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Sustainable Groundwater Management through Energy Pricing: Evidences from North Gujarat Region of Gujarat, India

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Abstract

Agriculture is the largest consumer of freshwater and it is projected that by 2030, there will be overall gap of 40% between water supply and demand. The irrigation wells are energised by the electric as well as diesel operated pumps. In India, total electricity consumption to farm sector was 159144 Gwh during 2013-14, which account for about 18.03% of the total electricity consumption in the country and it is growing with a compound growth rate of 6.50% per annum during 2005-06 to 2013-14. Due to unsustainable use of groundwater for irrigated crop production leads many negative consequences including groundwater depletion. Overall objective of the present study was to assess the impact of energy pricing on sustainable use of groundwater without negative impact on farm level farmers' income. The study was conducted in north Gujarat region of Gujarat State. The study suggests that the under the flat rate electricity pricing regime, farmers were getting lower net economic water productivity i.e. ₹ 4.15 m^3 as compared to unit pricing of electricity (₹ 9.06/m^3) at farm level. Therefore, government should make possible arrangement to charge electricity tariff on the basis of actual energy consumption at farm sector in water scare regions of the country to sustainable and efficient use of groundwater for irrigation.

Keywords: Water Productivity, Agronomic Water Productivity, Net Economic Water Productivity, Pro Rata Electricity Pricing, Flat Rate Electricity Pricing

Augmentation in population growth and mobility, economic development, international trade, urbanisation, diversification in food basket due to change in per capita income, changing lifestyle, culture, technological changes and climate change, the demand for freshwater, energy and food will increase significantly over the coming years (Hoff, 2011). As water, energy and food are essential for human well-being, it also triggers the wide-spread poverty reduction and sustainable development. The prime resources for producing energy, food and provision of supply of water for different uses are under increasing stress. This water stress would jeopardy the prime objectives of development i.e. economic development and poverty reduction.

Agriculture is the largest consumer for freshwater and it account for about 70% of total freshwater withdrawals globally followed by 20% water consumed by industries and remaining 10% used for domestic purpose (FAO, 2011a). Globally, total water withdrawals for irrigated crop production will increase by 10% as compared to current water withdrawal and it was projected that there will be overall 40% gap between water supply and demand by 2030. Due to rise in global population and their income, the demand for agricultural commodities will be 70% more than the 2009 base year demand in 2050. This implies that annual growth rate of one per cent for world level and up to two per cent in low-and middle income countries (FAO, 2011a).

The food production and supply chain consumes about 30% of total energy consumed globally (FAO, 2011b). As per projection made by the International Energy Agency, by 2030, overall energy demand will increase by 40% from 2010 level (IEA, 2010). In agriculture, energy being used for (a) pumping surface and ground water for irrigation purpose; (b) performing different cultural practices like ploughing, transportation of crop inputs, crop harvesting, etc.; (c) transport of agricultural produces from agricultural farm to markets; and (d) distribution of agricultural produces from farmers to ultimate consumers. Due to fast growth in demand of water, energy and land resources, many regions of the world are facing problems of resource scarcity and environmental degradation.

The inputs intensive, mechanised agriculture and intensive irrigation have contributed to rapid increase in crop production. The world's agricultural production has grown between 2.5 to 3.0 times during last 50 years, while the cultivated area has augmented by 12%. Out of total agricultural production in world, more than 40% increase in agricultural production comes from the irrigated area and world-wide irrigated area has doubled during the same period of time. Globally, per capita cultivated area gradually declined to less than 0.25 hectare uses 11% of the world's land surface. Due to intensive groundwater withdrawal are exceeding rates of natural replenishment, many regions of the world leading groundwater overexploitation that leads risk to local and global food production (FAO, 2011a).

