Inducing the Shift from Flat-rate or Free Agricultural Power to Metered Supply: Implications for Groundwater Depletion and Power Sector Viability in India

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ABSTRACT

India's farm sector sustains livelihoods for hundreds of millions of rural people, but faces serious management challenges for land, water, and energy resources. Growing dependence on groundwater threatens water resources sustainability and power sector viability. Sustaining India's rising prosperity rests on managing groundwater. This study shows that raising power tariffs in the farm sector to achieve efficiency, equity and sustainability of groundwater use is both socially and economically viable. The question is about how to introduce this shift. This paper discusses five different options for power supply, metering and energy pricing in the farm sector and the expected outcomes of implementing each vis-a-vis efficiency of groundwater and energy use, equity in access and sustainability of groundwater. It concludes that establishing an energy quota for each farm-based on sustainability considerations, and metering and charging pro rata for power used are the best options to manage groundwater and the energy economy.

Keywords: Water-energy nexus, Groundwater, Irrigation

1.0 INTRODUCTION

India's farm sector sustains rural livelihoods for hundreds of millions of people, ensures food security for well over a billion, and faces serious management challenges for land, water and energy resources. But, the growing dependence on groundwater – the backbone of India's irrigation – threatens land productivity, water resources sustainability, and power sector viability. Continuing the marvel of India's rising prosperity rests on getting the groundwater equation right. Raising social and economic equity nationally and minimizing inter-regional disparities are essential to under-gird urban-led economic growth. This will require continued growth of agriculture while at the same time, the farm sector must internalize it share of the effects of groundwater depletion and bankrupt power utilities. Agricultural power – supplied flat-rate or free and viewed as an entitlement – must increasingly be managed as a scarce input (World Bank, 2001). Raising power tariffs in the farm sector to achieve efficiency and sustainability of groundwater use is both socially and economically viable and urgently necessary. The fundamental question addressed is how to induce this shift.

In arid and semi arid regions of India, groundwater withdrawal for crop production exceeds the average annual recharge. Uncontrolled withdrawal of groundwater for crop production, which is supported by subsidized electricity in the farm sector, leads to rapid declines in water level in many parts of the country (Kumar, 2007; World Bank, 2010). As irrigation is the main user of groundwater in the country, raising water productivity in groundwater-irrigated areas to reduce total water use is essential for arresting groundwater depletion (Amarasinghe *et al*., 2005; Kumar, 2005; Kumar, 2007). Many Indian states are contemplating re-introduction of electricity metering in the farm sector to manage groundwater demand. The basic premise is that at higher power tariff, with induced marginal cost of electricity and water, the farmers will improve water use efficiency (Kumar and Singh, 2001; Kumar, 2005; World Bank, 2001) and enhanced water productivity. Such proposals face fierce resistance from farmers' lobby. Further, political parties and scholars alike argue that it will lead to a collapse of farming and the loss of untold rural livelihoods in many water-scarce regions due to reduced net farm returns, making electricity metering in the farm sector socially and economically unviable.

In 2001-02, agriculture accounted for almost 29 per cent of the total power consumption in India (GOI, 2002). Electricity to the farm sector in India is subsidised under both flat rate and pro rata tariff systems. The subsidy in terms of sale to agricultural consumers was estimated to have increased from US$ 3.4 billion in 1996-97 to US$ 5.16 billion in 2000-01 at constant prices (GOI, 2001). This is because of increasing use of electricity for groundwater pumping, which is the result of increased groundwater draft. Due to subsidized power supply to the agriculture sector, the annual losses to State Electricity Board have been estimated to be US$ 5.78 billion (GOG, 2002). In most states, farmers pay electricity charges based on connected load and not on the basis of units of power consumed. Some of the Indian states are providing electricity to the farm sector free of cost, though with ever-decreasing hours of supply and deteriorating quality of power that results from the due to poor financial condition of the State Electricity Boards (SEBs). Modes of electricity pricing under which the charges paid by farmers do not reflect actual consumption, creates incentive for inefficient and unsustainable use of both power and groundwater (Kumar, 2005; Kumar and Singh, 2001).

While metering appears to be a solution to the problem, researchers question its viability on three grounds: 1] transaction cost of metering is very high, which increases the cost of supply of electricity, thereby reducing net social welfare (Shah *et al*., 2004); and 2] tariff levels at which electricity and water demand curve becomes elastic to price changes would be so high that it becomes socio-economically unviable (Saleth, 1997); and 3] political opposition to metering is so high that governments shy away from the option.

Kumar (2005) questioned the validity of the first two arguments. Empirical evidence shows that with higher tariffs, the farmers use water more efficiently (by providing lower dosages to the crop), increase gross water productivity (Rs/m^3); and secure higher returns per unit of water used (exchange rate has remained approximately constant at US$ 1= Rs 45 during the study period and preparation of this paper). Also, they are motivated to shift to less water-consuming water efficient crops, provided they receive high quality, sustained water supply.

Some scholars cite positive impact of flat rate pricing of electricity on access and equity of groundwater (for instance, Shah, 1993). They argue that with competitive water markets that emerge as a result of flat rate pricing, water prices would be low with the result that a major share of the electricity subsidy benefits are transferred to water buyers. However, the zero marginal cost of production of water from wells does not seem to influence the prices at which water is traded, in favour of buyers of water for irrigation. Recent research shows that flat rate pricing increases the monopoly power of large well owners (Kumar, Singh and Singh, 2001). Flat rate pricing also leads to inequitable distribution of power subsidy benefits among well owners (Kumar and Singh, 2001; Howes and Murugai, 2003). Kumar (2007), on the basis of evidence from Mussafarpur in eastern Bihar state argued that the monopoly power enjoyed by water sellers cannot be reduced by pricing policies, but by improving the transferability of groundwater.

As a way to cope with the increasing financial burden due to revenue losses through subsidies and growing power deficits, the State Electricity Boards in many agriculturally prosperous states have introduced heavy cuts in power supply hours to the farm sector (GOI, 2002). Examples are Punjab, Andhra Pradesh and Gujarat. The assumption here is that this would reduce the energy use and groundwater draft for agriculture. The electricity boards have not analyzed the impact of such cuts on equity in access and efficiency in use of groundwater. On the contrary, with reduction in hours of power supply, the quality of irrigation can be adversely affected. Due to interruptions in power supply accompanied by poor quality of power, farmers do not have absolute control over irrigation water. Under this situation, they show increasing tendency to over-irrigate the crops when electricity is available. Water delivery often does not coincide with the critical stages of crop water demand. The result is that they are getting less output per unit of irrigation water. The economic prospects of irrigated farming are more elastic to the quality of irrigation water rather than to its cost (Kumar and Patel, 1995; Kumar and Singh, 2001). The rich well owners always find ways to overcome the crisis of power cuts. This can further increase their monopoly in water trading.

There have been some developments in metered power supply. For instance, since 2001, the government of Gujarat has only provided metered connections for agriculture. Nearly 12,000 farmers thus have metered power connections in north Gujarat alone. In West Bengal, the state power board has installed electronic meters in all farm wells and started charging for electricity on the basis of the actual number of units consumed. But, empirical studies on the impact of such policy interventions on efficiency, access equity and sustainability in resource use are lacking.

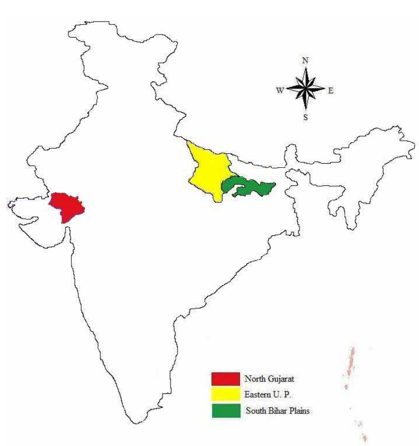
2.0 RESEARCH OBJECTIVES

The broad objective of this research study is to analyze the socio-economic viability of pro rata pricing of electricity in agriculture and to assess various technological options for implementing energy pricing policies. Specific objectives are: 1] to study the impact of the shift from flat rate power supply to metered supply on the efficiency and sustainability of groundwater use by well owners; 2] to analyze the overall impact of electricity pricing on the farming system of well owners, including the economic returns from farming; and, 3] to discuss various alternatives for implementing energy pricing policies and their likely outcomes vis-a-vis sustainability and efficiency of groundwater use, and equity in access to groundwater.

