear the brunt of this negative externality (Nagraj and Chandrakanth 1997). As a consequence, there emerges widespread apprehension that, instead of reducing relative inequalities among rural incomes, groundwater irrigation development may actually have enlarged both the absolute and relative inequalities already prevalent (Shah 1987 and Shah 1993). Many micro level studies have also highlighted these serious equity implications of groundwater exploitation with falling water levels particularly in the water-starved regions (Shah 1991, Bhatia 1992, Monech 1992, Nagraj and Chandrakanth 1997). While groundwater availability can be studied from an earth science perspective but to analyse its accessibility one needs deeper understanding of groundwater economy and its underlying socio economic dynamics.

The policy design aimed to achieve food security of the country in the sixties encouraged "grain revolution" with increasing area under water intensive rice-wheat cropping pattern in the Green Revolution belt making Punjab the 'Bread basket' of the country. During this time, the modern agricultural practices of HYV technology in Punjab also ushered in the shift from canal irrigation to tube-well irrigation as it was a more reliable and flexible source of irrigation and this gave boost to enormous increase in agricultural production. In the early phase of Green Revolution, rapid diffusion of groundwater technology was thus appreciated on grounds of it being economically superior to other sources of irrigation in terms of its efficacy and productivity (Dhawan 1975). The superiority of this irrigation source continued to enhance the intensive cultivation of water intensive crops on an extensive scale not withstanding the hydro-geological thresholds of this resource. Consequently the over exploitation of groundwater inevitably questions the accessibility of this resource and rises serious concerns about the equity in its distribution.

Literature highlighting the superiority of the modern water extraction machines has been too preoccupied with highlighting the superiority from individual or private point of view which only focuses on economic justification and economic efficiency without considering the economic equity. It should be noted that economic efficiency begins to introduce a concern for equity that was missing in economic justification, in the specification that the increase in welfare of one individual should not be at the expense of another. The economic justification although assures enough benefits generated to cover all the costs but do not take into account the economic equity criterion which requires the costs to be allocated in proportion to benefits received (Abu-Zeid 2001).

In this broader context, the paper examines three aspects inequity in access to groundwater irrigation across different classes of farmers in different phases of groundwater depletion in Punjab. The study 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. Firstly, it looks into the determinants of groundwater accessibility. Secondly, it empirically shows the difference in the physical and economic accessibility of groundwater resource and thirdly it evaluates the consequences of unequal access to groundwater irrigation by analysing the inequity in net returns to agriculture among agricultural communities dependent on groundwater irrigation.

Since depletion is a phenomenon, to capture the effects of groundwater depletion, in this study three villages are chosen from the same agro-climatic region with different levels of groundwater depletion. Three hundred households are interviewed from each village to collect field level data for the analysis. Table 1 gives the profile of the three study villages and figure 1 shows their locations.

Name of the Village	Tohl Kalan	Gharinda	Ballab-e-Darya
Slope	Gentle	Gentle	Gentle
Prevalent Soil Type	Alluvial	Alluvial	Alluvial
Average depth of water table below	12 meters	18 meters	46 meters
Type of irrigation	Mixed	Groundwater	Groundwater
Sources of Irrigation	canals – 43 % tube-wells – 57 %	tube-wells – 100 %	tube-wells – 100 %
Cropping Intensity (%)	204	217	178

Table 1. Profile of Study Areas

2. Determinants of groundwater accessibility

Studies have indicated that ownership and access to groundwater irrigation has almost replaced land in determining one's socio-economic and political status (Janakarajan S. 1993). In the groundwater dependant societies, the struggle for access to, and control over groundwater, shapes the course of agrarian change and development (Dubash 2002). Certain factors which govern the ownership of groundwater are central to understanding changes in access to groundwater over time. Under British common law, the basic civil law doctrine governing property ownership in most of India, groundwater rights are appurtenant to land (Singh 1992). If a person owns a piece of land, he/she can drill or dig a well and can pump out as much groundwater as he/ she is able for use on overlying lands. When land is sold the groundwater access rights pass with the land and can not legally separated from it. At present, groundwater rights are defined by the ability to chase water tables and ability to invest in changing water technology. If one can afford to deepen ones well, the water pumped out from it is theirs (Moench 1992). Groundwater accessibility is thus largely depend on a wide interplay of interconnected factors like land holding size, type and nature of ownership of tube-wells, productivity of tube-wells and density of tube-wells. The following section analyses the interplay of these dynamic factors among various size classes of farmers at different levels of groundwater depletion to understand the variability of groundwater accessibility with continuous resource depletion.

2.1 Land ownership and accessibility to groundwater

The distribution of land ownership and the extent of land subdivision and fragmentation affect the development and use of groundwater. Jairath (1985) argues that fragmentation of landholdings has led to underutilization of privately owned tube-wells in Punjab. Thus large farms may more beneficially utilize groundwater irrigation structures than the small ones. Moreover the higher farm productivity of large farms also facilitate the greater investments in buying and maintaining tube-well technology which is essential for continued accessibility of groundwater irrigation (Dubash 2002). Inequalities in the ownership of water extraction machines are closely related to the inequalities in land ownership and the inequalities in land and water ownership are seen to compound each other (Bhatia 1992). Thus the pattern of land ownership inevitably influences the farmers' ability to access groundwater and since availability of groundwater varies according to the levels of the existing water table, it is important to examine how different land holding categories at different levels of resource depletion differ in access to groundwater irrigation.

