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Is Irrigation Water Free? A Reality Check in the Indo-Gangetic Basin

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Summary. — "Getting prices right" is the silver bullet widely advocated to developing countries in fighting waste, misallocation and scarcity of water. In the vast, poverty-stricken Indo-Gangetic basin, however, high surrogate water price is driving out small-holder irrigation. With rising diesel prices, most small-holders who use borewells for irrigation find effective water use cost soaring, obliging them to economize on water use even by quitting irrigated farming. Electrified borewell owners, far fewer, face low marginal cost but have to contend with stringent electricity rationing. Public irrigation systems grossly under-price irrigation, but these are getting marginalized despite massive government and donor investments.

Key words — Indo-Gangetic basin, water pricing, water and poverty

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1. INTRODUCTION

Recent years have witnessed the rise of a new global discourse on treating water as an economic good. Several global summits endorsed the idea which also became central to the discussion on Integrated Water Resources Management (IWRM). This discourse, in its turn, has rekindled the "water pricing debate." At the heart of this debate is the travesty, throughout much of the developing world, of water becoming increasingly scarce and yet remaining nearly free at the same time. Especially in public irrigation projects, where an agency decision determines the user cost of water, woefully low irrigation charges have been blamed for a litany of ills: profligate water use, low water productivity, poor operation and maintenance of infrastructure due to insufficient resource generation, and failure to move scarce water to higher value uses. These concerns have given rise to much writing and discussion about how to move the debate from textbook price theory to the complex realpolitik of water pricing (Facon, 2002).

In irrigation economics, the challenge, as Briscoe (1996) highlighted, is of harmonizing three economic measures of water use: (a) the use cost—incurred by the user in obtaining and applying water to crops; (b) marginal value productivity of water in irrigation use; and (c) the opportunity cost, that is the value of irrigation water in the next best use. Where use cost is low on the margin, farmers will have no incentives to improve productivity; the distortions caused will be more serious where water is denied to other high value uses while farmers carry on intensive water use to irrigate low-value water-intensive crops.

Does raising irrigation water charges progressively generate incentives for raising water productivity? Significantly, at least some researchers think not (Molle & Berkoff, 2007). As De Fraiture and Perry (2007) argue, there is a threshold level below which farmers' demand for irrigation water remains price inelastic; below this threshold, farmers will not respond, no matter how much the price rises. As water price (or use cost) moves beyond the lower threshold, they argue that water demand remains price elastic within a range but then becomes inelastic as the farmer strives to save her crop from moisture stress. The De Fraiture–Perry irrigation water demand curve is shown as the right-most curve in Figure 1. Since in most public irrigation systems in developing countries, prevailing water rates stay way below this De Fraiture–Perry low "threshold," pricing is a blunt instrument for influencing the behavior of irrigators. As a result, De Fraiture and Perry (2007) and Molle and Berkoff (2007) and others suggest that water use cost is largely ineffective as a demand management tool in large-scale public irrigation; and making it effective requires profound and wide-ranging changes—in mass politics, in public irrigation infrastructure, in irrigation organization—all of which are unlikely to take place anytime soon (Facon, 2002). The conclusion that the "water pricing" debate is heading toward then is that the use cost of water (or effective water price) is unlikely to significantly shape farmer behavior in gravity irrigation, and is a blunt tool for water demand management. This mode of thinking has an overwhelming impact on shaping the ongoing global debate on making water an economic good.

In this paper, we explore in some depth a totally different dynamic in the irrigation economy of the vast Indo-Gangetic basin (IGB), an important exception to the above characterization. We posit that the water use cost that majority of small-holder irrigators in the IGB incur is substantially above the De Fraiture–Perry low threshold. We further pose that when the use cost of water rises above the low threshold, millions of small farmers here respond to rising irrigation prices initially by improving water use efficiency, by investing in lined channels or pipes for conveying water, and by switching to water-saving crops. However, when water use cost rises beyond some upper threshold, farmers are increasingly forced, in distress, to respond by drastically curtailing irrigation water use or even by exiting irrigated agriculture or agriculture itself. As suggested by the left-most curve in Figure 1, beyond the upper-threshold, irrigation water demand becomes super-elastic with respect to water use cost—and not inelastic as De Fraiture and Perry suggest—because a large number of irrigators subject to higher range of marginal irrigation costs are obliged to economize on water use in immiserizing ways. High water use cost achieves water use efficiency but threatens livelihoods and food security of millions of agrarian poor. Such stress is evident throughout the IGB, the only redeeming aspect of the situation being the up-turn in the global rice prices in 2008.

IGB spans an expanse of some 2.25 million km^3 in Bangladesh, India, Nepal, and Pakistan,

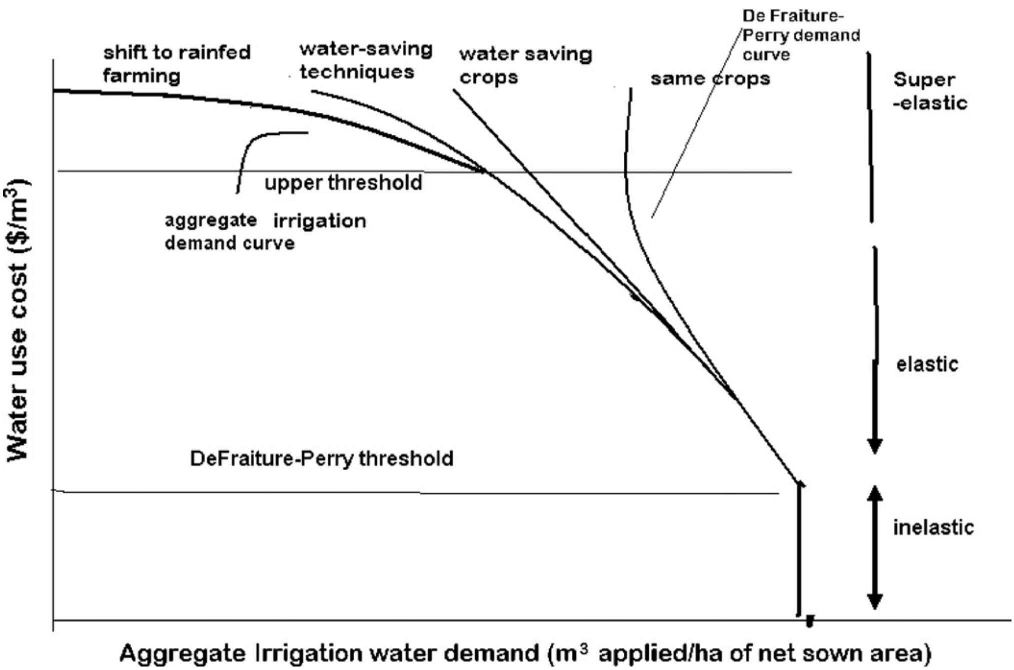

Figure 1. *Response of agricultural water demand to rising water use cost in the IGB.*

in the Indus–Ganga–Brahmaputra plain extending 3,200 km between the mouth of the Ganges to the east, and that of the Indus to the west. Major rivers in the basin include the Ganges, Indus, Beas, Yamuna, Gomti, Ravi, Chambal, Sutlej, and Chenab. The soil is rich in silt, making the plain one of the most densely populated and intensively farmed areas of the world since 2000 years ago. The IGB has one of the world's most prolific alluvial aquifer systems as also the world's largest concentrations of rural poverty. In 2000, over 30% of the 747 million people living in the basin were declared below the dollar-a-day poverty line; and nearly 75% were below 2 dollars-a-day poverty line. [1] Especially in its eastern reach, IGB is widely described as a basin with low productivity but high potential; the development of its vast groundwater resource for irrigation has been for long considered a big part of the answer to the challenge of alleviating agrarian poverty (Shah, 2001). This poverty-alleviating potential of IGB's groundwater resource has in recent years been eroded by the rising "surrogate price" of using it. "Getting prices right" has begun to conjure up altogether different images in the IGB than in the global water discourse.