3.0 STUDY AREA, APPROACH AND METHODOLOGY

North Gujarat, which is a water scarce region, and the eastern plain regions of Uttar Pradesh (UP) and south Bihar, which are water rich regions, are the study locations (see Figure 1). Water rich regions of UP and Bihar were selected for the study due to the reason that there were no other locations in India where comparison could be made between farmers who are confronted with marginal cost of using energy and groundwater for irrigation, and farmers who are not confronted with, other than Gujarat. The semi arid north Gujarat region receives a mean annual rainfall of 735 mm. Grey brown, coastal alluvium types of soils are found in this region. The mean annual precipitation in the eastern plain region of UP is about 1025 mm and the region's climate varies from dry sub-humid to moist sub-humid. The soil type in this sub-zone is light alluvial and calcareous clay. South Bihar plains receive a mean annual rainfall of 1103mm and climate condition of region varies from dry to moist sub-humid. The soil types found in the region are old alluvium sandy loam to clayey and the larger areas under traditional water storage and irrigation systems called *Tal* and *Diara*.

Figure 1: Geographical Coverage of Study



Primary and secondary data relating to crop and livestock production were obtained through surveys. The primary data included: quantum of crop inputs and outputs and their prices; cropping pattern; electricity prices; diesel consumption and price; well command area; number of water buyers and sellers; quantum of livestock inputs and outputs, and unit price of inputs and outputs. Banaskantha district in North Gujarat, Mirzapur and Varanasi districts in Eastern UP, and Patna district in South Bihar were selected for the study. The details of the sample design for each location are given in Table 1. At the time of undertaking this study, there were very few locations in India where farmers paid for electricity based on consumption. Gujarat was one such state. Therefore, to analyze the potential impacts of introducing pro rata pricing of electricity in farm sector in the other states, farmers using diesel pumps for groundwater irrigation and water buyers were selected as a proxy for pro rata tariff.

Table 1: Sampling Procedure and Sample Size

Name of the Region	Name of the District	Type of Energy Tariff				Diesel Pump		Total Sample Size
		Flat Rate		Pro Rata		Well owners	Water buyers	
		Well owners	Water buyers	Well owners	Water buyers			
North Gujarat	Banaskantha	60	-	60	-	-	-	120
Eastern UP	Varanasi and Mirzapur	60	60	-	-	60	60	240
South Bihar	Patna	60	60	-	-	60	60	240
Total		**180**	**120**	**60**	**-**	**120**	**120**	**600**

The price of electricity used for pumping groundwater influences water productivity in many different ways. They are equity in access, efficiency of use of water, economic viability of farming, and sustainability of groundwater use (Kumar, 2005). The efficiency impact of change in mode of pricing was analyzed by comparing water productivity of crops in physical terms. The impact of change in mode of pricing on economic viability of farming was analyzed by comparing the overall water productivity of crops, livestock and farming system in economic terms under the two conditions. The net return from unit area of land farmed was also considered. The sustainability impact of price changes is analyzed by looking at the changes in groundwater withdrawal for unit irrigated area by well owning farmers.

Here, we have considered the applied (pumped) water for estimation of water productivity at the field and farming system level, and not the depleted water that takes into account the contribution of rainfall to total water input to the crop and return flows into groundwater. This does not alter the inferences drawn from the study due to three reasons. First, we are concerned with the changes in water productivity in the same field or farm, which means that the level of use of rainfall by the crop does not change. Second, if rainfall use increases, it will not change the groundwater recharge component of irrigation. Third, return flows would be insignificant in semi arid north Gujarat due to deep water table conditions (Kumar *et al*., 2008a). Though return flows can be quite significant in both UP and Bihar plains due to alluvial formations and sub-humid climatic conditions, the farmers in these regions would be concerned with the total amount of water applied rather than the actual amount of water depleted. The reason is that applied water would determine the amount of energy required to pump groundwater, which is scarce in these regions.

The physical water productivity for a given crop (kg/m^3) is estimated using data on crop yield and the estimated volume of water applied for all sample farmers growing that crop. The volume of water applied to the crop was estimated from the discharge of the wells owned by the farmers (including those who sell the water) (Q); number of irrigations given to the crop (n); and duration of watering per irrigation (t) as $Q \times n \times t$. The discharge of the wells was measured in the field using a stop watch and a bucket with known capacity, by allowing the output of the well to fill directly in the bucket and then noting the time required to fill the bucket. The combined physical and economic water productivity in Rs/m^3 is estimated using data on net returns from crop production in Rs/ha and estimated volume of water. To estimate the net income from a particular crop, the data on inputs for each crop were obtained by primary survey of farmers. These included cost of seed, labour, fertilizer, pesticides and insecticides, irrigation, ploughing, harvesting and threshing.

The physical productivity of water in milk production for livestock is estimated using the methodology presented in Kumar (2007) and Singh (2004). The water productivity in farming operations, including crops and dairying is estimated using the methodology presented in Kumar *et al* (2008b), which was used for estimating the economic value of irrigation water in agriculture for individual farms.

4.0 RESULTS AND DISCUSSION

4.1 Distribution of Land Holdings

In north Gujarat, the average size of land holding is higher for tube well owner who are paying power tariff on connected load basis (3.45 ha) as compared to their counterparts with metered connections (2.95 ha). About 90 per cent of the area is under irrigated crop production and remaining 10 per cent area is cultivated under rain-fed condition.

In Eastern UP, the average size of land holding is larger for diesel well irrigated farms (used interchangeably with "well command/s") as compared to electric well commands. Differences are significant between well owners and water buyers. Diesel pump owners have average land holding size of 1.35 ha while their water buyers have landholding size of 0.94 ha. The average size of land holding for electric pump owner is 1.30 ha, whereas their water buyers have an average land holding size of 0.56 ha.

In south Bihar, the average size of land holdings for both well owners and water buyers in the diesel pump commands is higher than that of their electric counterparts. The well owners in electric well irrigated farms have larger sized holdings (0.73 ha) as compared to their water buyers (0.53 ha). In diesel pump commands, the differences are larger. The average size of land holding of well owners here is 1.26 ha, whereas for water buyers it is 0.57 ha.

Hence, the average size of land holding in water rich eastern UP and south Bihar plains is much smaller when compared to water scarce north Gujarat. This is one of the important factors that determine the utilization of available water resources. In case of water abundant region, the limited land availability should motivate farmers to maximize returns per unit of land. Against this, in water scarce region, water availability is a limiting factor for maximizing returns from crop production, and hence generally, they would be motivated to maximize the returns from every unit of water (Kumar *et al.*, 2008b). However, lack of resources for investing in wells and energizing devices is a limiting factor for many farmers in south Bihar and eastern UP to access the water.

4.2 Cost of Groundwater Irrigation

The cost of groundwater irrigation was estimated for well owners by taking into account the following: 1] cost of well construction and pump set installation; 2] cost of obtaining power connection; 3] cost of operation and maintenance of the well and the pump set; 4] life of the well and the pump set; 5] the average hours of groundwater pumping per year; and 6] discharge of the pump set. In the case of electric wells with metered connections, the hourly operation cost is worked out using the energy charges per kilowatt-hour (kWh) of use. Similarly, in the case of diesel wells, the operation cost was worked out using the price of one litre of diesel and the amount of diesel consumption per hour of running. The cost of irrigation was finally worked out per cubic metre of water using well output data. In the case of wells with flat rate electricity connection, the implicit cost per hour of irrigation is worked out using the annualized cost, and the number of hours of irrigation per annum. Based on the figures of well discharge, cost estimates were worked out for eastern UP, northern Gujarat and south Bihar and are presented in Table 2. The unit rates charged by diesel pump owners for irrigation services are much higher than those of electric pump owners.

