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Extent of Groundwater Extraction and Irrigation Efficiency on Farms under Different Water-market Regimes in Central Uttar Pradesh

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Abstract

Tube-well irrigation, through modern water extraction mechanisms (WEMs), has been vital to food security and sustainable livelihoods in India. However, due to skewed distribution of WEMs towards large farmers on account of huge investment needs, small and marginal farmers have to rely on owners of WEMs for irrigation water. This has resulted in the emergence of informal water markets. The present study has examined the groundwater extraction and water-use efficiency under different water-market regimes in the Central Plain Zone (CPZ) of Uttar Pradesh, where water-intensive cropping pattern is followed. The study is based on the primary data collected from 100 farmer-households of Central Plain Zone in the year 2007. Most of the farmers in the study domain are small and marginal, having less than 2 ha land. These resource-poor farmers buy water from the WEM–owners. Thus, groundwater market has been found to provide them easy accessibility to irrigation water and helps them in realizing better yields. The popularity of water-intensive crops, such as paddy, wheat and sugarcane, is responsible for the depleting groundwater tables in the region. Estimates of Data Envelopment Analysis (DEA) have shown that both buyers and owners of WEMs are technically inefficient in water–use, as the actual use of irrigation water has been found much higher than the optimum level. However, 'Buyers have been found comparatively more efficient than 'Owners' in water utilization. Overexploitation of groundwater resources raises concerns about the future sustainability of agriculture. It is, therefore, becoming increasingly important that groundwater is used efficiently and groundwater market can emerge as a better tool for improving the efficiency of irrigation water across farm-sizes and crops. Based on the results, the study has made some policy suggestions also for an equitable and sustainable development of agriculture in the region.

Introduction

With the rapidly growing population and expanding agriculture, water resources for agricultural purposes are becoming scarcer in most parts of India. Therefore, the importance of groundwater development is increasing rapidly on account of inherent weaknesses (maintenance and operational inefficiencies) in the canal (surface water) irrigation system (Kumar *et al*., 2003). Water conveyance loss in canal irrigation is twice (40-50%) than that of well irrigation (Sivanappan, 1995) and about 20 per cent of canal-irrigated area currently is seriously affected by waterlogging and/or salinity problems (Dhawan, 1988). The use of groundwater has, in many pockets, surpassed sustainable limits with severe shortages during the r*abi* seasons.

In many countries, water use rights (WUR) system has been introduced with tradable water quotas to reallocate and use water resources

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reasonably and efficiently through market-based economic instruments. However, in India *per se*, it is not easy to establish water rights trading markets due to many kinds of barriers. These barriers (political, legal, administrative, technical, cultural and geographical) vary from country to country (Bauer, 1997; Frederick, 2002). In India, conflicts over control and use of surface water are severe and sometimes become brutal. Besides, most of the groundwater developments have taken place in the private domain through modern Water Extraction Mechanisms (WEMs), i.e. tube-wells (from here on, these two terms have been used synonymously). Possession of these WEMs/ tube-wells is highly skewed in favour of large farmers due to need of huge capital investments. This has resulted in the emergence of groundwater markets. Water markets, though are in a nascent stage in India in the absence of any well-defined water-use rights (WUR), benefit both buyers and sellers, as small and marginal farmers can irrigate their crops without making huge initial investment (Singh and Singh, 2003). On the other hand, WEM owners could utilize their investment optimally by selling the extracted water. However, it is widely accepted that the water buyers face problems of inadequate and untimely irrigation of their crops.

Thus, the present study has examined the extent of groundwater extraction, its productivity and efficiency at the micro level under different water-market regimes in the Central Plain Zone (CPZ) of Uttar Pradesh. The CPZ has observed major upheaval in the cropping pattern in the recent past and the dependency on surface irrigation has decreased from more than 65 per cent in early-1960s to merely half of it at present. So, the major expansion in irrigated area has come through groundwater irrigation.

Conceptual Framework, Data Collection and Methodology

Water Market

Water markets exist in the regions of the world where there is a considerable water scarcity, such as Chile (Briscoe *et al*., 1998), Australia (Bjornlund, 2006) and in many parts of the United States, (Howitt, 1998). Berbel and Gomez-Limon (2000) have concluded that water pricing reduces the range of crops that can be irrigated profitably, thus increasing economic vulnerability in the farming sector due to the limited number of alternative strategies available.

