

## Valuation of irrigation water for two principal crops in Paliganj distributary of Bihar, India

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**Abstract:** A lot of investment has been done in creating irrigation potential in India. On account of this, it increased more than five times since 1951. But recovery from the created irrigation potential is very low, leading to poor performance of irrigation sector. Highly subsidised irrigation water price, which does not reflect true irrigation water supply cost, is the main cause of slow revenue recovery. Low irrigation water pricing results in indiscriminate and unscrupulous use of irrigation water in upper, middle and tail reaches of a canal, leading to either waterlogging or water deficit situations. Since more than two decades, irrigation water charges have not been revised in many states and as a result revenue from water is not increasing. In the future, agriculture is going to face a new challenge of producing more from less water available, because more water is being diverted towards industries, urban and domestic sectors. Under such an alarming situation, it was thought to assess the price of irrigation water for producing a kilogram of rice and wheat in the command of Paliganj distributary located in Bihar under Sone canal system in India. Data about price of tube well water and canal water to be paid by farmers as decided by State Water Resources Department were collected and data about agricultural inputs applied and outputs produced by the farmers were collected through a developed questionnaire. The price of irrigation water, expressed as Rs. per m<sup>3</sup>, was computed by employing Residual Value method. This method yielded a better assessment of irrigation water price. If cost of cultivation is calculated after properly assessing and incorporating irrigation water price, it may help Government in formulating better policies supporting revision of Minimum Support Price of agricultural products, ultimately benefitting farmers. Another important aspect of this study is to make farmers aware about the importance of water and promote efficient and judicious use of this scarce resource.

**Key words:** Irrigation water price; residual value method; cost of production; gross return; Paliganj distributary

### 1. INTRODUCTION

The importance of water needs no emphasis, as without water the existence of life on this earth cannot be imagined. Currently about 70% of world's fresh water abstraction is used in agriculture (FAO-COAG, 2007) and in the next 20 years irrigated land is projected to increase by 27% in developing countries (World Bank, 2008). In India, water is increasingly becoming scarce because diversion or allocation of water for agricultural use is reducing due to growing population, industrialization and urbanization. To grow more food to feed ever increasing population with limited or reduced availability of water is a great challenge. This challenge can be met out, if water is utilized efficiently and judiciously in crop production systems. For example, in rain deficit regions, food production can be enhanced by providing irrigation at critical crop growth stages. In irrigated areas, water is efficiently utilized if those crops are selected, which consume less water and give relatively better yields. Water productivity, which is the ratio of output produced in terms of kg, Rs. or \$ and water consumed, diverted or depleted in terms of m<sup>3</sup>, ha-cm is a very relevant concept, which is being discussed all over the world. Water productivity can be enhanced by either increasing the crop production without allowing water consumption to increase or sustaining crop production and reducing water consumption.

Cook et al. (2006) described two basic uses of water productivity estimates, i.e., (i) as a tool to diagnose the system water use efficiency and (ii) to explore opportunities for better management leading to enhanced water productivity. Upadhyaya and Sikka (2016) described the basic concepts

of water, land and energy productivity in agriculture and suitable land and water management technologies/ strategies capable of enhancing productivity. Upadhyaya (2018) assessed Rice and Wheat water productivity in India and discussed various influencing factors and their impacts on crop water productivity. Studies on water productivity clearly reflect the role and importance of water in crop production system and suggest the ways and means for utilization of water efficiently and effectively.

Irrigation water pricing is a very interesting subject of study. At some places, it is decided keeping in view the cost of water resources (Xian et al., 2014), whereas at other places preference was given to willingness of farmers to pay the price of water (Motta and Ortiz 2018). Jiang et al. (1993) proposed that the true value of water resources was in subsidization of water resource rent that would create the differences in price and value of water resources. Various water resources value estimation approaches based on value mosaic, equilibrium pricing, fuzzy comprehensive evaluation, energy estimation and rational pricing studied by many researchers have been reported in the literature.

Residual imputation model or Residual Value Method (RVM) is a mathematical approach, which is used to recognize the value of water, where water is one of the inputs used in agricultural production. Only few studies related to irrigation water pricing have been conducted employing residual imputation technique. Emad et al. (2012) assessed price of irrigation water for 12 crops in Jordan by employing RVM. Kiprop et al. (2015) determined the economic value of irrigation water in Kerio Valley Basin (Kenya) by employing Residual Value Method and reported higher estimated value of water for fruit trees as compared to field crops.