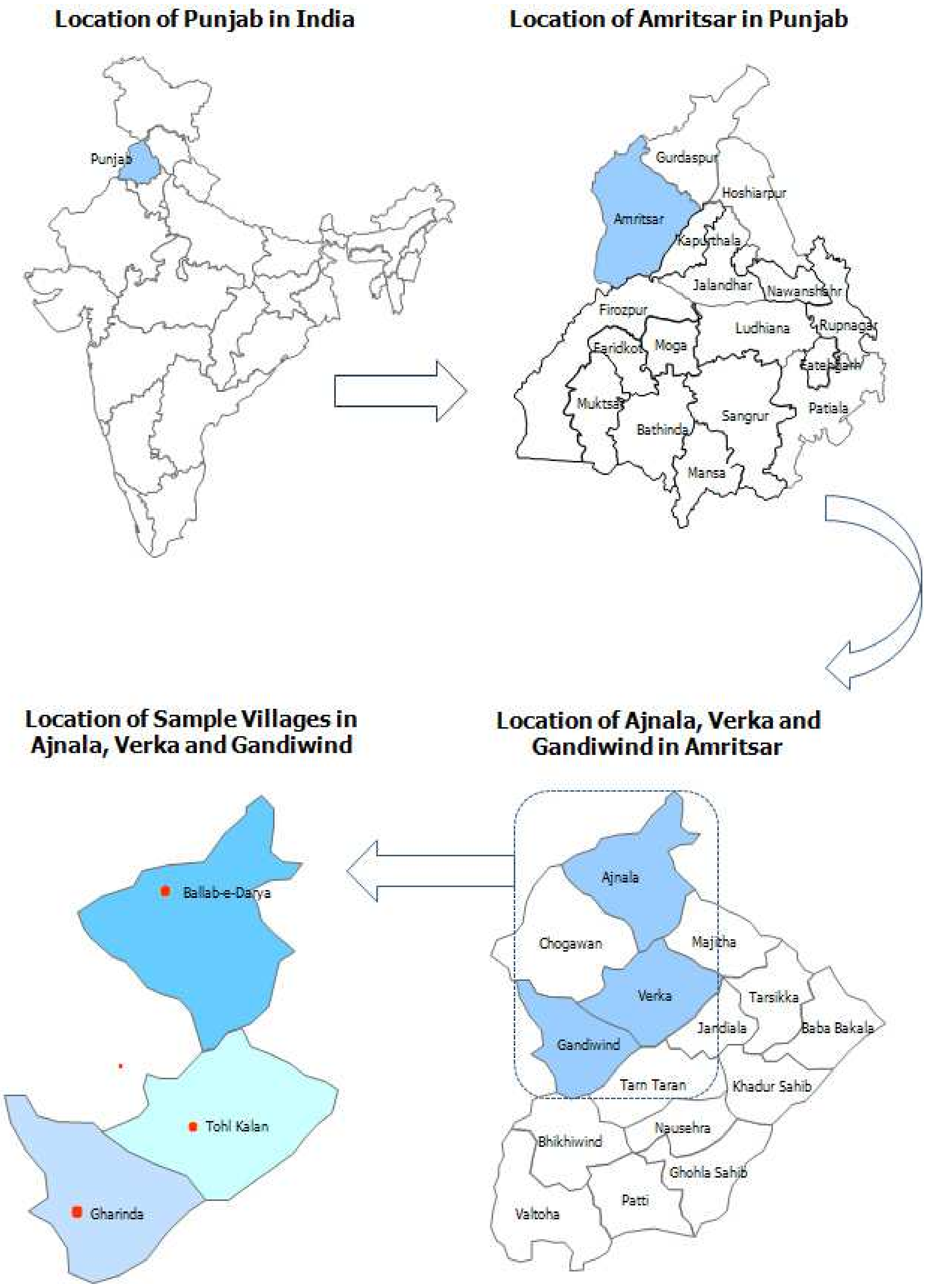

Fig. 1. Location of Study Areas

If we accept land as a reasonably good indicator of power in agrarian societies, then all the sample villages are societies with deep inequalities of power (Table – 2). Landownership and land operation through tenancy are linked in a way that they defy easy separation. Studies show that in Punjab "reverse tenancy" is a common phenomenon under which small and marginal farmers lease out land on cash terms to the medium and large farmers who have sufficient capital and have made investment in machinery and in water extraction machines (Siddhu 2002). A careful examination (Table–3) reveals that reverse tenancy is

Land owned (acres)	**Mixed Irrigation Village (Tohl Kalan)**	**Tube-well Irrigation Village (Gharinda)**	**Tube-well Irrigation Village with Problems of Depletion (Ballab-e-Darya)**
1 - 2	18	4	32
2 - 4	26	6	15
4 - 10	38	32	32
more than 10	18	58	21
Total	100	100	100

