Using Energy Pricing as a Tool for Efficient, Equitable and Sustainable Use of Groundwater for Irrigation:
Evidence from three Locations of India

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Abstract

This paper analyzes the potential impacts of energy pricing on efficiency, equity and sustainability in groundwater use. The analysis uses empirical data on water productivity in agriculture for crops, dairying and farms for north Gujarat, east US and south Bihar. For north Gujarat, the analysis uses data from well owners who pay flat rate tariff, and well owners who pay pro rata tariff. For eastern UP and south Bihar, the analysis uses data from well owners and water buyers from diesel and electric well commands. The analysis also compares data from diesel well owners and electric well owners in south Bihar. The findings are as follows.

Introducing marginal cost for electricity motivates farmers to use water more efficiently at the farm level through careful use of irrigation water; use of better agronomic inputs; optimize costly inputs; optimize livestock composition and carefully select crops and cropping patterns, which give higher return from every unit of water and grow low water consuming crops. It also shows that higher cost of irrigation water (because of higher energy cost) will not lower net return from every unit of water used as the farmers will modify their farming system accordingly.

Further, change in the structure of power tariff from flat rate to pro-rata will not have any adverse effects on access and equity in groundwater use. Nor will it increase the monopoly power of well owners. The number of potential water sellers and not the number of potential buyers of water govern the price of water. Pro rata pricing reduces cost of groundwater pumping per unit of land. It also reduces aggregate pumping, which is disproportionately higher than the reduction in net returns per unit of land. This leads to more sustainable groundwater use.

This means that in water scarce regions, it would be possible for farmers to maintain net farm surpluses at higher energy tariff by improving productivity of water use. The empirical evidence further reinforces that the arguments against pro rata pricing are flawed. Raising power tariff in the farm sector to achieve efficiency, equity and sustainability in groundwater use is socially and economically viable.

Keywords: Physical water productivity, water productivity in economic terms, effective water use, effective water productivity, farm level water productivity

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1.0 INTRODUCTION

In arid and semi arid regions of India, groundwater withdrawal for crop production exceeds the average annual recharge (Kumar, 2007). Uncontrolled withdrawal of groundwater for crop production, supported by subsidized electricity in the farm sector, leads to fast decline of water level in many parts of country. The alluvial areas of north Gujarat in western India, and hard rock areas of peninsular and central India are some such examples[3].

As irrigation is the main user of groundwater in India, raising water productivity in the ground water irrigated areas is essential for reducing groundwater draft (Amarasinghe et al., 2004; 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) 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 farmers in many water-scarce regions due to reduced net farm returns, making electricity metering in farm sector socially and economically unviable.

Agriculture accounted for almost 29 per cent of the total power consumption in India in 2001-02 (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 is estimated to have increased from Rs. 15586 crores in 1996-97 to Rs. 30462 crores in 2000-01. This is because of increasing use of electricity for groundwater pumping, which in turn increase groundwater draft[4]. In most of the 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 farm sector free of cost. Due to poor financial condition of the State Electricity Boards, they fail to supply good quality power to the agriculture sector. Pricing of electricity, in which the charge paid by farmers does 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 two 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 viable (Saleth, 1997); and 3] political opposition to metering is so high that governments shy away from the option.

A recent research by Kumar (2005) questions the validity of the first two arguments. Empirical evidence shows that with higher tariffs, the farmers use water more efficiently (by

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[3]Groundwater situation in Mehsana district of north Gujarat is a classical example of the groundwater depletion where groundwater level dropping about 0.90 meters to 6.0 meters per annum (CGWB, 1998).

[4] Due to subsidised power supply to agriculture sector, the annual losses to State Electricity Board are estimated to be Rs. 26000 crore and it is growing with a compound growth rate of 26 per cent per annum.

providing lower dosages to the crop), increase gross water productivity (Rs/m^3); and secure higher returns per unit of water used. They are motivated to allocate more water for 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, water prices are kept 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. A recent research shows that flat rate pricing increases the monopoly power of large well owners (Kumar, Singh and Singh, 2001). Also, flat rate pricing leads to inequitable distribution of power subsidy benefits among well owners (Kumar and Singh, 2001; Howe sand Murugai, 2003). Kumar (2007), on the basis of evidence from Mussafarpur in Bihar 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)[5]. They assume that this would reduce the energy use and groundwater draft for agriculture. There is no evidence to support this logic. 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[6]. The economic prospects of irrigated farming are more elastic to quality of irrigation water rather than 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.

Nevertheless, there are some positive developments in some states in the recent past. Since 2001, the government of Gujarat had only provided metered connections for agriculture. Nearly 12,000 farmers are already having metered power connections in north Gujarat alone. Here, farmers pay Rs.0.7/KWhr for electricity consumed. In Orissa, which is agriculturally one of the most backward states, electricity supply to farmers is through villages electricity co-operatives, known as *Vidyut Sanghs*, which does metering and billing. The agency does metering at the feeder level, and charges to the co-operatives. Studies on the impact of such policy interventions in promoting efficiency, access equity and sustainability in resource use are lacking.

[5] In the hard rock areas of Gujarat, farmers are unable to run their pump for 6-8 hours continuously due to lack of water availability in the wells and higher rate of drawdown, resulting farmers are forced to run tube wells only for a 2-3 hours at a time and stop pump for 3-4 hours to accumulate water in the well.

[6]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 watering of crops. The result is that they are getting less output per unit of irrigation water.

3.0 OBJECTIVES AND HYPOTHESIS

The overall objective of the study is to analyze the socio-economic viability of pro rata pricing of electricity in agriculture. Specific objectives are: 1] to study the impact of change in mode of electricity pricing on 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 prospects of farming; and, 3] to analyze the impact of change in mode of electricity pricing on the functioning of water markets.

The major hypothesis tested in this study is that with mounting cost of energy used for groundwater pumping, farmer would use energy and groundwater water more efficiently; shift their cropping system towards water efficient and high valued crops, take higher farming risks, thereby overcoming the potential negative impacts.

4.0 APPROACH AND METHODOLOGY

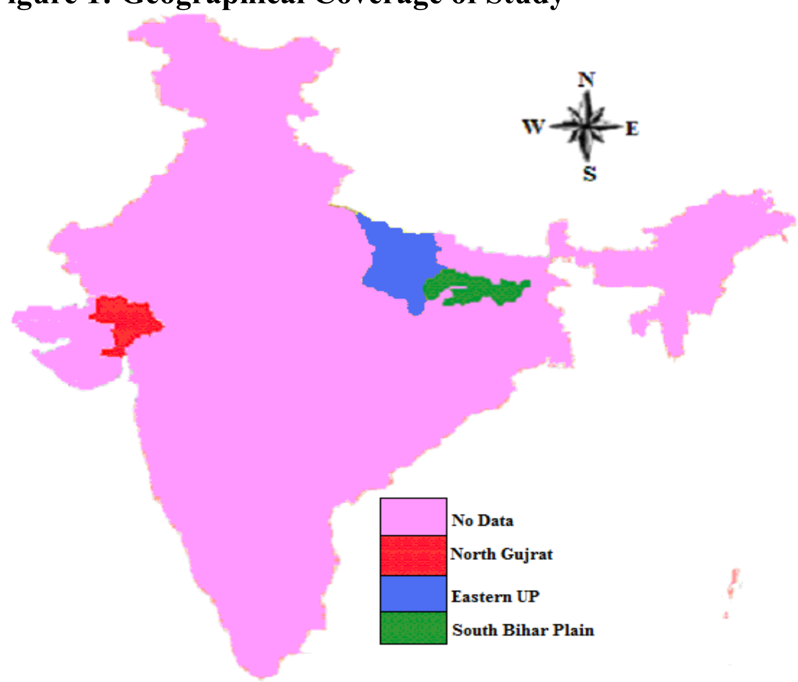
4.1 Study Area

North Gujarat, which is a water scarce region and the eastern plain regions of Uttar Pradesh and Bihar, which are water rich regions constitute the geographical area for the present study.