Table 2: Cost of Irrigation Water for Different Categories of Farmers from the three Study Locations

Area	Water source	Average (Rs/m^3)	Range (Rs/m^3)
Eastern UP	Electric Pump owner	0.18	0.10 – 0.30
	Electric pump buyers	0.65	0.52 – 0.84
	Diesel pump owners	1.38	0.99 – 2.04
	Diesel pump water buyers	2.81	2.07 – 3.63
North Gujarat	Metered connections	1.07	0.14 – 3.91
	Non metered connections	1.60	0.19 – 4.27
South Bihar	Electric Pump owner	0.77	0.17 – 3.39
	Electric pump water buyers	0.70	0.31 – 0.92
	Diesel pump owners	1.87	1.51 – 2.95
	Diesel pump water buyers	2.15	1.84 – 2.42

Source: Calculated from authors' primary data

4.3 Cropping Patterns

The cropping pattern of well owners and water buyers under different modes of energy pricing i.e., connected load (electric well) and unit consumption (diesel well) in eastern UP is presented in Table 3. The crops grown in the study villages are food-grains, pulses, oilseeds, vegetables, cash crops and fodder crops. Paddy and wheat are the dominant crops. During the kharif season, well owners and water buyers under both energy regimes allocate larger portion their land holding under paddy.

In diesel well commands, pump owners allocate about 26% of the gross cropped area to paddy cultivation, whereas in the case of water buyers, it is only 22%. In electric well commands, pump owners allocate 12% to paddy and water buyers allocate about 15% to paddy. Electric pump owners also grow groundnut. Water buyers in both electric and diesel well commands allocate larger portion of their cropped area under green fodder and other vegetables during kharif season as compared to pump owners. Water buyers in diesel well commands grow lentils of the *Arhar* variety. Water buyers in electric well commands grow lady's finger (okra).

Major crops grown during winter season are wheat and barley, potato, pea, gram, mustard, linseed and barseem. The percentage area allocated for crops viz., wheat, pea, potato and barseem is lower for well owners as compared to water buyers. Whereas, the area allocated to crops viz., mustard, gram, barley and linseed is higher for pump owners as compared to water buyers.

In diesel well commands, pump owners allocate larger share of their cropped area under winter crops as compared to water buyers. Such sharp differences are not seen in case of electric well commands. During the summer season, major crops grown in electric well commands are green fodder, sunflower and vegetables. While all these crops are grown by the electric pump owners, water buyers grow only green fodder. In diesel well commands, crops grown during summer season are green fodder and vegetables. Both diesel well owners and water buyers are found to be growing some green fodder.

Table 3: Cropping Patterns of Well Owners and Water Buyers under Different Energy Regime, Eastern UP

Name of the Crops	Electric Well Command				Diesel Well Command			
	Owner		Water Buyers		Owner		Water Buyers	
	Area (Ha)	% Area	Area (Ha)	% Area	Area (Ha)	% Area	Area (Ha)	% Area
Kharif Season								
1. Paddy	0.71	11.51	0.36	14.81	1.55	26.18	0.91	22.14
2. Bajra	0.32	5.15	0.14	5.85	0.23	3.85	0.13	3.25
3. Maize	0.24	3.97	0.12	4.78	0.23	3.81	-	-
4. Lady's Finger	0.32	5.18	0.23	9.53	-		-	
5. Other Vegetables	0.32	5.30	0.17	7.08	0.14	2.41	0.34	8.35
6. Arhar	-		-	-	-	-	0.30	7.42
7. Black gram	0.27	4.39	0.11	4.68	-	-	0.11	2.78
8. Green gram	0.37	6.06	-	-	-	-	0.11	2.78
9. Sesame	0.08	1.30	0.06	2.34	0.23	3.85	0.11	2.78
10. Groundnut	0.33	5.34	-	-	-	-	-	-
11. Sugarcane	0.11	1.77	0.06	2.34	0.16	2.68	-	-
12. Green Fodder	0.16	2.60	0.08	3.20	0.11	1.89	0.10	2.38
Rabi Season								
1. Wheat	0.67	10.94	0.29	12.00	1.27	21.48	0.83	20.29
2. Barley	0.23	3.73	0.08	3.28	-	-	0.09	2.23
3. Pea	0.23	3.80	0.13	5.47	0.34	5.73	0.17	4.08
4. Gram	0.17	2.85	0.04	1.46	0.42	7.02	0.20	4.84
5. Mustard	0.70	10.06	0.53	4.45	0.27	4.55	0.14	3.50
6. Linseed	0.06	0.93	-	-	0.34	5.78	0.10	2.50
7. Potato	0.50	8.15	0.29	11.94	0.37	6.24	0.23	5.57
8. Barseem (Green fodder)	0.07	1.14	0.05	1.89	0.06	1.05	0.07	1.64
Summer Season								
1. Sunflower	0.10	1.58	-	-	-	-	-	-
2. Vegetables	0.11	1.86	-	-	0.11	1.93	-	-
3. Green Fodder	0.15	2.38	0.12	4.89	0.09	1.55	0.14	3.48
Gross Cropped Area (GCA)	**6.13**	**100.00**	**2.44**	**100.0**	**5.92**	**100.00**	**4.10**	**100.0**

Source: Calculated from authors' primary data

In the case of north Gujarat, major crops grown by the tube well owners under both tariff regimes are green fodder, food grain crops, pulses, groundnut and cash crops such as cluster bean, cotton and castor. The farmers of this region allocate small area under green fodder throughout the year.

During kharif, tube well owners under pro rata tariff regime allocate slightly larger percentage of the cropped area under cotton, castor and fodder bajra. During winter, tube well owners under flat rate tariff regime are allocating more area under green fodder, wheat and mustard. The tube well owners under pro rata tariff regime allocate slightly larger area under cumin, which is a high valued cash crop. The major crops grown during summer season are green fodder and bajra. The area allocated by flat and unit tariff paying tube wells owners under the bajra crop is about 10% of the gross cropped area.

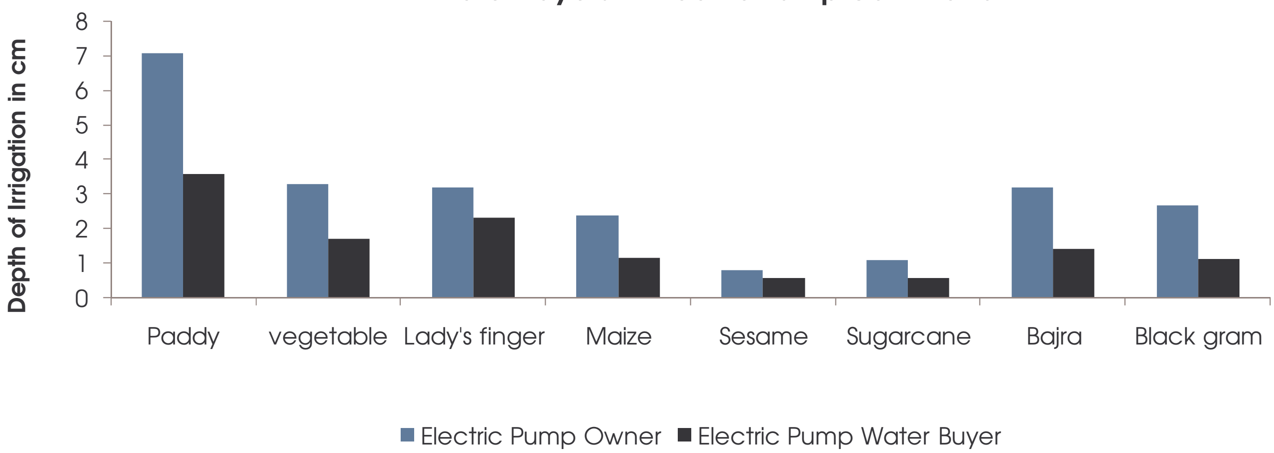
In South Bihar, very high monsoon rain results in submergence of most of the cultivated land during kharif season. During this season, farmers grow paddy and green fodder, with larger area under paddy. Out of the gross cropped area, nearly 38% is under paddy. During winter, farmers grow wheat, gram, mustard, barseem (fodder), potato, radish, carrot and coriander. During summer, farmers grow onion, maize and green fodder. There is no significant difference in kharif cropping pattern between well owners and water buyers in electric well commands or diesel well commands. During winter, water buyers in electric well commands cultivate gram and carrot. Diesel pump owners and water buyers in both diesel and electric well commands keep a larger area for growing potato. During summer, only diesel pump owners and water buyers in their commands cultivate green fodder. In general, electric pump owners allocate larger area under different crops as compared to electric pump water buyers. There is a similar trend in case of diesel pump command areas.