Source: Questionnaire surveys in various villages from May to July, 2009

Table 2. Land Ownership by Different Classes of Farmers (Percentages)

Land owned (acres)	**% of households in each group**	**% of households leasing in**	**% of households leasing out**	**leased in area as % of operated area**	**leased out area as % of operated area**
Mixed Irrigation Village (Tohl Kalan)					
1 - 2	18	11	6	9	21
2 - 4	26	23	0	11	0
4 - 10	38	13	0	6	0
more than 10	18	50	0	28	0
Total	100	22	1	18	2
Tube-well Irrigation Village (Gharinda)					
1 - 2	4	0	0	0	0
2 - 4	6	0	0	0	0
4 - 10	32	9	0	5	0
more than 10	58	17	2	5	9
Total	100	13	1	5	7
Tube-well Irrigation Village with Problems of Depletion (Ballab-e-Darya)					
1 - 2	32	0	28	0	29
2 - 4	15	0	7	0	9
4 - 10	32	13	0	5	0
more than 10	20	20	0	16	0
Total	100	8	10	10	2

Source: Questionnaire surveys in various villages from May to July, 2009

Table 3. Incidence of Tenancy by Landownership (percentage of land leased out to total land owned by each group)

prevalent in the sample villages and it is also more pronounced in the tube-well irrigated village of Ballab-e-Darya indicating close correspondence of this phenomenon with groundwater depletion.

Field observations reveal, in the tube well irrigated regions of Punjab, the small farmers who do not have their own source of irrigation and are also not in a position to buy water for irrigation are compelled to lease out their land to the large farmers especially in the kharif season when there is acute water scarcity on account of rice cultivation[1]. In spite of much exploitation, farmers prefer leasing out land in kharif season because it is still more profitable than rain-fed maize cultivation. The value of the land is calculated purely on the basis of availability of water supply for irrigation which in turn depends on the number of wells in that particular land, its depth and the capacity of the pump used to pump out water. It was seen that land endowed with sufficient groundwater irrigation was leased out at Rs 16,000 to Rs 20,000 per acre and land without any source of water was leased out for Rs 6,000 to Rs.8, 000.

Very exploitative tenancy relations were also common in lands without any water extraction machines. In such cases the owner (mostly small or marginal farmers) pays for all the inputs like seeds, fertilizers, insecticides, labour and the produce is divided equally between the owner and the tenant. The tenant who is a large land lord only provides with the irrigation water and takes away half of the produce. Thus, ownership of groundwater determines the terms and conditions of tenancy in groundwater depleted regions in Punjab. These indicate that with groundwater depletion, water becomes the most important factor of cultivation and even its importance exceeds that of land. In such groundwater dependant societies, land has no value unless it is endowed with water extraction machines and the bargaining power is also in the hands of those who own water along with land and not only land. Thus, there is a complete shift of power relation from the hands of 'landlords' to 'waterlords'.

The control and access over groundwater offers scope for interlinkages between ownership of land and water. Such 'interlinked contracts' have been observed for land, labour and credit, and similar contractual forms in the provision of irrigation may be an additional mechanism of marginalising resource poor to groundwater access. The link between credit and groundwater has several possible implications. Usurious credit relations driven by groundwater related investment, carry the potential for a long term debt trap. They also allow a creditor to dictate production decisions especially the decisions of cropping pattern. Creditors are mostly landowners, leading to credit relations being 'interlinked' with land and water arrangements in various combinations. In the villages of Punjab, such interlinked 'land-water-credit markets' were very common especially in regions of acute depletion. Interlinkages between these three important determinants of cultivation have lead to sever consequences in accessibility to groundwater irrigation and hence a profitable agriculture. Institutional credit is not available to set up new tube-wells and land without water can not be cultivated. Farmers owning smaller assets (lands) thus often fall prey to local money lenders. As cost of inputs increase with time, credits become a necessary condition to sustain cultivation. The farmers owning small land holdings without any water extraction machine have no alternative option but to take loan from local money lenders or lease out or sell out

[1] Rice and maize are grown in Kharif season. But the relative profitability of growing rice is much higher than maize. This is a half yearly lease.

his land. Thus, the interlinking of credit, land and water leads to much greater exploitation of the less endowed farmers and in the process they lose their land and turn into agricultural labourers or construction workers in urban areas from a cultivator.

2.2 Ownership of wells and access to groundwater

In agrarian societies heavily reliant on irrigated agriculture, control over water is an essential complement to landownership (Dubash 2002). Available evidences in literature indicate strong positive correlation between land holding size and ownership of modern water extraction machines (Shah 1988) which is also true in all the three sample villages (Table - 4). Since the development of a well for irrigation requires substantial investments, it is largely affordable by the resource rich farmers who are also the large landlords. This implies that better access to land is associated with the better access to groundwater. Along with this, the inequality in the distribution of operational tube-wells is most pronounced in the groundwater depleted village because with receding water tables more numbers of wells of small and marginal farmers dry up as they have no capital to chase water table. Positive correspondence with landholding size and average depth of tube wells and average land irrigated per bore well reiterating the same findings (Table - 4). Thus, along with the inherent inequality of tube-well ownership influenced by the unequal distribution of land ownership, groundwater depletion further increases the skewedness in the ownership of tube-wells.