Water markets in India are informal institutions, in which private tube-well owners sell surplus irrigation water after their own use to the farmers who don’t have their own WEMs in the vicinity of their land. Though, such buying and selling of water is quite an old practice, the charges/ prices are not governed by any economic criteria and are largely decided by informal agreement between the buyers and sellers. The water markets are crucial, where state machinery for (groundwater/canal) irrigation is non-existing or has failed to deliver water to the resource-poor farmers. From *the prima facie* evidence, marginal and small farmers have relatively little access to groundwater resources for irrigation, although according to the Indian Easement Act of 1872, groundwater rights are appurtenant to a land owner *de jure*. But *de facto*, these rights are ambiguous (Chandrakanth and Romm, 1990; Chandrakanth and Arun, 1997), as small farmers cannot afford to invest on construction of water extraction structure for irrigating their small landholdings. There are no well-delineated property rights for this resource and hence, there is no control over the resource pertaining to its extraction, use and market.

In the study area, there were four informal water-market regimes, viz. (a) Self-users: these are farmers who have their own water-extraction installation for irrigating their own land only and do not participate in the water market; (b) Self-users+ Buyers: these are large farmers with fragmented landholdings which necessitate to buy water in addition to their own sources (tube-well); (c) Only Buyers: these are primarily small and marginal farmers with poor resource base, who depend on others to buy water for irrigating their crops; and (d) Self-users+Sellers: these are farmers who sell groundwater after meeting their own irrigation requirements. In the study area, there was not a single household who was ‘Only a Seller’.

Data Collection

Multistage random sampling for field survey of 100 farmers was used in two randomly selected districts (Lucknow and Sitapur) of the CPZ. From each district, two clusters of 2-3 villages and from each cluster, 25 sample farmers were drawn randomly, thus making a total sample size of 100 farmers having different sizes of landholdings.

Extent of Groundwater Extraction and Accessibility

The amount of groundwater extracted and accessibility to irrigation water were studied through personal interview with farmers. Implication of groundwater accessibility on cropping pattern was examined through comparing the choice of crops under different water regimes. The volume of groundwater exploitation/ extraction (in litres) was estimated by using a pre-tested estimation model (Eyhom *et al*., 2005) given below:

$$Q = t*129574.1 * BHP / [d + (255.5998 * BHP^2) / d^2 * D^4)] \quad \ldots(1)$$

where,

Q = Quantity of groundwater extracted (in litres)

t = Total duration of irrigation (in hours)

BHP = Engine power of pump (in HP)

d = Average depth of the well (in metres)

D = Diameter of the suction pipe (in inches)

Water Productivity

Water productivity (WP) is defined as crop yield per unit of water consumption, including effective rainfall and diverted water from water systems. It varies from region to region and field to field, depending on many factors such as crop and climate patterns (if rainfall fits crop growth), irrigation technology and field water management, land and infrastructure, and inputs including labour, fertilizer, and machinery. Water productivity can be increased by either increasing crop yield or reducing water consumption and maintaining the yield level. However, in the present study, only applied irrigation groundwater was considered to estimate water productivity, as rainfall was assumed to be symmetrically distributed on all the farms and there was no surface irrigation on sample farms.

Water-use Efficiency

To estimate water-use efficiency, Data Envelopment Analysis (DEA) — a non-parametric linear programming approach—was used, as it is advantageous over the frontier production approach on several accounts. Firstly, it allows data to behave itself. Secondly, it details out the extent of overuse of inputs in relation to output among different farms (Rajashekharappa *et al.,* 2004).

If we have ‘s’ inputs and ‘m’ outputs on each of the ‘n’ farms or decision-making units (DMUs), then s×n input matrix, X, and m×n output matrix, Y represent the data pertaining to all n DMUs. For the i^{th} DMU, inputs and outputs are represented in terms of x_i and y_i vectors, respectively. To introduce DEA, we first obtain a measure of the ratio $u' y_i / v' x_i$, where u is an m×1 vector of output weights and v is a s×1 vector of input weights. To select optimal weights, we specify the following mathematical programming:

$$\begin{aligned} &\text{Max}_{u,v} (u' y_i / v' x_i) \\ &\text{subject to} \\ &(u' y_j / v' x_j) \le 1 \qquad j=1,2,\ldots\ldots\ldots,n \\ &u, v \ge 0 \end{aligned} \quad \ldots(2)$$

