Irrigation Development and Groundwater Extraction in Uttar Pradesh state: Emerging Issues of Distribution and Sustainability

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Abstract

Tubewell irrigation, through modern water extraction mechanisms (WEMs) has been vital to food security and sustainable livelihoods in India due to reliable and comparatively better efficiency than canal irrigation. Since installation and maintenance require huge capital, its distribution is highly skewed towards large farmers and, resource-poor farmers have to rely on them for irrigation water, resulting into an emergence of an informal water market. Thus, the present study was an attempt to examine the groundwater (GW) extraction, distribution and productivity under different water market regimes (buyer, self-user, self-user + buyer and self-user + seller) in Central Plain Zone (CPZ) of Uttar Pradesh. An attempt has also been made to examine the sustainability of GW resources in the region. The primary data was collected through multi-stage random sampling from hundred farmers-households of Central Plain Zone in the year 2007.

Most of the farmers in the study domain were predominantly small and marginal having less than 2 hectares (ha) of land. These resource poor farmers buy water from the WEM owners, and realizing better crop yield of water-intensive crops like wheat, potato and sugarcane. In terms of productivity of groundwater, Buyer category were more efficient user of irrigation water, as they applied 760 litres water to produce one kg of wheat, 40 and 154 litres of water for producing each kg of sugarcane and potato, respectively, which was much lower than WEM owners. Thus, although groundwater market helped in better realization of their resources to both the groups (Sellers and Buyers), but have various efficiency and equity considerations. Although, the lower use of GW may also be due to the fact that most of the surveyed tubewells were energized by diesel-engine on account of irregular electricity supply in the study domain, making irrigation very costly affair. On other hand, though there has been decline in annual precipitation over the years in the CPZ, but the region has also witnessed a tubewell explosion after eighties. Due to this, according to a conservative estimate, on average, 6 BCM of GW are being extracted every year and until proper corrective measures like change in cropping pattern, expansion of canal irrigation promoting conjunctive use and recharge of this resources are not taken, the region would face serious shortage of even drinking water in the future.

Key words: Groundwater extraction, Groundwater market, Water productivity, Incremental water-output ratio.

1. Introduction

Irrigation development has always been the priority sector for the policy makers for assuring food security in India. Currently, about 60 percent of the irrigated food grain production depends on groundwater irrigation. Besides, with passage of time, dependency of modern agriculture on groundwater irrigation has increased many fold, due to its well established comparative advantages over canal irrigation (Sivanappan, 1995) and lackluster efficiency of latter. In fact, the number of shallow tubewells roughly doubled every 3.7 years between 1951 and 1991.

Development of groundwater took a major stride through private modern water extraction mechanisms (WEMs), ownership of which are highly skewed towards large farmers due to huge capital investment needed and relatively better consolidation of land holdings among them (Dhawan, 1982 and Shah, 1993). Thus, small and marginal farmers and even large farmers with fragmented holdings have to depend on WEM owners to irrigate their crops, which led to emergence of an informal groundwater market with varied ramifications (Patel and Patel, 1970; Shah, 1985; Kolavalli *et al.*, 1993; Pant, 2004, Singh and Singh, 2003; 2006).

Many researchers have assessed the value of extra crop yield attributable to irrigation. These "marginal value products" for water vary widely in value from near zero to more than $100 per acre-foot in United States, depending on the crop and the geography of the area. As water markets mature, we can expect to see strategic shift of water use towards higher-valued uses as well as the price reflecting a more uniform marginal value. Within agriculture also, the distribution of groundwater across different farm-sizes and farm resource endowments never justifies the best uses as water productivity varies widely. In rural India, there always remain few sellers of groundwater and several buyers, mainly small land holders, thus creating a situation of oligopoly market, where producers/ sellers have better bargaining power. Obviously, this leads to unequal distribution of groundwater for irrigation purposes. Under such circumstances, the overall scenario of groundwater irrigation gets overstretched in terms of overexploitation by the large farmers (water sellers) more than their requirement, while small resource poor farmers may not get adequate access to irrigation water in absence of sufficient surface water and over dependency on diesel driven tubewells in rural area of poor regions, where electricity supply is very erratic.