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 regions The mean annual precipitation in the eastern plain region of Uttar Pradesh is about 1025 mm and the region's climate varies from dry sub-humid to moist sub-humid. The soil types in this sub-zone is light alluvial and calcareous clay.

The Patna district falls under the south Bihar plains; receives a mean annual rainfall of 1103mm and climate condition of region varies

Figure 1: Geographical Coverage of Study



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 the *Tal* and *Diara*.

4.2. Sampling Procedure and Data Collection

Primary and secondary data relating to crop and livestock production was obtained. 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 (dry and green fodder, feed, drinking water) and outputs, and unit price of inputs and outputs.

The districts of Mirzapur and Varanasi were selected from Bihar and UP for the study. Five contiguous villages were selected for primary survey to draw the required sample for diesel and electric well owners, and water buyers. The sample size was 60 electric pump owners, 60 diesel pump owners, 60 water buyers from electric pumps and 60 water buyers from diesel pumps.

Two talukas - Palanpur and Vadgam of Banaskantha district were selected from north Gujarat. Samples of 120 farmers who have metered electricity connection were obtained from 29 villages for data collection. Of this, 60 electric pump owners who paid power tariff on the basis of the connected load, and remaining 60 electric pump owners paid power tariff on the basis of actual consumption of electricity.

In south Bihar, Patna, Maner and Danapur development blocks were selected for primary survey. From each block, one village was selected. Thus, the two villages selected were Baluan and Hathiyakand. The sample farmers of the Baluan village were dependent on diesel pumps whereas in Hathiyakand, farmers are dependent on electric pumps. From Baluan village, 60 diesel pump owners and 60 water-purchasing counterparts were selected. Likewise, from Hathiyakand, 60 electric pump owners and their water purchasing counterparts were selected. The detail of sample size is given in Table 1.

Table 1: Sampling Procedure and Sample Size

Name of the Regions	Name of the district	Types of Energy Tariff				Diesel pump		Total sample size
		Flat Rate		Unit Pricing		Well owner	Water buyers	
		Well owner	Water buyers	Well owner	Water buyers			
Water Scarce								
North Gujarat	Banaskantha	60	-	60	-	-	-	120
Water Rich								
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**

4.3 Methodology

Analysing the efficiency and sustainability impacts of change in mode of pricing

There are very few locations in India where farmers pay for electricity based on consumption. Gujarat is one such state. Therefore, to analyze the potential impacts of introducing pro-rata pricing of electricity in farm sector, with marginal cost of using groundwater, the farmers who are using diesel pumps for well irrigation and water buyers are used as proxy for pro-rata tariff.

The price of electricity used for pumping groundwater influences water productivity in many different ways (Kumar, 2005). The efficiency impacts change in mode of pricing by comparing water productivity of crops in physical terms. We can examine the impact of change in mode of pricing on economic viability of farming by comparing the overall water productivity of crops, livestock and farming system under the two conditions. The sustainability impacts of price changes can be analyzed by looking at the changes in groundwater withdrawal by well owning farmers.

In the study, we only consider 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 disturb the inferences drawn from the study due to three reasons: i] 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. If rainfall use increases, it will not change the recharge to groundwater.

Return flows would be insignificant in semi arid north Gujarat due to deep water table conditions. However, return flows from irrigation can be quite significant in both UP and Bihar plains due to alluvial geology and sub-humid climatic conditions. The farmers in this region 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 the regions. The farmers in these two regions will not be concerned with reducing the depleted water per se, as it is in abundance.

B. Estimating Water Productivity of Farming System

The physical water productivity for a given crop (kg/m^3) will be estimated using data on crop yield and the estimated volume of water applied for all sample farmers growing that crop. 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 in cubic meter. To estimate the net income from a particular crop, the data on inputs for each crop was obtained by primary survey of farmers. This included cost of seed, labour, fertilizer, pesticides and insecticides, irrigation, ploughing, harvesting and threshing.

The physical productivity of water in milk production for livestock WP_{Milk} (litres/m^3) can be defined as:

$$WP_{Milk} = \frac{Q_{MP}}{\Delta_{Milk}} \quad \text{.. (1)}$$

Where, Q_{MP} is the average daily milk output by one unit of livestock category over the entire live cycle (litres/animal/day). Δ_{Milk} is the total volume of water used per animal per day, including the water embedded in feed and fodder inputs, used in dairying for an animal in a day, worked out for the entire animal life cycle (m^3/animal/day). It is estimated as:

$$\Delta_{milk} = \frac{Q_{cf}}{WP_{cf}} + \frac{Q_{df}}{WP_{df}} + \frac{Q_{gf}}{WP_{gf}} + \Delta_{DW} \quad \text{..................... (2)}$$ (Singh, 2004; Kumar, 2007)

Where Q_{cf}, Q_{df} and Q_{gf} are the average quantities of cattle feed, dry fodder and green fodder used for feeding a livestock unit per day (kg/animal/day); WP_{cf}, WP_{df} and WP_{gf} are the physical productivities (kg/m^3) of cattle feed, dry fodder and green fodder, respectively; Δ_{DW} is the daily drinking water consumption by livestock (m^3/day). It is the average volume of water required by a dairy animal per day over its entire life cycle, including the water embedded in feed and fodder.

Q_{cf}, Q_{gf}, Q_{df} and Δ_{DW} for a given category of livestock would be estimated for the entire life cycle of the animal from the following: i] weighted average of the average daily figures of these inputs for each season for animals in different stages of the life cycle, viz., calving, lactation stage, dry stage; and ii] the time period in each stage of animal life cycle for that category of life stock.

Since all the farmers in the sample may not have animals that represent all the different stages of the life cycle in a particular category of livestock at a given point of time, the average values of inputs are worked out as value of above mentioned variables for the sample farmers. Likewise, the average values of physical productivity of water in green fodder and dry fodder are used for estimation. Q_{MP} (lit/animal/day) is estimated from: i] the weighted average of average daily figures of milk yield for different seasons; and ii] the ratio of time period in lactation and the average life span of the animal in that category.

WP_{gf} and WP_{df} is estimated by taking their respective quantities and the volume of water required for growing that crop. In the case of by-products of crops used as fodder, the water used for growing that crop is allocated as the main product and by product in proportion to the market prices of the respective (Singh, 2004).

The net return of milk production, NR_{milk} (Rs/animal/day) is estimated using values of Q_{MP}, the price of milk (Rs/litre) and the cost of production of the average amount of cattle inputs required in a day (Rs/animal/day) estimated for the entire animal life cycle as proposed by Singh (2004) and Kumar (2007). It is important to mention here that with import of green or dry fodder in a farm, the cost of fodder input could also go up. This in turn would affect net water productivity in dairying WP_{Milk} (Rs/m^3). It can be estimated as:

$$WP_{dairy} = \frac{NR_{milk}}{\Delta_{milk}} \quad \text{.. (3) (Singh, 2004; Kumar, 2007)}$$

In the case of purchase of inputs market price is used. If the inputs are from the farmers' own fields, the actual cost of production is estimated. If farmer uses crop by-products for dairying, the total cost of production of the given crop is allocated among the main product and by-product on the basis of the potential revenues that can be earned from their sale. The quantity of inputs (feed and dry and green fodder) and milk outputs are worked out for the entire animal life cycle and not on the basis of the actual use of inputs and milk yield at the point under consideration.

The total volume of water used for milk production annually by one unit of livestock V_{dairy} (m^3 /animal/annum) is estimated by dividing the total annual milk production by one unit of livestock (Q_{AMP}) by the physical productivity of water in milk production (WP_{dairy}).