This involves finding values for u and v, such that the efficiency measure of the i^{th} DMU is maximized, subject to the constraint that all efficiency measures must be less than or equal to one. One problem with this particular ratio formulation is that it has an infinite number of solutions. To avoid this, we can impose constraint $v'x_i = 1$ which provides:

$$\begin{aligned} &\text{Max}_{\mu,v} (\mu' y_i) \\ &\text{subject to} \\ &v' x_i = 1, \\ &\mu' y_j - v' x_j \le 0, \qquad j = 1,2,\ldots\ldots..,n \\ &\mu, v \ge 0 \end{aligned} \quad \ldots(3)$$

where, the notation change from u and v to μ and v reflects the transformation.

Using the duality in the linear programming, we can develop input minimization version model as specified below:

$$\text{Min } Z_0$$

subject to

$$\Sigma\, y_{mj}\, \lambda_j \geq y_0,$$

$$\Sigma\, (x_{kj}\, \lambda_j - x_{ko} Z_0) \leq 0,$$

$$\Sigma\, \lambda_j \geq 0 \qquad \ldots(4)$$

where j=1,2,….,n is the number of farms or DMUs in the sample, m represents the number of output {here only one output (wheat/paddy/sugarcane/potato) at a time has been considered, as efficiency is to be estimated for individual crops}, k is the number of inputs included in the analysis, Z_0 is the relative efficiency score of the DMU '0' under study, λ_j are the weights to be used as multipliers for the input levels of a referent farm to indicate the input levels that an inefficient farm should aim to achieve efficiency, x_{kj} is the level of use for the k^{th} input on the j^{th} farm, y_{mj} is the level of the m^{th} output on the j^{th} farm, y_0 is the level of output on unit '0', and x_{ko} is the level of k^{th} input being used by the DMU '0'.

Solving of the linear programming problem in Equation (4) n-times yields the efficiency index for each of the n number of DMUs. Z_0 =1 value shows that '0' DMU is on the frontier and technically efficient and if $Z_0<1$, the DMU is technically inefficient and falls below the frontier. In addition to technical efficiency, we also get optimum amount of input to produce a given amount of output and through comparing with the actual input-use, resource-use efficiency can be estimated.

Results and Discussion

Socio-Economic Characteristics of Sample Farm Households

The socio-economic characteristics of the sample farms showed that the majority of farmers in the study domain were small and marginal farmers (Table 1). Marginal category (0-1 ha) included 57 per cent of the farmers with average family size of 11 with more than two-thirds educated up to primary level. Small category included 24 per cent of sample farmers (100) with average 9 members in the family. Education-wise there was not much difference between marginal and small farmers. On the other hand, farmers with more than two hectares of land had the family size of 12 and had a better education spread. As usual, distribution of landholdings was highly skewed towards large farmers.

Access to Groundwater Irrigation

A majority of farmers (51%) in the study are being predominantly small and marginal were water-buyers. The availability of groundwater market provided these resource-poor farmers an easy access to irrigation water and helped in realizing better crop yields (Table 2). In the absence of such groundwater market, about 27 per cent of land would have remained un-irrigated.

For large farmers, it was more economical to install their own water-extraction devices as the opportunity cost of reliance on sellers for irrigation

Table 1. Socio-economic characteristics of sample farm households

Particulars	Marginal (0-1 ha)	Small (1-2 ha)	Others (> 2 ha)
No. of farmers	57	24	19
Average size of family (No.)	11	9	12
Education of household-head (% of total)			
Illiterate	35.7	30.3	21.1
Primary	37.5	34.3	31.6
Secondary	23.2	29.3	36.8
Higher	3.6	6.1	10.5
Average size of landholding (ha)	0.5	1.5	4.2
Average number of fragments of total land	2.6	3.1	3.7
Average size of each fragment of land (ha)	0.2	0.5	1.1

Source: Field Survey, 2007

Table 2. Accessibility of sample households and farmers' area under different water market regimes

(Per cent)