The present paper therefore is an attempt to examine the trend of irrigation development by source in one of the largest foodgrains producing state i.e. Uttar Pradesh, to measure the groundwater extraction by sellers and its distribution among different farm sizes, productivity of groundwater at micro level and examine the sustainability of groundwater use in Central Plain Zone (CPZ) of Uttar Pradesh which has evolving groundwater market and exclusively engaged in growing water intensive crops.

2. Study domain and data sources

Uttar Pradesh state ranks fourth (after separation of Uttarakhand state from it) with respect to geographical area among the Indian states but have the largest (17 % of total) population. Average rainfall in the state ranges from 100-200 cm in the east to 60-100 cm in the west. The Central Plain Zone comprises 13 districts (Farrukhabad, Fatehpur, Hardoi, Kanpur Dehat, Kanpur Nagar, Lakhimpur-Kheri, Lucknow, Kannauj, Sitapur, Rae Bareli, Pratapgarh, Allahabad and Etawah) and falls in-between these two regions, where more than two-third of area is irrigated by shallow tube-well (groundwater). About 90 percent of the rainfall occurs during the southwest monsoon, between July to September.

The study is primarily based on primary data which was collected during 2006-07 using Multi-stage simple random sampling technique from randomly selected two representative districts- Lucknow and Sitapur- of Central Plain Zone of Uttar Pradesh. Two blocks from each selected district and a cluster of 2-3 villages from each selected blocks were selected randomly out of which 25 sample farmers were drawn randomly from each block. Thus, total sample size from two selected districts was hundred.

3. Conceptual framework and methodology

3.1. Groundwater market

Groundwater 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 old practice, but the charges/ prices are not governed by any economic criteria but largely by informal agreement between buyers and sellers. The water markets are very crucial from distribution of irrigation water point of view, where state machinery for (groundwater/canal) irrigation are non-existing or has failed to deliver the promises to the resource poor farmers, as they can not afford to invest themselves to construct water extraction structure for irrigating their small land holding.

In the study area, four kinds of stakeholders existed in the water regimes/markets *viz.* (a) **Self-users**, farmers having their own water extraction installation for irrigating their own land only and do not participate in water market; (b) **Self-user + Buyer**; large farmers with fragmented land holdings which necessitates them to buy water in addition to their own sources (tube-well), (c) **Only Buyer**, primarily small and marginal farmers, who depend on others to buy water for irrigating their crops and; (d) **Self-user+Seller**, includes those farmers who sell groundwater after meeting their own irrigation requirement. Buying and selling of water occurs across the farmers, which means all the water-sellers sell the surplus extracted water to many buyers, similarly, a buyer with fragmented holding may buy from different sellers depending on the location of their plots. In the study area, there was not a single household who was Only Seller.

3.2 Groundwater (GW) extraction

The volume of ground water extracted (in liters) was estimated as (Eyhorn *et al*., 2005):

$$Q = t*129574.1 * BHP / (d + ((255.5998 * BHP^2) / d^2 * D^4)) \qquad ... (1)$$

where,

Q = Quantity of groundwater extracted (in liters) in a year

t = Total duration of irrigation (in hours) for all crops in a year

BHP = Engine power of pump (in HP)

d = Average depth of the well (in meters)

D = Diameter of the suction pipe (in inches)

3.3 Distribution and productivity of GW extracted for irrigation

Distribution of groundwater extracted was studied mainly through examining the pattern of irrigation water bought and/ or used by different farmers. It is important to note that although there are several crops grown by all the farmers, but those crops are limited in which purchased water are applied by the small/marginal farmers in the study area.

Productivity of the groundwater can be understood at different levels. For a farmer, it means getting more crop output per drop of irrigation water. But, for a society as a whole, this means getting more value per unit of water resource used. Increasing water productivity is then the function of several factors working in the harmony at field, irrigation-system and river basin level (Kijne *et al*., 2003). It is worth to note that amount of water applied to produce one kilogram of output is a part of irrigation requirement of crop and it does not include rainfall water. In the present study, water productivity has been measured by estimating the quantity of irrigation water applied using equation 1 as follows:

$$\text{Water productivity (litres/kg of output)} = \frac{Total\ groundwater\ applied\ to\ crop\ (litres/ha)}{Yield\ of\ the\ crop\ (kg/ha)}$$

