Two faces of energy irrigation nexus in West Bengal, India: High flat rate electricity tariff and escalating diesel prices

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1.0 Introduction

Most of South Asia today is overwhelmingly dependant on groundwater irrigation for supporting its predominantly agrarian economies. South Asia (with India leading the pack) is the world's single largest user of groundwater accounting for almost 210 km^3 of withdrawals every year (Mukherji and Shah 2005, Shah et al. 2003). It is then no surprise that in such pump lift irrigation based economies, fortunes of groundwater and energy sectors are closely entwined. This relationship between the two sectors has been often called the 'energy-irrigation nexus' (Shah et al. 2003) or the 'energy irrigation conundrum' (Dubash 2006).

While the scope of the term energy is broad, yet discussions in this field have been limited to 'electricity-irrigation' nexus. Much of the debate so far has veered around the pros and cons of two different modes of electricity pricing, viz. rational flat tariff system and pro-rata metering. While one school of thought has propounded the superiority of rational flat tariff on grounds of equity and administrative ease[2] (Shah 1993, Shah et al. 2003), another group has alleged that such tariff system leads to loss of efficiency and endangers sustainability of both groundwater and electricity sectors (Briscoe 2005). Pre-occupation with electricity tariff is understandable because electricity sector provides the

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[2] The main argument being that rational flat tariff provides incentives to owners of water extraction mechanisms (WEMs) to proactively sell water to the non-owners. The non-owners in most cases are small and marginal farmers. Thanks to the existence of water markets, which are encouraged under a flat rate electricity tariff regime, these small and marginal farmers come within the ambit of irrigated agriculture. The second argument in favour of rational flat rate tariff is that it reduces the administrative burden on the part of the electricity utility companies and at the same time takes away the arbitrary power of a 'meter reader' over hapless farmers.

only formal point of contact with an otherwise informal groundwater economy and that electricity operated pumps are the only option in arid and semi-arid western and southern India which were the precursors in groundwater irrigation boom in the 1970s and 1980s.

The other major energy source for groundwater pumping, viz. diesel remained outside the ambit of discussions in the field of 'energy-irrigation nexus'. This is because diesel prices were heavily subsidised till recently and areas which are now highly dependant on diesel operated WEMs (i.e. the eastern and central parts of India) were in the 1980s and early 1990s relatively less dependant on groundwater irrigation than their counterparts in northern, western and southern India. However, over the last 10 years and so, this situation has changed completely. There has been a gradual removal of subsidies on diesel and second, the eastern states have seen intensive groundwater use. Hence there is an urgent need to broaden the scope of work on the 'energy-irrigation' nexus and move beyond the narrow 'electricity-irrigation' focus. This paper attempts to broaden the scope of debate in the field by looking at both the faces of 'energy-irrigation' nexus. In doing so, it will draw empirical evidence based on extensive fieldwork carried out in 2004-05 in the state of West Bengal, India.

Specifically, this paper will discuss two aspects of the energy irrigation nexus, viz. impact of mode of electricity tariff on groundwater supported irrigation services markets (referred hence forward as groundwater markets) and impact of rising diesel prices on the functioning of these markets in particular and agriculture in general.

The paper is organised thus. In the second section, I will set the stage for further discussion by giving a brief background on the state of West Bengal, its groundwater resources condition and threat perceptions surrounding the same. In the third section, I will discuss the 'first face' of the energy irrigation nexus, i.e. the role of rational flat tariff in sustaining pro-active water markets. I will also discuss the changes in nature of water market transactions due to increase in electricity tariff. Then I will go on to discuss the advantages of water markets in conferring benefits of irrigation to non WEM owners. Finally, in this section, I will discuss the recent move on the part of government of West Bengal to switch from flat rate tariff to metered electricity tariff and its possible impact on groundwater markets. In the fourth section I will discuss the 'other face' of the energy irrigation nexus, i.e. the impact of rising diesel prices on groundwater markets and the coping strategy adopted by farmers in face of rising pumping costs. In the fifth and the final section, I will sum up the discussion by suggesting some policy options which might ease the pressures that farmers in West Bengal face at present due to high diesel prices and low rates of rural electrification.

2.0 A land of abundant yet scarce groundwater: An oxymoron that is West Bengal!

West Bengal, an eastern state of India located within the Ganga-Meghna-Brahmaputra basin is a land of plentiful rainfall (1200 to 2500 mm annual rainfall), rich alluvial aquifers holding some 31 billion cubic meters (BCM) of groundwater (WIDD 2004) which is accessible at 5 to 10 meters below ground level in 95% of villages (3rd MI Census, GOI 2001). In terms of per unit availability of groundwater, West Bengal ranks second (MCM of groundwater/1000 hectare of net cultivated area) and third (MCM of groundwater/100km^2 of geographical area) among major Indian states.

Table 1. Total replenishable groundwater resources per unit of net cropped area and geographical area, May 2004

State	Gross replenishable GW per unit of NCA (MCM/'000 ha)	Rank	Gross replenishable GW per unit of geographical area (MCM/'100km^2)	Rank
Assam	9.03	1	31.52	4
West Bengal	5.55	2	34.12	3
Tamil Nadu	4.83	3	20.29	6
Uttar Pradesh#	4.78	4	34.45	2
Bihar*	4.53	5	19.28	8
Punjab	4.43	6	37.05	1
Kerala	3.51	7	20.33	5
Orissa	3.31	8	12.84	9
Andhra Pradesh	3.31	9	12.83	10
Madhya Pradesh@	2.68	10	11.48	12
Haryana	2.38	11	19.29	7
Maharashtra	2.13	12	12.31	11
Gujarat	2.13	13	10.40	13
Karnataka	1.56	14	8.44	14
Rajasthan	0.78	15	3.71	15

Source: Central Water Commission (data downloaded from website www.indiastat.com on 28th February 2006). # includes Uttar Pradesh and Uttaranchal, * includes Bihar and Jharkhand, @ includes Madhya Pradesh and Chattisgarh.

The level of groundwater development in the state varies from as high as 84.6% in Nadia district to as low as 5% in Jalpaiguri district, the average for the state being 41.3%. Thus, none of the 17 districts fall in the 'over-exploited'[3] category. As per groundwater estimation carried out jointly by the State Water Investigation Directorate (SWID) and the Central Groundwater Board following the GEC 97 methodology, of the 269 blocks in the state, as many as 231 blocks (or 86%) of the blocks were declared 'safe', while 37 blocks were declared 'semi-critical' and only 1 block was put in the 'critical' groundwater category (Ray Chowdhury 2006). Contrast this to recent statistics from the state of Punjab: of the 137 blocks in Punjab, 103 blocks (or 75%) are over-exploited; five blocks are in 'critical' stage, four blocks are in 'semi-critical' stage and only 25 blocks are in 'safe' category (Takshi 2006). Or the state of Gujarat: 45% of 184 blocks were in the category of 'over-exploited', 'dark' and 'grey' in the year 1997, a number that has almost certainly gone up by now (Hirway 2000, p. 7).

Yet the popular perception among groundwater professionals and other researchers is that West Bengal is in throes of a major groundwater crisis[4]. For example, in a recent conference organised by the Central Groundwater Board at New Delhi[5], the Director of the SWID justified the introduction of West Bengal Groundwater Resources (Management Control and Regulation Act 2005) on grounds of "…noticeable falling trend in the groundwater level during summer", (Ray Chowdhury 2006:221) which incidentally data from their own organisation refutes (see WIDD 2004 and see above). Similarly, representatives from the Central Groundwater Board based at Calcutta Regional Office (Kar, Gawri and Choudhary 2006) titled their paper as "Over-exploitation of aquifers: Need for proper planning, management tactics, awareness and legislation (examples from West Bengal and Orissa)" – a curious enough title and topic in those two states of India where groundwater is under-utilised rather than 'overexploited'. Table 2 juxtaposes the net groundwater available for irrigation with that of tubewell

3 The Central Groundwater Board (CGWB) currently uses a methodology called the GEC-1997 to classify blocks into safe, semi-critical and semi-critical. Earlier as per the old methodology (GEC 1984), blocks were categorized into white, grey, dark and over-exploited.

4 Part of this could be attributed to concerns regarding arsenic contamination of groundwater that emerged as a major issue in both West Bengal and Bangladesh.

