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Economic Value of Irrigation Water in Paddy Cultivation in Sri Lanka

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ABSTRACT. *Worldwide, population growth is generating water stress and water usage is increasingly exceeding natural replenishment and supply rates. As a result, policymakers are compelled to make decisions regarding the allocation of water among different sectors, i.e., irrigation, industrial and domestic. In order to efficiently allocate water among these competing sectors, the value of water in each sector should be known. The objective of this study is to estimate the value of irrigation water in the cultivation of paddy. Residual approach, with and without approach and production function approach were used as analytical tools. Secondary data on the cost of paddy cultivation in rain-fed and irrigated areas over a period of 20 years, published by the Department of Agriculture, were used for the analysis. The availability of irrigation water was represented by a dummy variable distinguishing irrigated areas and rain-fed areas in the production function. The value of water was estimated to be Rs. 5,727.63 acre^{-1} season^{-1} suggesting that irrigation plays a major role in determining the profitability of paddy cultivation in Sri Lanka.*

INTRODUCTION

Of all the natural resources that are vital for the sustainability of human health and civilization, water is one of the most important. Although more than 70 percent of the earth is covered with water, fresh water availability is only 2.5 percent. Out of this available water, only 0.26 percent is accessible for the demands of agriculture, industry, domestic, and numerous other uses (Shiklomanov, 2000). With increases in population, the demand for water has been rapidly growing and as a result, water has become a scarce commodity in many countries and is becoming a source of internal (within nations) as well as international conflict. In certain regions, though there is sufficient water to meet societal needs, it is inefficiently allocated among competing demands.

In Sri Lanka, 96 percent of the water supply is consumed by the agricultural sector and the remaining four percent is used up by the domestic and industrial sectors equally (ESCAP 1995). With the development of industries and the increase in population associated with urbanization, demand for water by both these areas will further increase. According to the indicators used by UN (United Nations), IWMI (International Water Management Institute), and Falkenmark, Sri Lanka is not expected to experience moderate or severe water scarcity at national level till 2025, due to its bi-monsoonal rainfall pattern (northeast and southwest monsoons). Nonetheless, experts predict that the country may experience spatial and temporal variations in water

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availability from time to time. This scarcity is evident mostly at the district level, especially in dry zone areas. As the dry zone is the major supplier of domestic food needs, water scarcity in dry zone areas may have serious repercussions, if proper water management plans are not formulated and implemented.

When demand for water by different sectors exceeds supply, policymakers are compelled to make decisions regarding allocation of water among sectors, *i.e.*, irrigation, industrial and domestic. In order to efficiently allocate water among various sectors, the value of water in each sector should be known. At present, irrigation water is supplied free of charge to farmers by the Sri Lankan government. As a result, water usage has become inefficient since farmers use water until the marginal productivity of water is driven to zero (Seagraves and Easter 1983). Also, due to this practice the value of irrigated water is not visible in market prices.

The first attempt to value irrigation water in Sri Lanka was by Upasena and Abeygunawardena (1993). They found that the value of irrigation water was Rs. 750 acre^{-1} rotation^{-1} (season) when the productivity change method is used for the analysis. They also found that the farmers' willingness to pay for water from an agro-well was Rs. 2,405 acre^{-1} season^{-1} and farmers would like to pay Rs. 560 acre^{-1} year^{-1} for water from the existing irrigation scheme in Dewahuwa in Sri Lanka. The authors stated that these amounts are higher than the operation and management cost of irrigation, which was Rs. 370 acre^{-1} year^{-1}. Piyasena (2000), who estimated the value of water using a linear programming model, showed that the value of water was Rs. 2,030 acre-feet^{-1} for a representative farm which cultivates a number of crops in Galnewa in the Mahaweli Program H area in *Yala* (short cultivation season) 1999. The next study was by Renwick (2000), who used a residual approach in calculating the value of water, and found that the value of irrigation water for paddy in the Kirindi Oya irrigation system in *Maha* (long cultivation season) 1999 was Rs. 16,748.00 ha^{-1} (Rs. 6699.20 acre^{-1}). According to Kumara (2003), who estimated the economic value of irrigation water obtained from agro-wells in the Northwestern province, the economic value for water for chillie was Rs18.81 m^{-3} and Rs. 33.06 m^{-3} based on the Cobb Douglas and Translog production functions, respectively. For red onions it was between Rs 19.76 m^{-3} and Rs. 29.99 m^{-3} based on the same functions. However, no attempt has been made in the previous studies to calculate the value of water used in paddy cultivation alone. Since paddy uses 90 percent of the 96 percent of available irrigation water in Sri Lanka (Amarasinghe *et al.*, 1998), it is crucial that the value of water for paddy cultivation is estimated.