Among the different sources of irrigation, groundwater has rapidly emerged to occupy a dominant place in India's agriculture. Over the past three decades, groundwater became the main source of growth in irrigated crop production and it account for about 60% of the total irrigated area in the country. It is estimated that over 70% of India's food-grain production comes from the irrigated agriculture (Gandhi and Namboodiri, 2009). The growth of agriculture has been possible because of timely and adequate supply of irrigation water to crops as groundwater is more reliable source of irrigation then surface water. For the extraction of groundwater, groundwater structures viz. wells and bore-wells have mushroom-up in different parts of country. The irrigation wells are energised by the electric as well as diesel operated pumps. In India, total electricity consumption to farm sector was 159144 Gwh during 2013-14, which account for about 18.03% of the total electricity consumption i.e. 882592 Gwh. Growth trend analysis suggests that electricity consumption to farm sector was growing with a compound growth rate of 6.50% per annum during 2005-06 to 2013-14 (GOI, 2015). Due to unsustainable use of groundwater for irrigated crop production, most of the regions of the country are facing problem of groundwater depletion. The number of irrigation blocks labelled as overexploited is increasing at an alarming rate of 5.5% per annum (Gandhi and Namboodiri, 2009).

Context

The per capita renewable fresh water in the Gujarat state as a whole is less advantaged as compared to many other Indian States. Going by M. Falkenmark's criterion, the Gujarat falls into the category of "water stressed". The per capita renewable freshwater resources availability in the State for the year 2001 was estimated to be 1137 m^3/annum (IRMA/UNICEF, 2001). North Gujarat region falls under the category of "absolutely water scarce" region where per capita renewable water availability was 427 m^3 per annum and water scarcity is to become a prime constraint to human survival itself (IRMA/UNICEF, 2001). Looking at the fragile nature of water ecology, the north Gujarat region cannot support irrigated crop production. Excessive withdrawal of groundwater for irrigation and other uses is leading in alarming drops in groundwater levels in many parts the region (Kumar, 2002), with the rate of decline in water levels ranging from 0.91 m to 6.0 m per annum (CGWB, 1998). During 2013-14, total electricity sale to farm sector was estimated to be 15547.90 Mkwh which account for about 24.71% of total electricity sale in the State (GOI, 2015). Looking the importance of groundwater, present study was an attempt to assess the impact of energy pricing on sustainable use of groundwater without negative impact on farmers' income. The specific objectives of the present study was: (a) to study the irrigation water use for crop production under flat rate and unit pricing of electricity in north Gujarat; (b) to estimate the agronomic and net economic water productivity of different crop grown by the farmers under flat rate and unit pricing of electricity in north Gujarat; and (c) to estimate the farm level water use and net economic water productivity under flat rate and unit pricing of electricity in north Gujarat.

Data and Methodology

Sampling Procedure and Data Collection

Present study was based on the primary as well as secondary data. Primary data was collected from farmers of Banaskantha district of North Gujarat region, Gujarat using pre-tested schedule. Palanpur and Vadgam taluka of Banaskantha district was purposively selected for primary data collection because in the both taluka sufficient number of farmers were running their tube-well using electricity and paying electricity charges on the basis of flat rate/horsepower basis and pro-rata (actual electricity consumption) basis.

A cluster of 10 villages from both selected taluka were purposively selected for primary data collection. The criteria for selection village were that to get both types of tube-well owners viz., farmers those were paying electricity charges on the basis of flat rate and actual energy consumption, in the same village. Generally, number of tube-well owners those were paying electricity charges on the basis of flat rate ware found more in the selected villages as compared to those tube-well owners were paying electricity charges on the basis of actual power consumption.

A list of all the tube-well owners were prepared and 50 tube-well owners were selected randomly using random table without replacement method for the primary data collection. For the selection of sample farmers those were paying electricity charges on the basis of actual electricity consumption, 50 tube-well owners were selected using snowball sampling method for primary data collection. For the selection of both types of farmers, the care was taken that both types of sample farmers fall in same village.

The primary data were collected on cropping pattern, area under each crop, inputs used for crop production in quantity and value terms, crop output, market price of agricultural produce, number of irrigation, hours of irrigation, electricity charges, pump discharge etc.

Analytical Procedure

Water Use for Crop Production

For the quantification of irrigation water use for crop production using following equation to estimate total irrigation water use (m^3) for crop production (Singh *et al*., 2004; Singh *et al*., 2014; Kumar, 2014).

$$\theta_{crop} = I_n \times H_{pi} \times P_d \quad \ldots(1)$$

Where θ_{crop} is total water used for crop production measured in term m^3; I_n is total number of irrigation given to particular crop during the crop period; H_{pi} is hours of pump run to provide an irrigation to crop; and P_d is pump discharge rate measured as m^3 per hour.