2. THE UNDERBELLY OF SOUTH ASIAN IRRIGATION

Holden and Thobani (1996, p. 1) reflected a view shared by most international water researchers when they wrote that "In most countries, the state owns the water and hydraulic infrastructure and public officials decide who get water rights, or the purpose for which water is used, and on the price to be charged for its use." South Asia, with more than a third of the world's irrigated areas, however represents a vastly different reality in which pubic systems have been increasingly marginalized during recent years by a rapidly expanding private tubewell irrigation economy. The pump irrigation boom is taking much of Asia by storm (Barker & Molle, 2004; Shah, in press); however, it has experienced explosive growth in South Asia. "Water as an economic good" demands a totally different narrative here than outlined in Section 1.

Like elsewhere in the developing world, South Asia's public irrigation systems too are notorious for keeping water use costs way below the De Fraiture–Perry "threshold"; and the debate summed up in Section 1 applies very well to public irrigation systems here. Much recent evidence coming from a wide variety of sources however suggests that the areas irrigated by gravity from tanks and government canal irrigation systems in South Asia are declining in *absolute* terms; and even within tank and canal commands, lift irrigation with diesel pumps is driving out gravity flow irrigation (Shah, in press). In Pakistan's Indus Basin Irrigation System, during 1990–2006, the area irrigated with tubewells increased by 38% while that under flow irrigation declined by 11% (Ul Hassan *et al.*, 2007). In the Bhakra command on the Indian side, canal irrigation at first drove out wells; however, especially since 1990, the trend has been reversed, and now, 75% of all irrigated areas in Indian Punjab depend upon well and tubewell irrigation (Dharmadhikari, 2005; see also Singh, 2006 citing a Government of Punjab 2005 document). During 1990–2002, gross sown area in Punjab increased by 440,000 ha, but the area served by flow irrigation from canals fell by 589,000 while that served by tubewells soared by 837,000 (Down to Earth, 2005). Even the Punjab government's 2005 State of the Environment Report lamented a reduction of 36% in the canal irrigation area since 1990. In Punjab, canals irrigated 1.3 million ha in 1970–71 and more than 1.6 million ha in 1990–91, but in 1999–2000, canal-irrigated area in Indian Punjab fell to 1 million ha (PSCST, 2005). In Uttar Pradesh, whose western parts have a long history of canal irrigation, the area irrigated by canals declined 40% and from "other sources" by 60%, while the area irrigated by tubewells increased 37% (Pant, 2005, Table 1). In eastern Uttar Pradesh, tubewell irrigation increased 13 times since 1964–65; and even as tubewell-irrigated areas expanded, canal-irrigated areas fell.

According to Selvarajan (2002), around 2000, canals were irrigating 3.06 million ha in Uttar Pradesh, compared with 3.33 million ha in 1985. In Andhra Pradesh, they were irrigating 11% less than 15 years ago. Uttar Pradesh, Andhra Pradesh, Bihar, Orissa, and Tamilnadu—which account for 45% of India's net irrigated area—all witnessed an absolute decline in canal-irrigated areas but large increases in pump irrigation from wells (Selvarajan, 2002). During the five-year period from 1997–98 to 2002–03, canal-irrigated area in Gujarat fell 46%, from 0.78 million ha to 0.42 million ha. [2] For India as a whole, despite public investments for an "Accelerated Irrigation Benefit Program" of the order of US $ 25 billion during 1991–2004, the area irrigated by public irrigation systems declined by 2.8 million hectare during that period. [3]

According to Government of India's official figures, net area irrigated by groundwater wells rose from 28% in 1950–51 to 61% in 2000 (Government of India, 2005a). But this government estimate is dwarfed by large-scale farmer surveys by other government agencies. In 2003, Government of India's National Sample Survey Organization asked 51,770 cultivators from 6,770 villages for the source of irrigation they used in *kharif* (rainy season crops) and *rabi* (winter crops); the response was that 69% of *kharif* acreage and 76% of the *rabi* acreage were irrigated with wells or tubewells (NSSO, 2005). In Bangladesh, shallow tubewells accounted for less than 4% of the irrigated areas in 1972 but 70% by 2000 [4] (Bangladesh Bureau of Statistics, 2000). And in Pakistan, where canal irrigation had crowded out wells during the colonial period, in 2001–02, of the gross irrigated area of 18.3 million ha, only 6.8 million ha was served exclusively by canals; 7.5 million ha, or 41%, was served by "canal tubewells and wells" and 3.4 million ha, or 18.6%, by wells and tubewells outside canal commands (Government of Pakistan, 2003). Despite massive public investments since the mid-19th century in

Table 1. *Sources of irrigation in South Asia: Results of a 2002 IWMI survey of 2,600 farmers* (Shah et al., 2006)

Region	Cultivable land of sample farmers (ha)	Rainfed (%)	Under pure canal irrigation (%)	Under pure groundwater irrigation (%)	Under conjunctive use of ground and canal water (%)	Other sources
India	150,534	57.1	2.7	32.8	5.0	2.4
Pakistan	75,091	55.8	17.5	5.3	20.0	1.4
Bangladesh	5,904	37.2	0.2	40.1	4.6	17.9
Nepal terai	4,542	42.1	26.1	31.5	0.3	0.5
Total for the sample farmers	2,306,071	55.8	7.8	26.5	9.7	2.0

the Indus irrigation system of Pakistan, today wells and pumps are involved in 60% of irrigated areas. Figures provided by different government agencies on area irrigated by different sources are so conflicting that in 2002, IWMI carried out a reality check by surveying 2,600 farmers from India, Pakistan, Bangladesh, and Nepal terai and asked them how they irrigated their crops (Shah, Singh, & Mukherji, 2006). The results set out in Table 1 showed pure canal irrigation to be even less significant than official figures cited above in all countries including Pakistan which boasts of the world's largest continuous irrigation system.

The decline in South Asia's public irrigation system seems recent and rapid. Comparing India's Minor Irrigation Census data for 1993–94 and 2000–01, and data from Pakistan Statistical Bulletin for those years, Table 2 shows that during the seven-year period during 1993–2000, South Asia lost over 5.5 million hectare of canal commands but experienced 7.3 million hectare increase in groundwater irrigation. Many argue that what tubewells pump is canal seepage. That may be; the point is that the *mode* of delivering water to crops—and the economics of irrigating crops—is undergoing profound change.

As a consequence of shrinking public irrigation and rapidly growing private irrigation, the fast changing profile of South Asian irrigation economy was somewhat like what is shown in Figure 2 during early years of the new millennium.

