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Research Note

Is Irrigation Water only Used for Irrigation? An Enquiry into the Alternative Uses and an Attempt on Valuation

Indira Devi P.[1] and K.P. Mani[2]

Abstract

Irrigation sector investments in Kerala have been mounting since Independence, but the financial performance of these investments has been far from satisfactory. In an era of growing divergence in water supply and demand, the emergence of water markets is imminent. This calls for a realistic pricing strategy for water use, whether in agriculture or other sectors. The canal water though targeted at the agriculture sector, is often put to non-irrigation uses. This paper has discussed a method to quantify the non-irrigation uses of canal water and has assessed the value of the same, based on a sample study in Peechi Irrigation Command Area in Thrissur district of Kerala, India . The value has been assessed for the water used directly for irrigation from the canal system, water used through the recharge facility from the canal and non-irrigation uses (domestic).

1. Introduction

The pricing of water service has been a sensitive issue since long. There is a wide variation in the water-rate structures across the states. Several committees/ groups have been constituted in India from time to time for suggesting ways to fix water rates. The role of water as a basic need, a merit good, and a social, economic, financial, and environmental resource makes the selection of an appropriate set of prices exceptionally

[1] Department of Agricultural Economics, College of Horticulture, Kerala Agricultural University P.O Thrissur, Kerala 680 656. Email: trc_indira@sancharnet.in

[2] Department of Economics, Dr John Mathai Centre, Calicut University, Thrissur, Kerala

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difficult. Further, the application of price-based instruments, once an appropriate value system has been agreed upon, is particularly difficult in the case of water. It is because the flow of water through a basin is complex phenomenon with wide scope for externalities, market failure, and high transaction costs.

The majority of the population in India depends on the major and minor irrigation projects for varied uses, not only for irrigation. But, the studies to address the issue of water pricing have been concentrating on irrigation uses, while the existing water rates in different states of India are too low to cover even the operation and maintenance costs of such projects (GoI, 1972; Patel and Himmat, 1990). Underpricing of canal irrigation is one of the major causes of its low productivity and this leads to over-irrigation, wastage and misutilization, leading to low productivity (NCAER, 1959; GoI, 1972; Asopa, 1977; Patel and Himmat, 1990). The collection of water cess was reported to be much below (11.72%) the O&M costs of the Peechi irrigation system in Kerala (Suresh, 2000). This necessitates restructuring of the existing policy in the irrigation sector for improving the efficient production, management and utilization of canal irrigation.

The present paper looks at the direct and indirect uses of canal water and the value the same which can form the basis of arriving at a pricing strategy which is economically viable and socially justified. The paper forms a part of a major study conducted with support from the World Bank aided India: Environmental Economics Capacity Building Programme implemented by the Indira Gandhi Institute of Development Research, Mumbai.

The Study Site

The Peechi irrigation project is one of the major irrigation projects of Kerala, India. The project consists of a masonry dam and a storage reservoir at Peechi and a system of irrigation canals which criss-crosses the Thrissur taluk. The project was started in 1947 and completed in 1959. It has a canal system consisting of two main canals, on either banks and its branches and distributories to irrigate an area of 18,623 hectares.

This dam is also the source of drinking water to the areas of Thrissur Corporation and the adjoining Panchayats.

Sampling Design and Database

The multistage stratified random sampling technique (stratification based on length of canal) was adopted for sample selection. The Right Bank Canal (RBC) and the Left Bank Canal (LBC) were divided into three approximately equal parts, based on the total canal length to demarcate the head, mid and tail portions. From each portion, one distributory was selected randomly.

A detailed list of beneficiaries of canal water who depended on canal system for different purposes was prepared. This included the following:

(i) Farms which were directly irrigated from the canal and farms which depended on the canal for recharging the wells in the command area (irrigation and domestic uses from the well), and

(ii) Households who depended on canal directly for domestic uses (not for irrigation). This included (a) human uses (washing, bathing), and (b) non-human uses (livestock). The industrial uses of canal water were not observed in the study site.