The water productivity of the farm WP_{farm} (Rs/m^3), including crops and dairy is estimated as:

$$WP_{farm} = \frac{\sum_{i=1}^{m} WP_{crop\,i} V_{crop,i} + \sum_{j=1}^{n} WP_{dairy} V_{dairy,j} N_j}{\sum_{i=1}^{m} V_{crop,i} + \sum_{j=1}^{n} V_{dairy,j}} \quad \text{............................ (4)}$$

Here, $WP_{crop,i}$ is the water productivity of main product of crop i; $V_{crop,i}$ is the total volume of water used for crop i; $WP_{dairy,j}$ is water productivity in dairy production for livestock type j; and $V_{dairy,j}$ is the volume of water used for dairy production per animal for livestock category j. N_j is the total number of livestock in category j

C. Impacts of Different Modes of Energy Pricing on Equity in Access to Groundwater

The equity impact of different modes of energy pricing on groundwater use is analyzed by comparing the water charges (Rs/m^3) paid by the water buyers under the flat rate and unit pricing of electricity against the cost (Rs/m^3) farmers have to incur for access to groundwater if he decides to have his own well under both situations i.e., flat rate and unit pricing. For this, data was collected on: [i] water charges paid by water buyers under both the tariff regimes; [ii] cost of installation of bore/tube well; [iii] energy charges under flat and unit pricing paid by farmers annually; [iv] the land holding size; and, [v] well repair and maintenance cost.

5.0 RESULTS AND DISCUSSION

5.1 Distribution of Land Holdings

The average size of land holding of different categories of farmers in the study area is provided in Table 2. In north Gujarat, the average size of land holding is higher for tube well owner who are paying power tariff on connected load basis (3.79 ha) as compared to their counterparts having metered connection (3.28 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 commands 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 like eastern UP, the average size of land holdings for both well owners and water buyers in the diesel pump commands is higher than that of their counterparts in electric pump commands. The well owners in electric well commands 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 owner here is 1.26 ha, whereas for water buyers it is 0.57 ha.

From the data presented in Table 2, it is also clear that in the average size of land holding in water abundant eastern Uttar Pradesh and south Bihar plains is much smaller compared to water scarce north Gujarat. This is one of the important factors for utilizing 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*., 2008). 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, which is available in plenty.

Table 2: Average Size of Land Holding of Sample Farmers in the three Locations

Name of the Regions	Name of the district	Electric Pump		Diesel pump	
		Unit Pricing	Flat Rate	Well owner	Water buyers
North Gujarat	Banaskantha	2.95 (0.33)	3.45 (0.34)	NA	NA
		Well Owner	Water Buyer		
Eastern UP	Varanasi and Mirzapur	1.30	0.560	1.35	0.940
South Bihar Plains	Patna	0.730	0.530	1.260	0.570

5.2. 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 operational 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 kwhr 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 western UP, northern Gujarat and south Bihar and are presented in the Table below.

Area	Water source	Average (rs/m^3)	Range (rs/m^3)
Western 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 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 buyers	0.70	0.31 – 0.92
	Diesel pump owners	1.87	1.51 – 2.95
	Diesel pump buyers	2.15	1.84 – 2.42

The unit rates charged by diesel pump owners for irrigation services are much higher than that of electric pump owners.

5.3 Area Allocated by Farmers for Different Crops in Eastern UP

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 (Given in the annexure). 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. It is because of the high rainfall, which can meet a large part of the crop water requirement.

In diesel well commands, pump owners allocate about 26% of the gross cropped area under paddy cultivation, whereas in the case of water buyers, it is only 22%. In electric well commands, pump owners allocate 11.51% to paddy and water buyers allocate about 14.8% to paddy. Electric pump owners also grow groundnut. Water buyers in both electric and diesel well commands allocate larger portion of the gross cropped area under green fodder and other vegetables during kharif season as compared to pump owners. Water buyers in diesel well commands grow *Arhar.* Water buyers in electric well commands grow lady's finger.

Major crops grown during winter season are wheat and barley, potato, pea, gram, mustard, linseed and barseem. In electric well commands, the area allocated under wheat, potato, pea, barseem is lower for pump owners whereas gram, mustard, linseed and barley area allocation is higher for 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 difference is not seen in case of electric well commands. This could be because the hourly rate for irrigation water charged by diesel pump owners is four times higher than that charged by electric pump owners. During the summer season, major cops grown in electric pump commands are green fodder, sunflower and vegetables. While all these crops are grown by the electric pump owners, only green fodder is grown by water buyers. In diesel well commands, crops grown during summer season are green fodder and vegetables. Both diesel well owners and water buyers here allocate some area under green fodder.

5.4 Cropping pattern in North Gujarat

In the case of north Gujarat, major crops grown by the tubewell owners under both tariff regimes are green fodder (fodder bajra and alfalfa), foodgrain crops (jowar and bajra), pulses (black gram and green gram), groundnut and cash crops (cluster bean, cotton and castor). The farmers of this region allocate small area under green fodder throughout the year (major crops are alfalfa, fodder bajra and chikudi). Table 4 in the annexure gives the cropping pattern of well owners in north Gujarat.

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 and sensitive cash crop. The major crops grown during summer season are green fodder (Kachchhi alfalfa[7] and fodder bajra) and bajra. The area allocated by flat and unit pricing tariff tubewells owners under the bajra crop is about 10% of the gross cropped area.

5.5 Cropping pattern in South Bihar

Cropping pattern of well owners and water buyers under different energy regimes and area allocated by the farmers under different crops in south Bihar are presented in Table 5 (in the annexure). In the region, very high monsoon rain results in submergence of most of the cultivated land during kharif season. During this season, farmers grow two crops viz.,

[7] Two types of alfalfa are grown in the region: [1] the first one is sown during winter and is harvested by month of April i.e., the crop duration is about 6 months; and [2] the second one is Kachchhi alfalfa, which has a duration of nearly three years. Those farmers having good irrigation facility grow Kachchhi alfalfa get green fodder through out the year.

paddy and green fodder, with larger area under paddy. Out of the gross cropped area, nearly 38% is under paddy and less than 3% is under green fodder. During winter, farmers grow wheat, gram, mustard, barseem (fodder), vegetables (potato, radish and carrot) and coriander. Largest area is under wheat. During summer, farmers grow onion, maize and green fodder.

There is very little difference in kharif cropping pattern found 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 allocate larger area for 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.

6.1 Irrigation Water Application and Crop Water Productivity

In this section, we present the estimates of irrigation water application, physical water productivity (kg/m^3) of main and by-products and net water productivity in economic terms (Rs/m^3) of different crops grown by electric/diesel pump owners and water buyers in their commands. 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 through better agronomic input.

Eastern UP: Electric Pumps

Table 6 presents the estimates of irrigation water dosage productivity of water in physical (kg/m^3) and economic terms (Rs/m^3) under electric pump ownership and irrigation water purchase for villages in eastern UP. In case of electric pump owner, total amount of irrigation water applied for crop production is higher as compared to irrigation water buyers. For most of the crops, both physical and economic productivity of water are higher for water buyers than their water-selling counterparts.

Eastern UP: Diesel well commands

Similar values for diesel pump owners and water buyers are presented in Table 7 (annexure). The cropping pattern of pump owners and water buyers is almost the same, 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.

Table 7 shows 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.

North Gujarat: Flat and Unit Energy Pricing Regimes

Table 8 (annexure) presents similar data for different energy pricing regimes. Electric pump owners pay marginal cost for electricity and therefore maintain higher water productivity in both physical and economic terms for all the crops.

The 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 are presented in Table 9 (annexure). Water buyers apply less water to their crops, and maintain higher physical water productivity values for many crops in comparison to electric well owners (paddy, maize, barseem, onion and summer maize). However, they maintain 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 the values of numerator of water productivity. Table10 (annexure) presents figures of water use and water productivity of diesel well commands of south Bihar plains - both in physical and economic terms.

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.

Consolidated picture of net water productivity in economic terms for different geographical segments of the study area and for different energy regimes is given in Table 13. The trends are as follows: A] The net water productivity of water buyers from electric pumps is more both in east UP and south Bihar; B] Net water productivity of electric pump owners under flat rate provision is comparatively less than that under unit price tariff; C] Water productivity of electric pump owners in economic terms is less than that of diesel pump owners; and, D] Economic water productivity of water buyers from electric pumps is less than those buying water from diesel pump sets.