Figure 2 presents the six irrigation sub-economies of South Asia in terms of their proximate size (million ha or Mha) on the *X*-axis and water use cost ($/m^3) on *Y*-axis. Information on area irrigated by different sources in India, Pakistan, Bangladesh, and Nepal is woefully inadequate and often incomparable across sources. Moreover, even in India with a fairly good statistical system, wide variations are found in estimates made by irrigation departments, agriculture departments (using land use data), and various censuses; and the estimates by all these, in turn, differ widely from estimates based on remote sensing data (see, e.g., www.iwmigiam.org). Figure 2 (not to scale) presents our best "guesstimates" of the area as well as water use cost under each of the six irrigation sub-economies arrived at by sifting government estimates, independent surveys by others, and our own surveys. The lowest range of water use costs (ranging from US $ 0.0025 to 0.02/m^3) is for flow irrigation from canals and tanks that partially supply, at most, 30–32 Mha; the highest (at US $ 0.15–0.25/m^3) is paid by farmers at the other extreme, hiring diesel generator sets to generate electricity to drive submersible pumps on deep tubewells. [5] Naturally, this last option is used *in extremis* on very small areas for a life-saving irrigation or two. [6] The point remains that the highest irrigation water cost/m^3 of water applied incurred in South Asia can be as much as 100 times the lowest, that more land is under irrigation at non-trivial use cost above the

Table 2. *Changing profile of irrigation in South Asia*[a]

	Net irrigated area under surface irrigation (000' ha)			Net irrigated area served by groundwater (000' ha)		
	1993–94	2000–01	Change (%)	1993–94	2000–01	Change (%)
Key Indian states	15,633	11,035	−29.4	17,413	21,760	+25
Pakistan Punjab	4,240	3,740	−11.8	8,760	10,340	+18
Sindh	2,300	1,960	−14.8	140	200	+42.9
Bangladesh	537	480	−10.7	2,124	3,462	+63
All areas	22,709	17,215	−24.2	28,437	35,762	+25.8

[a] Data for Indian states are from Minor Irrigation Census 1993–94 (Government of India, 2001) and 2000–01 (Government of India, 2005b). These are Andhra Pradesh, Arunachal Pradesh, Assam, Bihar and Jharkhand, Goa, Himachal Pradesh, Madhya Pradesh and Chhattisgarh, Orissa, Punjab, Rajasthan, Uttar Pradesh and Uttaranchal, West Bengal. Only states covered by both the censuses are included; which means that Gujarat, Maharashtra, Tamilnadu, Karnataka, and Haryana are excluded. Also excluded are smaller states and Union Territories where irrigated areas are small. Pakistan data are based on Pakistan Statistical Bulletins of different years. Bangladesh data are from Bangladesh Bureau of Statistics http://www.moa.gov.bd/statistics. Net irrigated area under surface irrigation in India includes area irrigated by major and medium projects as well as "other sources" which include surface flow as well as lift schemes. In Pakistan, area irrigated by wells and tubewells include area under canal wells and tubewells as well as other wells and tubewells. In Bangladesh, area under groundwater includes area served by deep and shallow tubewells and low-lift pumps.

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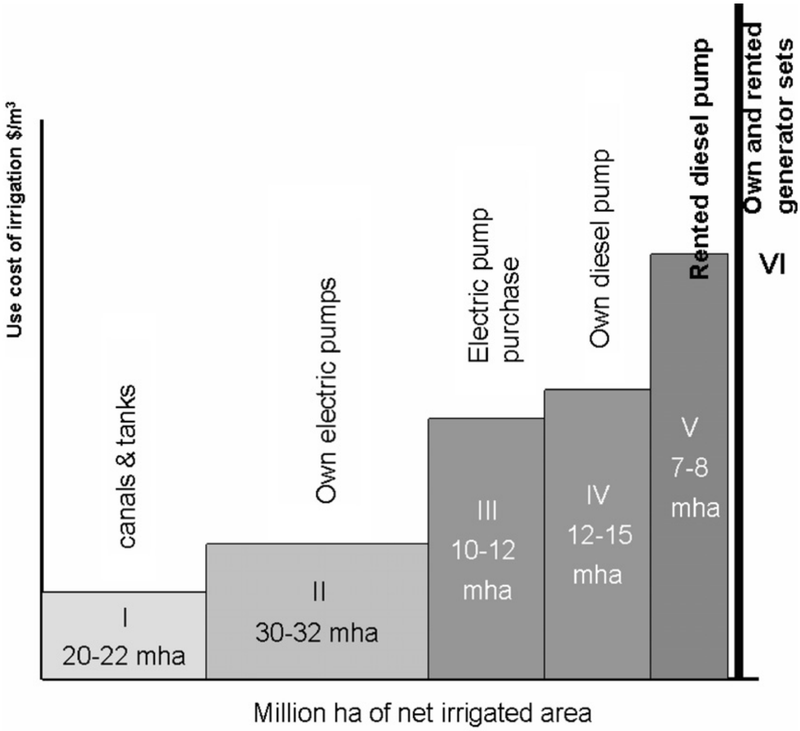

Figure 2. *Irrigation sub-economies of South Asia.*

Table 3. *Water economizing behavior of diesel pump owners versus electric pump owners: IWMI survey of 2,600 farmers in South Asia, 2002*

	Sample size	Average h/ha	Average horse power * h/ha
Diesel pump owners: paddy	806	226	1,641
Electric pump owners: paddy	455	558	2,233
Diesel pump owners: wheat	1,006	62.5	665
Electric pump owners: wheat	638	127	964

De Fraiture–Perry threshold, and that the productive value of water *at the margin* must exceed the use cost for such expensive irrigation to continue.

The global "water pricing" debate, reviewed for example in Molle and Berkoff (2007) applies partially only to the first—consisting of canal and tank irrigated areas—out of South Asia's six irrigation sub-economies; here, water use cost borne by farmers is neither volumetric nor anywhere near the De Fraiture–Perry "threshold." In all the rest, energy costs dominate the actual use costs of irrigation water. In sub-economy II, comprising areas irrigated by electrified tube-wells, the use cost of water is dominated by electricity costs which are high (at US c 1–1.75/kW h) and volumetric in Pakistan, Punjab, Sind, Nepal, and Bangladesh. In India, electric tubewell owners are subject to flat tariff, but increasingly, these have to contend with stringent rationing of increasingly unreliable power supply. What the "pricing debate" laments as a free lunch then is increasingly no lunch at all. For farmers in sub-economies II, III, IV, V, and VI, irrigation water *is* very much an economic good; and the user cost facing them is well above the "threshold" beyond which irrigation water demand becomes price elastic. Even within sub-economies I and II, increasingly, farmers are resorting to the use of diesel pumps to cope with the unreliability of surface irrigation as well as electricity supplies; thus, an increasing proportion of water use in sub-economies I and II in South Asian irrigation economy too is outside the purview of the global "water-pricing" debate, which at least in South Asia fails to reflect the ground reality.