5 This conference titled 'Groundwater Governance: Ownership of groundwater and its pricing' was organised by the Central Groundwater Board at New Delhi on 14th and 15th November 2006.

density (number of tubewells/1000 hectares of cultivable land). The results show that tubewells density is very low even in very high groundwater potential blocks, showing that if anything, there is an under-exploitation of groundwater resources in the state and that there is further scope of groundwater utilisation without putting groundwater sustainability in jeopardy.

Table 2. Net groundwater available for irrigation (MCM/1000 ha of cultivable land) versus density of tubewells (No. of tubewells/100 ha of net cultivable land) in 2000-01: A block level cross-tabulation

Sr. No	Category	Number of blocks	Percentage to total
1.	High groundwater potential- High tubewell density	68	26.0
2.	High groundwater potential- Low tubewell density	113	43.1
3.	Low groundwater potential- High tubewell density	3	1.1
4.	Low groundwater potential- Low tubewell density	78	29.8
5.	Total	262	100.0

Source: Author's calculation based on 3rd MI census (GOI 2001)
High groundwater potential: > 5MCM of net groundwater/1000 ha of cultivable land
Low groundwater potential: < 5 MCM of net groundwater/1000 ha of cultivable land
High tubewell density: > 20 tubewells/100 ha of net cultivable land
Low tubewell density: < 20 tubewells/100 ha of net cultivable land

The official view of impending crisis seems to be reflected among other scholars as well. For instance, Sarkar (2006) offered various reasons for slowdown in agricultural growth in the state in the 1990s, of which the most important one according to him was constraints in further expansion in summer *boro* paddy cultivation due to unavailability of water. While it the beyond the scope of this paper to analyse why such perceptions exist (see Mukherji 2006a for explanations along the lines of political ecology), the point I am trying to make here is that though West Bengal is well endowed with groundwater, there is a popular perception that the state's groundwater resources are at a risk.

Several policy prescriptions follow from this threat perception. First, farmers in West Bengal pay one of the highest flat electricity tariffs anywhere in India[6]. The state also has the rather dismal distinction of having the lowest number of electrified WEMs anywhere in the country. Only 12.2% of all WEMs in West Bengal are electrified (3rd MI Census GOI 2001) as against a national average of 50%. The process of electrification of pumps is governed by strict SWID regulations making the entire process lengthy and

[6] Farmers in West Bengal pay an annual fixed electricity tariff of Rs. 6800 for standard 5HP pumps, while their counterparts in Punjab, Haryana, Tamil Nadu and Andhra Pradesh enjoy free electricity. Farmers in Gujarat pay a nominal charge of Rs. 850/HP as compared to Rs. 1200/HP for a Bengal farmer.

cumbersome. All these facts, viz. abundance of groundwater, high electricity tariff, difficulty in getting new electricity connections and low rates of rural electrification (which makes West Bengal's groundwater economy largely diesel dependent) puts the state in sharp with other Indian states such as Punjab, Haryana, Gujarat and Tamil Nadu. In these states, in spite of precarious groundwater conditions, farmers get concessions from the state in terms of electricity subsidies.

In West Bengal then, the 'energy-irrigation' nexus takes on an entirely different hue than in other Indian states. The issue of electricity subsidy to agriculture and its impact on state fiscal deficits while being very important in most states of India, is a non-issue in West Bengal, given that only 12.5% of all pumps are electrified and electricity tariffs are quite high resulting in lower state deficits (see figure 3). On the other hand, impact of rising diesel costs on irrigation is a major issue in West Bengal given that 90% of all WEMs in the state are diesel operated. Thus, paradoxically, in a land of abundant groundwater resources, groundwater has become a scarce commodity thanks to high costs of pumping from diesel pumps. The implications of such 'economic' crisis of groundwater are quite serious. In the next section, I will discuss impact of rational flat tariff on the functioning of groundwater markets in West Bengal.

Figure 1. Electricity subsidy to agriculture as percentage of gross fiscal deficit 2000-01

Source: Briscoe 2005:24

3.0 One face of energy irrigation nexus: High flat rate electricity tariff and groundwater markets

Notwithstanding the negative perception on groundwater use held by the 'experts'[7], the farmers of West Bengal like elsewhere in India have come to rely extensively on groundwater irrigation for their livelihoods. Access to groundwater irrigation is either through ownership or through purchase of pump irrigation services. As per the 54th round of NSSO survey (NSSO 1999), of the 6.1 million farming households in West Bengal, only 1.1 million reported owning WEMs, while 4.6 million farming households reported using irrigation. Some of them certainly fell within the canal command areas, but an overwhelming number of 3.1 million households (or 50.4% of all farming households) reported hiring of irrigation services from other farmers[8]. My survey conducted in 40 villages spread across 17 districts shows that 70.5% of all households reported buying water from private WEMs, 75% of pump owners sold water to other, 33% of all WEM owners also bought water from others and 92% of all respondents came within the ambit of groundwater market either as a seller or buyer or both[9]. It is outside the scope of the present paper to delve into the details of various aspects of functioning of groundwater markets in West Bengal but details of the same may be found in Mukherji (2006b).

In this section of the paper, I will discuss the role of relatively high flat tariff in encouraging and sustaining groundwater markets. Farmers in West Bengal, as already mentioned earlier, pay a flat tariff of electricity. This rate at present is around Rs. 5500/year for centrifugal electric pumps and Rs. 6800/year for submersible electric pumps. There has been a rapid increase in electricity tariff over the last 10 years or so, as

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[7] Just as there exists a negative perception about groundwater irrigation as noted in the earlier section, similarly, groundwater markets too are perceived in a negative light by the officials as is clear from this communiqué from the Secretary, Minor Irrigation to the Secretary, Department of Power, GoWB in a letter dated 4th March 1993 where he stated that " ….. quite often the purpose of these (groundwater) structures are more commercial than personal…". This letter was written in support of instituting SWID regulations to control proliferation of pumps.

[8] This means that 1.1 million WEM owning households hired out their pumping equipment (or sold water directly) to another 3.1 million households.

[9] The sample size of this survey was 294 WEM owners and 286 'pure' water buyers. This survey was conducted from August to December 2004.

is shown in table 3. In this section I will discuss the implications of high flat rate electricity tariff on the functioning of groundwater markets.

Table 3. Change in flat rate electricity tariff in West Bengal, 1995 to 2003

Year	Electricity tariff for shallow tubewells (Rs/year/tubewell)		Electricity tariff for submersible tubewells (Rs/year/tubewell)	
	North Bengal	Other districts	North Bengal	Other districts
1991	1100	1100	1100	1100
1995	1380	1700	1380	1700
1996	1660	2040	2500	3060
1999	2676	3284	4028	4932
2001	4064	5008	5080	6252
2003	4434	5460	5540	6810

Source: WBSEB records, various years

Proponents of rational flat tariff argue in favour of it by proposing that under a relatively high flat tariff regime, owners of WEM have a positive incentive to sell water to others. This is because under a flat tariff regime, marginal cost of pumping becomes zero or very near zero. This means that additional hour of pumping does not entail additional costs. However, by selling water, the pump owner is able to recoup his or her electricity bill and also earn some profits. In case of diesel pump (which entails incremental costs for every hour of pumping) or under pro-rata or metered electricity tariff, this incentive will not be present and hence spread of groundwater markets will be limited. This will be more so given the escalating diesel prices in recent years. From these arguments, it is possible to derive the following hypotheses:

1. Electric WEM owners subject to flat tariff will be more likely to sell water than a diesel WEM owner
2. Similarly, an electric WEM owner will sell water for longer number of hours than a diesel WEM owner
3. Therefore, groundwater markets will be highly developed (where development of groundwater market is defined in terms of breadth and depth of water market transactions) in villages dependent predominantly on electric WEMs than in diesel WEM dependent villages.