Water Productivity for Crop Production

Water productivity for different crops grown by the well owners under flat rate and pro rata electricity tariff was estimated the combined water productivity i.e. agronomic water productivity (Kg/m^3) and net economic water productivity (₹/m^3) terms. The agronomic and net economic water productivity was calculated using following equation (Singh *et al*., 2004; Singh *et al*., 2014; Kumar, 2014).

$$WP_{Kg/m^3} = \frac{CY_{Kg-ha}}{\theta_{Crop}} \quad \ldots(2)$$

$$WP_{Rs/m^3} = \frac{NI_{Rs-ha}}{\theta_{Crop}} \quad \ldots(3)$$

Where: WP_{Kg/m^3} is the agronomic water productivity; $CY_{Kg}{}^{-ha}$ is per hectare crop yield; WP_{RS/m^3} is net economic water productivity measured in term of ₹/m^3; $NI_{Rs}{}^{-ha}$ is per hectare net income received from the particular crop.

Farm Level Water Productivity

Farmers are allocating their land for different crop grown during the different seasons. Therefore, farm level net economic water productivity (₹/m^3) was estimated using total net income from the all crops grown on the farm divided by the total volume of irrigation water used for grown all the crops on farm during the year.

$$WP_{Rs/m^3} = \frac{\sum_{i=1}^{m} NI_{Rs}}{\sum_{i=1}^{m} \theta_{crop}}$$

Where; WP_{Rs/m^3} is Net economic water productivity; $\sum_{i=1}^{m} NI_{Rs}$ is the total net income from different crops grown on the farm and $\sum_{i=1}^{m} \theta_{crop}$ is the total irrigation water used for all the crop grown on the farm.

Results and Discussion

Cropping Pattern

The cropping pattern of both types of farmers in the study area is presented in Table 1. The average size of land holding was found to be more (3.89 hectares) for farmers paying electricity charges on the basis of flat rare as compare to those farmers paying electricity tariff on the basis of actual consumption i.e. 3.28 hectares. The gross cropped area of the sample farmers were 6.67 heaters and 4.46 hectares for electricity bill paid on the basis of flat rate and actual consumption respectively.

Table 1: Cropping Pattern of Farmers under Different Power Tariff Regime, North Gujarat

Name of the Crops	Season	Cropped area (Ha)	
		Flat Rate Energy Pricing	Pro Rata Energy Pricing
1. Jowar	Kharif	0.34	0.14
2. Bajra	Kharif	0.51	0.34
3. Groundnut	Kharif	0.22	—
4. Gavar	Kharif	0.44	0.73
5. Cotton	Kharif	0.04	0.03
6. Castor	Kharif	0.66	0.51
7. Black gram	Kharif	0.12	0.04
8. Green gram	Kharif	0.19	0.16
9. Cumin	Rabi	0.18	0.11
10. Wheat	Rabi	1.15	0.74
11. Rajgaro	Rabi	0.29	0.13
12. Mustard	Rabi	0.90	0.45
13. Barley	Rabi	0.00	0.08
14. Bajra	Summer	1.63	0.99
Gross Cropped area		**6.67**	**4.45**

The crops grown by the both types of farmers were found more or less same, but in case of farmers paying electricity on pro-rata basis they do not grow groundnut during kharif season. The crops grown during the kharif season were jowar, bajra, groundnut, gavar, cotton, castor, black gram and green gram. Among these crops, cotton and castor is two season crop and it was grown in the study area during the kharif season and harvested during the rabi season. Among the kharif season crops, flat tariff tube-well owner were allocating larger area for castor crop and less area under cotton cultivation, whereas in case of unit pricing tube-well owners were allocating larger area under gavar crop and small area for cotton cultivation. During rabi season, farmers were allocating their area under cumin, wheat, rajgaro, mustard and barley cultivation. Among these crops, farmers were allocating larger area under wheat crops by both types of sample farmers. Bajra was grown by the farmers in the study area during the summer season.