3. THE DIESEL PRICE SQUEEZE

The rest of this paper is devoted largely to the analysis of the irrigation economy of the Indo-Gangetic basin (IGB)—encompassing Pakistan Punjab and Sind, Indian part of the IGB, Nepal terai, and Bangladesh. The IGB is the fertile ground for South Asia's groundwater revolution with well over 100 million horse power of installed groundwater pumping capacity in the form of millions of scattered small pumps and wells. As Figure 3 (based on the IWMI survey referred to earlier) highlights, the groundwater economy of the IGB is dominated by diesel pumps which impose a high volumetric water user cost on the basin's farmers. Barring Indian Punjab and Haryana, which have sizeable numbers of electrified tubewells, the rest of the IGB (Pakistan Punjab and Sind, Bangladesh, Nepal terai) overwhelmingly depends upon diesel pumps for irrigation. Electric pumps are insignificant because electricity supply to farms is metered and expensive as in Bangladesh and Pakistan or is simply not available (as in Bihar, Assam, and Nepal terai). [7] Farmers throughout the IGB have invested their own savings in installing over 100 million horsepower equivalent of diesel pump capacity as shown in Figure 4.

True, farmers in command areas of public irrigation systems in the IGB face a water use cost way below the "threshold" beyond which water demand becomes price elastic. However, the water use cost paid by a large majority of irrigators in irrigation sub-economies II, III, IV, V, and VI in the IGB is not only well above the "threshold" but is also approaching levels where it is beginning to squeeze out smallholder irrigation itself. Since 2000, all available evidence suggests that the region's groundwater economy has begun shrinking in response to a growing energy squeeze. This energy squeeze is a combined outcome of three factors: (a) progressive reduction in the quantity and quality of

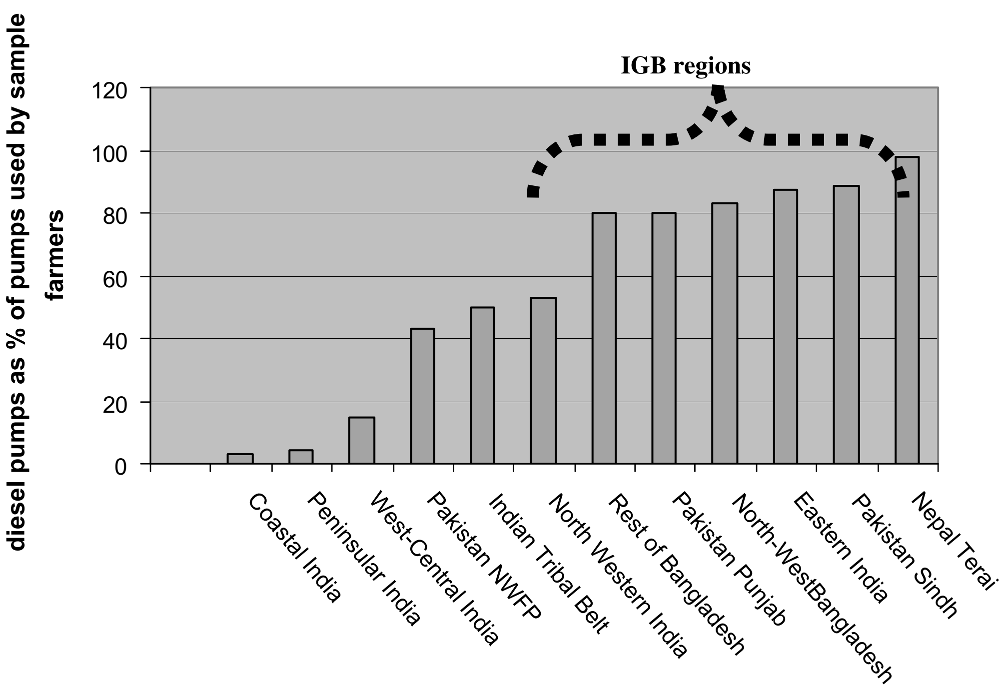

Figure 3. *Ratio of diesel to total installed pump horsepower in a sample of 2,600 South Asian farmers.*

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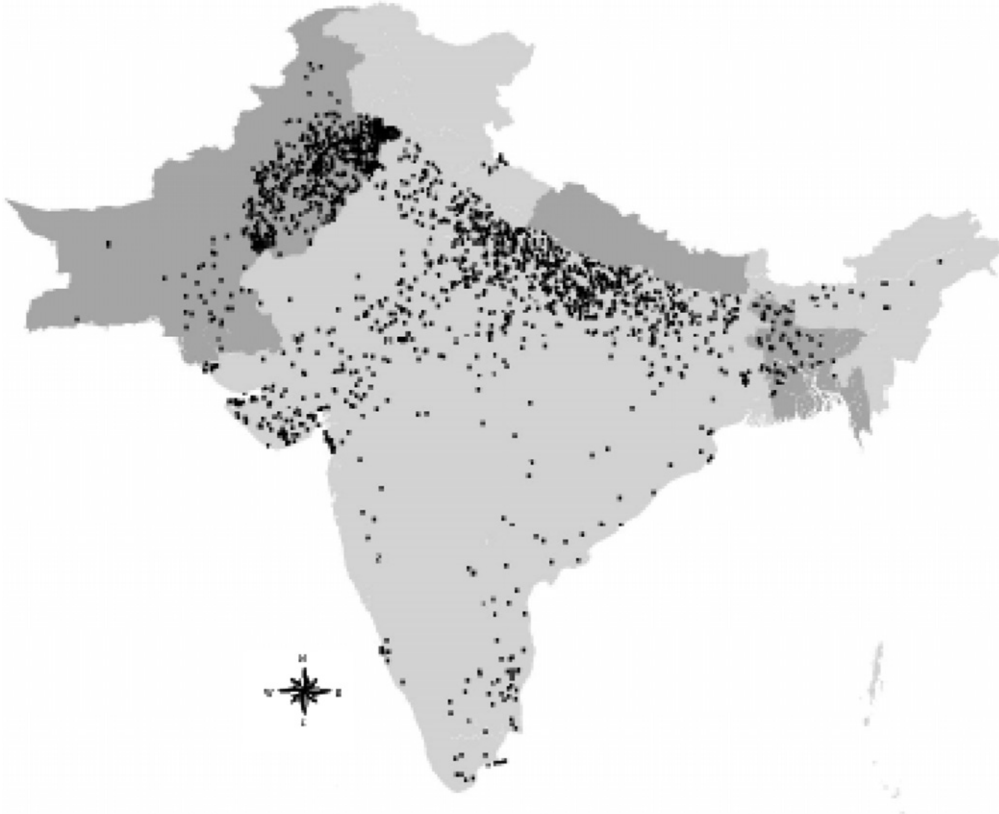

Figure 4. *Spread of diesel pumps in South Asia.*

power supplied by power utilities to agriculture as a means to contain farm power subsidies; (b) growing difficulty and rising capital cost of acquiring new electricity connections for tube-wells; and (c) a 6.7-fold increase in the nominal price of diesel during 1990–2006, a period during which the wholesale price index for all commodities for India a little over doubled [8] but more relevant, the nominal farm gate rice price rose by just over 60%.