3.1 Role of motive power of pumps in water selling decisions of WEM owners

Not all WEM owners' sell water. Of 294 WEM owners in my sample, some 220 (or 75%) report water sale. In this section I will try to answer the question: 'what factors affect water selling decision of the WEM owners?' As already hypothesised, owners of electric WEMs are more likely to sell water than owners of diesel WEM. Electric WEMs owners have to pay a fixed amount of electricity bill per year (this was Rs 5460 for EST and Rs 6810 for ESB in 2003-04) irrespective of hours of pumping. Hence for all purposes, their marginal cost of water extraction is zero and they have positive incentive to sell water. On the other hand, diesel WEM owners have to bear the incremental cost of pumping every unit of water and have to make upfront payment for purchase of diesel. Given the high diesel price (Rs 26.00-30.00/litre during the time of my fieldwork in 2004-05), water price tended to be high at Rs 50.00 per hour and this reduced the demand for water from diesel pumps.

Second, generally speaking, priority of farmers who invest in WEMs is to first meet his/her own irrigation demands and then sell surplus water to others. Thus, size of land owned by the WEM owner or his operated holding may affect his decision to sell water. Meinzen-Dick (1996) in her study area in Pakistan found that area owned by the tubewell owner was the most important factor affecting groundwater sale. But then farm sizes in Pakistan are very large. In the context of West Bengal, where farm sizes are quite small, it might affect the quantum of water sold but is unlikely to affect the water selling decision *per se*.

Third, it may be hypothesized that when households with alternative sources of income own WEMs, they will be less likely to sell water. This is because water selling involves supervision, monitoring, record keeping and collection of water charges – all requiring considerable investment of time – something that households with alternative sources of income might not be willing to invest. By the same logic, households with a larger number of family members may be more likely to sell water because they might have surplus labour available for supervision.

Another factor that may affect propensity to sell water is the level of groundwater development in the region. It may be hypothesized that in a region with high groundwater development, WEM owners would be more likely to sell water than in areas of low groundwater development. This is because quantum of groundwater extraction is directly related to number and type of WEMs. I have modelled water selling decision of a WEM owner as a binary logistical regression model. This is denoted as follows:

GWSALE = fn{MOTIVE, FAMSIZE, OPHOLD, ALTINCOME, GWDEV}

Where, GWSALE = Dichotomous dependent variable that that takes value of 1 if the WEM owner sold water and 0 otherwise

MOTIVE = Dichotomous variable that takes value of 1 if the WEM owner reports owning a electric pump and 0 if owning a diesel pump

FAMSIZE = Number of adults family members in the household

OPHOLD = Operational holding in 2003-04 (in acres)

ALTINCOME = Dichotomous variable that takes value of 1 if the WEM owner reports having alternative sources of income other than crop cultivation and 0 otherwise

GWDEV = Level of groundwater development (%) in the block in which the WEM owner resides

Table 4. Determinants of water selling decision of WEM owners: Results of a logistical regression

Sr. No.	Independent variables	B	S.E	Wald statistic	Exp (B)
1.	FAMSIZE	0.002	0.053	0.002	1.002
2.	MOTIVE	1.263	0.323	15.248*	3.536
3.	OPHOLD	-0.022	0.019	1.350	0.978
4.	ALTINCOME	-0.110	0.300	0.134	0.896
5.	GWDEV	0.016	0.005	9.133*	1.016
6.	CONSTANT	0.077	0.403	0.036	1.080
7.	H-L test	Not significant			
8.	Nagelkerke R^2	0.313			
9.	N	294			

Source: Primary data collected during questionnaire survey, August to December 2004. * indicates coefficients significant at 1% level of significance for two tailed t-test.

Negelkerke R^2 shows that this model has an explanatory power of 31%, while the classification table where actual and predicted value of the dependent variable is cross-tabulated shows that 74.5% of the cases of water sale by WEM owners have been correctly predicted. The model shows that motive power of the WEM is one of the most important determinants of water sale. Ownership of electric WEMs increases the log odds, odds and probability of selling water by 1.26 times, 3.5 times and 16.5% respectively after controlling for all other variables in the model. Similarly, WEM owners in blocks with high level of groundwater development are also more likely to sell water than those residing elsewhere. For one, blocks with high groundwater development are likely to be agriculturally developed thereby creating demand for irrigation water. At the same time, high WEM densities ensure surplus water that the WEM owners sell. Thus, motive power of WEMs coupled with level of development of groundwater affects the decision of the WEM owners to sell water while individual characteristics of the water sellers are not very important in this regard.

3.2 Role of motive power of pumps in determining actual quantum of irrigation hours sold

This analysis of determinants of hours of water sold by WEM owners is based on a sample of 243 WEMs belonging to 220 water sellers from 40 villages. Simple tabulation of my data (table 5) showed that number of hours of water sold by a WEM owner is a function of at least two variables, *viz.* motive power of the pump and the type of water extraction technology. This is because as already shown, the motive power of the WEM dictates the cost structure of water extraction and hence the nature of water transactions. *A priori*, I hypothesize that an electric WEM owner will sell more water than a diesel WEM owner. The second factor that affects the number of hours of water sold is the type of WEM. By type of WEM, I mean whether the WEM is a surface mounted centrifugal or a submersible pump[10]. The type of WEM thus reflects the hydrogeological condition in a region. Given the same horse power of pumps, discharge of a submersible pump is higher than the discharge from a surface mounted pump. So, *a priori* it may be expected that owners of submersible pumps would have higher amount of 'surplus' water available for sale than those of centrifugal pumps.

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[10] These two types of WEMs work on different principles. Centrifugal pumps are mounted at the ground level and they create vacuum through which water is sucked up to the surface. However, to be effective, water table has to be within 25-30 feet bgl. On the other hand, submersible pumps, as the name suggests are submerged below water and pushes water up to the surface level. Thus at least theoretically, there is no upper limit to the depth from which water may be pumped.

Table 5. Hours of pumping and hours of water sold to others by type of WEM, 2003-04

Sr. No.	Type of WEM	Sample size	Average hours of pumping	Average hours of water sold to others	% of hours of water sold to total pumping hours
1.	Diesel shallow tubewell (DST)	189	250.8	91.3	36.4
2.	Diesel submersible tubewell (DSB)	7	411.6	201.6	49.0
3.	Electric shallow tubewell (EST)	73	1649.3	863.3	52.3
4.	Electric submersible tubewell (ESB)	65	2151.7	1715.3	79.7
5.	All	334	929.1	579.9	62.4

Source: Primary questionnaire survey in 40 villages, August to December 2004.

While demographic and land owning characteristics of the WEM owners did not have significant impact on their water selling decision *per se* (see section 3.1), it might have significant impact on the volume of water sold. It may be hypothesised that area cultivated by the WEM owners would be negatively related to hours of water sold, as s/he will direct most of the pumped water for self-use. Presence or absence of alternative sources of cheap irrigation (such as government deep tubewell, river lift irrigation, canal, cooperative tubewells etc.) might negatively affect the quantity of water sold by a WEM owner. Level of groundwater development and long term trend in groundwater level (denoted by categories of safe, semi-critical and critical blocks) too might affect the total volume of water sold, though the exact way this variable would affect the water selling decision of a water seller is an empirical question. I specify a linear OLS model where:

HOURS = fn{MOTIV, TWEM, GCA, ALTIRR, GWDEV }

Where, HOURS = Hours of water sold by an WEM owner in the year 2003-04

MOTIV= Dummy variable for the motive power of the pump, 0 if diesel, 1 if electric

TWEM = Dummy variable for the type of WEM, 0 if centrifugal pump, 1 if submersible pump

GCA = Gross cultivated area of the WEM owner (*bighas*) in 2003-04

ALTIRR = Dummy variable for presence of alternate sources of irrigation in the village, 0= No, 1= Yes

GWDEV = Dummy variable for level of groundwater development and trend in water level, 0= safe, 1= critical and semi-critical

Table 6. Determinants of hours of water sold in 40 villages in West Bengal, 2003-04

Sr. No.	Variables	Unstandardised coefficient B	Standardised coefficient β	t- value
1.	Constant	294.867*	-	4.420
2.	MOTIV (dummy)	879.972*	0.514	11.532
3.	TWEM (dummy)	702.358*	0.370	8.021
4.	GCA	-9.142*	-0.194	-4.908
5.	ALTIRR (dummy)	-105.445	-0.062	-1.595
6.	GWDEV (dummy)	332.600*	0.173	4.395
7.	Adjusted R^2	0.646		
8.	Durbin Watson value	1.544		
9.	Sample size	243		

Source: Author's calculations based on questionnaire survey conducted between August to December 2004.
* Denotes significance at 1% level

The result of the regression equation is presented in table 6. Here too it is seen that the motive power of pump is the most important determinant of actual hours of water sold by a pump owner, followed by the type of pump owned. In sum, while land owning characteristics, sources of alternate irrigation and the groundwater resource condition in a village affect the quantum of water sold by a WEM owner, what seems to be the most important determinant of hours of water sold is the type of WEM and its motive power.