6.2 Livestock Water Productivity

1 <u>Feed and Fodder Use</u>

Farmers of eastern UP keep buffalos, crossbred cows and indigenous cows. Most of the farmers in the region keep a combination of livestock i.e., buffalo with indigenous cow or buffalo with crossbred cow. The reason behind this is that while buffalo milk fetches higher price, cow milk is used for domestic consumption. Green fodder includes chary, barseem and MP chary. *Bhusa* (which is a concentrate of barley flour and mustard cake) is used as dry fodder. In general, farmers feed larger quantity of green fodder for milking animals.

Weighted average of feed and fodder input to livestock worked out for the entire animal lifecycle by farmers for west UP are presented in Table 11.

Table 11: Average Feed and Fodder Used Based on Lifecycle of Animal in eastern UP

	Feed and Fodder Use (kg/day/animal)

	Electric Pump – Owner			Electric Pump – Water Purchaser		
	Buffalo	Crossbred Cow	Indigenous Cow	Buffalo	Crossbred Cow	Indigenous Cow
Total Green Fodder	14.09	14.88	13.61	13.77	19.49	14.81
Total dry fodder	10.11	12.07	9.58	8.89	12.73	9.29
Total Concentrates	1.19	1.53	1.13	1.01	1.78	1.17

Source: Author's own estimate based on primary data

Similar estimates for livestock inputs for farmers in diesel well command in eastern UP were carried out. In case of pump owners, the average amount of feed and fodder fed to livestock were about 36, 43.35 and 31.71 kg/day/animal for buffalo, crossbred cow and indigenous cow, respectively. The corresponding numbers for water buyers were 37.5, 38.06 and 33.72 kg/day/per animal, respectively.

In north Gujarat, estimates of average feed and fodder input were made separately for farmers with metered and non-metered power connections. Farmers with metered power connection on average fed 13.68, 15.77 and 9.39 kg/day/animal of green fodder and 14.96, 16.32 and 12.13 kg/day/animal dry fodder to buffalo, crossbred cow and indigenous cow respectively. Quantity estimates were greater for farmers with non metered connections at 19.56, 23.18, and 9.25 kg/day/animal green fodder and 21.78, 25.64 and 20.95 kg/day/animal dry fodder to buffalo, crossbred cow and indigenous cow, respectively.

Similar estimates are available separately for farmers in the electric well commands and diesel well commands for south Bihar. The average amount of feed and fodder supplied by pump owner farmers in electric well commands to buffalo, crossbred cow and indigenous cow are 24.07, 24.75 and 16.09 kg/day/animal, respectively. The corresponding figures for water buyer-farmers in electric well commands are 21.92, 33.37 and 19.81 kg/day/animal, respectively. In case of diesel well commands, the average feed and fodder fed by diesel pump owner to buffalo, crossbred cow and indigenous cow are 35.34, 25.82 and 21.05 kg/day/animal, respectively. The corresponding figures for water buyers are 26.31, 27.56 and 29 kg/day/animal, respectively.

In general, in eastern UP and south Bihar, water buyers (in both diesel and electric well commands) and farmers with non metered connections fed more input to their cattle.

2. Average Milk Production

The estimates of average milk production from dairy animals for electric well owners, worked out for the entire animal life cycle, are 2.91, 4.64 and 1.81litres/day/animal for buffalo, crossbred cow and indigenous cow, respectively. This is higher than that for water buyers, in whose case the figures are 2.64, 4.08 and 1.89 litres/day/animal. The corresponding estimates for farmers in the diesel well commands are; for well owners, 2.08, 4.01 and 1.95 litres and for water buyers, the values are 2.23, 3.23 and 2.01, for buffalo, crossbred cow and indigenous cow, respectively.

The estimates of average daily milk production in north Gujarat region are as follows. In case of farmers who have metered electricity connections, the average milk production from buffalo, crossbred cow and indigenous cow are 5.14, 7.5 and 1.91 litres/animal/, respectively. Same estimates for non metered connections are higher at 6.96, 9.32 and 6.43 litres. Such higher yields in the case of farmers with flat rate connections are due to the higher amount of feed and fodder that they are providing to dairy animals.

The estimates of average milk production for different dairy animals in electric well commands in South Bihar are as follows. For pump owners, 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 commands 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.

3 Water Use for Milk Production

The estimates of the volume of water used for 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 12. 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 irrigation water buyers.

Table 12: Water Use for Milk Production in Electric Pump Command Area, Eastern Uttar Pradesh (m^3/day)

Types of Feed & Fodder	Electric Pump – Owner			Electric Pump – Water Purchaser		
	Buffalo	Crossbred Cow	Indigenous Cow	Buffalo	Crossbred Cow	Indigenous Cow
Green Fodder	1.11	1.17	1.08	0.96	1.36	1.03
Dry Fodder	0.89	1.07	0.85	0.72	1.03	0.75
Concentrates	0.61	0.77	0.57	0.49	0.94	0.58
Drinking Water (m^3)	0.018	0.019	0.013	0.018	0.019	0.013
Total Water Use (m^3)	2.63	3.02	2.50	2.19	3.35	2.38
Milk Production (Lt)	2.91	4.64	1.81	2.64	4.08	1.89
Milk WP (Lt/m^3)	1.11	1.54	0.72	1.20	1.22	0.79
Gross WP (Rs/m^3)	11.95	15.52	6.72	12.97	12.31	7.35

Source: Author’s own estimates based on primary data

For diesel well commands, the estimates of volume of water used for milk production by water sellers are 3.02 m^3, 3.48 m^3 and 2.68 m^3/day/animal for buffalo, crossbred cow and indigenous cow respectively, whereas in case of irrigation water buyers, the corresponding figures are 3.00 m^3, 3.21 m^3 and 2.64 m^3/day/animal. The physical productivity of water for milk production are 0.69, 1.15 and 0.73litre/m^3, respectively for pump owner and 0.75, 1.00 and 0.76litre/m^3 for water buyers. The average values of gross water productivity in milk production in economic terms from buffalo, crossbred cow and indigenous cow are Rs. 11.03/m^3, 16.13/m^3 and 5.45/m^3 respectively for pump owner and Rs 11.93/m^3, 14.06/m^3 and 11.38/m^3 for water buyers.

For north Gujarat farmers, the estimates of embedded water used for milk production and the water productivity in physical and economic terms are as follows. In the case of farmers who have flat rate connections, average volume of water used for milk production from buffalo, crossbred cow and indigenous cow/day/animal are 9.77 m^3, 10.43 m^3 and 8.39 m^3, respectively. The corresponding average values of physical productivity of water in milk production (lt/m^3) are 0.53, 0.72 and 0.23, respectively and of gross water productivity in economic terms (Rs/m^3) are is 8.48, 10.43 and 2.96, respectively. In the case of well owner having metered connections, the average values of total volume of water used for milk production are 14.63 m^3, 17.39 m^3 and 10.90m^3/day/animal for buffalo, crossbred cow and indigenous cow, respectively. The corresponding values of physical water productivity for milk production (lt/m^3) are 0.48 litres, 0.54 and 0.59, respectively and of gross water productivity in economic terms (Rs/m^3) are 7.39, 6.47 and 8.85, respectively for buffalo, cross bred cows and indigenous cows respectively.

The estimates of embedded water used in milk production in electric well commands for south Bihar plains are as follows. The electric pump owners use an average of 3.96 m^3, 4.92 m^3 and 2.81 m^3 of water per animal per day for buffalo, crossbred cow and indigenous cow, respectively. The corresponding figures for water buyers in their commands are 4.09 m^3, 5.36 m^3 and 3.37 m^3, respectively. The physical productivity of water used in milk production (lit/m^3) from buffalo, crossbred cow, and indigenous cow in the case of water buyers are 0.45, 0.48 and 0.28. The corresponding values of gross water productivity in economic terms (Rs/m^3) are 7.01, 6.66 and 3.95, respectively.

The estimates available for farmers in diesel well commands are as follows. The diesel pump owners use an average of 4.88, 3.93 and 2.73 m^3 of water/animal/day for buffalo, crossbred cow and indigenous cow, respectively. For water buyers, the corresponding figures are 3.62, 3.18 and 3.04, respectively. The physical productivity of water for milk production (lit/m^3) in case of pump owners for buffalo, cross bred cow and indigenous cow are 0.35, 0.90 and 0.50, respectively. The corresponding figures for water buyers are 0.46, 0.72 and 0.39, respectively. The average values of water productivity in milk production in economic terms (Rs/m^3) are 4.85, 10.60 and 7.00 respectively for buffalo, cross bred crow and indigenous cow. The corresponding figures for water buyers are 6.50, 8.52 and 5.45, respectively.