In the 2002 IWMI survey of over 2600 farmers in India, Pakistan, Nepal terai, and Bangladesh, our respondents had unanimously ranked ‘‘energy cost and availability’’ as the top challenge to their farming, far above ‘‘groundwater depletion,’’ ‘‘high rate of well failure,’’ and ‘‘rising groundwater salinity’’ (Shah *et al.*, 2006). The impact of high marginal cost of diesel pump irrigation was evident in significantly lower hours of pumpage per hectare of paddy and wheat irrigation compared to electric pump owners among our sample farmers. These figures are set out in Table 3 which, besides hours of pumping per hectare, also provide ‘‘horse-power hours’’ to adjust for varying pump capacities and make the estimates more comparable. Since the time of our survey in 2002, diesel prices have jumped over 70%; no surprise then that the diesel price squeeze on small-scale irrigation is heading towards a crisis in all the countries of South Asia but is particularly visible in eastern India and Nepal terai where the ratio of rice to diesel price has turned particularly adverse as evident in Table 4. Small-holders in Pakistan and Bangladesh enjoy some respite thanks to higher subsidy they enjoy in

Table 4. *Farm gate rice price relative to diesel price in IGB countries*

	Diesel price per liter: February 2007	Farm gate rice price per kilogram: February 2007	kg of rice needed to buy a liter of diesel
India (Indian Rs.)	34.0 (US c 85)	6.4	5.7
Pakistan (Pak. Rs.)	37.8 (US c 64)	11.8	3.2
Bangladesh (Taka)	35.0 (US c 50)	9.0	3.9
Nepal terai (Nepal Rs.)	57.0 (US c 84)	10.0	5.7

Source: From various village studies undertaken for this research.

diesel prices. Rapid rise in global rice prices during 2008 will likely alleviate the squeeze somewhat making irrigated rice production more profitable. The fact remains that high marginal cost of irrigation with diesel pumps will keep irrigation water demand price elastic and stimulate IGB's small-holders to economize on water use in various ways.

4. ENERGY SQUEEZE LEVERAGED THROUGH WATER MARKETS

This would be particularly true for the poorest strata of IGB's peasantry who depend on pervasive pump irrigation service markets (or water markets) for securing their irrigation. Because decentralized, fragmented water markets are natural oligopolies (Shah, 1993), pump owners use diesel price increases to raise their pump rental rates *in tandem with* every major rise in diesel price despite the fact that pumps themselves have become cheaper in real terms during 1990–2007. Figure 5 shows the changes in the nominal price of diesel versus the price of pump irrigation in Uttar Pradesh. During 1990–2007, diesel prices here rose from US $ 0.125 to US $ 0.87 per liter; but the rate buyers incur per hour of pump irrigation has increased from US $ 0.75/h to US $ 2.50/h, the rise being

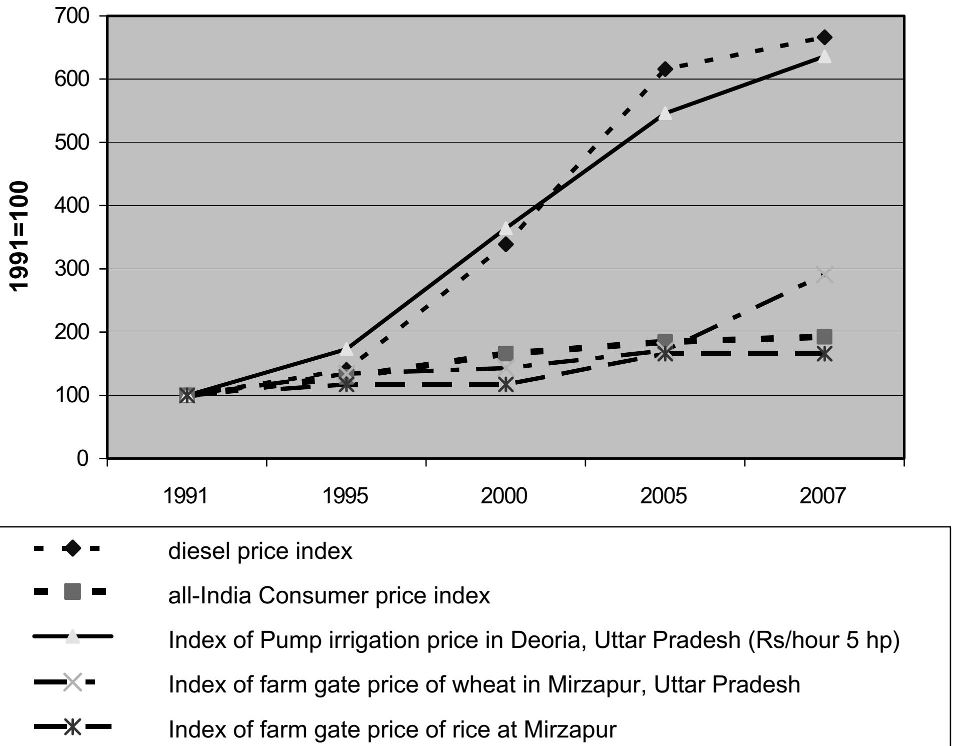

Figure 5. *Increase in relative price of diesel and purchased pump irrigation in Uttar Pradesh, India.*

far larger than needed to cover the increase in fuel cost. Another characteristic of this relationship has been the downward stickiness of pump irrigation prices; every time there is a big increase in diesel price, pump irrigation price tends to jump; however, the reverse is never the case because of the monopoly power of water sellers.

As a result, pump rentals relative to farm produce prices—which are what matters to the marginal farmers and share croppers–too have risen rapidly relative to rice and wheat prices up to mid-2007. In Deoria, eastern Uttar Pradesh, a marginal farmer could buy an hour of pump irrigation (around 30 m^3 of water at the well-head) for the farm gate price of a little over 3 kg of rice and wheat in 1990; today, this ratio is 10 kg of wheat and 12 kg of rice. Figure 5 shows the rise in diesel and pump irrigation prices relative to the all-India consumer price index. However, what matters most to farmers is irrigation cost relative to the farm gate prices of irrigated crops. Therefore the kg of rice and wheat needed to buy a liter of diesel or rent a pump for an hour—as shown in Table 5 for Deoria in Eastern Uttar Pradesh—is a better indicator of real increase in irrigation cost than nominal price deflated by national consumer price index or the national income deflator. It is not surprising then that in crop-sharing contracts for water sales in eastern India and Bangladesh, tubewell owners claim 1/3rd to half of the total output for pump irrigation alone when they pay for diesel. It is not surprising then that buying irrigation water against crop share is rapidly on a decline.

Electric tubewells, subject to flat horse-power linked tariff, are cheaper to operate than diesel pumps; their owners also sell pump irrigation to marginal farmers and share croppers at lower rates compared to diesel pump owners. Therefore, new electricity connections are avidly sought after. However, most IGB states—which in the early 1960s gave district collectors monthly targets for minimum number of tubewells to be electrified–now operate an embargo on new electricity connections to tubewells; and where they are issued, the entire cost of taking the power line to the tubewell—of poles, cables and transformers—is charged on the farmer. This has made new electricity connections scarce as well as prohibitively costly. Even so, existing electric tubewell owners and marginal farmers who are close enough to their tubewells to buy pump irrigation from them are luckier compared to diesel pump owners and their buyers. Since farmers who can buy pump irrigation from electric tubewell owners incur lower cost than by using their own diesel pumps, diesel pump owners in Uttar Pradesh today prefer purchased irrigation from electric tubewells than by irrigating with own diesel pump.

Under two research projects supported by the Challenge Program on Water and Food (CPWF), we have been tracking—through collaboration with location-based research partners—the impacts of growing energy squeeze on the predominantly small-holder irrigation in the Indo-Gangetic basin states. This paper summarizes the results of village case studies we carried out in 24 locations widely spread over India and Pakistan. The aim of the studies was to explore, identify, and document the main trends rather than to measure and quantify these impacts, something we intend to undertake in phase II of this research.