4.4 Irrigation Water Application and Crop Water Productivity

In this section, the estimates of irrigation water application, physical water productivity (kg/m^3) and water productivity in economic terms (Rs/m^3) of different crops grown by electric/diesel pump owners and water buyers in their commands are presented. Higher physical productivity of water use for a given crop indicates more efficient use of irrigation water through on farm water management or better farm management. Higher water productivity in economic terms means better economic viability of irrigated production, if land is available in plenty.

Figure 2 presents the estimates of irrigation water dosage (cm) for kharif crops of pump owners and water buyers in electric well commands in eastern UP villages. Figure 3 presents the estimates of water productivity of crops in physical (kg/m3) and economic terms (Rs/m^3) for pump owners and water buyers in these commands. Figure 4 and Figure 5 presents similar estimates for winter crops of pump owners and water buyers. As Figure 2 and Figure 4 show, the total amount of irrigation water applied for crop production is higher for electric pump owners as compared to irrigation water buyers. Further, for most of the crops, both physical and economic productivity of water are higher for water buyers than their water-selling counterparts (Figure 3 and Figure 5). Equally important is the fact that water buyers do not grow crops during summer when crop water requirement is generally high, whereas well owners grow water intensive vegetable crops.

Figure 2: Depth of Irrigation in Kharif Season (Eastern UP) for Well Owners and Water Buyers in Electric Pump Command



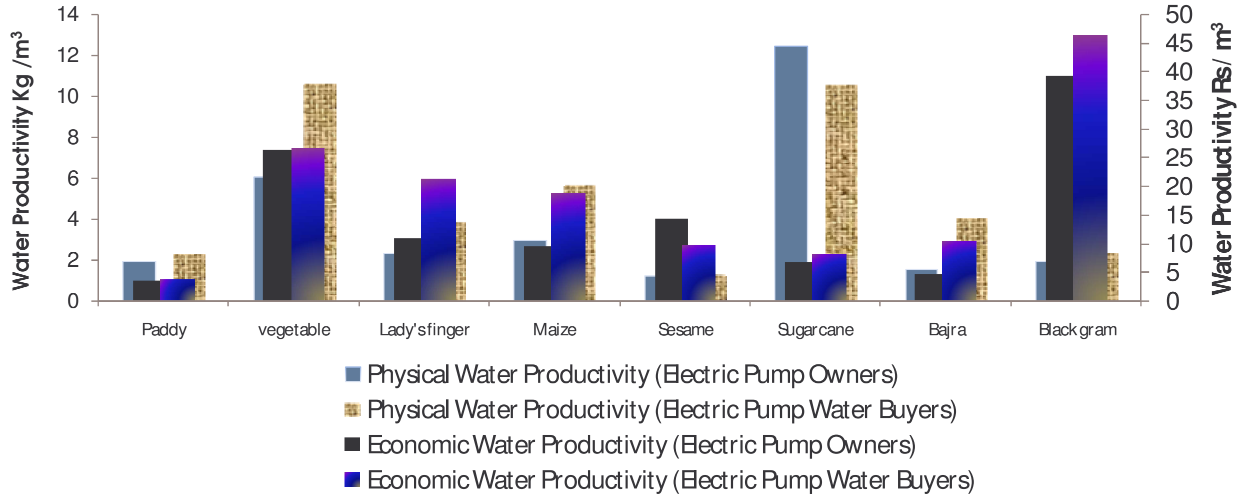


Figure 3: Water Productivity in Kharif Season (Eastern UP) for Well Owners and Water Buyers in Electrii Pump Command

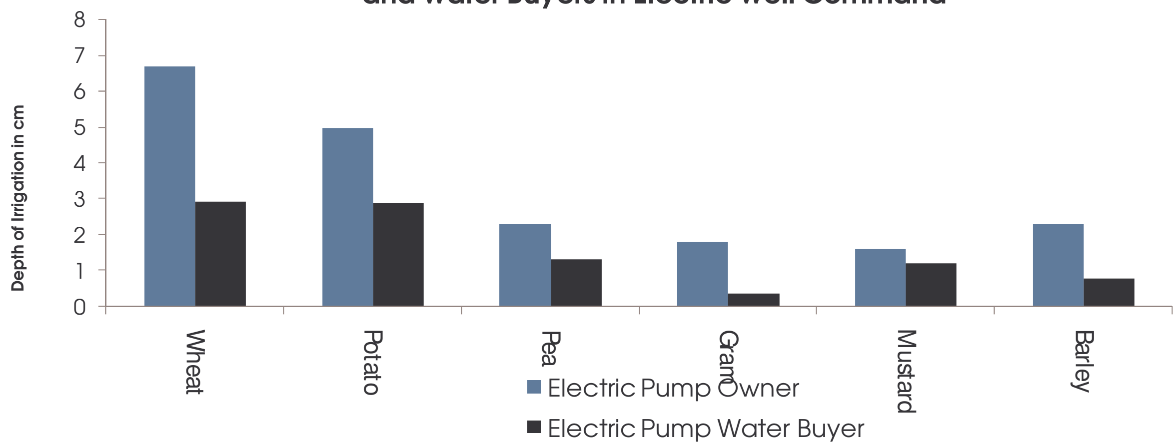


Figure 4: Depth of Irrigation in Rabi Season (Eastern UP) for Pump Owners and Water Buyers in Electric Well Command

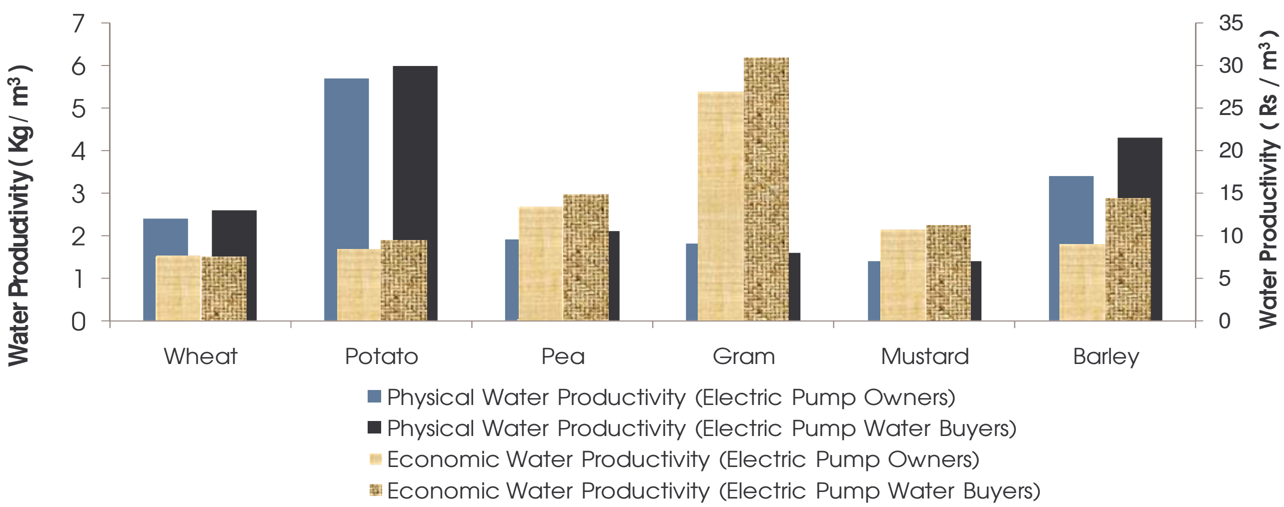


Figure 5: Water Productivity in Rabi Season (Eastern UP) for Pump Owners and Water Buyers in Electric Well Command

As regards diesel well commands, though the well owners as well as the water buyers are confronted with marginal cost of using water, the water buyers incur higher cost for irrigation water. But, there is not much difference in the cropping pattern of pump owners and water buyers, except that water buyers do not grow sugarcane and maize. To economize on irrigation water, water buyers cultivate water efficient crops such as arhar, black gram and green gram during kharif season. The cropping pattern during winter is same for diesel pump owner and water buyers. During summer season, only pump owners grow vegetables. The estimates of irrigation water dosage and water productivity in physical and economic terms for different crops show that the water buyers in diesel well commands apply less amount of water to their crops as compared to their water selling counterparts. Further, the physical productivity of water (kg/m^3) and water productivity in economic terms (Rs/m^3) is higher for water buyers as compared to diesel pump owners for all the crops. This could be owing to the higher marginal cost of irrigation water affected in the case of diesel well commands.