The objective of this study is to assess the value of irrigation water in paddy cultivation. It adopts the residual approach, with and without approach, and the crop-water production function approach using secondary data to identify the value of irrigation water.

METHODOLOGY

Three methods to value irrigation water are used in this study: residual approach, with and without approach and production function approach. The residual approach and with and without approach assess the value of water for per unit of water whereas the production function approach assesses the change in value of production to a unit change in water using a production function. The production function approach is preferred over the other two approaches from a policy perspective because it shows the value of water due to an incremental use of water, holding all other factors constant. When production technology is characterized by constant returns to scale, both approaches produce similar results.

Residual approach

In the residual approach the value of water is defined as the total crop value less non-water input costs, considering that zero profits characterize the producer equilibrium. By dividing the value of water by the total quantity of water used by the crop, the average value of water for that crop can be obtained. The following section shows the algebraic derivation.

$$Y = Y\left(X_i, Z_i\right) \tag{1}$$

Consider a firm in a perfectly competitive market who is a price taker in both the input and output markets, whose objective is to maximize profits. The firm produces output (Y), using variable inputs (Xj), such as labour, agro- chemicals, machinery, and fixed inputs (Zj), such as water and land. The production function is,

$$TVP_Y = \sum_{i}^{m} p_i\left(VMP_{Xi} \cdot X_i\right) + \sum_{i}^{n} P_j\left(VMP_{Zi} \cdot Z_j\right) \tag{2}$$

where, TVP_Y is the total value product of Y, VMP_{xj} is value marginal product of variable input j, and VMP_{zj} is value marginal product of fixed input j. Under the competitive equilibrium condition, price of the input (W) is equal to the value marginal product of the respective input. Hence,

$$P_W \cdot Z_W = TVP_Y - \sum_{j}^{m} P_j\left(W_{Xj} . X_j\right) + \sum_{j}^{n-1} P_j\left(W_{zj} Z_j\right) \tag{3}$$

where P_w is unit value of water, Z_w is the quantity of water. On the assumption that all variables are known except P_w, this expression can be solved for that unknown to impute the value of the residual claimant (water), as follows;

$$P_W = TVP_Y - \sum_{j}^{m} P_j\left(W_{Xj} \cdot X_j\right) + \sum_{j}^{n-1} P_j\left(W_{Zj} \cdot Z_j\right) / Z_W \tag{4}$$

In order to evaluate P_w, value of production, expenditure on all the inputs except water and quantity of water used need to be known.

With and without approach

The difference between the net returns of production per unit area in irrigated agriculture and non-irrigated (rain-fed) agriculture is considered as the value of irrigation water in with and without approach.

Production function approach

Consider that the objective of the firm in the short run is to choose the levels of variable inputs, in order to maximize the total revenue net of cost for variable inputs. The objective function of the firm in the short run can be written as,

$$\mathrm{Max}\pi = P \cdot Y - \sum_j W_j \cdot X_j \quad \text{st} \quad Y = Y(X_j, Z_j) \tag{5}$$

where, P and W are the prices of output and inputs respectively.