Incremental water-output ratio

has also been calculated to know that how much irrigation water is applied to produce 1 rupee value of output for each crop i.e. the amount of water required to produce additional value in exchange of the output. It gives better measure as comparing water productivity for rice and wheat with sugarcane and potato is meaningless, since per hectare yield of later two crops are always much higher than fine cereals.

$$\text{Incremental water-output ratio} = \frac{Total\ groundwater\ applied\ to\ crop\ (litres/ha)}{Value\ of\ output\ (Rs./ha)}$$

3.4 Groundwater sustainability

For estimating the sustainability of groundwater resources in CPZ, an indirect measure has been adopted. Although, recharge of groundwater resources depends on various factors like annual rainfall, run-off, availability of river basins, structure of lower surface permitting water percolation. However, assuming other things constant, actual rainfall pattern in any region against total annual GW extraction by tubewells (TW) for irrigation would give an indication of seriousness of unsustainable use of groundwater resources in the region which has been estimated as follows:

Total GW extraction (m^3) = No. of TW × Average GW extraction/TW/annum (m^3)

Where,

Average GW extraction/TW/annum (m^3) = Average GW extraction (m^3/ hour/TW) × Total no. of irrigations applied to all crops × Duration of each irrigation (hours/ha) × Average area irrigated by each TW (ha)

4. Irrigation Development and Groundwater Status in Study Area

4.1 Plan-wise expenditure on irrigation development and potential created in Uttar Pradesh state

For the sustainable development of agriculture, development of irrigation resources is the priority issue as irrigation water along with the modern inputs and technology is the key factor for the success of agriculture for any region. Development of irrigation resources can be grouped into major, medium and minor irrigation development projects. Major and medium irrigation projects aim at increasing the command area of surface irrigation by constructing and expanding the canals and dams, while minor irrigation projects give emphasis to lift irrigation to harness the potential of underdeveloped groundwater resource. In the recent past, considerable expenditure has been made by the state government of Uttar Pradesh state for the development of irrigation resources (Chart 1).

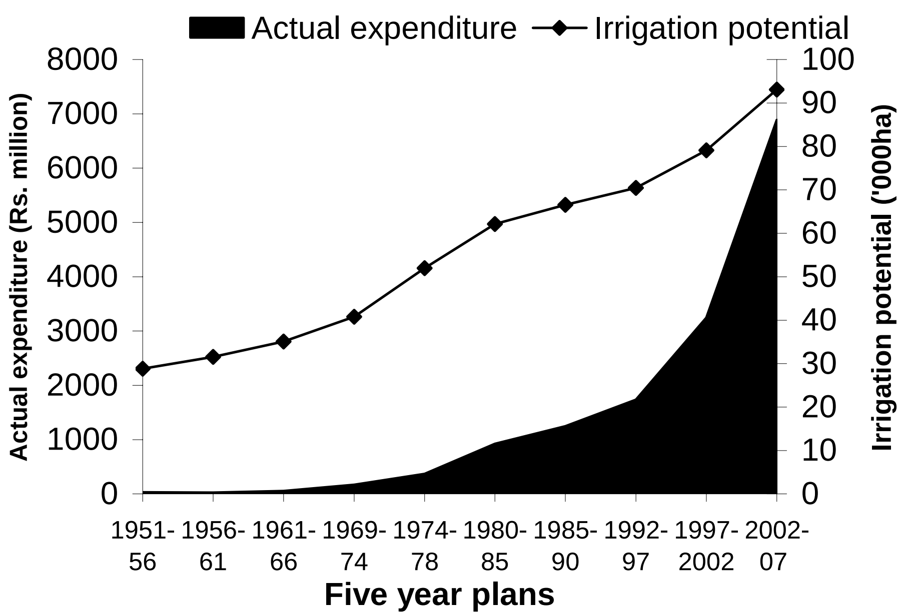

Chart 1. Plan wise expenditure and potential created in Uttar Pradesh

According to Department of Planning (Water and Related Statistics), Govt. of Uttar Pradesh, actual expenditure on irrigation development in the state has increased from Rs. 30.81 million during the first five year plan (FYP) to about Rs. 6888 million (capital + revenue expenditure) during tenth FYP, while irrigation potential created has increased from 28.83 thousand hectare to 93.10 thousand hectare only. In other words, during past five decades, the expenditure on irrigation has increased by annual compound growth rate of 11.43 per cent, while that of irrigation potential has increased by only 2.37 per cent. Consequently, the expenditure in creating every hectare of irrigation potential has increased from Rs. 1069 during first FYP to about Rs. 74000 at the end of tenth FYP. This calls for serious re-look of the strategy as well as on the efficacy of such plans in terms of governance and execution.