3.3 Level of development of groundwater markets and its relationship with motive power of pumps

In neo-classical literature, level of development of groundwater markets has been measured in terms of breadth and depth of water market transactions (Shah 1993). The breadth of groundwater markets refers to the horizontal spread of the market while depth refers to the vertical spread. While there are several measures of depth and breadth of groundwater markets, in this section using one indicator of each, I have classified all my 40 study villages into three levels of development of groundwater markets, viz. highly developed, moderately developed and under developed. The indicator of breadth that I have used here is: percentage of gross irrigated area (GIA) in the village irrigated through privately purchased groundwater. The indicator of breath that I have used is percentage of gross incomes of households derived from water selling and buying. I will relate the level of development of groundwater markets with the predominant type of WEM (defined by its motive power and technology of pumping equipment) in that village. Table 7 presents the results. It shows that all the villages that show high development of groundwater markets invariably have electric WEM dominated irrigation economy.

Table 7 Village wise measure of breadth and depth of groundwater market

Sr. No	Village code	District	% of GIA irrigated by purchased water	% of gross incomes derived from water sale and purchase	Breadth vs. depth comparison	Level of development	Predominant type of WEM by motive power and type of pump
1	BR02	Bardhaman	61.9	37.8	HB-HD	High	ESB
2	HW01	Howrah	50.0	38.1	HB-HD	High	EST
3	HG01	Hugli	69.5	52.9	HB-HD	High	ESB
4	HG02	Hugli	73.2	33.9	HB-HD	High	ESB
5	HG03	Hugli	64.9	32.4	HB-HD	High	ESB
6	HG04	Hugli	63.9	26.9	HB-HD	High	ESB
7	MS03	Murshidabad	63.3	63.8	HB-HD	High	EST
8	MS07	Murshidabad	58.4	50.4	HB-HD	High	ESB
9	MS05	Murshidabad	67.7	48.7	HB-HD	High	ESB
10	MS01	Murshidabad	68.3	47.8	HB-HD	High	ESB
11	MS04	Murshidabad	52.4	36.2	HB-HD	High	ESB
12	MS06	Murshidabad	54.5	29.7	HB-HD	High	ESB
13	MS02	Murshidabad	51.2	29.2	HB-HD	High	EST
14	NP01	N. 24 Prgs	56.6	45.9	HB-HD	High	EST
15	NP02	N. 24 Prgs	60.2	43.0	HB-HD	High	EST
16	NP04	N. 24 Prgs	61.6	37.6	HB-HD	High	EST
17	ND02	N. 24 Prgs	54.8	26.0	HB-HD	High	EST
18	ND06	N. 24 Prgs	51.5	25.8	HB-HD	High	EST
19	ND03	N. 24 Prgs	56.8	25.5	HB-HD	High	EST
20	BN01	Bankura	54.4	13.6	HB-LD	Moderate	DST
21	BR03	Bardhaman	70.0	19.8	HB-LD	Moderate	DST
22	BR01	Bardhaman	59.4	8.8	HB-LD	Moderate	DST
23	HG05	Hugli	58.3	24.0	HB-LD	Moderate	DST
24	JL01	Jalpaiguri	50.0	22.7	HB-LD	Moderate	DSB
25	KB01	Koch Bihar	50.0	22.7	HB-LD	Moderate	DST
26	ML02	Maldah	46.2	40.7	LB-HD	Moderate	DST
27	ML01	Maldah	24.7	25.2	LB-HD	Moderate	DST
28	MD01	Medinipur	56.7	18.0	HB-LD	Moderate	DST
29	MD02	Medinipur	25.0	31.5	LB-HD	Moderate	DST
30	NP05	N. 24 Prgs	50.4	21.2	HB-LD	Moderate	DST
31	ND01	Nadia	60.6	19.6	HB-LD	Moderate	DST

Sr. No	Village code	District	% of GIA irrigated by purchased water	% of gross incomes derived from water sale and purchase	Breadth vs. depth comparison	Level of development	Predominant type of WEM by motive power and type of pump
32	ND05	Nadia	40.7	25.9	LB-HD	Moderate	DST
33	BI01	Birbhum	21.1	7.1	LB-LD	Low	DST
34	DJ01	D. Dinajpur	26.9	21.2	LB-LD	Low	DST
35	NP03	N. 24 Prgs	42.2	12.2	LB-LD	Low	DST
36	ND04	Nadia	47.0	13.2	LB-LD	Low	DST
37	PR04	Purulia	28.7	13.6	LB-LD	Low	DST
38	PR03	Purulia	33.2	6.2	LB-LD	Low	DST
39	PR01	Purulia	48.8	3.7	LB-LD	Low	DST
40	PR02	Purulia	37.6	3.0	LB-LD	Low	DST

Source: Calculations by the author based on primary data collected during questionnaire survey, August to December 2004. HB= High breadth (> 50%), LB= Low breadth (<50%), HD= High depth (>25%), LD= Low depth (<25%)
ESB= Electric submersible pumps, EST = Electric centrifugal pump, DST = Diesel centrifugal pump, DSB = Diesel submersible pump

The forgoing analysis thus amply brings out the fact that electric WEM owners facing flat rate tariff are more likely to sell water than their diesel WEM owning counterparts, second, they are also likely to sell larger number of hours than diesel pump owners and finally, villages with pre-dominantly electric WEMs have highly developed groundwater markets in comparison with diesel WEM villages. All these confirm the hypothesis that flat rate electricity tariff encourages water markets. But then is water market as an institution beneficial at all? I will look into this aspect in section 3.5.

3.4 Historical changes in configuration of water market in response to rising flat rate tariff

Earlier, I had shown that there has been a steep increase in electricity tariff in West Bengal since 1995 or so. What has been the impact of rising flat rate tariff on the configuration of water markets? According to the standard neo-classical hypothesis, high flat rate would encourage expansion in groundwater market transactions. My discussions with the respondents in 40 villages elicited that there have been at least two types of changes in water market transactions – direct water sales have become more important now as compared to land tenancy agreements in the past and cash transactions have largely replaced kind transactions[11]. Fujita (2004:9), based on a comparative study of villages in Bangladesh and West Bengal too concluded that "(I)t seems that just as in the case of Bangladesh, the dominant mode of transaction in the groundwater market in West Bengal also experienced a drastic change from seasonal tenancy to water sales with cash payment".

Both these changes were directly related to increase in electricity tariff. In the early years of water market transactions, profitability from *boro* paddy cultivation was very high. At the same time, diesel costs were low as were the electricity tariff for electric WEMs. Thus, it was more profitable for the WEM owners to lease in land from prospective water buyers rather than sell water to them. However, direct water sales acquired importance in view of two changes, electricity tariff increased six-fold and profitability from paddy cultivation either stagnated or declined. This changed the incentive structure for the water sellers, who now found direct water sale more profitable than leasing in land. This in turn led to 'development' of the market in terms of depth and breadth. We already saw in the last section that all villages that have a highly developed groundwater market toda are predominantly dependent on electric WEMs. Shah (1993:113) had hypothesised that "….a group of sellers in a community subject to relatively high FR[12] will tend to sell more water, charge lower prices and enjoy lower monopoly power than if they were to pay heavily subsidized FR", the reason being "WEM owners paying low FR …… need not worry about selling water to increase the utilization of their equipment."

To sum up this section, I have shown that high flat rate electricity tariff coupled with abundant groundwater resources has led to rapid development of groundwater market in West Bengal. This is especially true in those villages that depend predominantly on electric WEMs, while villages with diesel WEMs tend to support an underdeveloped water market.

[11] In as many as 18 out of 40 villages in my sample, respondents reported that payment for water for irrigating paddy (especially *boro* paddy) in kind was prevalent in their villages and almost all the WEM owners said that they preferred land lease in the past.