Category of water market regimes	Average holding size (ha)	Farm category					
		Marginal		Small		Others	
		No. of households	Farm area	No. of households	Farm area	No. of households	Farm area
Buyer	0.82	68.42 (39)	57.31	37.50 (9)	29.32	15.79 (3)	15.37
Self-user	1.64	15.79 (9)	19.72	25.00 (6)	16.14	21.05 (4)	20.06
Self-user + Buyer	2.75	3.51 (2)	5.22	20.83 (5)	25.00	42.11 (8)	41.82
Self-user + Seller	2.00	12.28 (7)	17.75	16.67 (4)	29.54	21.05 (4)	22.75
Overall	1.46	100 (57)	100 (30.64)	100 (24)	100 (35.2)	100 (19)	100 (80.16)

Note: Figures within the parentheses for households are number of respondents under respective categories, while for farm area, these are total area cultivated by the respective categories of farmers together.

Source: Field Survey, 2007

water was a bit high. In the study area, about 15 per cent farmers were selling groundwater for irrigation purposes, which belonged to all the three categories.

Choice of Crops under Different Water Regimes

The choice of crops by an individual farmer is influenced by a number of factors such as soil type, size of holding, availability of irrigation facilities and other resources, household requirement, labour availability, public policy, marketing facilities, etc. In the study area, although, there was not any significant trend for specific choice of crops by the farmers, the number of farmers growing different crops varied widely across the groups. Moreover, wheat dominated the cropping pattern, while paddy was grown for household consumption only. It was also surprising to note that self-users or tube-well owners, who were also relatively large farmers, were also growing vegetables on significantly large areas (Table 3). This may be due to the assured irrigation facilities available to them.

Groundwater Extraction in Study Domain

The extraction of groundwater depends on water level, engine capacity, size of outlet and duration of draft for irrigating crops. From field survey, it was found that the average depth of tubewells was 36.7 metres and to lift groundwater, a majority of WEM-owners used 10 H.P. capacity pump with diesel engine. Electricity supply being highly erratic and unreliable in the study area, farmers largely depended on diesel engines. With 4.13 inch average diameter of outlet, 34950 litres of groundwater was being extracted per hour in the region (Table 4). On the other hand, the average annual net precipitation in the region was about 100 cm. It may be noted that the water requirement of the crops under study may differ from the water applied.

The total groundwater extracted by tube-well owners for either irrigating their own crops and/or selling was also estimated (Table 5), which could be used to estimate the net draft of groundwater in the region against the annual precipitation and recharge. The results showed that self-users extracted 22.87 lakh litres water to irrigate 1.64 ha land in the year. It was also interesting to note that the farmers with large landholdings (Self-user) tried to ensure their irrigation by installing high power bore-well with deeper depth, as frequent failure of tube-wells have been reported in the recent past.

On the other hand, in the case of Self-user+Buyer, the ratio of area irrigated by own tube-

Table 3. Cropping pattern of selected farms under different water-regimes

Crops	Buyer	Self-user	Self-user + Buyer	Self-user + Seller	Overall
Paddy	7.51	8.12	4.20	3.20	6.43
Wheat	36.26	34.37	35.47	38.93	38.28
Peal millet	3.43	0.60	2.74	4.53	2.95
Mustard	2.14	3.01	2.65	1.87	2.58
Pulses*	8.49	8.42	4.93	4.40	6.51
Sugarcane	20.34	32.36	19.47	19.20	18.80
Potato	4.28	3.51	15.54	8.27	8.18
Vegetables**	6.27	4.21	10.15	13.20	8.50
Others	11.28	5.41	4.85	6.40	7.80
Total	100	100	100	100	100
	(1.10)	(2.10)	(2.27)	(2.14)	(1.60)
Cropping intensity	130.05	115.98	100.43	114.05	120.29

Notes: Figures within the parentheses are the gross cropped areas for the respective group of farmers.
*Pulses include pigeon pea and black gram. **Potato has not been included in the vegetable group.
Source: Field Survey, 2007

Table 4. Mechanism of groundwater extraction in the study domain

Average depth of water level (m)	36.7
Average size of outlet (inch)	4.13
Engine capacity (HP)	10 (modal value)
Water extracted (L/hour of irrigation)	34950.04

Source: Field Survey, 2007

well to that of others' was about 2:1 and the total groundwater extraction was estimated to be 15.4 lakh litre. The total water extraction by Self–user+Sellers was 24.91 lakh litre to irrigate their own 2.0 ha land and the ratio of irrigating their own area to others' area was 2.73:1.