In India, Hellegers et al. (2007) studied the role of pricing policy in meeting the controlled abstraction of fresh groundwater to avoid decline and salinization of aquifers, along with increase in productivity of water in the context of declining long term availability in Haryana, India, with the help of Residual Value Method. Studies on irrigation water pricing are meagre, but experts always discuss, desire and show their interest in determining the price of irrigation water. When water suppliers and water users know the irrigation water price, they will realize its importance and it will be easy to convince and encourage the water users to utilize water more efficiently.

Keeping this in view, the objective of the present study is to determine the price of irrigation water for rice and wheat crops in Paliganj distributary of Sone canal system, Bihar, India, based on the price of tube well water and canal water obtained from State Departments, agricultural input data collected from farmers and thereafter application of Residual Value Method (RVM).

## **2. MATERIAL AND METHODS**

In this section, introduction to study area along with its location, basic characteristics like rainfall, canal water availability, groundwater availability, information about soil, crop, climate, evapotranspiration of rice and wheat crops computed using meteorological data, other data related to input cost, labour cost, fixed cost to calculate total cost of cultivation, monetary returns from (main product and by product) of rice and wheat crops, and total irrigation water applied collected from farmers in a prescribed format through developed questionnaire, have been presented. The simple and popularly used Residual Value method along with its basic assumptions and theoretical aspects has also been discussed briefly.

### **2.1 Study area**

The study was undertaken in Paliganj distributary, which emanates at 75 km of Patna main canal, in right side. It is controlled by Sone Canal Sub Division Bikram, Bihar, India. The total length of Paliganj distributary is 27.4 km and its design discharge is 5.1 cumecs. It has two sub distributaries, Chandos and Bharatpura, emanating at 10.45 km and 17.1 km, respectively, from Paliganj distributary with design discharge of 0.85 cumecs each. Paliganj distributary is divided into three

reaches. The lengths of I, II and III reaches are 10.45 km, 6.65 km and 10.3 km, respectively. The Gross Command Area (GCA) of these reaches are, respectively, 2767 ha, 2513 ha and 2794 ha, and Culturable Command Area (CCA) are 2479 ha, 2102 ha and 2400 ha, respectively. During 2017-18, only 1285 ha in I reach, 1070 ha in II reach and 764 ha area in III reach, totalling to 3119 ha, could be irrigated with available canal water. The index map of Paliganj Distributary of Sone Canal System in India is shown in Figure 1.