4.2. Share of different sources in total irrigated area

Canal and tube-wells are the main source of irrigation in Uttar Pradesh as well as Central Plain Zone (CPZ) due to technological advancement and more reliability of groundwater (tube-well) irrigation. In Uttar Pradesh, share of canal irrigation has declined from 35.42 per cent during 1965-75 to 25.18 per cent during the period 1995-2003 while that of tube-well has increased significantly from 30.37 to 66.94 per cent (Chart 2). Similarly, in CPZ also, the share of canal has nearly halved from 51.96 per cent during 1965-75 to 30.12 per cent during latter period (1995-2003). This may be mainly due to private ownership of tube-well, which makes it independent of Government's regulation and control. Furthermore, canal being poorly managed, the delivery of irrigation water to the farmers are not in sufficient amount as well as on time, when it is needed.

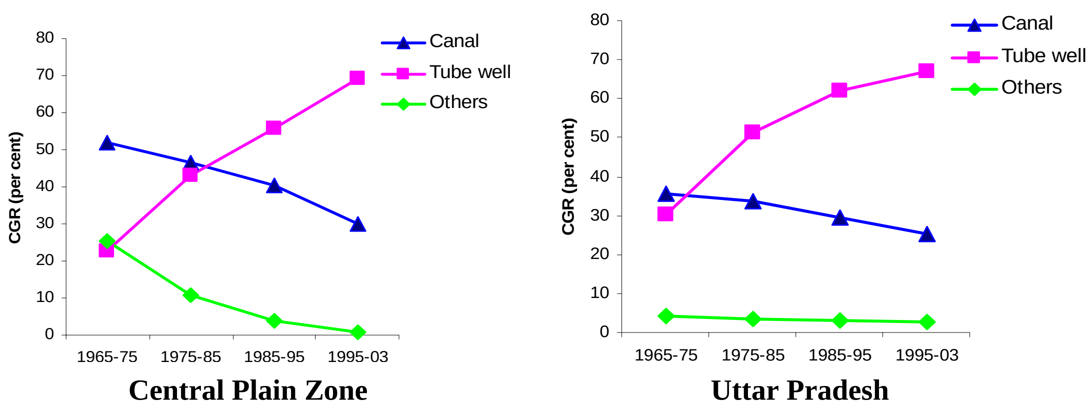

Chart 2. Share of different sources in total irrigated area in study domain

4.3 Groundwater status in the study region

According to Irrigation department of Uttar Pradesh state, total replenishable ground water resource of the state is 84 BCM, out of which 72 BCM (85.7%) is exploitable for irrigation purposes. Out of the total replenishable resource, present total extraction is about 40.95 BCM and the net exploitation is 27 BCM which is 65.9% of total extraction. Thus the ground water resource available for future exploitation is about 43.95

BCM. However, this resource is unevenly distributed in space. Out of 819 blocks in Uttar Pradesh/ Uttaranchal, there are 85 "Dark" block, 214 "Grey" blocks in the state, of which 15 dark & 38 grey blocks fall in CPZ. Furthermore, out of 13 districts in CPZ, in 9 districts (Farrukhabad, Fatehpur, Hardoi, Kanpur Dehat, Kanpur Nagar, Lucknow, Rae Bareli, Allahabad and Etawah), groundwater level has declined by more than 4 metres during 1981-2000 @>20 cm/year (Ministry of Water Resources, Govt. of India).

Seriousness of the issue of falling groundwater level in the region can be evidenced from the panic among the public due to several incidents of 4-8’ wide land cracks in many districts of CPZ (Allahabad, Etawah, Kanpur, Lucknow) alongwith in Bundelkhand region on June 16-18, 2008 (Photo). According to Geological Survey of India (GSI), exploitation of ground water was the main reason behind these cracks as the region had deficient rainfall during the past 4-5 years. Excessive withdrawal of groundwater created tension in the aquifer and due to sudden recharge of groundwater following heavy rainfall over a very short duration, these cracks have developed.