Particulars	*Marginal Farmer*	*Small Farmer*	*Medium Farmer*	*Large Farmer*	*Total*
Mixed Irrigation Village (Tohl Kalan)					
Average no of operational tube-wells (feet)	0.72	0.96	1.00	1.00	0.94
Average Depth of tube well	180	191	231	421	249
Average land irrigated per bore well (acre)	4.42	7.05	12.99	40.56	15.50
Tube-well Irrigation Village (Gharinda)					
Average no of operational tube-wells (feet)	1.00	1.00	1.06	1.34	1.22
Average Depth of tube well	120	185	210	217	209
Average land irrigated per bore well (acre)	2	4	7	13	10
Tube-well Irrigation Village with Problems of Depletion (Ballab-e-Darya)					
Average no of operational tube-wells (feet)	0.41	1.00	0.91	1.80	0.94
Average Depth of tube well	120	185	210	217	209
Average land irrigated per bore well (acre)	2	4	7	13	10

Source: Questionnaire surveys in various villages from May to July, 2009

Table 4. Tube Well Ownership and Area of Influence of Tube Wells across Farm Size Classes (Change into percentage)

Moreover, the poor farmers even after owning wells may be trapped in a regime of low well yields as not only water table is receding progressively but also many new wells are dug[2]. Because of declining water tables and increasing density of wells, it is difficult to access a new location to fix up a new well which is a necessary condition to avoid well interference and hence have a productive well. Large farmers owning large plots of land have greater opportunity to space his wells. On the contrary, the small and marginal farmers have little option to get a suitable place to dig his well as he owns a small fragment of land and very often he is a late initiator of the tube-well technology and the neighbouring plots already have deep tube-wells.

2.3 Nature of ownership of wells and access to groundwater

In Punjab, some of the most important factors affecting access to groundwater irrigation include whether wells are owned solely by individuals or held jointly. It is seen that the average individual ownership of tube-wells is much higher for large landowners than the marginal and small land owners (Table -5). The strong preference of individual ownership of tube-wells despite the higher costs involved reflects that individual exploitation of water even at higher costs is sufficiently productive to be economical. Individuals may also be prepared to bear higher costs because of difficulties in ensuring effective joint ownership and management of wells, and the risks depending on purchases from other tube-well owners. In conditions of continuous groundwater mining even available supplies are inadequate to meet the demand of the area served by an aquifer, these constraints become more severe (Janakarajan and Moench 2006). This fact is also reinforced by the much higher average number of sole ownership of tube-wells in the groundwater depleted village of Ballab-e-Darya than in the other two villages (Table-).

The incidences of hiring of tube-wells were not common phenomena in the villages because land and water extraction machines was considered as complementary resource and the leasing in and leasing out of land automatically resulted in the leasing in and leasing out of the tube-well in the respective land. Hiring of tube-wells also does not show any correspondence with land holding size. With groundwater depletion the farmers do not want to hire wells as disputes arise as to which party will deepen the well and repair the pump which becomes a hurdle for timely irrigation. The farmers, thus, prefer to lease out the entire land and tube-well to have complete control and responsibility of the tube-well. Due to these impediments of groundwater accessibility through hired tube-wells, hiring has become redundant in the villages of Punjab.

Since tube wells are indivisive, with successive generation number of land holdings increase and the numbers of shareholders consequently increase in a family owned well. Sometimes even the partners (subsequently the heirs of the partners) of the old water extraction technology like *hult*[3] continue to jointly irrigate and own wells. In many cases especially for newly owned joint wells, either the brothers and cousins or neighbouring farmers owning small fragments of (contiguous) land contribute jointly to install submersible pumps. Joint wells are commonly operated by installing a single pump set

[2] With many wells, the density of tube-wells increases lowering the yield of the neighbouring wells.
[3] *Hult* was a traditional water extraction machine and it needed lot of labour (both animal and human) to irrigate land. As it was labour intensive families jointly owned and operated *hults*.

and running the motor in rotation between shareholders for a fixed number of hours. It helps them to share the cost and also fully utilize the chunk of economic investment for (jointly) irrigating the combined portion of land. With the incresing number of joint ownership of wells, the dilemma and uncertainties associated with management of jointly owned wells create varied nature conflicts within communities and families which is important to analyse as it revolves round several issues of equity to accessibility of irrigation water among the shareholders.

Land Holding Category	*Solely Owned Tube-Wells*		*Hired Tube-Wells*		*Jointly owned Tube-Wells*		*operational Tube-Wells*	
Mixed Irrigation Village (Tohl Kalan)	*No*	*%age*	*No*	*%age*	*No*	*%age*	*No*	*%age*
Marginal Farmer	7	9	5	28	12	29	16	16
Small Farmer	22	28	6	33	11	26	26	27
Medium Farmer	32	41	3	17	14	33	38	39
Large Farmer	17	22	4	22	5	12	18	18
Total no of wells	78	100	18	100	42	100	98	100
Tube-well Irrigation Village (Gharinda)								
Marginal Farmer	4	3	0	0	0	0	4	3
Small Farmer	6	5	0	0	0	0	6	5
Medium Farmer	31	26	0	0	3	100	34	28
Large Farmer	77	65	1	100	0	0	78	64
Total no of wells	118	100	1	100	3	100	122	100
Tube-well Irrigation Village with Problems of Depletion (Ballab-e-Darya)								
Marginal Farmer	7	9	0	0	4	27	13	14
Small Farmer	5	7	0	0	10	67	15	16
Medium Farmer	28	37	0	0	1	7	29	31
Large Farmer	36	47	0	0	0	0	36	39
Total no of wells	76	100	0	0	15	100	93	100