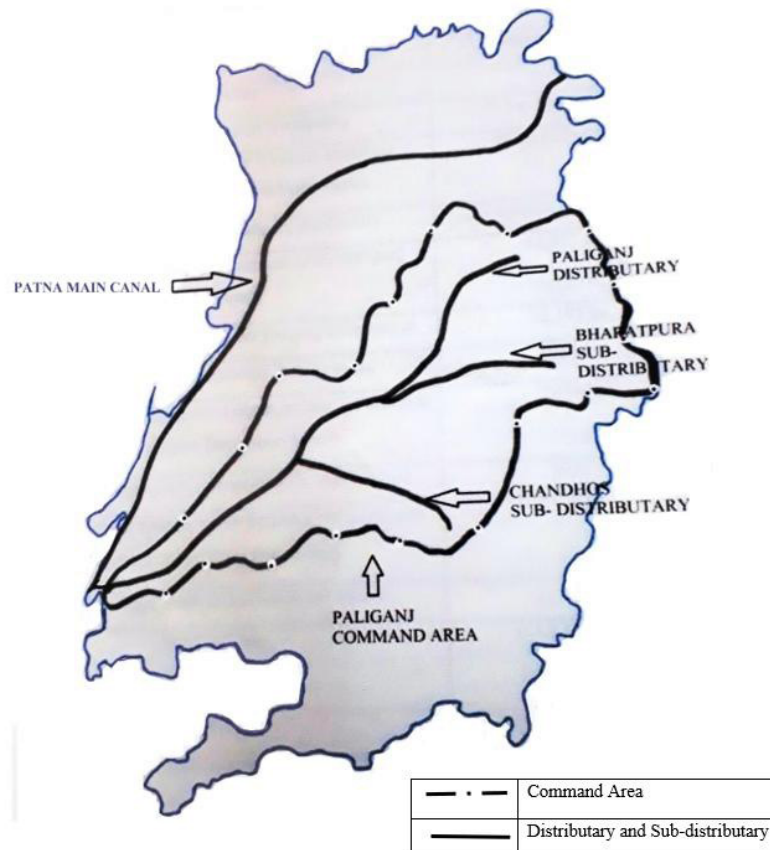


Figure 1. Index map of Paliganj Distributary in Sone Canal System

## 2.2 Rainfall characteristics

Rainfall analysis at Paliganj reveals that average annual rainfall is 888.9 mm, with maximum of 1342.4 mm in 1997 and minimum of 490.2 mm during 1998. 90.3% of rainfall occurs during monsoon months (June to September) and 9.7% during non-monsoon months. Among average monthly rainfall at Paliganj, July had the highest of 292.6 mm followed by 214.8 mm in August, 183.7 mm in September and 111.3 mm in June. Average weekly rainfall had a maximum of 75.4 mm in 28<sup>th</sup> week. The rainfall during this week varied in the range of 534.8 to 0.0 mm. Maximum weekly rainfall of 534.8 mm was observed in 28<sup>th</sup> week of year 1997.

## 2.3 Water delivered from Paliganj distributary and days of operation

Discharge at the head of Paliganj distributary during June 2017 to March 2018, as well as the days of operation, were collected from Daily Discharge Data Register, maintained at the Divisional office of Water Resources Department, Govt. of Bihar at Bikram and converted into monthly volume of water delivered, which is given in Table 1.

*Table 1. Irrigation water delivered through Paliganj distributary and days of operation*

Month	Volume of water (m <sup>3</sup> )	Days of operation
June, 17	1203384	10
July, 17	6225168	20
August, 17	6244744	17
September, 17	6626476	19
October, 17	6626476	18
November, 17	1585656	5
December, 17	-	-
January, 18	601962	8
February, 18	1137855	14
March, 18	922519	15

## 2.4 Canal water charges

The records of the revenue department show that from Rabi (i.e. during non-monsoon period) 1983 to Kharif (Monsoon period) 1995 canal water charges were at the rate of Rs. 36.20 per acre for rice, Rs. 20.70 per acre for wheat, Rs. 63.80 per acre for sugarcane and other crops. From Rabi 1995 to Kharif 2001 water charges were Rs. 70/- per acre for paddy, Rs. 60/- per acre for wheat, Rs. 120/- per acre for sugarcane and other crops. From Rabi 2001-02, till date, water charges are Rs. 88/- per acre for paddy, Rs. 75/- per acre for wheat, Rs. 150/- per acre for sugarcane and other crops.

Theoretically, water charges imposed by a State depend on the kind of crop, the irrigated area, the number of times each crop is irrigated and the total volume of water used by the farmers. Thus, enormous variation of water charges across States has been noticed. For example, in Maharashtra, the maximum rate for flow irrigation is Rs. 6,297/- per hectare and the minimum is Rs. 119/- per hectare, while in Himachal Pradesh it is Rs. 49.92/- per hectare for all irrigation uses.

The report of the Committee on Pricing of Irrigation Water Planning Commission Government of India New Delhi (1992), pointed out that optimum level of charges for use of water for irrigation as percentage of gross income estimated to be around 5% for food crops and 12% for cash crops. But the actual receipts vary from less than 1% to a maximum of 2.9% for all India. No uniformity was observed as regards to principle considerations adopted by the states in fixing of water rates. Some considerations as suggested in the report were (i) crop water requirement, (ii) assuredness of supply of water, (iii) paying capacity of farmers based on net or gross value of agriculture produce and (iv) cost of supply of water.

From the above, it is clear that canal water charges are very low and a revision of canal water charges is due since long, but due to political reasons or in the absence of will power, leaders/water managers do not dare to revise the water charges. In the absence of funds, operation and maintenance services are poor and timely supply of water in adequate quantity equitably among farmers is not assured.