4 Net Water Productivity in Economic Terms

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. The total cost of green fodder, dry fodder and concentrate, the income from milk and cow dung and total and effective water use for dairy production were estimated. Based on these data, both the net water productivity and effective net water productivity in economic terms were 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 are presented in Table 14.

Table 14: Water Productivity in Economic Terms in Milk Production, Electric Pump, Eastern Uttar Pradesh

Types of Feed & Fodder	Electric Pump – Owner			Electric Pump – Water Purchaser		
	Buffalo	CB Cow	Indigenous Cow	Buffalo	CB Cow	Indigeno us Cow
1. Green fodder (Rs)	3.29	3.50	3.29	4.52	6.4	4.9
2. Dry fodder (Rs)	3.03	3.62	3.03	2.67	3.82	2.79
3. Concentrates (Rs)	6.51	8.39	6.51	5.54	9.58	6.38
4. Total expenditure (Rs/day)	12.84	15.52	12.84	12.73	19.80	14.03
5. Milk production (Lt)	2.91	4.64	1.81	2.64	4.50	1.89
6. Gross income from milk (Rs)	31.39	46.86	16.83	28.44	45.48	17.51
7. Income from dung (Rs/day)	0.50	0.50	0.50	0.5	0.5	0.5
8. Gross income (Rs/day)	31.89	47.36	17.33	28.94	45.98	18.01
9. Net income (Rs/day)	19.05	31.84	4.50	16.21	26.18	3.98
10 Net water productivity (Rs/m^3)	7.25	10.55	1.80	7.39	7.82	1.67

Source: Author's own estimate based on primary data

Table 14 shows that well owners secure higher net water productivity in milk production than water buyers for all types of livestock. Analysis of similar estimates for diesel well commands in eastern UP shows the following. The values of net water productivity in economic terms for the pump 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 pump owners in electric well commands secure highest effective 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 effective net water productivity in economic terms for milk production from buffalo, crossbred cow and indigenous cow under flat energy pricing regime are Rs 3.73/m^3, Rs 5.88/m^3 and Rs -1.85/m^3, respectively. In case of farmers under pro rata pricing regime, the values are Rs 3.31/m^3, Rs 2.29/m^3 and Rs 3.37/m^3, respectively. It is clear that over all effective net water productivity is higher under pro rata pricing regime.

In south Bihar, the estimates of average effective net water productivity in milk production for electric well commands for electric pump well owner are Rs 2.18/m^3, 1.96/m^3

and -1.0/m^3 and for water buyers are the values are Rs 1.65/m^3, 3.89/m^3 and -0.64/m^3 for buffalo, crossbred cow and indigenous cow respectively. For diesel well commands, pump owner's effective net water productivity in economic terms (Rs/m^3) are -0.47, 5.68 and -250; and for water buyers are 0.07, 2.09 and -1.26, for buffalo, cross bred cow and indigenous cow, respectively.

7.1 Farm Level Water Productivity

Using more water means paying more for the pump rental services. Farmers should try and economize on the use of water, though it is not a scarce resource in eastern UP and south Bihar. Farms are the unit for many investment decisions by farmers in agriculture including water allocation decisions. They try to optimize water allocation over the entire farm, rather than individual crops, to maximize their returns. Hence, 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.

Table 15: Farming System Level Water Productivity in Agriculture under Different Pricing Regimes

Name of the Regions	Name of the district	Electric Well Command		Diesel Well Command	
		Flat Rate	Unit Pricing	Well owner	Water buyers
North Gujarat	Banaskantha	6.20	7.90	NA	NA
		Well Owner	Water Buyer	Well Owner	Water Buyer
Eastern UP	Varanasi and Mirzapur	10.95	11.18	8.67	12.89
South Bihar Plains	Patna	9.28	10.13	11.97	12.43

Our analysis clearly shows that the farm level water productivity is much higher for water buyers in diesel well commands in eastern UP and south Bihar. 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 unit 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. Water productivity difference is also quite substantial in north Gujarat between farmers with flat rate connection and those with metered connections.

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.

7.2 Impact of Different Modes of Energy Pricing on Equity in Access to Groundwater

As discussed in the methodology, the impacts of energy pricing on access equity in groundwater can be examined by studying how the increase in cost of production of groundwater influences the price at which water is traded. This can be studied by analyzing the changes in monopoly price ratios[8] for water traded in the market with change in mode of pricing. In the case of north Gujarat, we had a real life situation of farmers shifting from flat rate system to the pro rata system of electricity consumption. However, these farmers are not into water trading. Hence, the water markets in electric and diesel well commands of eastern UP and south Bihar were compared vis-à-vis the monopoly price ratios and the volume of water traded.

Through this analysis, we would test one dominant hypothesis by Shah (1993) that under flat rate system of pricing, well owners would have a strong incentive to pump out more water and as a result, the price at which water is traded in the market would come down, and come close to the cost of production of water. Kumar (2007) had challenged this hypothesis arguing that it is rather the number of potential sellers against the number of potential buyers citing evidences from Mussafarpur in Bihar.

Table 16: Selling Price of Well Water and the Monopoly Price Ratio under different Pricing Regimes

Name of the Regions	Name of the district	Selling Price of Water and Monopoly Price Ratio in			
		Electric Well Command		Diesel Well Command	
		Selling Price	MPR	Selling Price	MPR
North Gujarat	Banaskantha				
Eastern UP	Varanasi and Mirzapur	0.65	3.50	2.81	1.85
South Bihar Plains	Patna	0.70	0.90	2.15	1.15

Table 16 shows that in eastern UP, the MPR (monopoly price ratio) was higher in the case of electric well commands than that in diesel pump well commands. While the price charged by electric pump owners was 3.6 times more than their cost of pumping, the price charged by diesel pump owners is only 1.8 times higher than their cost of pumping. In south Bihar, the trend is just the opposite. The average price charged by electric well owners is lower than the implicit cost of pumping water (Rs.0.70/m^3 against Rs. 0.77/m^3). Whereas the average price charged by diesel well owners (Rs. 2.15/m^3) is higher than the cost they incur for pumping groundwater (Rs.1.87/m^3).

These are based on average figures of cost and price. A look at the cost and price figures for individual wells brings out a different picture. A few farmers have very high implicit cost of pumping groundwater, higher than the selling price. The reason is that the capital cost of the well and the pump set constitutes a major chunk of the cost, and the unit cost becomes high only because the wells run for fewer hours[9]. But, the monopoly price charged by many other farmers is higher under flat rate system for electric wells, as

[8] It is the ratio of the price of water and its actual cost of production incurred by the well owner.

compared to those for diesel wells. These are farmers who have larger holdings due to which the pumping becomes very low.

Another interesting phenomenon found in both electric and diesel well commands is that the selling price of water is more or less same across the farmers, though the unit cost of pumping water varies across farmers. The selling price is decided by the market conditions irrespective of the cost farmers incur for pumping water (Kumar *et al*., 2001). Fewer numbers of potential sellers against a large number of potential buyers would increase the monopoly power of well owners. This is due to the poor transferability of water. Perhaps this is what is happening in the village with electric pumps in eastern UP. On the other hand, presence of large number of sellers against a few buyers would reduce the monopoly power of well owners. They would be forced to sell water at prices conditioned by the market (Kumar, 2007). Perhaps this is what is happening in the village with electric pumps in south Bihar.

In nutshell, the mode of pricing of electricity does not influence the monopoly prices being charged by well owners in the market. On the other hand, the flat rate pricing puts large well owners in a very advantageous position as they could bring down their implicit unit cost of pumping groundwater.

7. 4 Groundwater Pumping

Often the distinction between efficiency and sustainability is not made (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 and the cropping intensity. 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 larger hours of pumpage per ha of cultivable area as value of numerator would increase and that of denominator would reduce.