Source: Questionnaire surveys in various villages from May to July, 2009

Table 5. Types of Tube Well Ownerships across Farm Size Classes

Data reveals that joint ownership of wells mostly rests with small and marginal farmers (Table-5). Large farmers mostly have wells under individual ownership. In some cases they consolidate their shares in the wells by purchasing from other shareholders. A positive correspondence is also noted for incidence of joint ownership and groundwater depletion (Table - 5). With depletion, the running cost of groundwater irrigation increases as continuous deepening becomes mandatory to sustain tube-well irrigation. In such situations the joint ownership helps the small and marginal farmers to share the cost and have access to groundwater irrigation. The cost of the well is borne by all the share holders in proportion to the number of shares they own and the proportion of the land they will be irrigating with the help of the shared water extraction machine. In cases where the shareholders don't cover their proportion of the costs, they are excluded from use of the pump set. If a shareholder voluntarily withdraws his share from a joint well the remaining shareholders contribute money to take out his share. The maintenance and deepening of the well is also jointly done by all the share holders.

In reality, however, the cost benefit sharing of the jointly owned wells are much more complex. While the details of the management of jointly owned wells for every case is not documented in detail, but interviews suggest that the incidence of conflict in the process of sharing of water from jointly owned wells is widespread and that practical difficulties surrounding pumping and management of shares and ownerships are of the most important source of conflict which often results in differential access between dominant owners and others who are less capable of exercising their partial ownership rights. Where scarcity is an issue, rights are likely to come in conflict. Conflicts among the shareholders are common regarding the number, spacing and time of the 'turns'[4] in irrigating their respective farms. The disputes are countless during the kharif season when virtual scarcity of water increases with cultivation of rice. Many disputes also arise due to the erratic power supply[5], which disrupts schedules for sharing available pumping time. Village panchayats (informal village courts) are often involved in resolving such disputes but conflicts continue to resurface in the next period of scarcity. Many disputes are only resolved when one shareholder buys the others out. In some cases this is accomplished by poor farmers selling their land along with their shares in a well. In addition disputes often occur over the need to deepen wells. Shareholders with different land holdings disagree regarding the distribution of the benefits from well deepening and one or more refuses to contribute to the cost. There are also instances of cases where wells are abandoned due to prevalence of too many shareholders and the emergence of numerous disputes. Conflicts were even noticed in cases where farmers voluntarily wanted to take out his share for reasons like migrating to urban areas or abroad, changing occupation, buying land somewhere else or even setting up individual well. The shareholders do not agree to pay for the withdrawn share in the joint wells. In such cases, the individual (who wants to leave the partnership) either goes without getting his share paid or sell off his land. Conflicts in crop selection were also common where some shareholders wanted to grow some other crop but could not do so because of the collective decision of the shareholders. In well sharing per person availability of water also declines (especially with incessant falling of water tables), the shareholders have to wait for their turns to irrigate their crop. This reduces the quality of irrigation as both availability and the control over the water supply decline.

While sharing of water from a joint well is often problematic, positive features also exist. The fact that about 62 % of the jointly owned wells are accessed by farmers owning less that 4 acres of land indicates greater groundwater accessibility to the small and marginal farmers through this system. In the villages there are informal rules governing the sharing of costs and benefits from a jointly owned well and village *panchayats* play a role in redressing disputes. Thus, joint ownership system promotes accessibility to groundwater irrigation and particularly benefits those who can not afford a well of their own because of lack of resource

[4] A specific number of hours and a specific time are fixed for each shareholder to use the pump or the tube-well to irrigate his land.

[5] During the peak time of irrigation of rice (May – June) the electricity supply in the villages on an average varies from 6 to 8 hours.

and also due to ownership of small fragments of land. While many joint wells fail due to two interrelated reasons; declining groundwater levels and the lack of finances for well deepening etc., many joint well ownership also become successful in providing groundwater access to small and marginal farmers who join hands in the time of scarcity to jointly harness and share the benefits of this (groundwater) resource which would not have been possible with individual efforts (investments). Many farmers believe that joint ownership of wells for this very reason is a better solution for groundwater accessibility especially in times of depletion but feel that joint ownership among kins and friends do not materialize as their individual small land holdings are spaced at greater distances and since joint ownership requires adjustability and compatibility to avoid conflicts the farmers are not comfortable to become partners of just any (neighbouring plot's) farmer. When the farmers of distant fields become partners in joint wells, disputes commonly arise as many farmers object to passing of irrigation pipes through their plots and mischievous incidences of damaging pipes and disrupting (stealing) water supplies takes place. In such cases when joint ownership of wells fails, they resort to buying water which not only becomes costly but also exploitative at times. While the share system (partially) promotes equity in access to groundwater, depletion reinforces inequality in the village societies where many joint owners become heavily indebted and are eventually forced to sell their shares along with their parcels of land.