One more important thing to note here is that already registered Water Users Association is here and its responsibility is to collect revenue from water users, keep 70% of revenue with Water Users Association for operation and maintenance of distributary in participatory mode under technical guidance of Water Resources Department, Govt. of Bihar and deposit 30% revenue to the Department. Earlier, under World Bank Project and through technical support of the International Water Management Institute (IWMI), Sri Lanka, the Water and Land Management Institute (WALMI) Patna initiated a pilot project and tried to reform the system by training, capacity building, and irrigation management transfer programme. It worked well for quite some time and farmers used to get sufficient water to irrigate their crops, but later on the gap in supply and demand started increasing due to poor leadership, wide gap in water supply and water use due to the absence of meetings and dialogues between water managers and water users. At present, canal water satisfies only I and II reaches and rarely water reaches in III reach. Accordingly, farmers in III reach, try to use groundwater or any other source of water to provide life saving irrigation to crop.

## ***2.5 Groundwater scenario***

As per Central Ground Water Board (2013) report, on 31<sup>st</sup> March 2009, the net groundwater availability assessed in Paliganj distributary command was 7177 ha-m, existing gross groundwater draft for irrigation was 1585 ha-m, net groundwater availability for future irrigation development was 5084 ha-m and stage of groundwater development was 27.1%, only. The depth to groundwater table was reported to vary between 2-5 m during post monsoon and 5-10 m in pre monsoon season. 95 diesel operated and 65 electric operated pumps are operational in the command (mostly in tail reach, where distributary water does not reach) to withdraw groundwater. The charge for groundwater withdrawn by diesel operated pumps was reported as Rs. 100/- per hour, whereas for electricity operated as Rs. 60/- per hour. Though there is scope of groundwater development, but due to tremendous difference in cost of water received from Paliganj distributary and below the ground, farmers wait for canal water and only in the absence of water from other sources, they use groundwater.

## ***2.6 Soils***

Soils are predominantly sandy loam, with clay loam at places, with low to medium nutrient status. These soils vary from moderately well drained to poorly drained and acidic to slightly alkaline in nature. Soils are suitable for growing rice and wheat crops, but farmers do not apply balanced dose of fertilizers. They apply only urea and its utilization efficiency is poor.

## ***2.7 Crops***

The cropping pattern survey was conducted in the command area of Paliganj distributary. The main crop during monsoon season was rice and during non-monsoon season the major cropped area was under wheat, followed by maize, pulses, oilseeds, sugarcane and vegetables.

## ***2.8 Climate***

The climate is subtropical, with wet monsoon and hot summer. South-west monsoon, starting in mid June and ending by mid October, provide most of the rainfall. About 403.9 mm of rainfall occurs in June and July (i.e. sowing period of rice) and 398.5 mm during August and September months (i.e. growth period). During October, also 4% to 6% of annual rainfall occurs, which is useful for maturity and replenishing soil moisture utilizable by Rabi (non-monsoon) crops. The temperature during summer is nearly 35°-43°C and 17°-30°C during winter. The relative humidity, which is the amount of moisture present in air, was reported at a maximum of 90% in August and a minimum of 32% during April.

## ***2.9 Rice and wheat crops evapotranspiration***

Reference crop evapotranspiration was estimated employing FAO 56 Penman-Monteith method that uses maximum and minimum temperature, maximum and minimum relative humidity, wind velocity and solar radiation. The values were multiplied by crop coefficients ( $K_c$ ) of rice and wheat crops (which are affected mainly by the crop characteristic, crop planting or sowing date, crop development rate, length of growing period and climate conditions) and considered as established for this region and then rice and wheat crops evapotranspiration was determined. Kumari et al. (2013) reported  $K_c$  values for rice as < 0.2 to 0.5 during July, 0.8 to 1.6 during August, 0.6 to 1.4 during September and < 0.4 to 1.0 during October. Similarly,  $K_c$  values for wheat crop were reported as < 0.2 to 0.5 during December, 0.5 to 0.9 during January, 0.5 to 1.3 during February, 0.5

to 1.3 during March and < 0.3 to 0.7 during April. In this study, average  $K_e$  values for various months were considered to compute crop evapotranspiration. Average seasonal rice crop evapotranspiration was estimated as 754.6 mm and average seasonal wheat crop evapotranspiration as 195.6 mm. Effective rainfall in the case of rice was determined by comparing the daily rainfall with dyke height around rice fields. If rainfall was more than dyke height then the rainfall, up to dyke height was considered as effective rainfall and more than dyke height as runoff or ineffective rainfall. Similarly, in the case of wheat, daily rainfall and evapotranspiration were compared. Rainfall more than the evapotranspirational requirement was considered as ineffective and up to evapotranspiration as effective considering soil moisture at field capacity. Finally, daily values were added to get monthly values. At 75% probability level of rainfall, rice and wheat crops evapotranspiration was always higher than rainfall and the total difference in rice as well as wheat crops evapotranspiration and rainfall during the growing seasons of rice and wheat at this probability level was found as 571.7 mm 168.4 mm, respectively.