Water and Crop Productivity under Different Water-market Regimes

The two primary economic instruments used in irrigation water management are water markets and water pricing. However, experience in using these instruments is limited and outcomes have been found to be unique to local conditions, including the institutional framework, extent of water scarcity, soil and climatic conditions, cropping patterns and water-conveyance infrastructure (Bjornlund *et al.*, 2007). Productivity of irrigation water has been expressed in terms of quantity of grain output of a crop by applying unit m^3 of groundwater, assuming annual precipitation and application of other inputs constant for all the farmers. Although, as discussed earlier, crop productivity and thereby, water productivity may vary due to the use of other critical inputs. Rosegrant *et al*. (2002) have estimated water (irrigation plus net precipitation) productivity of rice in India in the range 0.14 - 0.20 kg/m^3 of water during 1995, while for other cereals, it was in the range 0.2 - 0.7 kg/m^3 of water. It has been projected that water productivities for other cereals will increase from 0.6 to 1.0 kg per cubic metre in the developing countries during 1995 to 2025.

It may be observed from Table 6 that productivity of irrigation water was more in the wheat, sugarcane and potato crops for the buyer category of farmers as they applied less amount of water as compared to other categories to produce one unit of output. The low ratio in the case of buyers in wheat, sugarcane and potato could be due to the fact that they were predominantly small and marginal farmers with small landholdings and thus, they were engaged in intensive cultivation with proper utilization of resources.

Table 5. Groundwater extraction by tube-well owners

Water regimes	Average depth of water level (m)	Average size of outlet (inch)	Engine capacity (HP)	Number of irrigations applied to all crops	Average own irrigated farm area (ha)*	Duration of irrigation (hours/ irrigation/ ha)	Total ground-water extraction (lakh litre)
Self-user	44.20	4.00	10.00	14.13	1.64	26.17	22.87
Self-user + Buyer	30.08	4.00	8.44	13.98	1.58	36.93	15.40 (1.97:1)
Self-user + Seller	32.52	4.00	9.16	14.92	2.00	29.4	24.91 (2.73:1)

Note: * This area is irrigated by own tube-wells only
Source: Field Survey, 2007

In the case of paddy, Self-user + Seller applied least irrigation water for producing one kg of paddy — a rainy season crop. This could be mainly due to the fact that there were only few sample farmers (three in numbers) under this category growing paddy and most of them had low land area, where they had access to seasonal surface water accumulated in small ponds from rainfall for quite a reasonable period. Besides, being resourceful farmers, they could apply a higher amount of fertilizer as compared to other small farmers and therefore, could harvest better crop yield (5 t/ha) as compared to other farmers. Therefore, generalization of such low water-use and high water productivity for such category of farmers would not be logical. Among other categories, no significant difference in water productivity was noticed. It was worth noting that amount of water used to produce one kilogram of output was a part of the irrigation requirement of crop and it did not include rainfall water in the present study.

Incremental Water–output Ratio

Incremental water-output ratio shows the amount of water required to produce the additional value (in Rs) in exchange of the output. This ratio is the replica of water productivity. It was found (Table 7) that buyers were more efficient in wheat, sugarcane and potato. One more interesting thing appeared from these results from the sustainability point of view. Contrary to farmers' perception, potato and sugarcane emerged as the better remunerative crops as far as water-use was concerned, as these crops required about one-third quantity of water to yield a return of one rupee as compared to paddy and wheat.

Table 6. Water productivity for major crops under different water-market regimes

(W.U. in lakh litre/ ha, C.Y. in q/ha, W.P. in kg of output/m^3 of water)

Category	Wheat			Paddy			Sugarcane			Potato		
	W.U.	C.Y.	W.P.	W.U.	C.Y.	W.P.	W.U.	C.Y.	W.P.	W.U.	C.Y.	W.P.
Buyer	27.8	36.6	1.31	30.10	26.5	1.13	23.8	592	24.8	28.8	278	9.62
Self-user	40.7	37.6	0.92	27.9	30.1	1.08	55.1	629	11.4	39.1	211	5.38
Self-user + Buyer	41.0	37.7	0.91	35.2	34.1	0.97	45.4	550	12.1	36.3	274	7.54
Self-user + Seller	32.8	35.2	1.07	29.0	50.0	1.72	44.3	611	13.7	30.1	188	6.23
Overall	33.2	36.8	1.10	29.7	31.5	1.06	40.8	599	14.6	34.2	238	7.19

Notes: W.U.= Irrigation water applied, C.Y. = Crop yield, and W.P.= Water productivity
1 m^3 is equivalent to 1000 litres and 1 hecatre-cm is equivalent to 100,000 litres of water.