[12] Fixed rate tariff

3.5 Are groundwater markets beneficial?

In the previous sections, I have made the point that high flat rate electricity tariff results in pro-active water selling by the pump owners and creates developed water markets. Is that a good thing? In other words, are highly developed groundwater markets, and for that matter any groundwater market at all is a desirable things? If it is not, then the entire argument of making groundwater markets competitive through introduction of rational flat rate tariff collapses right away. Literature is divided on the question of impact of groundwater markets, ranging from highly positive ones that declare groundwater markets as the 'vehicle of poverty alleviation' (Palmer-Jones 2001) to accusations of groundwater markets 'creating water lords' (Janakarajan 1990) and appropriating surplus from the poor.

Theoretically, there are several advantages of groundwater markets. Firstly, it leads to increased use of tubewell capacity, thereby enhancing efficiency of tubewells. Secondly, it increases access to irrigation for those farmers who cannot afford their own irrigation equipments. Thirdly, water markets encourage farmers – even small and marginal ones – to invest in tubewells with the carrot of profiting from water sales. Fourthly, as a direct result of increased access to groundwater, cropping intensity goes up, as does demand for labour. Thus, net irrigation surplus[13] with groundwater market is higher than without it. Finally, a positive externality of groundwater markets in water surplus regions such as West Bengal is the lowering of water table through vertical drainage, which in turn controls water logging and flooding (Roy 1989).

My data supports all these claims. Firstly, in the absence of state provisioning of irrigation, groundwater markets have done a commendable job of distributing benefits of irrigation to those who do not have their own means of irrigation. Most of them also happen to be small and marginal farmers as table 8 clearly shows.

[13] Net irrigation surplus is defined as the gross value added by irrigation less the nominal cost of irrigation (Shah 1993).

Table 8. Size class classification of WEM owners and water buyers in West Bengal

Sr. No.	Size class category	No. of WEM owners	No. of Pure water buyers
1.	Sub-marginal (<0.5 ha)	56 (19.0)	142 (49.7)
2.	Marginal (0.51-1.0 ha)	80 27.2)	85 (29.7)
3.	Small (1.01- 2.0 ha)	90 (30.6)	46 (16.1)
4.	Medium (2.01-4.0 ha)	56 (19.0)	10 (3.5)
5.	Large (>4.01 ha)	12 (4.1)	3 (1.0)
6.	All	294 (100.0)	286 (100.0)

Source: Primary data collected during questionnaire survey, August to December 2004. Figures in parentheses are percentage to total.

Second, due to existence of groundwater markets and its efficient functioning, those without their own mean of irrigation (i.e. the water buyers) were still able to achieve similar cropping pattern cropping intensity, crop productivity and even similar gross income as owners of means of irrigation (see table 9).

Table 9. Impact of groundwater market: Evidence from West Bengal

Sr. No.	Indicator	Pump owners	Water buyers
1.	Cropping intensity (%)	184.0	180.0
2.	Percentage area under water intensive boro paddy to GCA	24.1	22.8
3.	Percentage of area under profitable potato crop to GCA	8.0	8.1
4.	Productivity (kg/bigha) of boro paddy	670	670
5.	Productivity (kg/bigha) of potato	2160	2400
6.	Hired labour use (mandays/bigha) for boro paddy	17.1	14.9
7.	Fertilizer use (kg/bigha) for boro paddy	66.8	62.1
8.	Gross income from crop cultivation (Rs/year/bigha)	4160	3811
9.	Sample size (Numbers)	294	286

Source: Author's fieldwork in 40 villages in West Bengal, August 2004 to December 2004

At a macro-level too, it was precisely the rise in groundwater irrigation through the operation of groundwater markets that propelled West Bengal to very high rates of agricultural growth in the 1980s and 1990s[14]. Thus, to sum up, groundwater markets have been beneficial to West Bengal's rural economy and introduction of flat rate tariff and its subsequent increase has helped in further developing such markets.

[14] While it is the beyond the scope of this paper to discuss in detail the role of groundwater irrigation in agrarian transition in West Bengal, it has been discussed at length in my thesis (Mukherji 2006b).

3.6 Possible impact of proposed switchover from flat rate electricity tariff to metered tariff

During the course of my fieldwork, I found evidence of widespread dissatisfaction among the respondents about rising diesel prices and electricity tariff. But unlike many other states (e.g. Gujarat, Haryana, Andhra Pradesh, Rajasthan) in India where the issue of irrigation and price of electricity became focal point for political mobilisation of peasants, West Bengal is yet to witness such large scale peasant demonstration around irrigation issues. I have discussed possible reasons for the same in Mukherji 2006a. In this section, I will discuss the possible impact of change in the mode of electricity tariff from flat rate to metered tariff. On 31st of August 2005, Ganashakti – the mouthpiece of the ruling CPI(M) party in West Bengal – published that the GOWB was planning to impose pro-rata metered tariff on irrigation tubewells[15]. For this purpose, three time slabs with differential tariff were declared. These rates are presented in table 10.

Table 10. Proposed pro-rata electricity tariff for irrigation tubewells in West Bengal

Sr. No.	Time	Number of hours	Tariff (Rs./unit of electricity consumption)
1.	2200 hrs-0600 hrs	8	Re. 0.97/unit[16]
2.	0060 hrs-1700 hrs	11	Rs. 1.55/unit
3.	1700 hrs-2200 hrs	5	Rs. 3.30/unit

Source: Ganashakti, 31st August 2005, Kolkata edition

For one, even without going into calculations, it can be said that change in mode of electricity pricing will immediately change the incentive structure facing the pump owners. Under a flat rate electricity tariff, cost per hour of pumping will decline with increase in overall pumping hours. A water seller will therefore want to maximize his hours of pumping and will have to resort to selling the surplus water. Thus, a sufficiently high fixed rate tariff with reliable power supply is likely to promote aggressive water selling among the pump owners and my data supports this hypothesis as I have shown earlier. In contrast, under a pro-rata system of power tariff, pump owners will not have any additional incentive to sell water to others and therefore will behave very much like the present diesel WEM owners behave. I have shown earlier that diesel WEM owners operate their pumps for only 200-300 hours in a year on an average and sell only 20-30%

[15] However, this proposed change which was to take place during 2006-07 financial year has not been implemented so far. Instead, flat rate tariff was increased by Rs. 1500/year for both ESTs and ESBs.
[16] 1 unit = 1 kilowatt hour (KWH)

of the pumping hours, as opposed to 1600-2000 hours of annual pumping and sale of 50-80% of those pumped hours by the electric WEM owners (table 6). Therefore, there are good chances that under a pro-rata tariff system, a substantial portion of the current water buyers will lose their access to irrigation due to unwillingness of the pump owners to sell water[17]. Even when water sellers choose to sell water[18], price at which water is sold is likely to go up (see the calculations later in the section) and water selling contracts might undergo a change. In West Bengal, seasonal cash contracts are the most important contract for water sale for *boro* paddy. *Boro* paddy is the most commonly and intensively irrigated crop in West Bengal. However, once electricity is metered, water sellers might prefer selling water on an hourly contract[19] – but this contract will be cumbersome for the water buyers in that they would have to enter into repeated transactions given 30-50 irrigations needed for *boro* paddy. Thus, there are at least three likely impacts on water market as a result of change from fixed tariff to metered tariff – unwillingness of water sellers to sell water leading to shrinkage of water markets, change in contractual arrangements that might go against the interests of the water buyers and increase in water price.

I will now try to derive a quantitative estimate of these changes. For doing so, I will make a few assumptions. First, I will relax my first assumption, *viz*. pump owners will be unwilling to sell water and instead assume that they will continue doing so[20]. Second, I will assume average hours of irrigation for a crop will remain unchanged under flat rate

[17] Selling water, though a remunerative occupation, is not a pleasant one. It involves having to wake up in the middle of the night to switch on pumps, pursuing water buyers for payment (often coaxing and threatening them to extract a payment), frequent quarrels with water buyers regarding dissatisfaction with service and so on. However, these pump owners continue to sell water in order to recoup their electricity bills. Many will possibly exit the market once the compulsion of selling water to meet their electricity bill is removed. In that case, they can simply choose to irrigate their own land and pay whatever is the electricity bill to the state electricity board without undergoing the hassle of selling water.