The information was compiled from various sources (Department of Agriculture, Command Area Development Authority, local Non-Governmental Organisations, Neighbourhood Groups, etc.). A random sample of fifty farmers was selected from the directly-irrigated farms and recharge category and sixty from the non-irrigation use group. From the list of farmers in the command area of each distributory, a proportionate number of random samples was identified. This proportion was the ratio of residents in the command area of the selected distributory to the total number of residents in the command area of the project.

Data were collected through the personal interview method using structured questionnaire, direct observation and participatory methods. A multivisit programme schedule was resorted to the collection of data. The following chart shows the data collected by each method:

Type of data collected	Method of data collection
Cropping pattern, Farm income Socio-economic parameters	Questionnaire/ Direct observation
Water-use measurements (Direct irrigation, recharge, non-irrigation uses)	Direct observation, Participatory method

The amount of water used for irrigation was measured using a ‘V notch’ designed for the purpose, in consultation with the Department of Agricultural Engineering, Kerala Agricultural University. The volume of recharged water was measured through monitoring the level of water in the wells in the sample homesteads at different intervals of time and computing the same. Measuring scales were fixed in the chosen wells and readings at definite intervals were recorded. The volume of recharge was computed from the readings and diameter of the well, which was considered as the consumption in the farm/household.

For non-irrigation users, the exact duration of activity (washing/bathing), frequency (hours/day, days/week, week/month, month/year), distance from dam, and measurement of canal at the point of use were the important data gathered for estimating the water consumption.

Similarly, the costs and income estimations were based on the prices prevailing at the time of survey, i.e. 2000-01 and 2001-02.

Analytical Tools Employed

The value of water was computed through the cost-based valuation approach. The cost of providing the service was considered as the basic factor reflecting its value. The different costs were:

(A) Fixed Cost

The Peechi reservoir caters to the needs of irrigation and drinking water supply of the neighbouring Corporation of Thrissur. Of the total volume release of 117.55 million m^3 /year, 89.82 million m^3 was given to the Kerala Water Authority and the rest for irrigation supply.

The fixed cost component included the investment on plant and machinery, distribution system and the related initial expenses. The Dam was commissioned in the year 1957 and the total initial investment cost was Rs 235 lakhs. However, considering the long life-span of the Peechi irrigation system, this component was not included in this study.

(B) Variable Costs

The total variable cost incurred in the project during the 10-year period from 1990 to 2000 was collected from the concerned department.

The Marginal Cost (MC) was estimated from the function, $C = a.Q^b$, by taking the first derivative.

$$MC = b*\bar{C} / \bar{Q} \qquad \ldots(1)$$

where,

C = The total variable cost incurred in the project per year (Rs) and
Q = The quantity of water used per year (m^3)

Demand Function

Demand Function for Irrigation Water in the Farms (Directly-irrigated)

Amongst various functions such as Cobb Douglas, linear, transcedental, quadratic and square root (with and without intercept) , the most suited production function according to R^2 and standard error criteria was:

$$W = a + b_1.X_1 + b_2.X_2 + b_3.X_3 \qquad \ldots(2)$$

where,

W = Water consumed for irrigation during the whole season, per ha (m^3). The water at the point of entry from the distributory to the farm was measured using the V notch, on all days on which the farm was irrigated during the season from Nov. to May, 2002.

X_1 = Distance from the main canal (m) (Since the farmers adopted canal to field irrigation directly, the distance from the main canal was expected to have an influence on the water-use)

X_2 = 1/I, where I was income from farm (Rs/ha) (farm income for the previous year)(Farmer level management decisions were often governed by the farm income. Hence, this variable was taken)

X_3 = 1/C, where C was Diversity Index (Diversity Index reflected the crop water requirement, for the whole farm)

For the analysis, the Diversity Index was formulated for each sample farmer. The area under each crop was compiled and weighted average was taken and converted to a scale ranging from 0 to 1. The weight was formulated as a percentage of the total area under that particular crop, i.e.

$$W_i = \frac{\text{Total area under crop, i (ha)}}{\text{Gross cropped area (ha) of sample farmers}}$$

where, W_i was the weightage given to crop i under homestead farming.