Photo: Villagers stand around sunken earth, in front of their house at Kona village, 51 kms from Allahabad

5. Groundwater Extraction, Distribution and Productivity in Study Domain

5.1 Distribution of land holding and access to groundwater

Primary survey conducted in Central Plain Zone revealed unequal distribution of land holding with pre-dominance of small and marginal farmers. Overall average size of land holding in the region varied between 0.82 hectares for water buyer category to 2.75 hectare) for Self-user + Buyer category (Table 1). On account of fragmented land holding, large farmers also had to buy water for the fields where they couldn't have own water extraction installation. In the study area, farmers under buyer category having uneconomic land holding (0.82 hectares) became an important agent of water market. Availability of groundwater market provided these resource-poor farmers easy access to irrigation water and helped in realizing better crop yield, in absence of such groundwater market, about 27 percent of land would have remained un-irrigated. Sharma and Sharma (2006) also opined that groundwater markets have facilitated in mitigating inequality in terms of providing physical access to the irrigation water, particularly among the resource- poor small farmers in many cases. On the other hand, farmers under Self-user + Seller category were having 2 hectares of land holding and were the net sellers of groundwater.

Table 1. Accessibility of sample households and farmers' area under different water market regimes

(Per cent)

Category of water market regimes	Average holding (ha)	Farm category					
		Marginal		Small		Others	
		No. of house-holds	Farm area	No. of house-Holds	Farm area	No. of house-holds	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)

Figures within parentheses for households are number of respondents under respective category while for farm area, those are total area (ha) cultivated by the respective categories of farmers together.

Source: From field survey, 2007

5.2 Groundwater extraction and distribution

Extraction of groundwater depends on water level, engine capacity, size of outlet as well as duration of draft for irrigating crops. From field survey, it was found that the average depth of tubewell was 36.7 metres and to lift groundwater, majority of WEMs owners used 10 horse power (H.P.) capacity pump with diesel engine. Electricity supply was very much erratic and unreliable in the rural area, and therefore farmers largely depended on diesel engine. With 4.13 inch average diameter of outlet, 34.95 cubic metre (m^3) of groundwater per hour per tubewell (TW) was being extracted in the region (Table 2). On the other hand, the average annual net precipitation in the region is about 100 centimeter. It is important to note that only water applied through irrigation has been accounted to estimate the water productivity in the study. It may be noted that the water requirement of the crops under study may differ from the water applied.

Table 2. Mechanism of groundwater extraction in the study domain

Particulars	Range	Average value
Average depth of water level (meter)	18-91	36.7
Average size of outlet (inch)	4-6	4.13
Engine capacity (HP)	5-15	10 (modal value)
Water extracted by each TW (m^3/ hour)	30.17- 40.97	36.51

Source: From field survey, 2007

Total groundwater extracted by tube-well owners either for irrigating their own crops and/or selling to others were also estimated (Table 3), which has been further used to estimate the net draft of groundwater in the region against the annual precipitation. The results showed that self-users extracted 150090 m^3 of GW to irrigate 31.24 hectares land in a year. It is also interesting to note that the farmers with large land holding (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 by the respondents in the recent past. On the other hand, in case of Self-user+Buyer (SU+B), ratio of area irrigated by own tube-well to that of others' was about 2:1 and the total groundwater extracted was estimated to be 80740 m^3/annum. Total water extracted by Self–user+Sellers (SU+S) was 118800 m^3 to irrigate their own 25.78 hectares land and 9.45 hectares of other non-TW owners. For relatively large farmers, it is more economical to install their own water extraction devices as the opportunity cost of reliance on sellers for irrigation water was a bit high. In the study area, about 15 percent farmers were selling groundwater for irrigation purposes, which belonged to all three categories. Few studies have also exhibited the possibility of increasing the productivity of major irrigated crops like sugarcane and wheat by reducing the excessive water- use on self-users' farms, which in turn would increase the availability of water on the buyers' farms (Singh and Singh, 2006).