[18] In a rural society where pump owners and water buyers live in close proximity to one another, water sellers might not be able to refuse to sell water due to societal and moral pressure. However, under such a circumstance, when he does sell water, he might do it as an act of favour. The terms of transaction then become distinctly in his favour.

[19] As the diesel WEM owners do in West Bengal and metered electric WEM owners do elsewhere in the country, for instance in Gujarat (see Mukherji and Kishore, 2003).

[20] I make this assumption because there is no way in which I could predict which WEM owners will refuse to sell water after a switch-over and who will not.

tariff and pro-rata tariff[21]. Third, pump owners will first cultivate their entire land and sell only the 'surplus' water to others. Fourth, water sellers will try to maintain their water price to cost ratio even after change in electricity tariff regime, i.e. they will try to realize the same profit for every unit of water sold. Finally, there are no constraints on full capacity utilisation of pumps, i.e. pumps may be operated for 24 hours at a stretch. I will calculate the effect of change from flat rate tariff to metered tariff for *boro* paddy given that it is the single most important irrigated crop in West Bengal. I will generate three scenarios—first in which the pump owners pump only for those eight hours in the day (10 pm at night to 6 am in the morning) when the electricity tariff is the lowest (@Re. 0.97/unit). In the second scenario, I will assume that pump owners are also willing to pump during those 11 hours in the day (6 am in the morning to 5 pm in the evening) when the electricity tariff is Rs. 1.55/unit. In the third scenario, I will assume that pump owners are willing to operate their pumps for the entire 24 hours in a day, including those five hours when electricity tariff is Rs. 3.30/hour. In calculating cost, I will assume that overheads will remain fixed under flat rate and pro-rata tariffs. I will also assume that roughly 3.5 units of electricity are consumed for every hour of pump operation. I will compare the three scenarios mentioned above with the current scenario of water market under a fixed rate tariff. Table 11 shows the results of my calculations.

Table 11. Economics of water extraction and water selling under fixed rate tariff and metered tariff for ESB type of WEM in West Bengal

Scenario	Cost of water extraction/hour (Rs/hour)			Total hours of operation in summer	Hours of operation per day in the season*	Total area irrigated (*bigha*)		Cost of water extrac-tion in Rs/*bigha* **	Water price in Rs/*bigha*	w/ac ratio ***
	Electricity	Others	Total			Own	Others			
Current	2.79	2.0	4.79	1901	18.1	7.8	22.5	300.3	620	2.06
S 1	3.34	2.0	5.34	840	8.0	7.8	5.6	334.8	690	2.06
S 2	4.57	2.0	6.57	1995	19.0	7.8	24.0	412.0	850	2.06
S 3	6.02	2.0	8.02	2520	24.0	7.8	32.4	502.9	1036	2.06

Source: Author's fieldwork in 40 villages in West Bengal, August to December 2004. Calculations based upon data collected for ESB type of WEM.
* Assuming there are 105 days in *boro* season.
** Assuming 62.7 hours of irrigation needed for one bigha of *boro* paddy
*** Water price to long term average cost of water extraction ratio

[21] This assumption is made for the sake of simplicity of calculations. It is highly possible that with overall increase in unit costs of pumping, water sellers will use water more efficiently than before.

Table 11 shows that under scenario 1, when the pump owners can operate their pumps for only eight hours, irrigated area belonging to the water buyers will reduce drastically from 22.5 bighas to only 5.6 bighas in the summer *boro* season. In scenarios 2 and 3, when pump owners operate their pumps for 19 hours and 24 hours respectively in a day, while there will be no decline in the irrigated area of the water buyers, water prices will increase substantially. This will lead to reduced profits for the water buyers and share of irrigation cost to total cost of cultivation will go up. In table 12, I have presented the value of net income from *boro* paddy cultivation under the three alternative scenarios presented in table 11 along with share of irrigation cost in total cost of cultivation. It shows that under all three alternate scenarios, net return/WEM will reduce from the current scenario, thereby squeezing the already narrow profit margins of the farmers further.

Table 12. Net returns for *boro* paddy cultivation under alternative scenarios with different pro-rata rates of metered tariff in West Bengal

Sr. No.	Scenario	Net returns without imputing family labour costs	Net returns after imputing family labour costs	% share of irrigation costs in total cost of cultivation	Net returns/WEM* after imputing family labour costs (Rs.)
1.	Current	1718	1365	25.3	41360.0
2.	Scenario 1	1648	1295	28.2	17353.0
3.	Scenario 2	1488	1135	34.9	36093.0
4.	Scenario 3	1302	949	42.5	38149.0

Source: Author's fieldwork in 40 villages in West Bengal, August to December 2004. Calculations based upon data collected for ESB type of WEM.
* This is based on figures of total area irrigated as given in table 11

Thus on the whole, it will be reasonable to conclude that metered tariff will lead to contraction in water market by stifling the very incentive that encourage pump owners to sell water. The proposed tariff rates would also almost certainly lead to increase in water prices. Both of these will affect the small and the marginal farmer – who depends almost exclusively on the private groundwater markets for access to irrigation. Private groundwater market – though not perfectly efficient – have still resulted in fairly equitable outcomes as reflected in similar cropping intensity, cropping pattern and crop productivity of major crops among the pump owners and water buyers. Therefore, on an average, those who do not own means of irrigation are not disadvantaged *vis-à-vis* the owners of means of irrigation in terms of access to irrigation and the benefits thereof.

This is an encouraging finding and contradicts those who model groundwater markets as being exploitative. In the absence of state provided irrigation services, private water markets fill demand and supply gap of irrigation. Rational flat rate tariff has further helped in expanding the scope of water markets.

4.0 The other face of energy irrigation nexus: Escalating diesel prices, its impacts on groundwater markets and coping strategies adopted by the farmers

Electricity-irrigation nexus is but one face of the energy irrigation nexus. In the context of West Bengal, given that only 12.5% of all WEMs are electric operated, the electricity-irrigation nexus is also relatively less important than it is in other states of India. The other and more important face of energy irrigation nexus in West Bengal is the impact of rising diesel prices on the groundwater economy. This is specially so because almost 80-85% of all WEMs in the state are diesel driven. Escalating diesel prices have had at least three impacts on agricultural sector in general and functioning of groundwater markets in particular. First, the most immediate impact has been contraction in water market operations. Second, there has been a shift away from water intensive (but profitable) boro paddy cultivation to rainfed crops, or vegetable and orchard crops. Third, in order to break even in face of rising fuel costs, farmers have adopted innovative means. In this section, I will discuss all the three aspects separately.

4.1 Impact of rising diesel prices on spread of groundwater markets

Cost of water extraction is central to the economics of groundwater pumping and water selling. The major part of this cost of water extraction consists of energy costs – either diesel or electricity. Over the last few years (from 1998 or so) both diesel prices and electricity tariffs have gone up considerably and this has influenced the functioning of water market. Table 13 shows the changes in diesel prices since 1973 to 2005.

Table 13. Diesel prices at retail markets in Kolkata, 1973-2005

Year	Diesel price (Rs/litre)	Year	Diesel price (Rs/litre)	Year	Diesel price (Rs/litre)	Year	Diesel price (Rs/litre)
01.01.1973	0.90	13.01.1981	2.66	06.02.1986/ 01.04.1986	3.60	01.04.1996	7.24
01.01.1974	0.87	11.07.1981	3.01	01.04.1987	3.30	01.04.1997	8.32
01.01.1975	1.10	01.04.1982	3.01	01.04.1988	3.30	01.04.1998	10.55
01.01.1976	1.35	15.02.1983	3.31	01.04.1989	3.30	01.04.1999	10.18
01.01.1977	1.36	01.04.1983	3.30	01.04.1990	4.20	01.04.2000	14.20
01.01.1978	1.36	01.04.1984	3.30	01.04.1991	5.20	01.04.2001	16.92
01.01.1979	1.49	01.06.1984	3.30	01.04.1992	5.31	01.04.2002	16.97
17.08.1979	1.68	17.03.1985	3.35	01.04.1993	6.43	01.04.2003	23.51
11.09.1979	1.60	26.03.1985	3.48	01.03.1994	7.27	01.04.2004	23.99
08.06.1980	2.25	01.02.1986	3.68	08.04.1995	7.25	01.04.2005	28.72

Source: Ministry of Petroleum and Natural Gas, Government of India, downloaded from site www.indiastat.com on 12th July 2006

I have shown earlier that increase in flat rate electricity tariff led to change in the incentive structure for pump owners – who were now inclined to sell water more aggressively than before to be able to recoup their fixed electricity charges. Thus, increase in flat rate electricity tariff led to an expansion in water market as hypothesized by Shah (1993).