The diversity index of the ith farm was computed as:

$$\text{D.I.} = \frac{\sum (A_{ij} \ . \ W_i)}{\sum A_j}$$

where, D.I = Diversity Index
A_{ij} = Area under crop i under farm j
W_i = Weightage for crop I, and
$\sum A_i$ = The total farm size.

The marginal productivity of each factor was found by using the first derivative of the function.

Farms Irrigated from Recharged Wells

The factors determining the recharging of the farm wells were identified. The best-fitted model selected according to R^2 and standard error criteria was linear function (5):

$$W = a + b_1 D + b_2 I + b_3 F + b_4 C \qquad \ldots(5)$$

where,

W = Net water recharge in wells (m^3)/ well/ season of irrigation (Nov. to May)

D = Distance from main canal (m)

I = Initial level of water (before opening the canal, m^3)

C = Cost on irrigation structures (Rs) (The recharge facility could be effectively used if only irrigation investment for drawing water from the well was there. So this variable was included)

F = Farm size (ha) (small farms generally had a single well whereas larger ones had more. This influenced the recharge level and hence farm size was taken as a variable)

a = Intercept

b_i = Slope coefficient

For Non-irrigation Purposes

(i) Human Uses (bathing, washing)

$$Y = a + b_1 B + b_2 Di + b_3 F \qquad \ldots(6)$$

where,

Y = Quantity of water used for the purpose (m^3/ year/household)

B = Benefit (Rs / household/ year)(cost of adopting alternate methods–cost of using canal water)

D = Distance of user point from house (m), and

F = Family size (No.).

(ii) Non-human Uses

$$Y = a + b_1 B + b_2 Di + b_3 L \qquad \ldots(7)$$

where,

Y = Quantity of water used for the purpose (m^3/ year/household)

B = Benefit (alternate cost of adopting other sources–cost of using canal water) (Rs/ household/ year)

D = Distance of user point from house (m)

L = Number of livestock

For estimation of demand function for each group, the value was found by multiplying unit cost with mean consumption.

Results and Discussion

The total variable cost incurred during the period 1991-2000 was compiled from the records of Irrigation Department (Table 1).

It was estimated that

$$\ln C = -60.04 + 3.9936 \ln Q \qquad \ldots(8)$$
$$(27.23) \quad (1.44^*)$$

$R^2 = 0.4273$

$F = 7.72^*$ (*Statistically significant at 1% level)

where,

C = The total variable cost incurred on the project per year (Rs), and

Q = The quantity of water used per year (m^3).

As such the marginal cost per water m^3 released was estimated as Re 0.14. It must be pointed out that this was the cost at the point of release and did not include the various social costs associated with the Command Area Development Programme. The conveyance loss was also not estimated. But, the study proposed a separate pricing strategy for all the uses of canal in the command area, which included the households which used the recharge facility from the wells, as well as other uses of canal system. The conveyance loss was captured as the recharge and other domestic and non-domestic uses.

General Information on Sample Respondents

The Command Area of Peechi irrigation system had continuous stretches of wet lands (paddy lands) and garden lands. The garden lands were either

Table 1. Total variable cost incurred in Peechi irrigation project: 1999-2000

Year	Cost, Rs
1991	1356136
1992	12434491
1993	32520515
1994	14981341
1995	8249881
1996	3248727
1997	3498905
1998	3414522
1999	4567871
2000	5490049

Source: Kerala State Irrigation Department

Table 2. Personal characteristics of sample farmers of Peechi Irrigation Command

Personal characteristics	Mean value	Mean value* (recharged wells)	Mean value *(non-irrigation uses)*
Family size, No.	5	5	4
Years of schooling	8	9	6
Age, years	48	47	51
Landholding size			
Agricultural use, ha	0.99 (96.11)	0.74 (97.37)	0.04
Non-agricultural uses, ha	0.04 (38.89)	0.02 (2.63)	0.03
Total, ha	1.03	0.76	0.07
Farm income			
Crops, Rs/year	81,569 (94.79)	65,010 (95.07)	12548.26 (19.32)
Livestock , Rs/year	4480 (5.21)	3,370 (4.93)	52387.45 (80.67)
Total farm income, Rs/year	86,049 (76.81**)	68,380 (56.65**)	64935.71 (67.21*)
Non-farm income, Rs/year	25972 (23.18)	52,310 (43.34)	31682.45 (32.79)
Total income of farmer, Rs/year	112,021	120,690	96618.16

Note: Figures within the parentheses show percentages to total

homesteads or multi-cropped systems. The major crops in these lands included, coconut, arecanut, pepper, banana, vegetables and fruit crops.