Table 3. Groundwater (GW) extracted by tube-well owner in the study year

Water regimes	Avg. depth of water level (meter)	Avg. size of outlet (inch)	Engine capacity (HP)	Number of irrigations applied to all crops	Total irrigated own farm area (ha)	Duration of irrigation (hours/ irrigation/ ha)	Total GW extraction ('000 m^3 per annum)
Self user	44.20	4.00	10.00	15.60	31.24	30.93	150.09
Selfuser + Buyer	30.08	4.00	8.44	14.72	30.36	29.75	80.74 (1.97:1)
Selfuser + Seller	32.52	4.00	9.16	14.32	25.78	26.37	118.80 (2.73:1)

Source: From field survey, 2007
Figures within parentheses indicate the ratio of land irrigated by own TW & other's TW in case of SU+B, while it is ratio of own land & other's land irrigated in case of SU+S.

5.3 Inputs use and yield of irrigated crops in study area

According to meteorological department, during 2006-07, there was about 30 per cent deficit in rainfall during main rainy (monsoon) season followed by more than 70 per cent deficit in post-monsoon season in CPZ, which was the main crop growing season. In the study, crop-wise detailed analysis has been done for four crops- Paddy, Wheat, Sugarcane and Potato, as these were the major irrigated crops in the study area. Input-use pattern and corresponding yield realized in these water intensive crops were examined and presented in Table 4.

Out of four crops, potato followed by sugarcane was found to be most water intensive crop requiring maximum amount of irrigation water. Potato being short duration cash crop, farmers applied maximum irrigation to the crop. In all the four crops, highest amount of water was applied by either Self-user or Self-user+Buyer category, while farmers under Buyer category applied minimum amount due to constraint in irrigation water. In addition to water, farmers under Buyer category also used minimum amount of fertilizer than other categories in case of wheat crop resulting into lower crop yield realized by these small farmers as compared to their counterparts. Interestingly, Banerji *et al* (2007) in his case study of sugarcane growers in Western UP observed that tube well owners wanting to maximize profits from water sales could choose to sell little water, using most of it on their own plots, given the fairly low water price and the relative shortage of water (due to paucity of electricity). Instead, 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.

Table 4. Application of critical inputs and yield realized by selected farms

Particulars	Irrigation (No./ha)	Quantity of irrigation water (m^3/ha)	Fertilizers applied (kg/ha)			Yield (Kg/ha)
			N	P_2O_5	K_2O	
WHEAT						
Buyer	2.99	2784	140.11	71.90	25.5	3665
Self user	3.53	4084	195.30	98.91	30.0	3767
Self-user + Buyer	3.47	4091	157.23	84.35	37.5	3777
Self-user + Seller	3.32	3057	163.23	93.64	-	3525
Overall	**3.33**	**3504**	**157.03**	**82.40**	**28.8**	**3681**
PADDY						
Buyer	2.75	2658	130.50	56.00	-	2657
Self user	2.71	2577	155.39	73.50	7.5	3010
Self-user + Buyer	3.00	3648	165.84	62.71	-	3417
Self-user + Seller	3.00	2422	145.13	80.50	12.0	4556
Overall	**2.87**	**2826**	**153.65**	**66.72**	**8.5**	**3159**
SUGARCANE						
Buyer	2.26	2384	169.44	59.37	9.0	59200
Self user	3.86	5639	251.66	89.10	-	62875
Self-user + Buyer	3.11	3766	198.00	82.80	-	55018
Self-user + Seller	3.33	3647	237.60	86.25	-	61111
Overall	**3.14**	**3859**	**211.71**	**77.49**	**9.0**	**59868**
POTATO						
Buyer	5.00	2886	196.88	138.89	135.38	18783
Self user	5.50	4955	228.75	153.33	150.00	21086
Self-user + Buyer	5.14	4585	185.22	149.91	131.82	27434
Self-user + Seller	5.00	3928	223.17	148.06	135.00	19771
Overall	**5.02**	**4089**	**150.11**	**147.33**	**136.02**	**22643**

Source: From field survey, 2007

Contrastingly, paddy, which is grown in *kharif* (rainy) season in the study area, depend more on rainfall water and did not found to be depended exclusively on irrigation water. Thus, in spite of high water requirement than wheat, quantity of irrigation water used per hectare in paddy was less than that of wheat. Self-user+Sellers were observed to secure considerably higher yield as compared to others because of balanced use of fertilizer and modern technologies like HYV seeds. Similar pattern was found in case of sugarcane and potato crops. Due to resource constraints, Buyers could harvest comparatively low yield showing under utilization of resources.