On the other hand, increase in diesel prices have led to shrinkage of water market transactions in diesel dominated WEM villages. I have already shown earlier that breadth and depth of water markets are considerably limited in diesel WEM dominated villages (Table 7) and also that diesel WM owners are less likely to sell water to their neighbors than electric WEM owners. Add to this the fact that groundwater markets have positive equity and efficiency impacts in water abundant West Bengal. Then, it logically emerges that with the contraction of groundwater market operations and absence of any other affordable sources of irrigation negatively affects those who are dependent on diesel pumps to access irrigation. I have also earlier shown that most of the water buyers tend to be small and marginal farmers. Therefore, it follows that any contraction in water market operations hits the poorest farmers the hardest. This is what has been happening in West Bengal over the past five years or so.

4.2 Changes in cropping pattern in response to rising diesel prices

How are the farmers coping with rising diesel costs? One of the obvious ways in which they are doing this is through change in cropping pattern away from water intensive boro paddy cultivation to less water intensive crops. While some of these less water intensive crops at times are more profitable (but risky) than boro paddy cultivation, it is not always so. For instance, in various parts of West Bengal, farmers have reverted to rainfed crops in the winter season.

I have mentioned earlier, that *boro* paddy is one of the most profitable crops in West Bengal. In my sample of 40 villages, in as many as 20 villages, *boro* paddy is cultivated in less than 20% of the gross cropped area of the village. Of these, 18 villages have DST type of water market. In all of these villages, area under *boro* paddy has declined sharply since 2001 in response to rising diesel prices (see table 14).

Table 14. Area under *boro* paddy and the pre-dominant WEM type in 40 villages of West Bengal, 2003-04

Sr. No.	Area under *boro* paddy cultivation	Number of villages	Pre-dominant type of WEM (number of villages)*
1.	Less than 10%	12	DST (7), DNO (4), DSB (1)
2.	10-20%	8	DST (4), ESB (2), HNO (1), DNO (1)
3.	20-30%	10	ESB (7), EST (1), DST (2)
4.	More than 30%	10	EST (6), ESB (2), DST (2)

Source: Author's fieldwork in 40 villages in West Bengal, August to December 2004
* DST = Diesel shallow tubewell, DNO = Diesel pumps not permanently attached to any tubewell, HNO = Honda and Chinese pumps not permanently attached to any tubewell, DSB = Diesel submersible tubewell, EST = Electric shallow tubewell, ESB = Electric submersible tubewell.

Given that almost 80- 85% of all water extraction devices in West Bengal are diesel operated (GOI 2001), this will have serious repercussions on *boro* paddy cultivation in the state. It is widely acknowledged that it was increase in area under *boro* paddy coupled with productivity increases in *aman*, *aus* and *boro* paddy had propelled spectacular growth in agriculture in West Bengal (Rogaly et al. 1999). This scenario is likely to change given the very high diesel prices. In an unfavorable input output price regime[22], those farmers who depend exclusively on diesel pumps are at disadvantage vis-à-vis

[22] Time series data on cost of cultivation of paddy in West Bengal shows that it has gone up by 55% to 81% from 1991 to 1997(depending on various estimates of cost of cultivation), while paddy prices have declined in terms from 1995 to 2003, thereby squeezing farmer's profits.

those who have access to electric WEMs. Table 15 shows net profitability from *boro* cultivation for electric WEM owners, diesel WEM owners and their respective buyers. It shows the very low profit for the diesel WEM owners and even lesser profits for those who buy water from diesel WEM owners. Ghosh and Hariss-White too voiced this concern when they (2002) found a “deep crisis in rice economy” – a crisis that has since then deepened in intensity and severity.

Table 15. Cost of cultivation and net returns from boro paddy for diesel and electric pump owners and water buyers in West Bengal, 2003-04

Sr. No.	Crop	WEM type	Water transaction status	N	Yield (Quintals per bigha	Gross revenue (Rs. per bigha)	Cost of cultivation (Rs./bigha)		Net returns (Rs./bigha)	
							Cost of cultivation without including family labour	Cost of cultivation including family labour	Net returns without imputing family labour	Net returns after imputing family labour
1	*Boro*	Diesel	PO	55	6.7	3685	2380	2692	1305	993
2	*Boro*	Diesel	WB	28	7.0	3850	3106	3610	744	240
3	*Boro*	Electric	PO	64	7.3	4015	1651	1996	2364	2019
4	*Boro*	Electric	WB	61	6.9	3795	2077	2430	1718	1365

Source: Author’s calculations based on fieldwork in 40 villages in West Bengal, August to December 2004.

Vegetable cultivation and orchards crops have emerged as viable alternatives to water intensive boro crop. However, in view of inadequate marketing channels and lack of insurance and credit markets, cultivation of capital intensive vegetables and orchard crops tends to be a risky venture. Vegetable cultivation is a more profitable than paddy cultivation provided the villages are well connected to the market and has the suitable soil type. These two conditions do not obtain in most of the villages and therefore, direct impact of increase in diesel prices is lowering of cropping intensity and changing cropping patterns away from remunerative irrigated crops to rainfed cropping systems.

4.3 Technical innovations in face of rising diesel costs

In response to escalation in diesel prices, farmers have been resorting to various innovations for cutting their total irrigation costs. For instance, traditional large 5-HP diesel pumps are now seldom used. Instead, farmers use light weight pumps (that goes by the generic name of Honda pumps) or Chinese pumps smuggled from across the

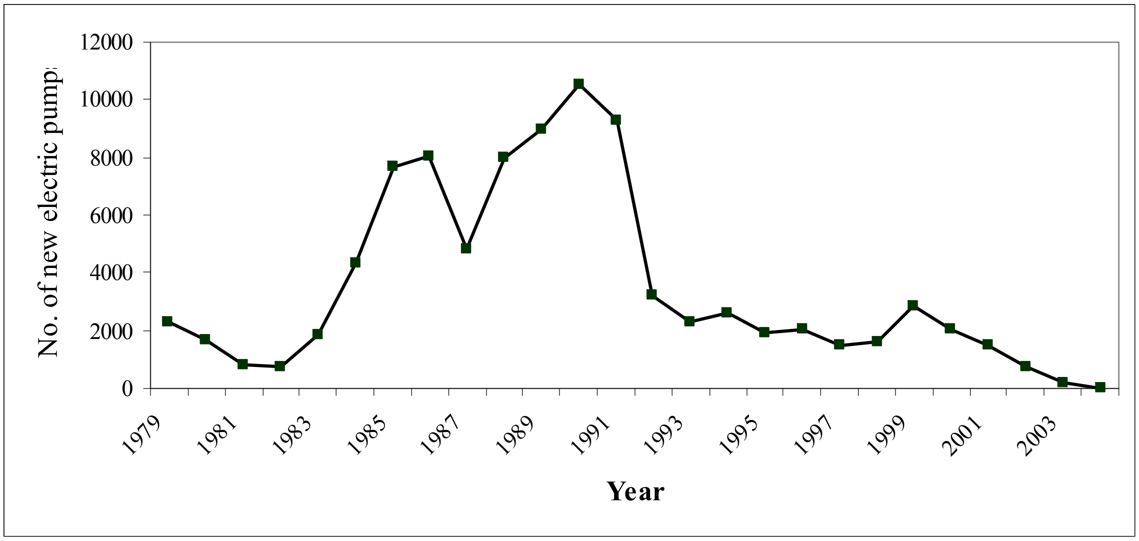
Bangladeshi border. Both these types of pumps consume only 300 ml to 500 ml of diesel per hour and alternatively, may be operated with kerosene. Traditional diesel pumps consume 800 to 1000ml diesel in an hour. Thus, when I classified the pumps in my sample by the year of purchase of pumps, I found that all the diesel pumps purchased in or after 2001 were either Honda or Chinese pumps. I found some other types of innovations aimed at reducing energy cost. One such innovation was the use of cooking gas cylinder to operate pumps. This reduces the cost of water extraction by 50% - 60%. Similarly, instead of using solely diesel, farmers increasingly mix kerosene (which continues to be subsidized) with diesel to operate their pumps, though continued use of kerosene reduces the effectiveness of pumps. In the course of my fieldwork I found that rural pump mechanics too are constantly making small changes in the pump design (for example, altering the size of the fuel intake pipe etc.) in order to increase its fuel efficiency. In a way therefore, while rise in diesel prices have adversely affected a large number of small and marginal farmers, at the same time it has forced farmers to economize on use of diesel by making pumps more fuel efficient.