5. SHRINKING WATER MARKETS

A key finding of our reconnaissance is that the energy squeeze has raised the use cost of pump irrigation water and thus imposed a "surrogate water price" on farmers that is well beyond the "threshold" to a level that is proving immiserizing for marginal farmers and share croppers. Most social impacts of the en-

Table 5. *Deoria, eastern Uttar Pradesh: Rise in diesel and pump irrigation price relative to farm prices of wheat and rice (source: interviews with farmers)*

Year	kg of wheat to buy 1 l of diesel	kg of wheat to pay for 1 h of pump irrigation	kg of rice to buy 1 l of diesel	kg of rice to buy 1 h of pump irrigation
1990	1.24	3.14	1.45	3.67
1995	1.61	4.04	2.17	5.43
2000	3.71	8.00	5.30	11.43
2005	5.63	10.00	6.75	12.00
2007	3.39	6.86	6.29	12.73

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ergy squeeze on small-holder irrigation—and the agrarian poor—work out through groundwater markets. Confronted with the energy squeeze, these are shrinking; and soaring water prices are driving out water buyers and diesel pump irrigators who abound in the IGB. The key result is the shrinking of water markets.

Around 1990 and before, when diesel was 1/7th its present price, and farm power supply better than today, electric tubewell owners were natural oligopolists forced to behave in a highly competitive market. Flat electricity tariff, which reduced their marginal cost of pumping to near-zero levels, created powerful incentive for them to maximize pump irrigation sale, and in the process pare down the prices. Diesel pump operators were able to offer some competition because diesel price was low and their portability allowed diesel pumps to irrigate where electric tubewells could not reach.

Numerous field-based studies showed that such local groundwater markets emerged as the mainstay of ultra-marginal farmers and share croppers, especially in eastern India and Bangladesh. In Bangladesh, Fujita and Hossain (1995) had noted that thanks to pump irrigation markets, "the economic value of land... has decreased in a relative sense" in farm income generation and "opportunities for the landless and near-landless to climb the social ladder [have] expanded greatly." In Uttar Pradesh (India), Niranjan Pant (2005) wrote: "...the smallest farmers with land-holdings up to 0.4 ha are the largest beneficiaries of the groundwater markets as 60% of the farmers of this category irrigated their wheat crop by water purchased from the owners of private Water Extraction Devices..." Shah and Ballabh (1997) based on a study of water markets in six villages of North Bihar (India) concluded that these had opened up new production possibilities for the poor which left them better off than before, and thereby imparted a new dynamism to the region's peasant economy. Even, Wilson (2002, p. 1232), otherwise critical of profiteering by water sellers in Bihar (India), wrote: "extension of irrigation through hiring out [mobile diesel pump sets] to small and marginal holdings is in fact the major factor accounting for the further increase since 1981–82 in cultivated area irrigated at least once to approximately 73% in 1995–96. Those hiring in pump sets are overwhelmingly small and marginal cultivators; they cultivate an average of 1.35 acres (compared with an average of 3.89 acres cultivated by pump set owners)..." Most recently, Mukherji (2007) in an extensive study of water markets in West Bengal (India) reaffirmed their myriad benefits to the agrarian poor. Water markets, and indeed groundwater irrigation itself, have been a source of much succor to the agrarian poor. Studying rural poverty ratios across the Indian states over five points during 1973/74–1993/94, Narayanamoorthy (2007) concluded that, " there is a significant inverse relationship between the availability of groundwater irrigation and the percentage of rural poverty..."

With soaring diesel prices and shrinking power supply to tubewells, this happy situation has rapidly changed for the worse. Table 6 presents the estimates of rising pumping costs and their impacts on water prices charged by a sample of 60 diesel tubewell owners and buyers in Eastern Uttar Pradesh and South Bihar collected by Kumar, Singh, and Sivamohan (2008). It shows that some of the poorest farmers in the IGB are paying Rs. 2.11–2.67 (US c 5–7)/m^3 of irrigating crops. At such prices, irrigation cost would amount to a third or more of the value of crop output. Pump irrigation markets—which boomed during 1980–90s and probably served more area than all public irrigation systems in the IGB (Mukherji, 2005)—are shrinking rapidly; and so is the size of the basin's groundwater irrigation economy itself. During 1980–90s millions of farmers in northern and eastern India and Pakistan Punjab and Sind purchased diesel pumps often as stand-by's for their increasingly unreliable electric pumps. Now these have come full circle; diesel becoming unaffordable, especially for water buyers, the preference for electric tubewells has increased. However, electric tubewells are unable to meet these expectations because electricity supply as well as connections are dwindling.

In eastern India, Nepal terai and Bangladesh, electric tubewells are few and far between. Where we find some, two impacts follow: first, their owners find their monopoly power enhanced, which they use to increase their share in groundwater markets and irrigation surplus; second, they are able to moderate the energy squeeze on marginal farmers especially when power supply situation is good and tubewell owners pay flat electricity tariff. We found this to be the case in Uttar Pradesh, West Bengal, and Orissa in India. Where they are found in significant numbers, electric tubewell owners have driven diesel pump owners out of business. So unequal is the competition that even

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Table 6. *Behavior of groundwater pumping costs and selling price charged by a sample of diesel tubewell owners in South Bihar and Eastern Uttar Pradesh*

Year	South Bihar		Eastern Uttar Pradesh	
	Pumping cost (Rs./m^3)	Selling price (Rs./m^3)	Pumping cost (Rs./m^3)	Selling price (Rs./m^3)
1990	0.41	1.16	0.47	0.98
1995	0.51	1.40	0.56	1.31
2000	0.95	1.75	1.00	1.63
2006	1.60	2.11	1.64	2.67

Source: Kumar *et al*. (2008).

owners of diesel pumps prefer to purchase irrigation from electric tubewell owners rather than use own diesel pumps. In Uttar Pradesh, a 5 hp electric tubewell connection is a cash-cow for its owner: it entails a monthly charge of a little over US $ 10 but can generate up to US $ 225/month as gross income from water sale, a highly profitable proposition. In Birbhum district of West Bengal, our research collaborator wrote, "…by charging such high price for electric pump irrigation the submersible owners are getting their own irrigation free of cost and, on top of that, they make some profit as well.'' Here, the flat tariff paid by electric submersibles increased from US $ 136.5/year to US $ 223.75/year during 1990–2007; in response, irrigation rates charged for *boro* (pre-summer) rice too doubled from US $ 69/ha to US $ 140.6/ha. This rise was much smaller than the rise in the cost of purchased diesel pump irrigation. This has diverted the diesel pump owners' business to electric tubewell owners and served to strengthen their monopoly power. While electric submersible owners make merry, it is also increasingly the case that marginal farmers of Bengal can grow boro rice only if they can tie up irrigation with an electric shallow/mini-deep tubewell owner.