The average landholding size ranged from 0.99 ha (directly irrigated farms) to 0.04 ha (non-irrigation uses). The details of socio-economic and demographic profile of the respondents are furnished in Table 2.

(A) Consumption of Water and Its Value (directly-irrigated farms)

To delineate the effect of various factors on the water used by the sample homestead farms, a mixed production function was employed. The results are presented in Tables 3 and 4. As expected, the water used for irrigation by the distant farms (from the main canal) was less than the nearer ones. Figure 1 shows the relation between the discharges from distributory and the distance from the main canal. The Diversity Index was affecting the water-usage positively. The distribution of sample farmers according to the Diversity Index is shown in Fig. 2. The MPP of factor “distance from main canal” was -1.4020. This implied that additional units of increase in distance by 1 metre over the mean level tended to reduce the water-use

Table 3. Consumption of irrigation water in the homesteads (direct irrigation)

Variables	Coefficient	Standard error	*t*-value
X_1(Distance)	-1.4020*	0.3374	-4.1552
X_2 (1/Income)	97802.99*	26866.78	3.6403
X_3 (1/CPI)	-0.1214*	0.0325	-3.7414
Intercept	29.8566*	3.9939	7.4756
Regression Statistics			
Multiple R		0.6590	
R^2		0.4343	
Adjusted R^2		0.3896	
Standard error		10.640	
Observations		42	
F-value		9.72*	

*Statistically significant (at 1 per cent level)

Table 4. Marginal physical product of factors contributing to canal water-use

Independent variables	Marginal physical product
Distance of farm from main canal (m)	-1.4020
Income from farm (Rs)	-0.0004
Cropping pattern index	5.3140

(water availability) by 1.40 cubic metres. The Diversity Index had a positive influence on water-use, the MPP being 5.31. The homesteads of Kerala were reported as systems of high levels of diversity, which included perennials and annuals . The presence of commercially important crops like banana and vegetables were more pronounced in the irrigated systems.

The farm income depicted a negative marginal productivity, which was primarily due to the overuse of irrigation water, especially in the head reaches. This could be due to the flooding system of irrigation practised by the farms, especially in the head region of the canal, primarily due to the savings in labour cost in this system. The water was simply let into the farm and the entry point was closed once the farm was flooded. The family members could manage this operation. This saved the labour as it also required minimum network of canals in the farm. In some cases, the flooding system was followed due to practical difficulties in regulating the water flow.

The marginal cost per unit of water (m^3) released per year was estimated as Re 0.1434 and the average level of water-use in sample farms was estimated at 18.9 m^3 per day per farm (ha). Thus, Rs 2.71 (product of average water used and marginal cost per unit of water released) was the cost incurred by the Irrigation Department on a sample farm per day, for