Table 17: Average Hours of Groundwater Use by Farmers under Different pricing Regimes

Name of the Regions	Name of the district	Groundwater Pumpage by Electric Pump Owners		Diesel pump	
		Unit Pricing	Flat Rate	Well owner	Water buyers
North Gujarat	Banaskantha	303.88	443.88	NA	NA
		Groundwater Use in Electric Well Command by		Groundwater Use in Diesel Well Command by	

[9] Such an approach to working out the unit cost, in which the capital cost is considered along with O & M, is valid only in long term marginal cost calculations. But, in reality the farmers do not consider this cost in their decision making framework is for short time duration. Therefore, the real marginal cost of pumping is very low, which means the MPR is high.

		Well Owner	Water Buyer	Well Owners	Water Buyers
Eastern UP	Varanasi and Mirzapur	175.38	183.93	222.23	148.00
South Bihar	Patna	329.97	249. 74	231.11	197.91

But, the results from three locations 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. The data for north Gujarat shows that in spite of having smaller sized land holdings (2.95 ha against 3.45 ha), the pump owners having metered connections use much less water per unit of land as compared to their counterparts having flat rate connections (303.88 hours per year against 443.88 per year). The difference in aggregate pumping is much higher between farmers with meters and those without meters. 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.

But, in spite of slight reduction in pumping, the net return from unit of land is higher for water buyers in eastern UP and South Bihar plains. This is achieved through high enhancement in water productivity through selection of crops that are less water consuming and high valued.

Table 18: Net Income from Crop and Milk Production, three Locations

Type of Well Command	Type of farmer	Gross cropped area (Ha)	Net income from crops (Rs)	Net income from dairying (Rs/day)	Total Farm level Income (Rs)	Farm level net income (Rs/Ha)
Electric Well	Well owner	5.29	124587.3	7152.3	131739.6	24880
	Water buyer	2.21	54637.6	6165.0	60802.6	27570
Diesel Well	Well owner	5.66	74764.5	7429.5	82193.9	14528
	Water buyer	3.79	62323.1	6260.6	68583.7	18075
	Flat Rate	13.35	369119.7	30048.0	768287.4	57531
Electric Well	Metered	11.77	311806.9	45636.0	669250.2	56882
Electric Well	Well owner	3.14	120477	10292.6	130769.5	210345
	Water buyer	1.70	61517.7	8130.9	76023.9	190031
Diesel Well	Well owner	2.49	140105.0	9958.1	150063.6	191387
	Water buyer	1.60	71810.0	12232.2	84042.5	197895

Authors' own estimate based on primary data.

8. 1 MAJOR FINDINGS

The major findings emerging from the analysis of data from three locations are as follows:

1. Farmers who have metered power connection not only pay positive marginal cost of using well water, but also pay higher cost for every unit of irrigation water (Rs/m^3) as compared to their counterparts having flat rate connections. Similarly, farmers who are buyers of water from electric pump owners and diesel well owners in eastern UP and south Bihar also pay positive marginal cost of using irrigation water pay higher unit costs of irrigation water compared to water selling counterparts.

2. Minor differences are found in the cropping pattern of well owners and water buyers in electric and diesel well commands; and between farmers with metered electricity connections and farmers with flat rate connections. The water buyers (in eastern UP and south Bihar) and farmers who have metered electricity connections allocate some amount of land for highly water-efficient crops, which are also less water consuming.

3. Water buyers in diesel and electric well commands, and the farmers who have metered power connections in agriculture pay for water on volumetric basis. Our analysis suggests that they secure higher water productivity in physical terms (kg/m^3) for most crops as compared to water selling well owners through: careful use of irrigation water (as reflected in lower water application rates) and agronomic practices (as reflected in higher yield rates). This means that when confronted with positive marginal cost of irrigation water, farmers are encouraged to use water more efficiently.

4. Water buyers in diesel and electric well commands, and farmers who have metered electricity connections secure higher water productivity in economic terms for many crops as compared to water selling well owners through: careful use of irrigation water, optimizing costly inputs and obtaining higher yield rates through farm management. This means that when confronted with positive marginal cost of irrigation water, farmers would be encouraged to improve economic efficiency of water use.

5. The estimated values of net water productivity in economic terms estimated for dairy animals in case of water buyers in diesel and electric well commands, and the farmers who have metered power connections in agriculture are not higher than that of water selling well owners. This could be because the cost of production of animal inputs are higher in the case of water buyers due to the higher cost of production of inputs in lieu of the higher cost of irrigation water. However, the water productivity in dairying is much lower than that of many crops grown by both well owners and water buyers in all the locations.

6. Water buyers in diesel and electric well commands, and the farmers who have metered power connections secure higher water productivity at the farm level as compared to water selling well owners through: careful use of irrigation water; agronomic inputs; optimizing costly inputs for crops; and through judicious selection of crops, cropping pattern and livestock composition, which give higher return from every unit of water consumed. The diesel well owners also secure higher water

productivity at the farm level as compared to electric well owners, as shown by data from south Bihar. These results have two major implications for policy: 1] when confronted with positive marginal cost of irrigation water, farmers are encouraged to use water more efficiently over the entire farm from economic point of view; and 2] when confronted with higher cost of irrigation water, the farmers venture into adopting farming system and optimizing use of inputs to secure higher returns from every unit of water to offset the increase in costs of irrigation.

7. Higher net water productivity in economic terms (Rs/m^3) which farmers obtain even at high cost of irrigation water is indicative of the fact that it is possible to keep irrigation costs high enough to induce improved efficiency in water use in both physical and economic terms without compromising on farming prospects.

8. Comparison of water prices charged to water buyers in diesel and electric well commands against the cost of production of water clearly show that the monopoly price charged by well owners is not a function of the mode of energy pricing. The farmers who are confronted with zero marginal cost of using energy charge even higher monopoly rates for water as compared to diesel well owners. On the other hand, the flat rate pricing puts large well owners in a very advantageous position as they could bring down their implicit unit cost of pumping groundwater. The major policy implication of this analysis is that pro rata pricing of electricity would promote equity in groundwater use, if many farmers from within the same area have access to electricity connections.

9. The water buyers in diesel and electric well commands are using much less water for every unit of net cultivated area as compared to the farmers who are well owners. In addition, the farmers who are using metered power connections are using less amount of water per unit of cultivated land. Such reduction in groundwater pumping, with a disproportionately lower reduction in net return from unit of land in the case of farmers with metered connections in north Gujarat, and no reduction in net returns in the case of eastern UP and south Bihar plains, is possible through water productivity improvement in economic terms. This indicates that introducing marginal cost for water and electricity not only promotes efficient use of water, as manifested by higher farm-level water productivity, but also more sustainable use of water.

8.2 CONCLUSIONS AND POLICY IMPLICATIONS

The past one and a half decades have seen intense debate on the potential impacts of introducing electricity pricing in the farm sector on efficiency, equity and sustainability in groundwater use, and its overall socio-economic viability thereof. There is limited empirical work in India, which shows the potential impacts of pro-rata pricing of electricity on efficiency in groundwater. It showed that the levels of electricity tariff that encourage efficient and productive use of groundwater are socio-economically viable. However, the analysis was based on comparative analysis of crop water use and water productivity data from water buyers and well owners from a single location, rather than that of farmers who pay for electricity on pro rata basis.

Introducing marginal cost for electricity motivates farmers to use water more efficiently at the field level from physical, agronomic and economic point of view through careful use of irrigation water, use of better agronomic inputs and optimizing costly inputs. Also, it would motivate farmers to use water more efficiently at the farm level through careful use of irrigation water in crops; better agronomic inputs; optimizing costly inputs for crops; careful selection of crops and cropping patterns, and livestock composition that give higher return from every unit of water and low water consuming crops. It also shows 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.

The analysis also shows that changing the power tariff structure from flat rate to pro-rata would not have any adverse effects on equity of access in groundwater in terms of increasing the monopoly power of well owners. This is because the monopoly prices are largely governed by the number of potential water sellers against the number of potential buyers of water in an area. In addition, 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 shows positive impact on sustainability of groundwater use.