3. Equity to groundwater irrigation accessibility

To examine the access to the groundwater resource, two parameters, namely, physical and economic access to the resource is discussed. The physical access to resource is the groundwater used by the farmers measured in volume (acre-hours); economic access is the cost per unit volume of water used/accessed. The equity to resource was examined by classifying the farmers in two ways – on the basis of holding size and on the basis of the different agro-ecosystems at different levels of resource depletion. It is evident that physical access to groundwater resource is skewed towards the higher landholding classes (Table- 6). The inequality to physical access to groundwater resource is due to the inequality to land holding sizes. If we negate the land holding factor and work out the physical access realised to groundwater resource on the basis of per unit of holding size for each class, we observe that the groundwater realised per acre of holding size is lowest in the groundwater depleted village of Ballab-e-Darya which indicates towards low yield of tube-wells due to progressive water table depletion. There is also inequality in water accessibility among marginal and large land holdings as farmers of marginal and smaller land holdings are incapable for chasing water tables as fast as the resource rich farmers. The per acre accessibility of groundwater is almost same among the tube-well irrigation village of Gharinda where since the water table is comparatively at shallower depths, the farmers across all categories can access groundwater. In the mixed irrigation village of Tohl Kalan the per acre accessibility to groundwater is low for the marginal farmers because most of them (marginal farmers) irrigate with canal water as investment in tube-well for small plots of lands are not economical and with availability of canal water it is also not a mandatory option. The other parameter of equity, the economic access to groundwater, is also more skewed towards the larger land holding groups (Table - 6). Thus on one hand there is worsening physical shortage of water for small and marginal farmers and on the other there is also a scarcity of economically accessible water.

Particulars	*Marginal Farmer*	*Small Farmer*	*Medium Farmer*	*Large Farmer*
Mixed Irrigation Village (Tohl Kalan)				
Total water used across all farms (acre-hour)	13208 (3)	46074 (11)	141384 (34)	219460 (52)
Water accessed per unit of holding size (acre-hour/acre)	403	593	601	817
Economic accessibility of groundwater = acre-hour of ground water per rupee of a motorised cost of well*	48624	121872	258149	831172
Economic accessibility of ground water per Rs. 1000	49	122	258	831
Tube-well Irrigation Village (Gharinda)				
Total water used across all farms (acre-hour)	4126 (1)	13128 (2)	147850 (18)	646938 (80)
Water accessed per unit of holding size (acre-hour/acre)	515.75	625.14	634.55	652.16
Economic accessibility of groundwater = acre-hour of ground water per rupee of a motorised cost of well*	64702	144432	306179	745554
Economic accessibility of ground water per Rs. 1000	64.70	144.43	306.18	745.55
Tube-well Irrigation Village with Problems of Depletion (Ballab-e-Darya)				
Total water used across all farms (acre-hour)	10702.5 (3)	27558 (8)	109765 (31)	210711 (59)
Water accessed per unit of holding size (acre-hour/acre)	365.90	314.05	442.16	565.67
Economic accessibility of groundwater = acre-hour of ground water per rupee of a motorised cost of well*	21858.81	121194	227474	708611
Economic accessibility of ground water per Rs. 1000	21.86	121.19	227.47	708.61

Note: Figures in parentheses are percentage to total and the cost is calculated as actual running cost incurred if diesel pumps were used
Source: Questionnaire surveys in various villages from May to July, 2009

Table 6. Equity to Groundwater Irrigation Accessibility for Farm Size Classes

4. Equity in net returns from agriculture

To examine the extent of inequity in access to groundwater irrigation, the extent of inequity of net returns per acre realized for different landholding size classes is taken as a proxy variable. Various measures of income inequality were estimated (Table-7) and is also presented in the Lorenz curve (figure-2). Inequality of agricultural return distribution is indicated by the degree to which the Lorenz curve departs from the diagonal line: the further the curve is from the diagonal line, the more unequal is the farm income distribution, and vice versa. For all these measures as well as the Lorenz curve, it can be

Inequity measures	Mixed Irrigation Village (Tohl Kalan)	Tube-well Irrigation Village (Gharinda)	Tube-well Irrigation Village with Problems of Depletion (Ballab-e-Darya)	Total of all samples
Gini concentration ratio (GCR)	0.070	0.008	0.218	0.099
Theil Entropy index	0.039	0.003	0.040	0.028
Standard deviation of logarithmic income	1.006	0.204	1.687	0.966
coefficient of variation	0.444	0.270	0.544	0.420