Table 4 presents similar data for different energy pricing regimes for north Gujarat. Electric pump owners, who pay marginal cost for electricity, maintain higher water productivity in both physical and economic terms for all the crops as compared to those who are paying for electricity on the basis of connected load (pump horsepower). Further, they do not keep highly water intensive alfalfa, which is a fodder, in their fields during summer.

Table 4: Water Use, and Water Productivity in Physical and Economic Terms under Flat and Unit Energy Pricing Regime, North Gujarat

Name of Crop	Electric Pump Owner			Electric Pump Water Buyer		
	Depth of Irrigation (mm)	Water Productivity (kg/m^3)	Water Productivity (Rs/m^3)	Depth of Irrigation (mm)	Water Productivity (kg/m^3)	Water Productivity (Rs/m^3)
Kharif						
1. Alfalfa	36.3	5.42	-	41.1	5.64	-
2. Cluster bean	85.2	1.02	9.09	106.2	1.11	9.37
3. Jowar	107.1	2.76	8.27	101.4	2.26	6.62
4. Bajra	98.1	1.00	5.13	89.4	1.45	6.39
5. Black gram	81.3	1.07	15.14	52.6	1.50	16.75
6. Green gram	76.2	0.91	10.85	87.3	0.98	11.20
7. Groundnut	94.7	0.58	3.58	51.4	0.56	4.68
8. Cotton	62.9	0.41	5.34	61.0	1.15	19.28
9. Castor	116.6	0.59	5.06	110.2	0.62	6.52
Rabi						
1. Alfalfa	32.7	3.65	-	28.3	5.71	-
2. Wheat	127.2	0.82	4.64	96.3	0.91	5.17
3. Barley	22.9	0.47	0.70	62.9	1.11	6.17
4. Rajgaro	91.4	0.56	4.11	72.7	0.89	8.50
5. Mustard	113.8	2.86	22.25	74.6	2.10	23.50
6. Cumin	89.5	0.82	36.71	81.4	0.99	47.71
Summer						
1. Alfalfa	38.2	2.30	-	-	-	-
2. Bajra	168.7	1.95	6.43	129.2	1.94	7.31

GF: Green Fodder
Source: calculations from authors' primary data

Comparison of estimates of mean values of irrigation water dosage and water productivity in physical and economic terms for both pump owners and water buyers in electric pump command area in south Bihar plain for all crops (Table 5) shows that water buyers apply less water to their crops, and maintain higher physical water productivity for many crops in comparison to electric well owners. However, they secure lower water productivity in economic terms for most of the crops, except radish and onion. This could be due to the higher cost of irrigation water, which eventually reduces net return from crop production, the value of numerator of water productivity.

Table 5: Water Use, and Water Productivity in Physical and Economic Terms under Electric Well Command, South Bihar Plain

Name of Crop	Electric Pump Owner			Electric Pump Water Buyer		
	Depth of Irrigation (mm)	Water Productivity (kg/m^3)	Water Productivity (Rs/m^3)	Depth of Irrigation (mm)	Water Productivity (kg/m^3)	Water Productivity (Rs/m^3)
Kharif						
1. Paddy	75.1	2.5	6.35	46.7	2.69	8.4
2. Maize	25.0	20.5	-	12.5	27.34	-
Rabi						
1. Wheat	48.2	1.8	5.56	35.1	1.76	5.8
2. Potato	192	13.1	43.16	20.0	11.74	41.8
3. Barseem	5.6	10.4	-	4.0	11.91	-
4. Mustard	26.7	1.8	20.16	-	-	-
5. Gram	-	-	-	9.3	0.66	9.2
6. Radish	12.7	10.0	13.92	9.6	9.59	18.5
Summer						
1. Onion	46.0	4.4	18.48	21.8	5.40	23.2
2. Maize	20.7	5.9	21.66	17.6	6.86	19.1

GF: Green Fodder
Source: Calculated from authors' primary data

Comparing the water use and water productivity of crops raised by two categories of farmers in diesel well commands of south Bihar plains - both in physical and economic terms shows that diesel pump owners and water buyers grow almost similar crops. For all crops except onion and summer green fodder, water buyers in diesel well commands secure higher physical water productivity as compared to pump owners. Again, for all crops except onion, the water buyers secure higher water productivity in economic terms as compared to pump owners.

The trends emerging from the foregoing analysis are as follows: 1] the net water productivity of water buyers from electric pumps is greater than from diesel pumps both in east UP and south Bihar; 2] net water productivity of electric pump owners under flat rate provision is comparatively less than that under pro rata tariff; 3] water productivity of electric pump owners in economic terms is less than that of diesel pump owners; and, 4] economic water productivity of water buyers from electric pumps is less than those buying water from diesel well owners.

4.5 Water Productivity in Milk Production

Estimates of weighted average of feed and fodder input to livestock for the entire animal lifecycle by farmers were carried out for farmers in electric and diesel well commands in eastern UP, farmers with metered and non-metered power connections in north Gujarat, and farmers in the electric well commands and diesel well commands in south Bihar. The overall observation is that water buyers in eastern UP and south Bihar and farmers in north Gujarat with non metered connections fed more input to their cattle.

The figures of average milk production from dairy animals worked out for the entire animal life cycle for electric well owners of eastern UP are 2.91, 4.64 and 1.81litres/day/animal for buffalo, crossbred cow and indigenous cow, respectively. The corresponding estimates for farmers in the diesel well commands are 2.08, 4.01 and 1.95 litres for well owners; and 2.23, 3.23 and 2.01 for water buyers, for buffalo, crossbred cow and indigenous cow, respectively.

In north Gujarat, in the case of farmers having metered electricity connections in north Gujarat, the average milk production from buffalo, crossbred cow and indigenous cow are 5.14, 7.5 and 1.91litres/day/animal, respectively. Similar estimates for non metered connections are higher at 6.96, 9.32 and 6.43 litres. Such higher yields in the case of dairy animals owned by farmers with flat rate connections are because of the higher amount of feed and fodder that they are being provided with. Since they are not confronted with marginal cost of using electricity and groundwater, they grow water intensive alfalfa, which have high nutrition value, more intensively, and feed their animals.

In the case of electric pump owners in South Bihar, the average milk production figures from buffalo, crossbred cow and indigenous cow are 2.0, 2.36 and 0.79litres/day/animal, respectively. In the case of water buyers, they are 1.86, 2.97 and 0.88 litres/day/animal. The figures for farmers of diesel well owners are 1.69, 3.53 and 0.96 litre/day/animal respectively, whereas, in case of water buyers, the corresponding values are 1.68, 2.30 and 1.18 litre/day/animal.

The estimates of the volume of water used for milk production, physical productivity of water in milk production and gross water productivity in milk production in economic terms for buffalo, crossbred and indigenous cows for the sample farmers in the electric well commands in eastern UP are presented in Table 6. The estimates of total water used for animals consider the embedded water in feed and fodder. Detailed discussion on embedded water in milk production can be seen in Singh (2004) and Kumar (2007). Dairy farmers, who own pump-sets, use larger quantity of water for producing green and dry fodder, in comparison to water buyers. However, the amount of water embedded in the concentrate used for dairy production is higher for water buyers. The net result is that the gross water productivity for milk production is higher for electric pump owner as compared to water buyers.