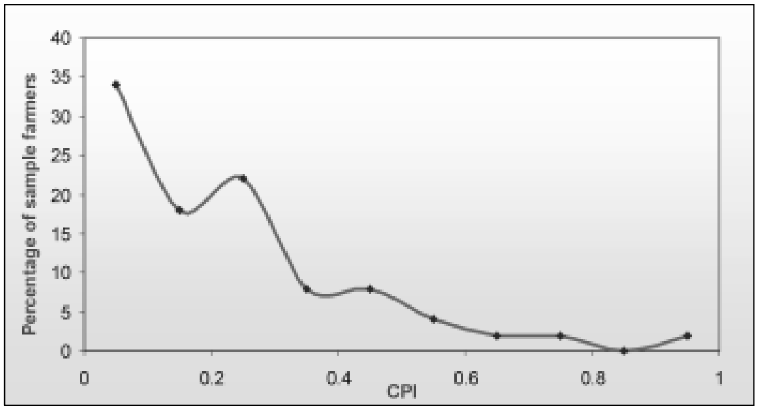
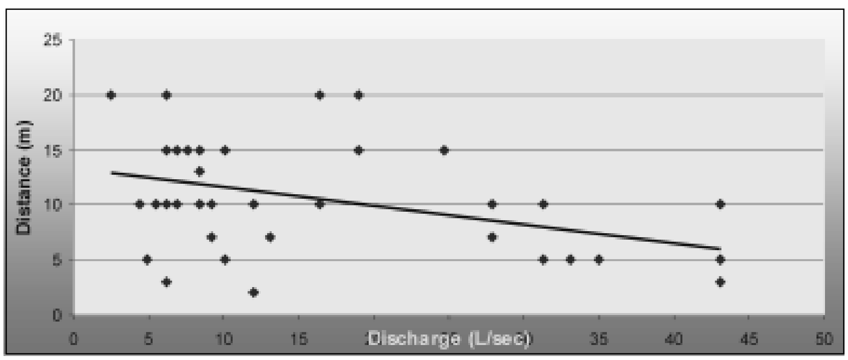


Fig. 1. Distribution of sample farmers (irrigation) according to the cropping pattern index



Discharge, L/s

Fig. 2. Discharge from distributary and distance from main canal

using irrigation water. The total number of days irrigated in a year were found to be 71 and hence the annual cost worked out as Rs 192.41/ farm/ year.

(B) Consumption of Water and Its Value (recharged wells)

The farms in this category were using nearly 57 per cent of the total income from agriculture, mainly from crops. However, their share of non-farm income was considerably higher than that of the directly-irrigated farms.

The level of water consumption through recharged wells in these farms was estimated and the result are presented in Tables 5 and 6. It was seen that the distance of farm from the irrigation canal had an inverse relationship with the net recharge of the wells, the slope coefficient being -0.3980. The unit increase in distance from the main canal reduced the net recharge by

0.3980 m^3. The initial level of water-table, which was determined by factors like proximity to wet land, position of well, etc., had positive relationship with the net recharge. The farm size (ha) also positively influenced the net water recharge.

The recharge of the wells due to the proximity of canal could be considered as a positive externality and on an average the water-table rise was measured as 12.50 m^3 per well per year. The MC of m^3 water released was Re 0.1434, and the total positive externalities associated with the water recharge could be quantified as Rs 225.67 per well per year (product of marginal cost of water released and quantity of water recharge per year (12.5×126 days of water release). This specified that the households depending on recharged wells were enjoying a positive externality equal to Rs 225.67 per year.

Table 5. Relationship between net recharge in wells and distance from main canal

Net recharge due to canal proximity (m^3)	Frequency	Percentage to sample farmers	Distance from canal (m)
Less than 10	13	26	101.2
10 to 20	22	44	76.9
> 20 to 30	11	22	81.2
More than 30	4	8	31
Total	50	100	

Correlation coefficient: 0.2512 (statistically significant at 5 per cent level)

Table 6. Consumption of irrigation water in the farms with recharged wells

Variables	Marginal productivity coefficient	Standard error	*t* value
Distance from main canal (m)	-0.3980*	0.05437	-7.3199
Initial level of water (before opening the canal) (m^3)	0.8391*	0.2176	3.8564
Farm size (ha)	2.2836**	0.9440	2.4192
Cost on irrigation structures (Rs)	0.00002	0.00005	0.4358
Intercept	19.7433*	1.7007	11.6091
Regression Statistics			
Multiple R		0.9176	
R^2		0.8420	
Adjusted R^2		0.8048	
Standard error		3.7744	
Observations		22	
F-value		22.6508*	

*, ** denote statistically significant at 1 and 5 per cent levels, respectively.