### 2.10 Data collection process for other relevant data

In order to collect required data / information about agricultural inputs used and their costs, labour cost involved in agricultural operations, value of land, implements, infrastructure, output (main, as well as by-product) produced along with their sell price, a structured questionnaire was developed. Thirty farmers, representing I, II and III reach of Paliganj distributary were interviewed and questionnaires were filled up. Irrigation water price was assessed by considering water actually used by crops (i.e. on the basis of crop evapotranspiration), as well as water applied by farmers depending on availability.

### 2.11 Residual value method

In this section, the Residual Value Method (RVM), which has been employed to compute irrigation water price of rice and wheat, is discussed. According to Euler's theorem, for an agricultural production function involving constant returns to scale, the summation of the marginal products will actually yield the total product. For a homogeneous agricultural production function,  $f(x_1 \dots x_n)$  of degree 1, if the price of each input  $i$  is its "marginal product"  $f'_i(x_1 \dots x_n)$  then the total cost, i.e.  $\sum_{i=1}^n x_i f'_i(x_1 \dots x_n)$  is equal to the total output, i.e.  $f(x_1 \dots x_n)$ . Agricultural Production function 'Y' is assumed to be influenced by four factors i.e. Money invested (M), labour force used (L), available natural resources such as land area (A) and water (W) utilized. It may be expressed as:

$$Y = f(M, L, A, W) \quad (1)$$

Assuming agricultural production and prices are known and technology is constant,  $P_o$  is the price of output;  $P_i$  is the price of input under perfect information. Assuming that objective of the farmers is to maximize production, the production function may be written as:

$$PF = \sum_{j=1}^n P_o \cdot Y_j - \sum_{i=1}^n P_i X_i - P_w Q_w \quad (2)$$

The optimal profits can be determined, if the first derivative of 'PF' with respect to  $x$  is equal to zero.

$$\frac{dPF}{dx} = P_o \cdot \frac{df(x)}{dx} - P_i = 0 \quad (3)$$

Therefore,  $P_o(dy/dx) = P_i$ .

If all the inputs, including water are exchanged in a competitive market and employed in a production process, the value of water will be:

$$P_w \cdot Q_w = P_o \cdot Y - \sum_{i=1}^n P_i \cdot X_i \quad (4)$$

RVM basically calculates the incremental contribution of each input in the production process, if all the inputs except water are assigned appropriate prices. The residual obtained by subtracting the non-water input costs equals the gross margin and can be interpreted as the maximum amount paid by the farmer for water, after covering the cost of production. The price of irrigation water is calculated using the following formula:

$$P_w = \frac{\sum_{j=1}^m Y_j \cdot P_o - \sum_{i=1}^n X_i \cdot P_i}{\sum Q_w} \quad (5)$$

### 3. RESULTS AND DISCUSSION

Data was collected from 30 farmers (10 each from head (I), middle (II) and tail (III) reaches) in Paliganj distributary command through structured questionnaire and analysis was done, but here, results of 3 representative farmers having 1 ha or near 1 ha area in I, II and III reach of Paliganj distributary are presented in Table 2.

Irrigation water applied by these farmers through canal and tube well was computed and given in Table 3.