Profit equation (5) can be used to assess the change in profitability due to a unit increase in irrigation water, *i.e.*, value of water. The first derivative of the profit equation with respect to irrigation water (Z_w) provides the shadow price for water, or the value of water as given below in equation (6),

$$\partial\pi/\partial Z_w = P \cdot MP_{zw} \tag{6}$$

where MP_{zw} is the marginal product of the production function with respect to irrigation water. The above can be quantified if parameters for the production and output price are available.

Hence an estimation of a production function is needed to evaluate the value of irrigation water in paddy cultivation when this method is used for the analysis. The selection of a functional form in estimation is crucial in such an exercise as the functional form determines the nature of relationships described above. A linear functional form was selected in this study.

Linear function for inputs Xj and Zj can be written as;

$$Y = \alpha + \sum_j^m \beta_{xj} X_j + \sum_j^n \gamma_{zj} \cdot Z_j \tag{7}$$

where, Y is for paddy production (kg acre^{-1}), and α denotes the constant or intercept term. Xj refers to the following variable inputs: labour in man-days, seed in kg cost of machinery and weedicides and pesticides in rupees, and fertilizer in kg. Zj denotes fixed inputs like irrigation water, weather (rainfall), and season. β_{xj} and γ_{zj} are production coefficients and they show the marginal productivities. If variable Z_w denotes irrigation water, the value of irrigation water is given by $P*MP_{zw}$ as shown in equation (6).

Data and estimation

In order to assess the value of water using the above approaches, data on production levels and variable input usage such as labour, seed, machinery, fertilizer and fixed input usage such as irrigation water, rainfall and season are required. A panel data set collected from cost of cultivation reports of the Department of Agriculture were used for the analysis. The data set is a 20-year one for the *yala* and *maha* seasons; under irrigated and rainfed conditions in 6 districts of the country. Data for irrigated cultivation were from Anuradhapura, Polonnaruwa, Kalawewa, and Kurunegala (irrigated area) districts. Data for rain-fed cultivation were from Kurunegala (rainfed area), Kandy, and Kalutara districts. Rainfall data were collected from the Natural Resource Management Centre of the Department of Agriculture. Six rainfall collection centres were used to represent each district. These are Aralaganvila, Palagantana, Bombuwela, Maha-Illippallama, Peradeniya, and Batalagoda for Anuradhapura, Kalawewa, Kaluthara, Pollnnaruwa, Kandy and Kurunegala districts, respectively.

In the residual approach, labour, agrochemicals and seeds were considered as variable inputs. Water and management were considered as the fixed inputs. Calculations were conducted on per acre basis.

In the production function approach, production per acre was considered as the dependent variable. Per acre labour usage, agrochemical cost, seed cost and other costs and rainfall were considered as the quantitative independent variables. Rainfall was included as an independent variable to all as the impact of weather. As the data on irrigation water allocation was not available in secondary sources, variable "water" was included as a dummy variable. Number 1 was assigned for irrigated agriculture and 0 was assigned for rainfed agriculture. The seasonal effect to distinguish *Maha* and *Yala,* was too included as a dummy variable. Number 1 was assigned for *Yala* season and 0 was assigned for *Maha* season. Models were estimated (OLS) using the SPSS statistical package (SPSS, 1968).

RESULTS AND DISCUSSION

Residual approach

As described earlier, the difference between the output value and the values of inputs was used to calculate the value of water through the residual approach. The cost of cultivation reports of the Department of Agriculture only provides data on labour, seed, machinery and agrochemicals. Therefore, the value of water obtained through the residual approach reflects the value of water as well as the value all the fixed inputs such as fertility of land and weather. The value of managerial skills of the farmer was considered to be 5% of the value of production, following Young (1996) and Renwick (2001).

Table 1. Value of irrigation water in selected seasons using the residual approach (Rs. acre^{-1}).