Source: Authors own calculation

Table 7. Measures of Income Inequality in Different Sample Villages

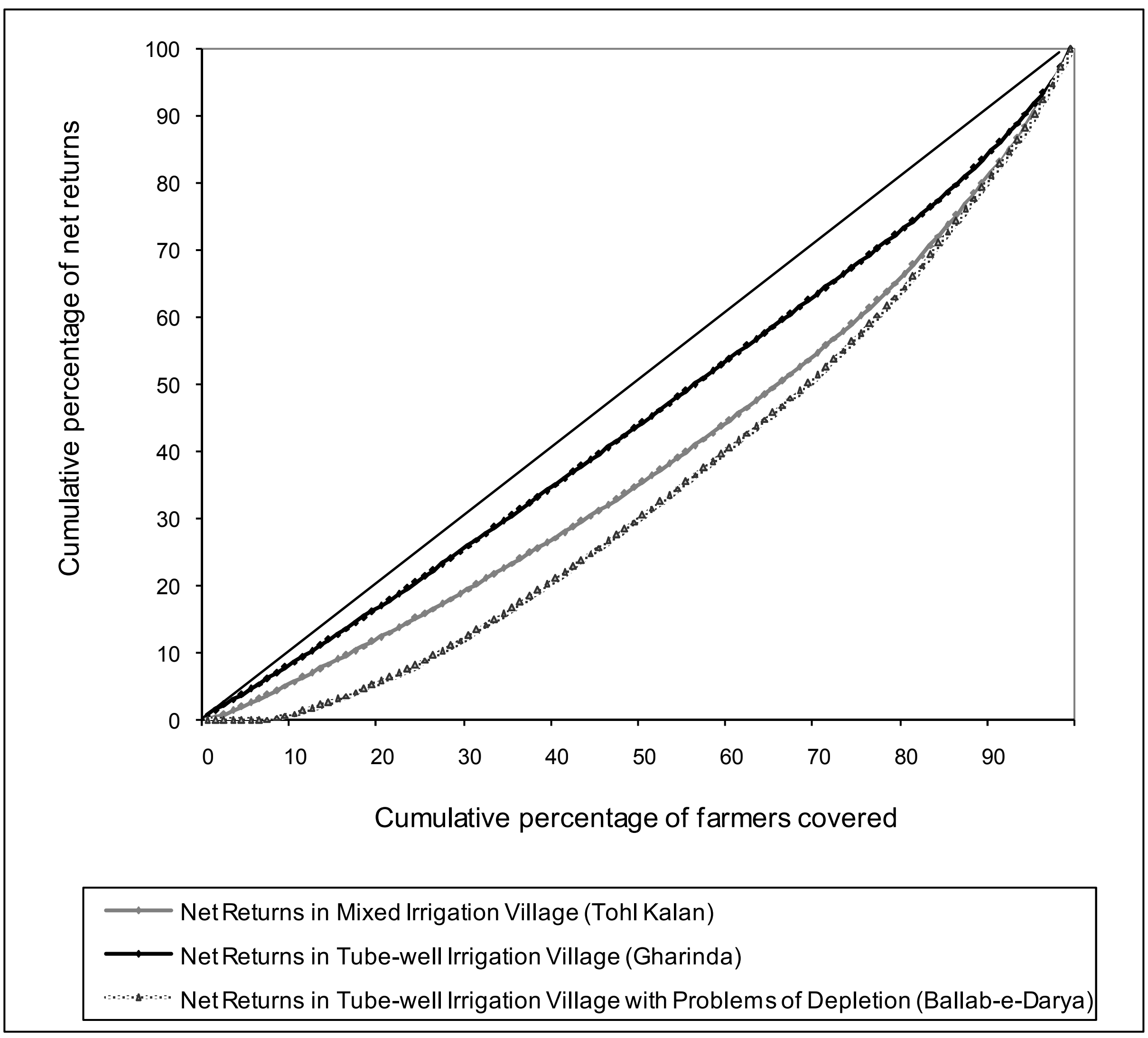

Fig. 2. Distribution of Net Returns to Cultivation

concluded that the net returns realized by farmers using groundwater irrigation in Gharinda is more evenly distributed than and in Ballab-e-Darya where there is problems of groundwater depletion. This is due to the more skewed access (distribution) to groundwater irrigation among the various classes of farmers in Ballab-e-Darya. Only a few marginal and small farmers have access to groundwater in Ballab-e-Darya on account of rising cost due to depletion. However it was not in case of Gharinda where groundwater accessibility was more equal. In Tohl Kalan the less inequality in net returns from agriculture was due to fact that a majority of small and marginal farmers who do not have tube-wells use canal water and have a large number of joint wells to supplement canal irrigation. A high proportion of marginal and small farmers being shareholders in joint wells in Tohl Kalan reduce inequality in resource among the different classes of farmers and thereby to irrigation surplus. But in Ballab-e-Darya due to deeper water tables and progressive receding of water table, the investment costs and maintenance of water yield in wells are very high. So the marginal and small farmers are fearful to go in for new bores on an individual as well as joint basis, thereby limiting their access to the resource. The non existence of any subsidiary source of irrigation other than tube-well irrigation further worsens the inequality in groundwater access and income distribution in Ballab-e-Darya. This shows that groundwater depletion plays a major role in inequitable distribution of groundwater irrigation access in a water scarce region like Punjab.