Table 2. Data of 3 farmers from I, II, and III reach of Paliganj distributary

Sr. No.	Particulars of inputs / outputs	Reach I Area 1.13 ha		Reach II Area 1 ha		Reach III Area 1 ha	
		Rice	Wheat	Rice	Wheat	Rice	Wheat
1.	Input cost (including seed, organic matter, fertilizer, insecticide, pesticide etc. But excluding water) (Rs.)	11680	16605	9930	14170	10010	15550
2.	Labour cost involved in ploughing / rotavator / tilling/ harrowing / sowing / dibbling / planting / transplanting / weeding / harvesting / threshing etc.(Rs.)	27100	23100	22500	19000	22500	19000
3.	Fixed cost including rental value of land, depreciation cost of farm building and implements and interest on fixed cost (Rs.)	48000	23820	44500	25408	43100	20160
4.	Total cost of cultivation (Rs.)	86780 (76796 per ha)	63525 (56217 per ha)	76930	58578	75610	54710
5.	Yield of Main Product (T)	6	3.5	5.5	3.2	5.3	3
6.	Sale Price (Rs./T)	17500	18400	17500	18400	17500	18400
7.	Yield of Bi-product (T)	3	3	3	2.5	3	2.4
8.	Sale Price (Rs./T)	5000	5000	5000	5000	5000	5000
9.	Output from Main product and Bi-product (Rs.)	120000 (106195 per ha)	79400 (70265 per ha)	111250	71380	107750	67200
10.	Output – Input (Rs.)	33220 (29398 per ha)	15875 (14048 per ha)	34320	12802	32140	12490

Table 3. Irrigation water price (Rs./m<sup>3</sup>) computation based on water applied and irrigation requirement

Source of water	Volume of water applied (m <sup>3</sup> )					
	Reach I Area 1.13 ha		Reach II Area 1 ha		Reach III Area 1 ha	
	Rice	Wheat	Rice	Wheat	Rice	Wheat
Canal	5835	1160	5160	1060	4950	-
Tube well	1190	1670	1450	1525	1750	2000
Total irrigation applied	7025	2830	6610	2585	6700	2000
Profit (Rs.)	33220	15875	34320	12802	32140	12490
Irrigation water price (Rs./m <sup>3</sup> )	4.73	5.61	5.19	4.95	4.80	6.24
Irrigation requirement (ET - 75% dependable rainfall) (m <sup>3</sup> )	6460	1902	5717	1684	5717	1684
Irrigation water price based on actual irrigation requirement (Rs./m <sup>3</sup> )	5.14	8.35	6.00	7.60	5.62	7.42

It may be observed from Table 3 that irrigation water price considering irrigation water applied through canal and tube well in Reach I, II and III for rice crop is 4.73, 5.19 and 4.80 Rs./m<sup>3</sup>, respectively and for wheat crop is 5.61, 4.95 and 6.24 Rs./m<sup>3</sup>, respectively. When irrigation water price was computed considering actual irrigation requirement (crop water requirement - effective rainfall), in reach I, II and III for rice crop it is 5.14, 6.00 and 5.62 Rs./m<sup>3</sup>, respectively and for wheat crop it is 8.35, 7.60 and 7.42 Rs./m<sup>3</sup>, respectively. It is also observed that in all the three reaches, price of irrigation water for rice and wheat crops computed considering actual irrigation requirement is always more than irrigation water price computed based on total irrigation water applied through canal and tube wells. It may also be observed from Table 3 that in reach III, canal water could not be available to irrigate wheat crop and it was solely irrigated by tube well water. Though profit was not much even than irrigation water price was relatively higher. Results of all the farmers in head, middle and tail reaches of Paliganj distributary obtained after analysis of data collected from them is quite similar to the results of three cases of farmers presented here, so it can be said with confidence that irrigation water price determined here represent the whole Paliganj distributary command.

#### 4. SUMMARY AND CONCLUSIONS

Price of irrigation water for rice and wheat crops in Paliganj distributary of Patna Main Canal under Sone Canal System was estimated employing Residual Value Method. In this method, each input contribution in the agricultural production process with proper assessment of prices to all the inputs except water was considered. The residual obtained by subtracting the non-water input costs was made equal to the gross margin and was interpreted as the maximum price of water to be paid by farmers after covering the cost of production. The study indicated that irrigation water price for rice and wheat crops in Paliganj distributary varied in the range of 4.73 Rs./m<sup>3</sup> to 6.24 Rs./m<sup>3</sup> when total water applied was considered and between 5.14 Rs./m<sup>3</sup> and 8.35 Rs./m<sup>3</sup> when actual irrigation requirement was considered. For wheat crop irrigation water price, when irrigated by tube well water alone, was higher as compared to irrigated by both canal and tube well. This study may also be helpful in convincing farmers, planners and policy makers about efficient and judicious use of water and to review/revise the canal water charges, which were revised in the year 2001-02 and were fixed at 88, 75 and 150 Rs./acre for Kharif, Rabi and other annual crops.

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