Table 6: Water Use, Input Costs and Water Productivity (Physical and Economic) in Milk Production in Electric Pump Command Area, Eastern UP (m^3/day)

Types of Feed & Fodder	Electric Pump Owner			Electric Pump Water Buyer		
	Buffalo	Crossbred Cow	Indigenous Cow	Buffalo	Crossbred Cow	Indigenous Cow
1. Total Water Used for Feed, Fodder and Drinking (m^3)	2.63	3.02	2.50	2.19	3.35	2.38
2. Milk Production (Lt)	2.91	4.64	1.81	2.64	4.08	1.89
3. Milk WP (Lt/m^3)	1.11	1.54	0.72	1.20	1.22	0.79
4. Gross WP (Rs/m^3)	11.95	15.52	6.72	12.97	12.31	7.35
5. Total expenditure (Rs/day)	12.84	15.52	12.84	12.73	19.80	14.03
6. Milk production (Lt)	2.91	4.64	1.81	2.64	4.50	1.89
7. Gross income-milk & dung (Rs)	31.89	47.36	17.33	28.94	45.98	18.01
8. Net income (Rs/day)	19.05	31.84	4.50	16.21	26.18	3.98
9. Net water productivity (Rs/m^3)	7.25	10.55	1.80	7.39	7.82	1.67

Source: Calculated from authors' primary data

The volume of water used for milk production by water sellers in diesel well command are 3.02 m^3, 3.48 m^3 and 2.68 m^3/day/animal for buffalo, crossbred cow and indigenous cow, respectively. The corresponding figures for water buyers are 3.00 m^3, 3.21 m^3 and 2.64m^3/day/animal. The physical productivity of water for milk production are 0.69, 1.15 and 0.73 litre/m^3, respectively for pump owner and 0.75, 1.00 and 0.76 litre/m^3 for water buyers. Similar estimates are available for the two categories of farmers in north Gujarat, and four categories of farmers in South Bihar.

The net water productivity in economic terms for dairy production was estimated by considering the cost of milk production, which includes the cost of production of dry fodder, green fodder, cattle feed and other expenses for maintaining dairy animals in the water productivity analysis. Based on these data, the net water productivity in economic terms was estimated for all the three locations, i.e., for well owners, and water buyers in electric and diesel well commands in eastern UP and south Bihar, and electric well owners with and without metered connections in north Gujarat.

The results for farmers in electric commands in eastern UP (Table 6) show that across livestock types, well owners secure higher net water productivity in milk production than water buyers. The values of net water productivity in economic terms for the diesel well owners are 1.74, 6.89 and 0.46 for buffalo, cross bred cow and indigenous cows, respectively. The corresponding values for water buyers are 0.43, 1.8 and -1.72. Comparing electric and diesel well commands, it appears that electric well owners secure highest net water productivity in economic terms, followed by water buyers in their command, diesel pump owners and lowest for buyers of water from diesel pump owners.

In north Gujarat, the average values of net water productivity in economic terms for milk production from buffalo, crossbred cow and indigenous cow for farmers under flat energy pricing regime are Rs 3.73/m^3, Rs 5.88/m^3 and Rs -1.85/m^3, respectively. Against these, the values for farmers under pro rata pricing regime are Rs 3.31/m^3, Rs 2.29/m^3 and Rs 3.37/m^3, respectively. Thus, overall net water productivity is higher under pro rata pricing regime, wherein the farmers have to pay for every unit of water used for growing fodder crops and cereals, indirectly through electricity charges.

In south Bihar, the estimates of average water productivity in economic terms in dairy production for electric well owner are Rs 2.18/m^3, 1.96/m^3 and -1.0/m^3. The corresponding values for water buyers are Rs 1.65/m^3, 3.89/m^3 and -0.64/m^3 for buffalo, crossbred cow and indigenous cow, respectively. For pump owners in diesel well commands, net water productivity in economic terms (Rs/m^3) are -0.47, 5.68 and -2.50; and for water buyers, the values are 0.07, 2.09 and -1.26, for buffalo, cross bred cow and indigenous cow, respectively.

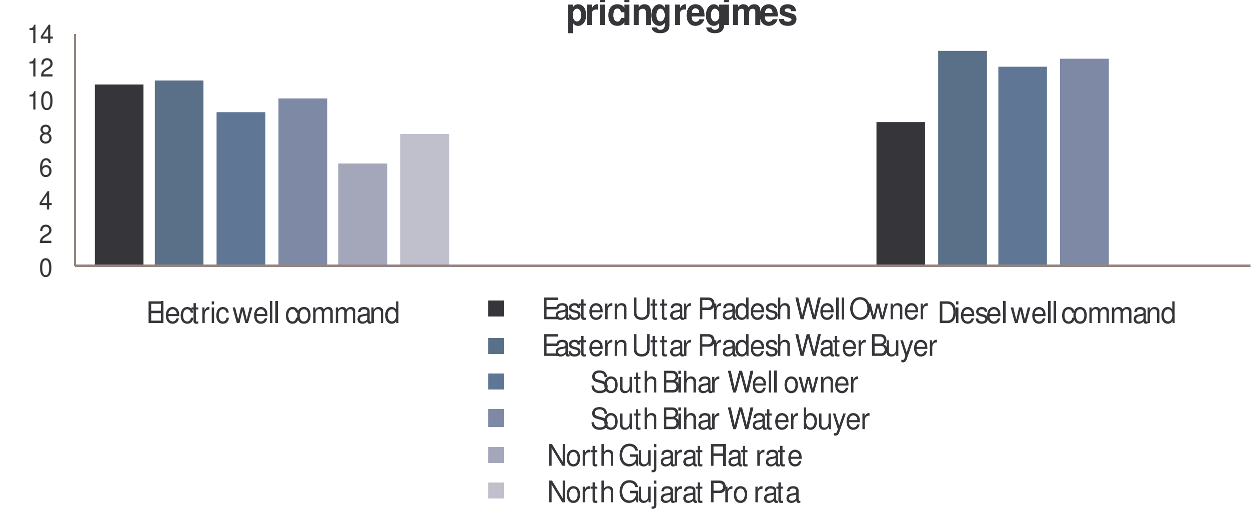
4.6 Water Productivity in Overall Farm Operations

In eastern UP and south Bihar, farmers should try and economize on the use of water, though it is not a scarce resource in these regions in physical terms. The reason is that using more water means paying more for pump rental services. Farms are the unit for many investment decisions by farmers in agriculture including water allocation decisions. Hence, they try to optimize water allocation over the entire farm, rather than individual crops, to maximize their returns. Therefore, the impact of power pricing on the efficiency with which water is used by farmers should be analyzed by looking at the water productivity for the entire farming system.

Our analysis clearly shows that water productivity in overall farm operation is much higher for water buyers in diesel well commands in eastern UP and south Bihar (Figure 6). In electric well commands also, the differences exist in favour of water buyers in spite of very low marginal cost of using water (Rs.0.65/m^3). The farm level water productivity is much higher for farmers who are confronted with marginal cost of electricity in north Gujarat as compared to those who pay for electricity based on connected load. The water productivity improvement in highest in eastern UP in the diesel well commands, where the water buyers' marginal cost of using irrigation service is Rs. 2.81/m^3. Difference in water productivity between farmers with flat rate connection and those with metered connections is also quite substantial in north Gujarat.

Further, comparison between electric well owners and diesel well owners in both the locations substantiates the earlier point that positive marginal cost promotes efficient use of water at the farm level.