5. Conclusion and policy implication

The study reinforces the fact that growing inequity in access to groundwater leads to a process of continued social differentiation, which results in deprivation, poverty and the consolidation of inequitable power relations within local communities. Declining water levels and overexploitation of groundwater further leads to equity and sustainability problems and deteriorating socio-economic conditions. The immediate consequence of groundwater depletion is linked with the increasing cost of groundwater irrigation in terms of both capital and operating costs which is an increasing function of depth of water table. If the receding water table becomes a common phenomenon, the cost of groundwater irrigation rises in perpetuity. In case of considerable decline in water table, the external effect could not be only extra capital and operational costs but also lower farm output because of either reduced availability of water or lesser use of water at the enhanced cost of lifting it, or both. When the enhanced cost of water lifting exceeds the benefits from the use of such water for small farmers with traditional modes of groundwater irrigation that they are forced to give up irrigated farming altogether. Thus with continuous decline in the water table, the small and marginal farmers get deprived of groundwater or pay higher irrigation charges or they adjust their agriculture operations according to the accessibility of the water which largely depend on the tube-well owners who are generally large framers. This increase cost and severely affects the small farmers' production in the long run.

In the last twenty years gradual increase in groundwater access has undermined maintenance of canal irrigation systems Punjab which is evident from the government statistics which shows net area irrigated by canals has been declining and at present it is less than 27%. Field investigations reveal that the actual area under canal irrigation is further less as most of the canals have dried up and there is hardly any supply of canal water. Lack of maintenance of canal network and declining public investment in canal infrastructure have consequently led to shrinking area under canal irrigation further compelling the farmers to increasingly depend on groundwater for irrigation. It seems that the subsidy in irrigation has shifted from canal subsidy to electricity subsidy in agriculture in Punjab to the extent that agricultural electricity is free in Punjab. In the process it has shifted the determinants of water access away from communities and into the hands of few resource rich individuals who can invest capital in upgrading water technology and continuously deepen wells with depletion.

This has broader repercussions in the agricultural communities in Punjab. Firstly with an inherent inequality attached to groundwater ownership and accessibility on account of being privately initiated and monitored, the electricity subsidy consequently is disproportionately shared. But with declining water tables (for which large farmers are more responsible as they pump out more water and have large plots of land), the small and marginal farmers lose out on improvising their groundwater technology and competitive deepening and in the process get increasingly excluded form the financial grants (in this case free electricity) given by the government to facilitate the farmers to augment agricultural production. Secondly, when canal water is available in the villages, the small and marginal farmers (can at least) avail of irrigation water from canals or use canal water supplemented by tube-well water even when they do not own groundwater technology which (as of now)[6] is entirely a private initiative to start with and maintain. So in such cases where canals exists, these marginalised farmers can at least use some form of government grant (the canal water subsidy) to augment production (if not the groundwater subsidy) rather than being completely deprived. But the irony is that, the canal water subsidy although exists, due to lack of maintenance, most of the canals have dried out leaving the farmers no option but to depend on groundwater for irrigation. Thirdly, since this (electricity subsidy) financial assistance is not 'targeted' it is (mis)appropriated by the wealthy and does not reach the needy farmers who actually require this support. Lastly, the electricity subsidy is enhancing groundwater depletion which in turn is enlarging the gap between the rich and the poor making the agriculture ecologically unsustainable and socially impoverished in Punjab.

In the absence of surface water irrigation, groundwater withdrawals will tend to outstrip the groundwater recharge, with consequent downward pressure on the water table. In the presence of canal irrigation the pressure on water table eases in two ways: part of the demand for irrigation water shifts to canal water and seepage from unlined part of the canal network augments groundwater recharge. Thus a policy of simultaneous development of surface and groundwater irrigation will prevent permanent decline of water table in arid or semi-arid or low rainfall areas because of over-exploitation of groundwater which in the long run will also lead to sustainale agriculture. Sustainable water management should consider the environmental and equity issues and should cater to the needs of the poor and underprivileged who are generally marginal and small farmers.

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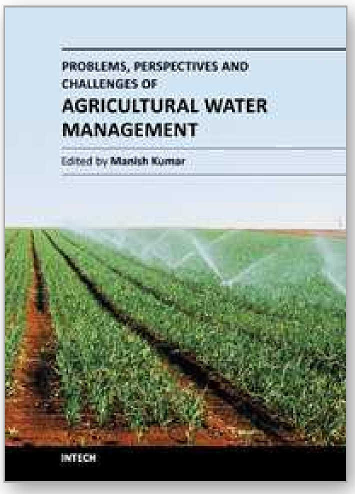

Problems, Perspectives and Challenges of Agricultural Water Management
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Food security emerged as an issue in the first decade of the 21st Century, questioning the sustainability of the human race, which is inevitably related directly to the agricultural water management that has multifaceted dimensions and requires interdisciplinary expertise in order to be dealt with. The purpose of this book is to bring together and integrate the subject matter that deals with the equity, profitability and irrigation water pricing; modelling, monitoring and assessment techniques; sustainable irrigation development and management, and strategies for irrigation water supply and conservation in a single text. The book is divided into four sections and is intended to be a comprehensive reference for students, professionals and researchers working on various aspects of agricultural water management. The book seeks its impact from the diverse nature of content revealing situations from different continents (Australia, USA, Asia, Europe and Africa). Various case studies have been discussed in the chapters to present a general scenario of the problem, perspective and challenges of irrigation water use.