5.0 Conclusions and policy options

Energy and irrigation are closely and often inextricably linked. In the context of West Bengal, there are two faces of this 'energy-irrigation nexus' – one is the 'electricity-irrigation nexus' and other is the 'diesel-irrigation nexus'.

The 'energy-irrigation' issues facing West Bengal are also somewhat different from the issues in other states of India. In most other states of India "groundwater economy has boomed by bleeding the energy economy" (Shah et al. 2003:v). However, this is not the case in West Bengal, where electricity subsidies form only a miniscule part of the state fiscal deficits. Given the favorable hydro-geological conditions, groundwater markets have positive equity and efficiency impacts in the state. This may not be necessarily true in western and southern parts of the country where groundwater resources are scarce and under threat of depletion. Therefore, under conditions of abundant groundwater availability and relatively low levels of groundwater development, flat rate electricity tariff has promoted efficient and largely equitable groundwater markets *sans* the threat of resource depletion. As I have already shown, these pump irrigation services markets have been instrumental in providing access to irrigation to the small and marginal farmers who would have otherwise remained outside the ambit of irrigated agriculture. However unfortunately, rate of rural electrification has been very slow in West Bengal with the result that only 12.5% of all pumps in the state are electrified.

Figure 2. Number of incremental (new) electric pump connections given by WBSEB in West Bengal, 1979–2004



Source: West Bengal State Electricity Board (WBSEB) Yearbook (several years)

Therefore, the benefits from rational flat tariff system have been only partially realized. On the other hand, negative implication of the 'diesel-irrigation' nexus has been much more serious than the positive implication of the 'electricity-energy' nexus. . Escalation in diesel prices has had negative impact on spread of water market transactions thereby putting the livelihoods of millions of poor farmers in jeopardy. The policy makers in the state seem to be quite unaware of the benefits that groundwater irrigation has conferred to millions of farmers in the state. In view of this, what are the policy options?

5.1 Rural electrification, high flat rate tariff, competitive water markets

While groundwater sector in West Bengal does not warrant extensive regulation (contrary to what the GoWB thinks), it does merit electrification. West Bengal is a state with lowest ratio of electric pumps to total pumps. I have shown in this paper that increased diesel costs have negatively impacted area under *boro* paddy cultivation on the one hand

and farmers' profitability from cultivation on the other. In view of this, re-introduction of subsidised (at least partly subsidised) rural electricity programme in those districts and villages that missed out on the opportunity in the first phase is needed. Special attention needs to be given to the relatively backward districts of North Bengal. It may be credibly argued that government spending on rural electrification will fetch high returns for the state economy as a whole. A careful analysis of varying returns from various public investments (e.g. rural electrification, rural roads, health care, education etc.) may be undertaken in order to see whether investment in rural electrification is justified[23].

West Bengal has one of the highest flat rate tariffs in the country – this has encouraged rapid development of groundwater market in villages with electric WEMs and promoted competitive water selling. As a result, I have shown that water buyers earn higher net returns from cultivation in electric WEM villages (especially in ESB villages), than in diesel WEM villages. There is a recent proposal in the state for switchover to metering of irrigation tubewells. I have shown that it would lead to shrinkage in water market and the hardest hit would be the water buyers. Other states who are trying to meter their irrigation tubewells are doing so in order to rein in huge losses suffered by the state electricity boards (SEBs). However, this is not the case in West Bengal. In this context, rather than metering, a better policy option would be managing the electricity supply schedule to match the irrigation demand (Shah et al. 2003). As is well known, there are peaks (as during March-May) and dips (during monsoon months) in demand, but the supply of electricity remains uniform (12 to 20 hours on an average depending on the district) across the year. The WBSEB may cut its losses by restricting electricity supply in slack periods, while it may 'delight' its customers by supplying high quality electricity in peak seasons. Users may then be willing to pay higher electricity tariff. This could be another area for future research[24].

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[23] See Fan et al. 1999 for a similar analysis at an all-India level.
[24] Similar research has been carried out at an electricity transformer level in Gujarat in order to see how far electricity supply regime may be fine-tuned to meet the irrigation demand schedules (Shah 2005).

5.2 Adaptive strategies, National food policy and virtual water

In this paper, I have shown that West Bengal is one of the most well endowed states in terms of groundwater resources. Yet, due to strict groundwater regulation, slowdown in rural electrification and escalation in diesel prices, groundwater led agrarian economy has stagnated and even contracted in some villages. There is therefore an economic scarcity of groundwater in the state. Farmers have responded in various ways to this crisis – by changing cropping pattern from field crops to orchards and vegetables, increased use of fuel efficient Honda and Chinese pumps, mixing kerosene with diesel to bring down fuel costs, using cooking gas as a substitute fuel etc. These are what Moench and Burke (2002) call 'adaptive strategies' in face of groundwater crisis.

Given the current fiscal realities of the state and shift in investment focus of international donors (from rural electrification to rural roads and educational infrastructure), it might not be very realistic to expect substantial investment in rural electrification in the short term. Therefore, a better and practical strategy would be to help farmers adapt better to restricted groundwater access through increased water productivity. Water productivity may have myriad connotations, some of the common ones are: more crops per drop, more jobs per drop and more income per drop of water use (see Hernandez-Mora et al. 2003 for these concepts).

Farmers in West Bengal generally achieve higher irrigation water productivity (i.e. tons of crop grown/cubic meters of irrigation water applied) than their counterparts in Punjab and Haryana – where due to lower rainfall, irrigation requirements are higher. Therefore, a cogent case could be made for realigning the food procurement system in India away from the north and the northwest to Eastern parts of the country. This would be similar to the case made for virtual water (Allan 2003 and 2006, Ramirez- Vallejo and Rogers 2004) in the context of international food trade, but in this case, it will involve movement of grains within the country – from water abundant eastern India to rest of water scarce India.

There are some other ways in which state policies too could help farmers in view of declining farm profits. One would be allowing import of cheap and fuel efficient Chinese pumps – currently they are being smuggled into India through the Bangladeshi border. Second, much on the same lines as in Bangladesh[25], the GoWB might consider supplying diesel at a subsidised price to small and marginal farmers during the *boro* paddy season (though as always, proper targeting and leakage problems might mar the efficacy of such a programme). More importantly, the government can encourage farmers to shift to lucrative vegetable cultivation by investing in proper infrastructure such as cold storages, processing plants, good road networks etc. Recently, Reliance Industries Limited, one of the largest private sector firms in India announced investment to the tune of USD326 million to USD435 million in agro-retail businesses in West Bengal. They propose to buy agricultural produce (mostly fruits and vegetables) in order to feed its newly introduced retail business[26].

These shows that very often, levers to manage the groundwater economy lie outside the groundwater sector – Food Corporation of India (FCI) and SEBs could have higher impact on groundwater use than groundwater bill or other direct regulations. The challenge therefore is to understand these broader macro-level linkages and govern groundwater in a way that manages the long-term negative impact of groundwater over-exploitation without significantly reducing the present benefits. Understanding the manifold manifestations of the energy-irrigation nexus is a crucial first step in this regard.

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[25] The government of Bangladesh announced in 2005 that it would supply small and marginal farmers with subsidised diesel during the four months of boro paddy cultivation. Implementation of the scheme, however was quite predictably dismal (http://www.newagebd.com/2005/mar/20/home.html downloaded on 29th of July 2006)

[26] This business venture was announced in Kolkata on 20th of June, 2006 (http://in.news.yahoo.com/060621/137/659ed.html downloaded on 29th of July 2006)

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