Figure 6: Water productivity in farming operations under different pricing regimes



4.7 Groundwater Pumping and Net Farm Returns of Farmers

Often no distinction is made between efficiency and sustainability in groundwater use (Moench and Kumar, 1993). Pricing would introduce efficiency, but may not ensure sustainability of resource use

(Kumar, 2005). The total amount of groundwater pumpage per unit of cultivated area is determined by the cropping pattern, the cropping intensity, and the degree to which crop water needs are met. Increased allocation of cultivable area under highly water intensive crops would increase the demand for irrigation water by a farmer. Hence, total pumpage per unit cultivated area could be a good indicator of the sustainability impacts of change in mode of pricing on groundwater. However, farmers with very small land holding size are more likely to intensify cropping, which would increase the total pumpage. This would mean longer hours of pumpage per ha of cultivable area as the value of numerator would increase and that of denominator would decrease.

But, the results from eastern UP and south Bihar show that the pumpage of groundwater per unit area of cultivated land is lower for water buyers, in spite of them having lower sized holdings (Table 7). The data for north Gujarat show that the pump owners having metered connections, in spite of having smaller sized land holdings (2.95 ha against 3.45 ha) use much less water per ha of land as compared to their flat rate counterparts (304.0 hours per year against 444.0 per year). The difference in aggregate pumping is much greater between farmers with meters and those without meters (Table 7). Such a high reduction is water usage per unit of cultivated land, which is disproportionately higher than the reduction in net return per unit of land, is made possible through high improvements in water productivity in economic terms.

Table 7: Average Hours of Groundwater Use/Ha of Crop Land by Farmers under Different pricing Regimes

Name of the Regions	Name of the district	Groundwater Pumpage by Electric Pump Owners		Diesel pump	
		Pro rata Pricing	Flat Rate	Well owner	Water buyers
North Gujarat	Banaskantha	304.0	444.00	NA	NA
		Groundwater Use in Electric Well Command by		Groundwater Use in Diesel Well Command by	
		Well Owner	Water Buyer	Well Owners	Water Buyers
Eastern UP	Varanasi and Mirzapur	175.0	184.0	222.0	148.0
South Bihar	Patna	330.0	250.0	231.0	198.0

In spite of slight reduction in pumping, the net return from unit area of land is higher for water buyers in eastern UP and South Bihar plains (Table 8). This is achieved through high improvement in water productivity through selection of crops that are less water consuming and high valued. As Reddy (2009) notes, improving productivity of land and water are the two ways of making pricing affordable to the farmers. Though the net returns per unit of land were marginally lower for farmers who paid on pro rata basis in north Gujarat (Table 8), this is not a concern, as in water-scarce regions like north Gujarat farmers would not have land constraints in maximizing returns. Even if the farmers attempt to expand the area to maintain the net farm return at the previous levels, the aggregate water usage would still be lower than the previous levels.

Table 8: Net Income from Farming Operations in the three Study Locations

Region	Type of Well Command	Type of farmer	Net income from crops (Rs)	Net income from dairying (Rs/day)	Total Farm level Income (Rs)	Farm level income per Unit Land (Rs/Ha)
Eastern UP	Electric Well	Well owner	124587	7152	131740	24880
		Water buyer	54638	6165	60803	27570
	Diesel Well	Well owner	74765	7430	82194	14528
		Water buyer	62323	6261	68584	18075
North Gujarat	Electric Well	Flat rate Pricing	369120	30048	768287	57531
		Pro rata pricing	311807	45636	669250	56882
	Electric Well	Well owner	120477	10293	130770	210345

South Bihar		Water buyer	61518	8131	76024	190031
	Diesel Well	Well owner	140105	9958	150064	191387
		Water buyer	71810	12232	84043	197895

Source: Calculated from authors' primary data

5.0 IMPLICATIONS OF FARM-SECTOR ENERGY PRICING FOR GROUNDWATER SUSTAINABILITY AND POWER SECTOR VIABILITY

The foregoing analysis showed that introducing marginal cost for electricity motivates farmers to use water more efficiently at the field level from physical, agronomic and economic points of view through careful use of irrigation water, use of better agronomic inputs and optimizing costly inputs. This is evident from:1] the lower irrigation dosage applied by farmers who are either using diesel wells or buying water from well owners or paying for electricity on pro rata basis, with lowest dosage found in the case of water buyers of diesel well commands, who pay higher unit price for irrigation water; and 2] the higher physical and economic productivity of water in crop production secured by the farmers who are either using diesel wells or buying water from well owners, or paying for electricity on pro rata basis.

The analysis also showed that introducing marginal cost for electricity motivates farmers to use water more efficiently at the farm level through careful selection of low water intensive crops, and livestock composition that give higher return from every unit of water. This is evident from the higher water productivity secured in farming operations by those who purchase water as compared to their well-owning counterparts, and those farmers who pay for electricity on pro rata basis. The results also showed that higher cost of irrigation water affected by higher energy cost will not lead to lower net return from every unit of water used as the farmers modify farming system itself in response to increase in energy cost, as indicated by the higher water productivity obtained by farmers who purchase water from diesel wells as compared to the well-owning counterparts.

The analysis also shows that pro rata pricing has significant impact in reducing groundwater pumpage from every unit of irrigated land, which is disproportionately higher than the reduction in net return from unit of land. This means that even if farmers expand the area to maintain the net farm returns at the previous levels, the groundwater use would still be lower, implying positive impact of pro rata pricing on sustainability of groundwater use.

The empirical evidence further reinforces the inference drawn by Kumar (2005) that the arguments against pricing are flawed. One dominant argument against price change is the higher marginal cost of supplying electricity under metered system owing to the high transaction cost of metering, could reduce the net social welfare as a result of reduction in: 1] demand for electricity and groundwater in irrigated agriculture; and 2] net surpluses individual farmers could generate from farming. The second argument is that for power tariff to be in the responsive region of power demand curve, prices have to be so high that it may become socially unviable. We would illustrate this point.

It is understood that the aggregate demand for electricity and groundwater in irrigation is a function of the demand rates (electricity and water requirements per unit of land), and the total area under irrigation (Kumar, 2005). The empirical analyses show that the demand for water and energy per unit of land was lower for water buyers due to increase in unit price of water and energy. However, the net income surpluses from every unit of water and energy used increased. Also, the net aggregate return was higher in Bihar and UP. Though the net returns per unit of land were marginally lower for farmers who paid on pro rata basis in north Gujarat, this is not a concern as in water-scarce regions farmers would not face land constraints in maximizing farm returns. With higher water productivity (Rs/m^3), they would be able to maintain the same level of net farm return as in the past, but with much less amount of water.

The increase in income surplus from every unit of water and energy will be more under pro rata pricing because there is no need for regulating power supply, which is done by state electricity boards for restricting revenue losses through subsidy at the macro level, under pro rata pricing, whereas it is compulsory under flat rate system of pricing. Now, if one considers the positive externalities on the society due to energy and water saving due to their efficient use, the net social welfare would be even more. Groundwater-scarce regions such as western and north western India and south Indian peninsula (Kumar *et al.*, 2010), are also facing severe energy shortage, and hence such welfare effects are likely to be high.

6.0 TECHNOLOGICAL INNOVATIONS FOR INTRODUCING ELECTRICITY METERING IN FARM SECTOR

The SEBs and policy makers in government recognize the importance of metering electricity from the point of both cost recovery and improving energy efficiency. This means reducing the unaccounted for losses in electricity distribution, improving the financial working of the SEBs and reducing the overall power deficits. But, for almost two decades, they were also toiling with the idea of carrying out metering of farm-power connection in a way that makes it fool-proof as well as cost effective. The problem was the rampant tampering of meters in rural areas, and malfunctioning meters. Today, technologies exist not only for metering but also controlling energy consumption by farmers (Kumar and Amarasinghe, 2009; Zekri, 2008). The pre paid electronic meters, which are operated through scratch cards and can work on satellite and internet technology, are ideal for remote areas to monitor energy use and control groundwater use online from a centralized station (Zekri, 2008). It is important to note here that over the past 7-8 years, there has been a remarkable improvement in the quality of services provided by internet and mobile (satellite) phone services, especially in the rural areas, with a phenomenal increase in the number of consumers. As Zekri (2008) notes, such technologies are particularly important when there are large numbers of agro wells, and the transaction cost of visiting wells and taking meter reading is likely to be very high. It is inevitable that they will be adopted in rural India.