Season	Total revenue*	Total variable cost*	Net return*	Value of mgt*	Value of water**
1979/80 *Maha*	3,068.18	1,705.10	1,363.08	153.40	1209.68
1982 *Yala*	4,259.45	3,114.13	1,145.32	212.97	932.35
1984/85 *Maha*	5,391.40	3,517.49	1,873.32	269.55	1,604.07
1985 *Yala*	5,212.45	3,565.07	1,647.49	260.62	991.99
1989/90 *Maha*	12,471.91	6,595.75	5,870.16	623.59	5,252.57
1990 *Yala*	12,090.57	7,112.24	4,978.33	604.52	2,395.05
1995/96 *Maha*	15,300.62	13,965.91	1,334.71	765.03	569.68
1995 *Yala*	11,021.20	11,521.85	1,324.96	642.33	682.63
2000/01 *Maha*	20,342.48	16,578.53	3,763.95	1017.12	2,746.83
2000 *Yala*	19,842.00	15,730.93	4,111.07	992.10	3,118.97

(*Cost of cultivation Reports. Department of Agriculture, ** Authors' calculations; [2]When value of management is taken as 10% and 15% the value of water for Maha and Yala for year 1990 and 2000 are Rs. 3999.47, Rs. 3164.71, Rs.712.57, and Rs. 1134.37 respectively.)

Results in table 1 indicate the residual values for selected years which could be attributed for irrigation water in various years including family labour, treating the opportunity cost of family labour as the market wage rate. Table 1 shows the average value of irrigation water calculated using data from six districts for a few selected years. In the 1995 *Yala* season it is only Rs. 2,395.05 acre^{-1} and in the 1995 *Maha* season it is Rs. 569.68. This shows that values differ significantly in different years and seasons.

With and Without Approach

Value of water can be obtained through with and without approach by comparing net returns from irrigated and rainfed agriculture. When all the factors such as soil type and weather are similar, the difference in net returns between irrigated and non-irrigated agriculture can be attributed to irrigation water. Table 2 shows the value of irrigation water calculated using with and without approach. According to the Department of Agriculture, the net return from paddy cultivation is negative in rainfed areas since 1995/96, when the opportunity cost of family labour is considered to be equal to the market wage rate. Therefore, the value of irrigation water is quite high when calculations are performed in this manner.

Table 2. Value of irrigation water in selected seasons calculated using the with and without approach.

Season	Net return (Rs acre^{-1})		
	Irrigated*	Rain fed*	Difference**
1979/80 *Maha*	1,363.08	576.65	786.43
1982 *Yala*	1,145.32	380.14	785.18
1984/85 *Maha*	1,873.62	929.83	943.79
1985 *Yala*	1,647.49	208.09	1,439.4
1989/90 *Maha*	5,876.16	3,666.58	2,209.58
1990 *Yala*	4,978.33	963.89	4014.44
1995/96 *Maha*	1,334.71	-2,135.27	3469.98
1995 *Yala*	1,324.96	-3,058.92	4,383.88
2000/01 *Maha*	3,763.95	-3,685.92	7,449.79
2000 *Yala*	4,111.07	-6,088.24	10,199.31

*Cost of Cultivation Reports, Department of Agriculture, **Authors' calculations.

Production function approach

The parameters of a production function explain the contribution of each input affecting production levels including irrigation water. As stated earlier, due to limitations in data, only six districts were used in the estimation of the national-level production function. A separate production function was estimated for the Kurunagala district to minimize district bias as it covers both rainfed and irrigated areas. As explained earlier, water is included as dummy variables in both models giving a value of 1 for irrigated areas and 0 for rainfed areas. Therefore, the coefficient for the dummy variable shows the productivity difference between the two areas. It should be noted that the "availability of irrigation water" is one such difference and soil conditions, rainfall, temperature and sunlight are some other differences. As a result, the co-efficient for the dummy variable provides a composite impact.