4.4 Productivity of groundwater irrigation

Rosegrant et al. (2002) estimated water (irrigation plus net precipitation) productivity of rice in India in the range of 0.14 to 0.20 kg/m^3 of water during 1995, while for other cereals, it ranged between 0.2 to 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 kilograms per cubic meter in developing countries between 1995 and 2025. It can be observed from Table 5 that farmers belonging to Buyer category were more efficient user of irrigation water in wheat, sugarcane and potato crops, which were major water consuming crops, as they applied less amount of water to produce one unit of output.

Table 5. Crop productivity in terms of water use under different water market regimes

(Litres of water/ Kg of output)

Category	**Wheat**	**Paddy**	**Sugarcane**	**Potato**
Buyer	760	1000	40	154
Self user	1084	856	90	235
Self-user + Buyer	1083	1068	68	167
Self-user + Seller	867	532	60	199

Source: From field survey, 2007

In case of paddy, Self-user + Seller applied least irrigation water for producing each kg of paddy. This was mainly due to the fact that there were only few farmers (3) under this category growing Paddy and most of them had low land area, where rainfall water stagnated for longer period. Besides, with balanced use of fertilizer, they could harvest better crop yield (4.5 t/ha) as compared to other farmers. The reason for the low ratio in case of Buyers in wheat and sugarcane may be the fact that Buyers were predominantly small and marginal farmers with small land holding size and thus they were engaged in intensive cultivation with proper crop management and utilization of resources like weeding, insect-pest management, etc.

It must be noted that magnitude of ratio was the lowest in case of sugarcane because yield of sugarcane, as compared to other sample crops, was very high which comes in denominator term of the ratio. Similarly, in case of potato, although Self-user + Buyer emerged to be better water-use efficient, but the number of observations under such categories being very small, it was difficult to reach to such conclusion. Again Self-users with assured irrigation facilities were found to be using irrigation water injudiciously with 235 litres of water to produce one kilogram of potato.

4.5 Incremental water – output ratio under different water regimes

Incremental water-output ratio shows the amount of water required to produce additional value in exchange of the output. Results presented in Table 6 were found to be similar to that of previous section with Buyers being most efficient in case of wheat, sugarcane and potato, while in case of paddy, Self-user + Seller were more efficient. From social point of view, it looks very serious in nature that to create value of one rupee, on an average 40 to 209 litres of water is being used. The results are also in line with the classification of crops that the cash crops (potato and sugarcane) require less water to create additional revenue to the farmer than the cereals.

Table 6. Incremental water – output ratio for major crops under different water regimes

(Litres of water/ Rs. of value of output)

Category	Wheat	Paddy	Sugarcane	Potato
Buyer	108	209	40	43
Self user	164	158	71	58
Self-user + Buyer	157	204	62	46
Self-user + Seller	117	102	53	52

Source: From field survey, 2007

4.6 Sustainability of groundwater resources in CPZ

Planning Commission in its Report of the Expert Group on Groundwater Management and Ownership (2007) states that since ground water is an open access resource, the tragedy of commons often occurs where everyone tries to extract as much water as one can. This raise a number of questions *viz.* how do we make ground water use sustainable, who owns the GW, what policies, institutional and legal framework can promote sustainable use of GW? In Uttar Pradesh state, annual GW draft for irrigation is 45.36 BCM, while total replenishable GW resources is 76.35 BCM, out of which 58 per cent is from rainfall alone. It means, if there is deficient rainfall, there would be considerable loss in GW recharge. Thus, the stage of GW development in the state is 70 per cent while 19.52 BCM GW resource is available for irrigation. However, this resource is highly variable space-wise (CGWB 2006).

In Central Plain Zone, the situation doesn't appear as comfortable as that of state as a whole. During past 20 years, actual annual rainfall has declined from 1436 mm in 1981 to 789 mm in the year 2005 with an annual deceleration of 1.44 per cent. On the other hand, number of live tubewells has increased from 513059 in 1992 to 868882 in 2006. It means during last 15 years the number of tubewells has increased 150 per cent, thereby annual GW extraction for irrigation alone has increased at annual growth rate of 3.36 per cent (Chart 3). The divergence between actual annual precipitation and groundwater extraction is increasing day-by-day in the region (CPZ). This raises serious question of sustainability of GW resources in the future.