Irrigation water use and crop yield

Per hectare irrigation water used and crop yield for different crops grown by sample farmers in North Gujarat region is presented in Table 2. The major source of irrigation water in the study area was groundwater and farmers are using electric operated tube-wells for pumping groundwater. During the kharif season, crops were using both green and blue water, but for the present study, only blue water was considered for study purpose.

In case of flat rate energy pricing, highest irrigation water was applied by sample farmers for cotton crop (10065.79 m^3/ha) during kharif season and lowest for green gram with 1468.41 m^3 per hectare. During rabi season, highest irrigation water was used by the wheat crop (7680.54 m^3 per hectare) and lowest for cumin crop with 3624.81 m^3 per hectare. Among the different crops grown during kharif season, highest yield was obtained for cotton crop (40.47 quintal per hectare) and lowest crop yield was obtained from green gram with 11.58 quintal per hectare. During rabi season, highest yield was obtained by sample farmers for wheat crop and lowest for cumin crop (Table 2).

In case of unit pricing of electricity, during kharif season, farmers in the study area were applied highest irrigation water for castor crop (6247.05 m^3 per hectare) and lowest for black gram with 598.03 m^3 per hectare. During rabi season, highest irrigation water used for wheat crop production and lowest for cumin with 5514.20 and 2429.77 m^3 per hectare respectively. Among different crops grown by sample farmers, the highest yield was obtained for castor crop and lowest for black gram during kharif season. During rabi season, highest crop yield was obtained by the sample farmers from the wheat crop and lowest for rajgaro.

Crop Water Productivity

The crop water productivity for different crops grown by the sample farmers in the study area is

Table 2: Irrigation Water used and Crop Yield under Different Power Tariff Regime, North Gujarat

Name of the Crops	Season	Flat Rate Electricity Pricing		Pro Rata Energy Pricing	
		Water use (m^3/ha)	Yield (Qt/Ha)	Water use (m^3/ha)	Yield (Qt/Ha)
1. Jowar	Kharif	1802.89	15.66	2358.30	16.41
2. Bajra	Kharif	1973.81	19.07	1710.29	14.80
3. Groundnut	Kharif	5122.44	18.88	—	—
4. Gavar	Kharif	1965.36	16.60	1379.18	13.36
5. Cotton	Kharif	10065.79	40.47	3009.33	29.17
6. Castor	Kharif	6090.59	27.25	6247.05	32.03
7. Black gram	Kharif	2515.51	19.64	598.03	8.53
8. Green gram	Kharif	1468.41	11.58	1171.03	11.34
9. Cumin	Rabi	3624.81	23.70	2429.77	21.55
10. Wheat	Rabi	7680.54	37.31	5514.20	29.58
11. Rajgaro	Rabi	3648.64	17.04	2645.01	20.28
12. Mustard	Rabi	3680.08	19.66	3349.57	21.69
13. Barley	Rabi	7968.38	35.00	3934.54	27.34
14. Bajra	Summer	5271.68	41.71	4621.37	30.15

Table 3: Crop Water Productivity under Different Power Tariff Regime, North Gujarat

Name of the Crops	Season	Flat Rate Electricity Pricing		Pro Rata Energy Pricing	
		Water Productivity (Kg/m^3)	Net Economic Water Productivity (₹/m^3)	Water Productivity (Kg/m^3)	Net Economic Water Productivity (₹/m^3)
1. Jowar	Kharif	0.98	7.78	1.22	5.92
2. Bajra	Kharif	1.08	6.10	1.04	6.61
3. Groundnut	Kharif	0.58	3.58	-	-
4. Gavar	Kharif	1.02	9.27	1.17	10.10
5. Cotton	Kharif	0.41	5.34	1.15	19.28
6. Castor	Kharif	0.64	5.88	0.62	6.54
7. Black gram	Kharif	1.07	15.14	1.50	16.75
8. Green gram	Kharif	0.91	11.22	1.09	13.61
9. Cumin	Rabi	0.88	37.82	0.99	47.71
10. Wheat	Rabi	0.62	4.59	0.68	5.86
11. Rajgaro	Rabi	0.57	4.48	0.89	8.50
12. Mustard	Rabi	0.62	4.79	0.74	7.61
13. Barley	Rabi	0.44	3.17	0.77	5.94
14. Bajra	Summer	0.96	6.55	0.80	7.31