Table 7. Incremental water–output ratio for major crops under different water-regimes

(Litres of water/ Rupee of output)

Category	Wheat	Paddy	Sugarcane	Potato
Buyer	107.70	172.10	40.74	36.77
Self-user	163.23	196.78	69.44	45.86
Self-user + Buyer	157.77	209.05	75.85	42.26
Self-user + Seller	126.14	149.65	64.61	45.05
Overall	138.71	181.49	62.66	42.49

Water-use Efficiency: Data Envelopment Analysis (DEA) Approach

For the estimation of water-use efficiency crop-wise, all the sample households were categorized under Buyers or Sellers/Owners, since for some crops, the number of observations under four categories were too small to draw general conclusions. Data Envelopment Analysis was applied for both the categories – Buyers and Owners of the water-extraction facilities. The actual normal vs optimal water-use along with technical efficiency of groundwater irrigation have been presented in Table 8. It was found that both groups of farmers — Buyers and Owners — applied much higher irrigation water than the optimum level. For all the crops, optimum quantity of irrigation water slightly varied for both the groups due to difference in the use of other inputs like seed, fertilizer, plant protection measures, etc.

The technical efficiency for water-use for Buyers and WEM-owners for wheat crop was estimated to be 65.07 per cent and 45.27 per cent, respectively. In the case of paddy, the difference in water-use efficiency was marginal for the two categories. For the cash crops like sugarcane and potato, 'Buyers' were found to be more efficient than 'Owners'. The technical efficiency for the buyer group in the case of sugarcane and potato crops was found to be as high as 86.73 per cent and 93.15 per cent, respectively. Contrary to it, 'Owners' depicted only 43.40 per cent and 67.70 per cent efficiency levels for these crops, respectively.

Categorization of Farmers according to Water-use Efficiency for Different Crops

All the farmers under two groups — tube-well owners and water buyers — were further classified into different technical efficiency levels of water-use for different crops. In the case of wheat, a majority of the 'Buyers' (about 64 per cent) were found to be efficient in the range of 60 - 100 per cent, while 'Owner' were spread almost uniformly in different categories of efficiency range (Table 9), showing 'Buyers' to be relatively more efficient in water-use than 'Owner'. Although the crop yield harvested by the 'Buyers' was a bit lower than that of 'Sellers', due to lower use of other inputs, water-use efficiency favoured the 'Buyers'..

For the paddy crop, in both the groups of farmers, more than three-fourths of the respondents (75 - 85 %) were concentrated towards the less than 60 per

Table 8. Category-wise actual and optimum quantity of water-use and technical efficiency in different crops

Crops	Buyers			Owners		
	Actual water-use (m^3/ha)	Optimum water-use (m^3/ha)	Technical efficiency (%)	Actual water-use (m^3/ha)	Optimum water-use (m^3/ha)	Technical efficiency (%)
Wheat	2784.89	1812.28	65.07	3850.86	1743.26	45.27
Paddy	2658.55	763.72	28.72	2751.71	766.25	27.85
Sugarcane	2384.09	2067.74	86.73	4942.54	2145.10	43.40
Potato	2887.90	2690.23	93.15	3494.68	2365.94	67.70

Table 9. Distribution of farmers across water-use efficiency and use of other inputs