The empirical evidences further reinforce the fact that the arguments against pricing are flawed. One argument against price change is the higher marginal cost of supplying electricity under metered system, could reduce the net social welfare as a result of reduction in: 1] demand for electricity and groundwater; and 2] net surpluses individual farmers could generate from cropping. The second argument is that for power tariff levels to be in the responsive region of power demand curve, prices are often so high that it may become socially unviable.

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. The empirical analyses from all locations show that the demand for water/energy per unit of land was lower for water buyers due to increase in unit price of water/energy. However, the net income surpluses from every unit of water/energy used increased.

Overall, the net returns per unit of land were marginally lower for farmers who paid on pro rata basis in north Gujarat. This is because in water-scarce regions like north Gujarat, farmers would not have constraint of land in maximizing 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 with much less amount of water by slightly expanding the irrigated area. This is more so because there is no need for regulating power supply under metered system of pricing, whereas it is compulsory under flat rate system of pricing to control the revenue losses to the electricity boards. 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 under pro rata pricing. Also, in spite of the higher prices, the net economic returns from farming per unit of land were higher for water buyers as compared to water selling diesel and electric well owners in eastern UP and south Bihar plains.

General argument against pro rata pricing is that it raises the prices at which water is traded in the market. This is based on the assumption that introduction of marginal cost of energy, farmers would not have any special incentive to pump out extra water for sale, with the result that the monopoly power of well owners would increase. However, evidence provided in the paper suggests that the monopoly price charged by well owners is not dependent on whether well owners are confronted with marginal cost of using electricity or not.

In sum, the evidence provided in the paper corroborates with the earlier evidence provided by Kumar (2005) to the effect that raising pro-rata power tariff to levels that induce improvement in productivity of energy and water use would not have any adverse impacts on the economic viability of farming. This means that introducing high power tariff in the farm sector would be socio-economically viable.

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Annexure

Table 3: Cropping Pattern of Well Owner and Water Buyers under Different Energy Regime, Eastern Uttar Pradesh

Name of the Crops	Electric Pump				Diesel Pump			
	Owner		Water Buyers		Owner		Water Buyers	
	Area (Ha)	% to GCA	Area (Ha)	% to GCA	Area (Ha)	% to GCA	Area (Ha)	% to GCA
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. Sesamum	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. Chary (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. MP chary (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: Author's own estimate based on primary data

Table 4: Cropping Pattern of Well Owner under Different Energy Pricing Regime, North Gujarat

Season	Name of the Crops	Electric Pump Owner – Flat Rate		Electric Pump Owner – Unit Pricing	
		Area (Ha)	% to GCA	Area (Ha)	% to GCA
Kharif	1. Fodder Bajra	0.26	1.58	0.39	2.91
	2. Alfalfa (Green Fodder)	0.36	2.23	0.41	3.05
	3. Jowar	1.07	6.58	1.01	7.52
	4. Bajra	0.98	6.03	0.89	6.63
	5. Black gram	0.81	5.00	0.53	3.90
	6. Green gram	0.76	4.69	0.87	6.47
	7. Groundnut	0.95	5.82	0.51	3.81
	8. Cluster bean	0.85	5.24	1.06	7.87
	9. Cotton	0.63	3.87	0.61	4.52
	10. Castor	1.17	7.17	1.10	8.17

Rabi	1. Alfalfa (Green Fodder)	0.33	2.01	0.28	2.10
	2. Chekudi (Green Fodder)	1.33	8.15	0.23	1.69
	3. Wheat	1.27	7.82	0.96	7.14
	4. Barley	0.23	1.41	0.63	4.66
	5. Rajgaro	0.91	5.62	0.73	5.39
	6. Mustard	1.14	7.00	0.75	5.53
	7. Cumin	0.90	5.50	0.81	6.04
Summe r	1. Alfalfa	0.38	2.35	-	-
	2. Fodder Bajra	0.25	1.55	0.41	3.01
	3. Bajra	1.69	10.37	1.29	9.58
	Gross Cropped Area (GCA)	**16.27**	**100.00**	**13.49**	**100.00**

Source: Author's own estimate based on primary data

Table 5: Cropping Pattern of Well Owner and Water Buyer in Diesel and Electric Well Commands, South Bihar Plain

Name of the Crops	Electric Pump				Diesel Pump			
	Owner		Water Buyers		Owner		Water Buyers	
	Area (Ha)	% to GCA	Area (Ha)	% to GCA	Area (Ha)	% to GCA	Area (Ha)	% to GCA
Kharif Season								
1. Paddy	0.751	38.97	0.467	38.42	1.083	37.68	0.541	38.02
2. Masureya (Green fodder)	0.028	1.47	0.016	1.34	0.077	2.69	0.026	1.83
3. Maize (Green fodder)	0.004	0.22	0.002	0.17	-	-	-	-
Rabi Season								
1. Wheat	0.474	24.63	0.351	28.88	0.625	21.74	0.315	22.17
2. Potato	0.13	6.98	0.120	9.86	0.343	11.94	0.145	10.1

	4							7
3. Barseem (Green fodder)	0.042	2.18	0.024	1.97	0.066	2.31	0.029	2.05
4. Mustard	0.059	3.05	-	-	0.207	7.21	0.077	5.39
5. Gram	-	-	0.011	0.89	-	-	-	-
6. Radish	0.025	1.32	0.023	1.85	-	-	-	-
7. Carrot	-	-	0.002	0.17	-	-	-	-
8. Coriander	-	-	-	-	0.019	0.65	-	-
Summer Season								
1. Onion	0.353	18.32	0.170	14.03	0.356	12.38	0.218	15.36
2. Maize	0.055	2.87	0.029	2.42	0.093	3.25	0.068	4.79
3. NP Chary (Green fodder)	-	-	-	-	0.005	0.16	0.003	0.22
Gross Cropped Area (GCA)	**1.93**	**100.0**	**1.22**	**100.0**	**2.88**	**100.0**	**1.42**	**100.0**

Source: Author's own estimate based on primary data

Table 6: Water Use, and Water Productivity in Physical and Economic Terms under Electric Pumps, Eastern Uttar Pradesh

Name of the Crops	Electric Pump – Owner			Electric pump – water buyer		
	Depth of irrigati	Water productivity (Kg/m^3)	Net water productivity (Rs/m^3)	Depth of irrigati	Water productivity (Kg/m^3)	Net water productivity (Rs/m^3)

	on water use (cm)	Main Product	By-product		on water use (cm)	Main Product	By-product	
Kharif Season								
1. Paddy	7.1	1.9	8.47	3.4	3.61	2.3	10.59	3.6
2. Chary (GF)	1.6	14.3	-	-	0.78	26.2	-	-
3. Vegetable	3.3	6.0	-	26.3	1.73	10.7	-	26.6
4. Lady's Finger	3.2	2.3	-	10.8	2.33	3.9	-	21.2
5. Maize	2.4	2.9	19.4	9.4	1.17	5.7	18.79	18.8
6. Sesamum	0.8	1.2	-	14.2	0.57	1.3	-	9.6
7. Sugarcane	1.1	12.4	-	6.7	0.57	10.6	-	8.1
8. Bajra	3.2	1.5	10.2	4.5	1.43	4.1	30.83	10.5
9. Black gram	2.7	1.9	-	39.1	1.14	2.4	-	46.3
10. Groundnut	3.3	2.6	-	31.7	-	-	-	-
11. Green gram	3.7	2.0	-	46.2	-	-	-	-
Rabi Season								
1. Wheat	6.7	2.4	11.3	7.8	2.93	2.6	12.36	7.6
2. Potato	5.0	5.7	-	8.6	2.91	6.0		9.6
3. Pea	2.3	1.9	-	13.5	1.33	2.1		15.0
4. Barseem	0.7	12.6	-	-	0.46	12.3		-
5. Gram	1.8	1.8	-	27.03	0.36	1.6		31.1
6. Mustard	1.6	1.4	-	10.8	1.20	1.4		11.4
7. Linseed	0.6	0.9	-	4.4	-	-	-	-
8. Barley	2.3	3.4	16.0	9.1	0.80	4.3	14.57	14.6
Summer Season								
1. MP chary	1.5	11.1	-	-	1.19	10.8	-	-
2. Sunflower	1.0	1.0	-	3.40	-	-	-	-
3. Vegetables	1.1	2.4	-	15.15	-	-	-	-