presented in Table 3. In case of flat rate electricity tariff, the highest agronomic water productivity was found for bajra (1.08 kg per m^3) and lowest for cotton (0.58 kg per m^3), whereas highest net economic water productivity was found to be ₹ 15.14 per m^3 for black gram and lowest for cotton with ₹ 5.34 per m^3 during kharif season. During rabi season, highest agronomic water productivity was observed for cumin (0.88 kg per m^3) and lowest for barley with 0.44 kg per m^3, whereas net economic water productivity was found to be ₹ 37.82 per m^3 for cumin and lowest for barley (₹ 3.17 per m^3). During the summer season, the agronomic and net economic water productivity for bajra crop was 0.96 kg per m^3 and ₹ 6.55 per m^3 respectively.

In case of unit energy pricing, the highest agronomic water productivity was observed for black gram (1.50 kg per m^3) and lowest for castor with 0.62 kg per m^3, whereas net economic water productivity was highest for black gram (₹ 16.75 per m^3) and lowest for jowar with 5.92 kg per m^3 during kharif season. Among the rabi crops, highest agronomic water productivity was found to be 0.99 kg per m^3 for cumin and lowest for wheat crop with 0.68 kg per m^3, whereas in case of net economic water productivity was highest for cumin (₹ 47.71 per m^3) and lowest for wheat crop with ₹ 5.86 per m^3. During summer season, the agronomic and net economic waster productivity for bajra crops was estimated to be 080 kg per m^3 and ₹ 7.31 m^3 respectively.

Farm Level Net Economic Water Productivity

In case of flat rate power tariff regime, the marginal cost of pumping groundwater is zero because energy charges are fixed and farmers having no incentive for reducing groundwater pumping, therefore, farmers under flat rate regime trying to pump groundwater as much as possible. In case of unit pricing tariff regime, the marginal cost of pumping groundwater is equal to per unit cost of electricity, because farmers are paying electricity on the basis of actual energy consumption. Therefore there, is an incentive for reducing groundwater pumping, so farmers in the study area trying to reducing groundwater pumping.

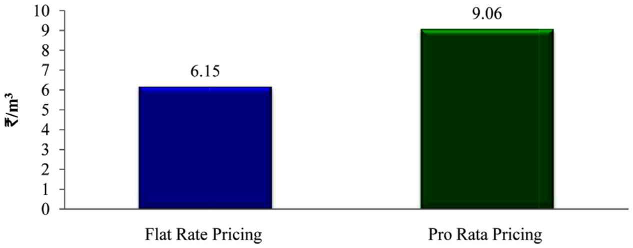

Fig. 1: Farm Level Net Economic Water Productivity, North Gujarat

The farm level net economic water productivity (₹/m^3) is presented in Fig. 1. Under the flat rate electricity, on an average total irrigation water applied to different crops grown during the year was 62878.94 m^3 and net income received by the farmers was ₹ 386598.40. The farm level water productivity from the crop production was estimated to be ₹ 4.15 per m^3. In case of unit pricing of electricity, on average total irrigation water used for different crops production during the year was found to be 38967.65 m^3 and net income received by the farmers from different crop grown during the year was ₹ 353219.28. The farm level net economic water productivity was estimated to be ₹ 9.06 per m^3.

Summery and Conclusion

In India, the electricity consumption to farm sector was mounting with a compound growth rate of 6.50% per annum during 2005-06 to 2013-14. On other hand the groundwater draft for irrigation purpose is also growing very fast resulting widespread problems of groundwater overexploitation in many parts of the country. At the individual crop level and farm level farmers were applying less irrigation water under pro-rata pricing of electricity as compared to flat rate. The net economic water productivity was much lower (₹ 4.15 per m^3) under the flat rate tariff of electricity as compared to pro rata pricing of electricity (₹ 9.06 per m^3). Pro rata pricing of electricity supply to farm sector along with power rationing of energy supply to farm sector is the best option for the co-management of electricity and groundwater use in water scarce regions. From the above discussion it is clear that introducing marginal cost for electricity encourage farmers to use irrigation water more efficiently and sustainable manner at field level from agronomic and economic point of view through efficient water use without compromising the net income from crop production.

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