Pre paid meters prevent electricity pilferage through manipulation of pump capacity. They can be operated through tokens, scratch cards, magnetic cards or recharged digitally through internet and SMS. It helps electricity company restricts the use of electricity. The company can decide on the "energy quota" for each farmer on the basis of reported connected load and total hours of power supply, or sustainable abstraction levels per unit of irrigated land. But, for operationalizing this, database for every agricultural consumer of the connected load, coordinates, and field data to assess sustainable withdrawal levels, among other data, are required. Farmers can pay and obtain activation code through mobile SMS (Zekri, 2008).

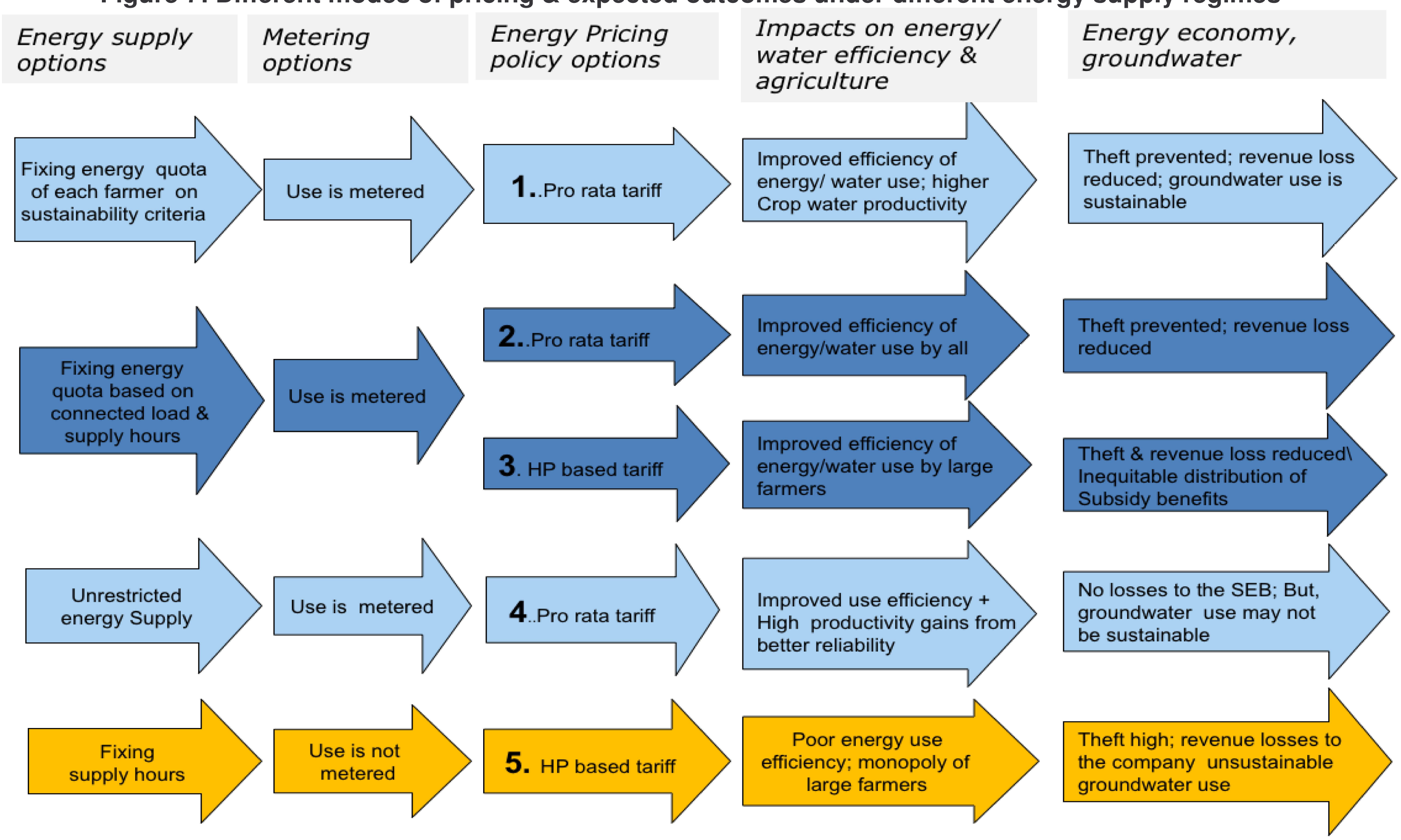
Restricting farmers' energy use for pumping groundwater is analogous to rationing water allocation for irrigation volumetrically. As Kumar (2005) has shown, when water allocation is rationed in volumetric terms, farmers would allocate the available water to economically more efficient uses. Hence, restricting energy use will have positive impact on efficiency of groundwater use by all categories of farmers. But, in such cases, it is important that the consumers are informed about their energy quota (in KWhr), and the approximate number of hours for which they could pump water from their wells using this quota, well in advance of the agricultural season. Such information would help them choose the crops depending on the availability of power over the entire crop year. Here again, the energy quota will have to be decided on the basis of the geo-hydrological environment prevailing in the area and the optimum irrigation requirements.

Power supply policies will also impact on farm productivity. Unlimited power supply with stable voltage will ensure better quality of irrigation water, than restricted power supply with voltage fluctuations. As some studies had indicated, the returns from irrigation are highly elastic to its quality (Kumar and Singh, 2001; World Bank, 2001).

Hence various policy options are possible with regard to energy supply, metering and power pricing, enabled by the use of pre paid meters. Five of them are presented in Figure 7. Under all the options except Option # 3 and 5, farmers would pay higher tariff for electricity. But, they would also gain in terms of improved quality of power. As a study by World Bank (2001) in Haryana showed, many farmers understand that ability of state electricity boards to offer improved electricity service depends on higher tariffs and metering. Fewer understand the need to invest in more efficient pump sets. To ensure continued and increasing support from the farming lobby for the reforms that are put into action, policymakers must clearly communicate, to them that the new strategy balances higher costs of power with improved service performance over a time frame. The likely outcomes and impacts of these policy interventions are also summarized in Figure 2.

It can be seen from Figure 6 that option 3 is easily implementable to manage the groundwater-energy nexus in agriculture. Here, the energy quota is decided on the basis of the connected load of the farmer, which means that those who have large capacity pump sets would be entitled for large quantum of electricity. Therefore, equity in access to groundwater and water use efficiency in small farms could still be an issue. One way to overcome this issue is to fix higher charges per HP of connected for farmers who enjoy large quotas. Option 2 is slightly difficult, but would conserve groundwater also. Option 1 is best for co-management of groundwater and electricity and would address the issues of equity, efficiency and sustainability. But, implementing this requires great political will as rights of farmers to use groundwater would be regulated by this policy intervention. Government can offer subsidies for meters if farmers are willing to go for option 1 and 2 on account of the positive welfare effects. For implementing any of these options it is necessary that SEBs setup computerized database of all agro wells, comprising their latitude & longitude, physical characteristics and land use data.

Figure 7: Different modes of pricing & expected outcomes under different energy supply regimes



There are some initial transaction costs in introducing pre paid meters even under the present scenario with several technological advancements changing the communication networks in rural areas, though they will be much less as compared to the past when SEBs have to take meter reading manually from hundreds of thousands of individual farmers in remote rural areas. Also, there are processes involved in putting the systems such as fixing energy quota of individual farmers, generating database of well owners, and providing extension services to the farmers for effectively using the new technologies such as pre paid meters, apart from informing them about their energy quotas. All these would take time, technical and human resources and finance. But, what is important is that the opportunity costs of not doing this will be low agricultural productivity, and threat to sustainability of groundwater resources and livelihoods of millions of farm households. On the other hand, there are economic benefits of following the new system of supplying electricity, metering and charging higher tariff such as improved productivity of use of electricity and water, greater agricultural outputs, increased revenue for the state electricity boards from farm sector, and improved financial viability of power sector. All these can be done without adversely affecting the economic viability of irrigated production.

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