Similar impacts highlighted our inquiries in Pakistan. In Sekhan village we studied in North West Frontier Province, we found the cost of wheat irrigation rising 8-fold since 1990. The landless here rent the land from large land-owners for 400 kg of wheat/ha; rising diesel prices have squeezed the residual gains for the tenant after land rent and input costs are paid. In Jam Samo village of Sind, we found such tenancy, which was for long the mainstay of poor, has declined by over 80%. Almost everywhere in Pakistan Punjab and Sind, we found diesel pump irrigators, especially water buyers, taking a yield-cut by irrigating fewer times, investing more labor on land preparation to save on irrigation cost, reducing irrigated area, and commonly irrigating more intensively but on a smaller plot of land to grow high-value crops and vegetables for the market. In Fatehpur Afghana village in Norowal district of Punjab, responses to energy-squeeze included reduced summer rice cultivation, increase in rain-fed crops, especially, fodder crops; intensified cultivation of vegetable crops by marginal farmers and tenants; fewer irrigations than before; switch to water-saving crops/varieties; increase in holdings of small and large bovines to cut costs and reduce risks. The same story got repeated village after village in Pakistan.

6. RESPONSE OF WATER DEMAND TO SOARING USE COST

Soaring diesel prices and shrinking farm power supply are forming a pincer that first began forcing IGB's small-holder irrigators to make myriad adaptations to increase the efficiency of energy use in pump irrigation; some of these involved reducing pumping cost/m^3 either by switching to fuel efficient Chinese diesel pumps, or by switching from diesel to kerosene, and where possible, to electric power. A good deal also involved reducing water withdrawals. But more recently, the pincer has begun to throw the baby with the bath-water; and the energy-squeeze is gradually driving small-holders out of irrigation, and increasingly, from farming itself. Detailed documentation on the myriad responses of small farmers to the energy squeeze is available in Ul Hassan *et al*. (2007) for our Pakistan village studies and Shah (2007) for our Indian village studies. Here, we summarize—in Table 7– some of the prominent trends we found emerging in the 19 villages we covered in the IGB. The number of $\surd$ signs suggests the pervasiveness of a particular response among irrigators in the case study village.

Estimating quantitative responses of aggregate water demand to rising groundwater use cost in the Indo-Gangetic basin would require far more detailed surveys which are direly needed. However, our case studies of 19 villages in Indian and Pakistan portions of the IGB do suggest two classes of responses which we may call *efficiency responses* and *distress responses.* In the first category come all the adaptations made by small-holders to retain their irrigated agriculture by reducing somehow their groundwater use costs. These include attempts to curtail water use per acre by improving distribution efficiency (through lining field channels or using flexible pipes to convey water from wellhead to plants), by resorting to just-in-time irrigation and reducing the frequency of watering, by switching to low water demanding crops and crop varieties. These were evident in many areas with most farmer categories. In India as well as Pakistan, soaring diesel prices have rapidly increased the demand for electricity connections; however, these are getting increasingly difficult and costly to get because government power utilities now expect farmers to pay for cables, poles, and the transformer—all of which may double or even triple the cost of electric tubewells. In eastern India, therefore, besides reducing number of irrigations and area under irrigation-intensive boro (pre-summer) rice, a common response was to switch from Indian to Chinese diesel pumps. Chinese pumps are cheaper to buy, costing US $ 175–210 for 3.5 and 5 hp against US $ 350 for a 5 hp Indian pump of standard Kirloskar brand. The Chinese 5 hp pump runs for 2 h from a liter of diesel, which a Kirloskar 5 hp burns in an hour or less. Finally, while a Kirloskar needs a bullock cart to move around, the Chinese pump can be easily carried by a male farmer on his shoulders. Kolkata has emerged as the epicenter of Chinese pump diffusion. Several brands of Chinese and Chinese–Indian pump assemblies are on offer here (Greeves China, Tricircle China, GK200, Chhanta China, Zenith China, Changfa China, ZL 175 China, *etc*.). All these are selling at 35–40% of the price of Kirlosker 4 and 5 hp engines, which remained market leaders for decades, and Honda 4 hp pumps. Interviews with pump dealers in Kolkata confirmed that farmers preferred these for their low price, their much higher fuel efficiency (0.35–0.4 l/h), and most importantly, their ability to work on kerosene which is cheaper than diesel due to government subsidy for cooking fuel. Chinese pumps suffer more wear and tear and have shorter life; but Chinese pump mechanics have come up in every village, and their spare parts are cheaper and easily available.

Distress responses sometimes included forced exit from farming all together. In eastern parts, those quitting farming were mostly marginal farmers and share croppers dependent on expensive purchased irrigation service from water sellers. As we move west, rising groundwater use cost has hastened the exit of medium-scale farmers many of whom had already invested in off-farm livelihoods. These typically leave their farms in the hands of migrant share croppers who now take the brunt of the energy cost squeeze. Another distress response of small-holders is switching to high-risk–high-value crops on a small plot of land while leaving the rest of the farm holding fallow or under rain-fed crop. The primary driver of the high-risk, capital-intensive cropping strategy is the need to maximize the crop (and cash) per drop of diesel. In many areas, poorer farmers, whose main concern was food-grain security for the family, were cajoled into learning the new skills of vegetable cultivation and of marketing it to maximize their household income after irrigation costs were covered. High-value crops on small plots would pay for intensive irrigation in good years but leave small farmers indebted in years when crops fail or output markets crash. In the Bihar village we studied, forced to give up winter wheat, share croppers and marginal farmers took to intensive cultivation on small plots of fully irrigated onion crop during summer. As early pioneers struck it rich from the onion crop, others joined until a quarter of the village's farm land was under summer onion. The crop was capital intensive but high returns justified borrowing working capital at high interest. However, after some years of bumper returns, untimely summer rains ruined area's onion crop in 2005 and 2006, leaving the small tenants in a huge debt trap. We encountered a similar story of rise and decline of the "cabbage economy" in some villages of Purulia district in West Bengal; crash in local vegetable market induced by a cabbage glut left many small-holders in a deep debt trap. That the choice of high-value–high-risk crops was more common among marginal farmers and share croppers dependent on purchased irrigation than among medium farmers with own tubewells was an indication that high groundwater use cost was the driver of this "gambler's choice."

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Table 7. *Small-holders' responses to rising use cost of water in 19 IGB villages across the IGB*

Number	Village, province	Evidence of farmers responding to rising use cost of water by:					
		Applying fewer irrigations	Shifting to water-saving crops	Adopting water-saving techniques	Adopting energy cost-saving techniques	Reducing irrigated area	Other major responses
1	Sheikhan, Nowshera, NWFP			√	√√ √	√√	
2	Gandi Umer Chikad, Lakki Marwat, NWFP	√√			√	√√√	
3	Dhok Katarian, Rawalpindi, Punjab, Pak					√√ √	Rent land out; seek non-farm work
4	Shahia, Attack, Punjab, Pak		√√√			√√	Seek non-farm work
5	Khawanwala, Jehlum, Punjab, Pak					√√√	Super-intensive production of high-value crops and livestock; off farm work
6	Chak 7 NB, Balwal, Sargodha, Punjab, Pak				√√ √	√√	Super-intensive high-value crops; seasonal out-migration
7	Fatehpur Afghana, Norowal, Punjab, Pak	√√	√√√	√			
8	Barameel, Khanewal, Punjab, Pak			√		√ √	Intensive vegetable farming; high-value crops
9	Jam Samao, Matiari, Sindh			√			Priority to sugarcane from canal irrigation; casualization of farm labor
10	Kendradangal, Birbhum, West Bengal				√√	√√√	Marginal farmers and share croppers exit farming
11	Kaya, Murshidabad, West Bengal		√√√		√√		Adopt Chinese pumps; substitute kerosene for diesel
12	FerozpurRanyan, Haryana	√√√			√√	√	Marginal farmers begin quitting farming
13	Badhkummed, Ujjain, Madhya Pradesh	√			√√√	√√	
14	Berkhedakurmi, Sehore, Madhya Pradesh		√		√√√	√√	