Water- use efficiency range (%)	Buyers				Owners			
	Percentage of farmers	Irrigation water applied (m^3/ha)	Fertilizer applied (kg/ha) N:P:K	Crop yield (kg/ha)	Percentage of farmers	Irrigation water applied (m^3/ha)	Fertilizer applied (kg/ha) N:P:K	Crop yield (kg/ha)
Wheat (Buyers = 46, Owners = 47)								
Below 40	13.04	2476.37	248.69	2081	38.30	4680.57	279.87	1951
40-60	21.74	2509.53	198.38	2785	23.40	4398.06	285.06	4642
60-80	43.48	2914.18	233.00	4195	19.15	3266.67	274.13	5012
Above 80	21.74	2982.16	214.41	4433	19.15	2106.83	249.15	4722
Paddy (Buyers = 8, Owners = 13)								
Below 40	75	3078.55	202.08	2903	76.92	2959.97	181.84	2427
40-60	12.5	1415.56	119.00	3333	15.38	2293.50	230.13	4375
60-80	12.5	1381.49	245.83	3333	-	-	-	-
Above 80	-	-	-	-	7.69	1585.56	132.50	6250
Sugarcane (Buyers = 9, Owners = 18)								
Below 40	-	-	-	-	33.33	6147.71	295.37	53764
40-60	11.11	3237.73	166.80	50000	44.44	4949.59	355.03	66797
60-80	11.11	1953.03	283.75	50000	22.22	3120.68	284.22	58929
Above 80	77.78	2323.72	181.67	61829	-	-	-	-
Potato (Buyers = 5, Owners = 16)								
Below 40	-	-	-	-	12.5	2565.35	412.96	11250
40-60	-	-	-	-	25	3729.49	316.87	17210
60-80	20	2717.88	366.54	23750	25	3913.47	290.28	22367
Above 80	80	2930.40	310.93	28776	37.5	3368.72	401.35	32639

cent efficiency range. This may be due to fact that paddy in the study domain being a primarily rainfed crop, farmers applied irrigation only during long dry spells of crop season. For both the cash crops, sugarcane and potato, 'Buyers' were predominantly efficient as compared to 'Owners' as a majority of farmers under 'Buyers' category had efficiency level more than 80 per cent.

Conclusions and Policy Options

Over the years, irrigation potential in Uttar Pradesh has increased many folds. Although, it has happened in the backdrop of declining share of canal irrigation and subsequent increasing share of groundwater (tube-well) irrigation (around three-times) during the past four decades. The repercussions of such trends are emerging in terms of frequent failures of tube-wells and drying up of wells/ hand-pumps in the summer seasons, on which most of the rural poor depend for drinking water. Easy access to irrigation water due to emergence of water markets has also led to the shifting of cropping pattern towards water-intensive crops, replacing gram, pigeon pea, groundnut and green gram by rice, wheat and sugarcane. Most of the farmers in the region have been found applying more irrigation water than the optimum level due to lack of adequate knowledge and under the impression that water alone can replace the requirement of other critical inputs. On the other hand, due to lack of clear-cut policy directions, large and resourceful farmers are installing higher capacity tube-wells and extracting more water than their requirements to cultivate water-exhaustive crops like sugarcane, which are more remunerative. But, it is leading to the failure of shallow tubewells of resource-poor farmers.

Although there is some inefficiency in irrigation water-use, the study has shown that mere re-allocation of water may not lead to significant productivity gains. Villagers in the study area work together informally to fix water prices at the beginning of a growing season. Given the fairly low water price and the relative shortage of water (due to paucity of electricity), tube-well owners wanting to maximize profits from water sales could choose to sell little water, using most of it on their own plots. It is remarkable that tube-well owners actually do not try to maximize profits in this fashion. They sell substantial volumes of water, even though it would make better economic sense to use the water to boost the productivity of their own land.

Keeping the above findings in view, following policy suggestions are being made for an equitable and sustainable development of agriculture in the region under study:

Firstly, due to lack of concerted efforts on canal irrigation development in the region, farmers have no option but to opt for groundwater irrigation. On account of recent trends in groundwater depletion in this zone, there is a need to make investments in canal irrigation for conjunctive use of groundwater and surface water for irrigation purposes, which will also reduce the cost of production for poor farmers.

With the development of groundwater market, small and marginal farmers are also benefited, as they get access to irrigation. However, due to lack of assured electric supply, the farmers have to largely depend on diesel-operated tube-wells, which cost them heavily and affect their net profit. Therefore, attempts should be made to provide assured electricity for irrigation purposes with economic electricity charges.

The water productivity and use-efficiency in the region have not been found encouraging, which are mainly due to application of sub-optimal level of other inputs alongwith sub-standard seeds/ crop varieties. Furthermore, inefficiency has been recorded more rampant among tube-well owners, which suggests that these farmers should be made aware about the consequences of over-exploitation of groundwater and use of other inputs in a balanced form.

Note

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