(C) Consumption of Water and Its Value (non-irrigation uses)

The people living on either side of the canal depended on the canal for various non-irrigation uses (bathing, cleaning kitchen / household utensils, vehicles and livestock, etc). The people who resided up to 200 m from the canal were found to use the canal for these purposes. The sample respondents in this case were confined to the head and mid portions, with a higher proportion of consumption of water in the head region.

Naturally, the proportion of sample population who depended on the canal both for human and non-human uses decreased with the distance from the release point as well as from the main canal. The farther the house, the fewer number of people used the canal water. On the contrary, the proportion of sample respondents who owned well was in the reverse order of the distance of their residence from the canal. This was primarily due to the recharge facility due to canal as most of the parts of the canal were unlined. The recharge beyond 200m was found to be rather poor, which was also influenced by the gradient. This was further evidenced by the average volume of water utilized by the respondents in the non-irrigation use category. The volume per time of use (day) was highest for the

Table 7. Consumption of irrigation water (human uses)

b_1	b_2	b_3	R^2	F
		Reciprocal form		
0.0032 (0.07)			0.943	271.52
	0.138 (0.008)		0.843	111.73
		0.0094572 (0.00003)	0.989	913.98
71.28 (0.003)	18.72 (0.14)	-91.45 (1.92)	0.634	4.96
		First difference form		
0.00082 (0.071)			0.893	7614.97
	3.33 (0.74)		0.784	413.92
		1.99 (0.58)	0.793	418.94
0.137 (1.94)	0.242 (1.33)	-0.137 (0.0003)	0.641	39.95

Values within the parentheses are *t*-values.
The value of a was zero

respondents who resided farther away, as they had to fully depend on the canal for their all water requirements (owned wells were not there and the recharge was poor). However, the farmers towards the mid-portion of the canal system were reluctant to use the canal water for human use, for the fear of quality loss, i.e. the dependence on canal water for non-irrigation (human) uses was skewed in favour of head region residents, that too within a distance of 200 m on either side of the canal.

The human use of water primarily included bathing and washing of clothes, utensils, and vehicles. It was also seen from the estimates that the identified variables were significantly influencing the water-use. The R^2 was found to be statistically significant and F ratios were reasonably high, except for the pooled equation. Multiplying the consumption level with MC, the value was estimated at Rs 294.18/family/year (Table 7).

The non-human use of water was mainly in the livestock uses. Usually, the livestock were taken to canals for the bathing purpose after the work hours (in the case of draught animals) or anytime during the day in the case of milch animals. The number of animals had little influence on the quantity of water used as the consumption was estimated based on cross-section area of the canal at the point of use and velocity of flow and durtation.

Table 8. Consumption of irrigation water (non human uses)

b_1	b_2	b_3	R^2	F
		Reciprocal form		
0.0014				
(0.000017)			0.942	614.92
	0.3427		0.824	518.33
	(0.0061)			
		0.572	0.724	619.92
		(0.37)		
67.18	15.63	-2.84	0.983	913.42
(0.007)	(0.37)	(1.34)		
		First difference form		
0.003			0.631	73.14
(0.00031)				
	2.97		0.731	24.18
	(0.032)			
		1.93	0.634	32.18
		(0.004)		
0.0082	3.18	-1.64	0.584	46.84
(0.0064)	(0.37)	(0.58)		

Note: The values within the parentheses are *t*-values.

Mostly all the animals of a household were brought together and hence this variable even tended to have a negative influence. As stated earlier, the depence of farther households on the canal system for non-human uses was more. Due to high cost of alternative strategies and more time taken for the travel to and fro, these variables displayed a positive influence. The value of water used for non-human purpose was estimated at Rs 5715.50/ year/ household (Table 8).

Conclusions

Valuation of water for irrigation purpose could be taken as the basis for evolving pricing strategies. In an era of shrinking water resources and competing stakeholder interest groups, the priority given to agriculture in water allocation decisions, might be largely questioned. This may result in the emergence of water markets and concessional attitude to agriculture may be re-examined. The true value of water can be a reflection of its productivity. But under the farm situation, the productivity may be unattractive due to over/unregulated use. Considering the social and political dimensions of the issue, the cost of supplying this resource can be the basis for valuing the resource taking it as the lower bound of the value.

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