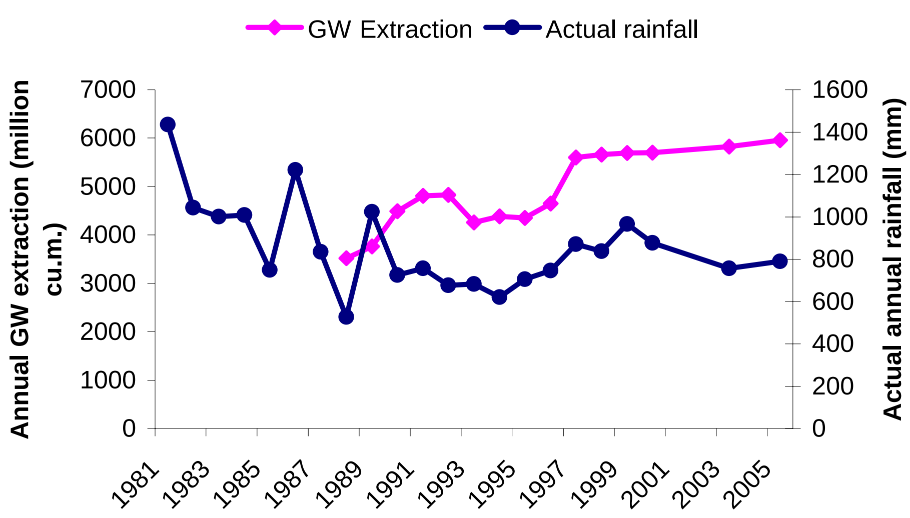

Chart 3. Actual rainfall and annual groundwater extraction in CPZ

5. Conclusion and Policy Options

Large canal infrastructure network for providing irrigation has been the prime goal of the Government of India since the First five year Plan. However, off late, it could not hold the promise, as there has been exponential growth in tubewells across the region due to its reliability. In India, there exists huge contrast in terms of opportunities of groundwater irrigation/ exploitation. In the states of Punjab, Haryana and western Uttar Pradesh, comparatively better electricity availability lure the farmers to overuse groundwater for crop irrigation, on the other hand, relatively economically poor regions like Bihar, Central & Eastern Uttar Pradesh are facing acute shortage of electricity supply in rural areas, in particular. Such scenario forces the farmers to depend on diesel operated private tubewells for drafting groundwater and providing minimum irrigation to their crops. Although, it is making an uneconomical proposition to use diesel to fuel the pump to run the well under soaring crude oil prices (Banerji *et al.*, 2007). According to Department of Agriculture, Uttar Pradesh, out of 29 GW depletion affected districts, CPZ alone constitutes 8 districts, where there is GW depletion in the range of 0.15 to 0.80 metre per year. The farmers of this region are exclusively engaged in growing water intensive crops (like paddy, wheat, sugarcane and potato) and thus depend on groundwater as a reliable source of irrigation to a great extent. However, due to income and resource disparities in the zone, groundwater market emerged as an informal institution and provided predominantly resource-poor small and marginal farmers physical access to irrigation water. Although, farmers under all categories are not applying more water than any other areas of the country, nevertheless, about 6 BCM of water are being extracted annually from the region to irrigate these crops. In fact, CSA University of Agriculture & Technology, Kanpur has suggested Maize-Mustard–Sunflower, Maize-Potato-Sunflower, Maize-Potato-Wheat / Moong cropping system for the CPZ instead of existing Paddy or Sugarcane based cropping system.

From the study, following policy options emerges:

- Though existing water market helped irrigating around 60 % of area in the region, but in absence of assured electricity and without augmenting with surface irrigation, it would be difficult to sustain current cropping pattern for a long period. Thus expanding canal irrigation in the region will help these poor farmers in various ways.

- Groundwater productivity in the region across the users are far below any standard, which may be due to inefficient use of other critical inputs like quality seeds, balanced use of fertilizers, etc. Therefore, technological breakthrough along with the proper awareness program towards utilization of these inputs would also help in reducing the use of groundwater significantly and thus improving the productivity to desired level.
- Any methods for enhancing groundwater recharge through rain water harvesting or through different Soil Conservation measures alongwith training for judicious use & management of available ground water to the farmers would help in sustaining this vital natural resources.
- Assured electricity supply in rural area with economic price will not only help the farmers in reducing the cost of crop production but also help in judicious use of groundwater for irrigation.

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