Table 7—*continued*

Number	Village, province	Evidence of farmers responding to rising use cost of water by:					
		Applying fewer irrigations	Shifting to water-saving crops	Adopting water-saving techniques	Adopting energy cost-saving techniques	Reducing irrigated area	Other major responses
15	Keotkuchi, Barpeta, Assam				√√√	√√	Exit from farming
16	Shergarh, Hoshiarpur, Punjab, India	√				√√	Renting out land to migrant laborers; exit from farming
17	Simra, Phulwari, Bihar					√√√	Pumps used only for summer onion crop; share-cropping with pump irrigation declines.
18	Akataha, Deoria, Eastern UP	√					Pump irrigation concentrated on vegetables for market; greater use of canal irrigation
19	Abakpur Mobana, Mirzapur, Uttar Pradesh	√√	√				Pump irrigation reserved for high-value crops

7. CONCLUDING DISCUSSION

Global debate on "water as an economic good" presumes that irrigation water supply is delivered, controlled, and priced by public institutions; that in the developing world, the price of water is kept so low that water use cost leaves farmers no incentive to use it efficiently. From this characterization emerges the battle cry: get the water prices right. When water prices are very low, the debate argues, tinkering with them does not result in efficiency improvements. Getting the price right may then mean raising the water price above the threshold beyond which water demand begins responding to price increases. We have shown in this paper that at least in South Asia, a major irrigating region of the world, this characterization needs a reality check. In a region where irrigation is viewed as an instrument to alleviate agrarian poverty, the dominant emerging trend is the opposite of what the "water-as-an-economic-good" debate highlights.

We showed that public irrigation systems and their pricing policies are losing relevance to the irrigation dynamic of the Indo-Gangetic basin, including in their command areas. In the real irrigation economy of the IGB dominated by diesel tubewells and pervasive pump irrigation service markets, the "surrogate water price" facing millions of small-holder irrigators has for quite some time been well above the De Fraiture–Perry "low-threshold," and is now crossing the upper threshold beyond which water demand becomes highly responsive to the "surrogate water price." We also find that particularly post-2000, the energy squeeze—and the soaring use cost of groundwater—is inducing small-holders to adapt/respond in myriad ways. It is indeed rare to find the De Fraiture–Perry characterization reflecting the reality of irrigation demand in the IGB; instead of water demand becoming inelastic at high use cost, we contend it tends to become super-elastic. At prevailing irrigation water use cost, we find small-holders fostering *efficiency responses*, that is, shifting to water-saving crops, water and energy-saving irrigation technologies, and improved conveyance efficiency. But the poorest are also forced into *distress responses*, that

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is, switching to high-risk crops, reducing irrigated areas, and even getting out of farming itself. Since the onset of the 1990s, small-holder agriculture in the IGB has been stressed by an overall input cost-price squeeze anyway; but rising diesel prices are proving the last straw on the camel's back.

In the IGB, then, the emerging situation gives rise to an altogether new "water price debate," nearly opposite in its tenor to the global water pricing debate summed up in Section 1. Briscoe's (1996) exposition focused on striking a balance between water use cost, marginal product of water, and water's opportunity cost. In some eastern parts of the IGB, the true opportunity cost of groundwater pumped is negative. Here, private groundwater irrigation development has controlled massive "rejected recharge" that left vast areas with surface-flooding causing enormous damage to life and property (Shah, 2001). In the western parts, it did what a multi-million dollar SCARP tubewell program could not do as well: control water logging. Groundwater irrigation ought to be subsidized for creating such positive externalities in these parts of the IGB; yet, it is here that soaring use cost of groundwater is shrinking the groundwater irrigation economy.

In the IGB, the water pricing debate is then coming full circle. Here, the major challenge is to find ways of bringing down water use cost below the "upper threshold" beyond which abundantly available water becomes too expensive for the poor to use to maintain livelihoods and food security. Prevailing "surrogate prices" of groundwater irrigation in the IGB are proving so "efficient" that they are pricing out small-holder irrigation which has been the mainstay of hundreds of millions of agrarian poor. Small-holders using Chinese pumps are already diverting rationed quota of subsidized kerosene allotted for cooking purposes to run irrigation pumps; and in states like Bihar, there is demand for allotting farmers subsidized diesel quota, much like how fisher-folk are provided in Indian coastal states. Elsewhere, the lead author has argued that investing in farm electrification and providing rationed electricity at an affordable price—as under Gujarat's new *Jyotigram* Scheme (Shah & Verma, 2007)—might provide succor to small-holders in eastern India. The challenge in IGB is then altogether different, and needs to be incorporated in the global debate on "water as an economic good." Johansson, Tsur, Roe, Doukkali, and Dinar (2002, p. 192) hit on the bulls eye, when they say:

> "Marginal cost pricing and water markets will serve to increase the cost of irrigation to most globally, and when the scarcity value of water is high, may force subsistence-level farmers out of production. In such cases, water quotas, which can be tailored to equity considerations, may be the preferred mechanism of allocation. The trade offs between efficiency and equity and the use of water allocations to address poverty in many areas of the world are important questions that require further enquiry."

NOTES

1. http://www.waterandfood.org visited on May 4, 2008.

2. See *Divya Bhaskar,* Ahmedabad edition, September 4, 2007, 3.

3. http://www.sandrp.in/irrigation/100000_crores_spent_no_irrigation_benefits_SANDRP_PR_Oct2007.pdf, visited on October 12, 2007.

4. Khan (1994, p. 81), however, asserted that "in 1990–91, the minor irrigation lifting devices provided irrigation water to about 88% of irrigated area" in Bangladesh.

5. Singh and Kumar (2008, Table 3) estimated groundwater costs per m^3 for a sample of farmers in western Uttar Pradesh at: Rs. 0.18 for electric pump owners, 0.65 for buyers from electric tubewell owners, 1.38 for diesel pump owners and 2.81 for buyers from diesel tubewell owners. For South Bihar, their estimates for the same groups, respectively, were: Rs. 0.77, 0.70, 1.87, and 2.15. Singh and Kumar compared water productivity by different groups of irrigators and concluded that "water buyers in diesel and electric well commands.. secure higher water productivity in economic terms for most crops as compared to water sellers." (p. 435).

6. Through this paper, 1 US $ = Indian Rs. 40 = Pakistan Rs. 59 = Nepal Rs. 70 = Bangladesh taka 68.

7. We have adjusted the diesel tubewell density for the fact that the average size of diesel pumps in use in Pakistan Punjab and Sind is over three times larger compared to pumps used in the rest of the IGB. This difference is accounted mostly by the greater inequality

of land holdings in Pakistan Punjab and Sind. Tubewell owners here, typically large farmers, need pumps that match the areas they want to irrigate.

8. http://rbidocs.rbi.org.in/rdocs/Bulletin/PDFs/79844.pdf visited on September 25, 2007.

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