GF: Green fodder

Source: Author's own estimate based on primary data

Table 7: Water Use, and Water Productivity in Physical and Economic Terms under Diesel Well Command, Eastern Uttar Pradesh

Name of the Crops	Diesel Pump – Owner			Diesel pump – water buyer		
	Depth of	Physical water productivity	Net water productivity	Depth of	Water productivity	Net water productivity

	irrigation water use (cm)	(Kg/m^3)		(Rs/m^3)	irrigation water use (mm)	(Kg/m^3)		(Rs/m^3)
		Main Product	By-product			Main Product	By-product	
Kharif Season								
1. Paddy	15.53	1.86	8.50	2.62	9.09	2.39	8.49	2.92
2. Chary (GF)	1.12	18.44	-	-	0.98	29.74	-	-
3. Vegetables	1.43	0.77	-	0.37	3.43	1.94	-	25.26
4. Arhar	-		-	-	3.05	3.54	-	46.49
5. Maize	2.26	2.56	20.05	13.20	-	-	-	-
6. Sesamum	2.29	0.89	-	17.39	1.14	0.88	-	17.72
7. Sugarcane	1.59	10.13	-	2.50	-	-	-	-
8. Bajra	2.29	3.43	15.54	7.47	1.33	4.41	22.24	17.83
9. Black gram	-	-	-	-	1.14	1.30	-	28.69
10. Green gram	-	-	-	-	1.14	1.73	-	59.98
Rabi Season								
1. Wheat	12.74	2.57	13.34	6.22	8.33	3.50	14.40	7.80
2. Potato	3.70	7.23	-	17.87	2.29	7.40	-	-
3. Pea	3.40	1.56	-	12.19	1.67	1.74	-	12.36
4. Barseem (GF)	0.62	15.97	-	-	0.67	14.57	-	-
5. Gram	4.16	1.58	-	15.33	1.99	1.82	-	17.78
6. Mustard	2.70	1.56	-	10.87	1.44	1.15	-	11.99
7. Linseed	3.43	1.36	-	13.70	1.03	1.53	-	16.77
8. Barley	-	-	-	-	0.91	5.61	14.90	14.90
Summer Season								
1. MP Chary (GF)	0.92	10.68	-		1.43	11.77	-	-
2. Vegetable	1.14	2.41	-	17.49	-	-	-	-

GF: Green fodder

Source: Author's own estimate based on primary data

Table 8 Water Use, and Water Productivity in Physical and Economic Terms under Flat and Unit Energy Pricing Regime, North Gujarat

Name of the	Electric Pump Owner – Flat Rate	Electric Pump Owner – Unit

Crops					Pricing			
	Depth of irrigation (cm)	Physical water productivity (Kg/m^3)		Net water productivity (Rs/m^3)	Depth of irrigation (cm)	Water productivity (Kg/m^3)		Net water productivity (Rs/m^3)
		Main Product	By-product			Main Product	By-product	
Kharif Season								
1. Rajka Bajra	2.57	8.24	-	-	3.93	10.83	-	-
2. Alfalfa (GF)	3.63	5.42	-	-	4.11	5.64	-	-
3. Jowar	10.71	2.76	4.06	8.27	10.14	2.26	1.51	6.62
4. Bajra	9.81	1.00	3.48	5.13	8.94	1.45	2.14	6.39
5. Black gram	8.13	1.07	-	15.14	5.26	1.50	-	16.75
6. Green gram	7.62	0.91	-	10.85	8.73	0.98	-	11.20
7. Groundnut	9.47	0.58	-	3.58	5.14	0.56	-	4.68
8. Cluster	8.52	1.02	-	9.09	10.62	1.11	-	9.37
9. Cotton	6.29	0.41	-	5.34	6.10	1.15	-	19.28
10. Castor	11.66	0.59	-	5.06	11.02	0.62	-	6.52
Rabi Season								
1. Alfalfa (GF)	3.27	3.65	-	-	2.83	5.71	-	-
2. Chekudi (GF)	13.26	2.96	-	-	2.29	5.45	-	-
3. Wheat	12.72	0.82	2.64	4.64	9.63	0.91	2.08	5.17
4. Barley	2.29	0.47	9.33	0.70	6.29	1.11	2.89	6.17
5. Rajgaro	9.14	0.56	-	4.11	7.27	0.89	-	8.50
6. Mustard	11.38	2.86	-	22.25	7.46	2.10	-	23.50
7. Cumin	8.95	0.82	-	36.71	8.14	0.99	-	47.71
Summer Season								
1. Alfalfa (GF)	3.82	2.30	-	-	-	-	-	-
2. Rajka Bajra	2.53	3.27	-	-	4.06	8.15	-	-
3. Bajra	16.87	1.95	2.36	6.43	12.92	1.94	3.02	7.31

GF: Green Fodder

Source: Author's own estimate based on primary data

Table 9: Water Use, and Water Productivity in Physical and Economic Terms under Electric Well Command, South Bihar Plain

Name of the Crops	Electric Pump – Owner				Electric Pump – Water Buyer			
	Depth of irrigation water use (cm)	Physical water productivity (kg/m^3)		Net water productivity (Rs/m^3)	Depth of irrigation water use (cm)	Water productivity (kg/m^3)		Net water productivity (Rs/m^3)
		Main Product	By-product			Main Product	By-product	
Kharif Season								
1. Paddy	7.51	2.5	12.90	6.35	4.67	2.69	12.60	8.4
2. Masureya	0.40	11.7	-	-	0.35	10.15	-	-
3. Maize (GF)	2.50	20.5	-	-	1.25	27.34	-	-
Rabi Season								
1. Wheat	4.82	1.8	8.87	5.56	3.51	1.76	7.43	5.8
2. Potato	1.92	13.1	-	43.16	2.00	11.74	-	41.8
3. Barseem	0.56	10.4	-	-	0.40	11.91	-	-
4. Mustard	2.67	1.8	-	20.16	-	-	-	-
5. Gram	-	-	-	-	0.93	0.66	-	9.2
6. Radish	1.27	10.0	-	13.92	0.96	9.59	-	18.5
Summer Season								
1. Onion	4.60	4.4	-	18.48	2.18	5.40	-	23.2
2. Maize	2.07	5.9	-	21.66	1.76	6.86	-	19.1

GF: Green Fodder

Source: Author's own estimate based on primary data

Table 10: Water Use, and Water Productivity in Physical and Economic Terms under Diesel Well Command, South Bihar Plain

Name of the Crops	Diesel Pump – Owner				Diesel Pump – Water Buyer			
	Depth of irrigation water use (cm)	Water productivity (kg/m³)		Net water productivity (Rs/m³)	Depth of irrigation water use (cm)	Water productivity (kg/m³)		Net water productivity (Rs/m³)
		Main Product	By-product			Main Product	By-product	
Kharif Season								
1. Paddy	8.96	2.40	15.13	7.50	5.41	2.98	19.77	9.56
2. Masureya	1.08	8.8	-	-	0.74	10.92	-	-
Rabi Season								
1. Wheat	5.88	2.0	8.71	5.97	3.16	2.27	9.27	6.80
2. Potato	3.89	12.9	-	44.57	1.81	13.92	-	49.83
3. Barseem	0.89	12.7	-	-	0.60	16.03	-	-
4. Mustard	3.89	1.5	-	16.18	1.92	1.60	-	16.25
5. Coriander	2.81	2.3	-	38.72	-	-	-	-
Summer Season								
1. Onion	3.70	5.8	-	21.50	3.06	5.34	-	21.27
2. Maize	2.24	5.3	-	17.05	1.64	7.65	-	31.84
3. MP Chary	0.92	8.9	-	-	0.94	7.46	-	-

GF: Green Fodder
Source: Author's own estimate based on primary data