Econometric results at the national level

Table 3 shows the descriptive statistics of the data used and table 4 shows the results of the econometric estimation. The model explains 61% of the variation according to the R-squared value. All the coefficients are statistically significant at 5%, except for the seed and dummy variable for "season". The co-efficient for irrigation water is 450.64 indicating that productivity in "irrigated areas" is 450.64 higher by kg acre^{-1} (price of paddy was Rs.12.71 kg^{-1} (Central Bank, 2001)). The value of water per acre can be calculated by multiplying the value of production due to irrigation by the price of paddy. This is equal to Rs. 5,727.63 acre^{-1} as in 2001.

Table 3. Descriptive statistics of the data used.

Variable	Units	Mean value for six districts	Standard deviation
Yield	kg/acre	1395.37	399.06
Labor	Man days/acre	51.47	15.26
Seed	kg/acre	103.55	526.86
Fertilizer	kg/acre	152.37	29.02
Other costs	Rs/acre	1,915.11	1,347.82

Source: Cost of Cultivation Reports, Department of Agriculture.

Econometric Result for Kurunegala

Table 5 shows the descriptive statistics of the data used and table 6 shows the results of the econometric estimation. The model explains 42% of the variation according to the R-squared value. All the coefficients are statistically significant at 5%, except for seed, fertilizer and the dummy variable for "season". The coefficient for irrigation water is 311.94 indicating that productivity in "irrigated areas" is 311.94 higher by kg acre^{-1}. When the price of paddy was considered as Rs.12.71 kg^{-1} the value of water acre^{-1} (which is the change in the value of production due to irrigation and is equal to 311.94 kg multiplied by Rs.12.71 kg^{-1}) is Rs. 3,964.75 per acre.

Table 4. Econometric results[1] for the national model.

Independent variables	Coefficient	Std. error	T value
Intercept	452.80***	123.62	3.662
Labour	4.137***	1.26	3.25
Seed	-0.033	0.031	-1.08
Fertilizer	2.075***	0.678	3.07
Other costs	0.104***	0.015	6.86
Irrigation water	450.64***	37.29	12.08
Season	-27.5	33.14	-0.83

[1]When rainfall was used as an explanatory variable, results obtained were unsatisfactory.

(Dependent variable: paddy yield, kg acre^{-1})

**** Significant at 5% level.*

$R^2 = 0.61$ Adj. $R^2 = 0.595$ $F = 58.936$ $DW = 1.821$ $N = 238$.

Table 5. Descriptive statistics for the Kurunagala model.

Variable	Units	Mean	Standard deviation
Yield	Kg/acre	1438.08	313.68
Labour	Man days	51.87	12.27
Seed	Kg/acre	49.36	8.01
Fertilizer	Kg/acre	392.86	1978.97
Other cost	Rs/acre	2383.39	1797.81

Source: Cost of Cultivation Reports, Department of Agriculture.

Table 6. Econometric results for *Kurunagala* model.

Independent variable	Coefficient	Std. Error	T value
Intercept	752.74***	298.13	2.52
Labour	7.13***	3.33	2.14
Seed	0.94	3.90	0.24
Fertilizer	-0.011	0.01	-0.70
Cost	0.06***	0.02	2.68
Water	311.94***	63.36	4.92
Season	-76.56	60.99	-1.25

(Dependent variable: paddy yield, Kg acre^{-1})
**** Significant at 5% level*
$R^2 = 0.421$ $Adj.R^2 = 0.35$ $F = 7.45$ $DW = 1.727$ $N = 71$

Note that at the national level returns for water is Rs. 5,727.63 acre^{-1} season^{-1}, and it is higher than the value obtained for Kurunagala. As a large sample was used to estimate the function at the national level, it can statistically provide better estimates. However, the return to water may have been overestimated or underestimated as the coefficient for water accounts for differences among districts as well. The estimated return to water using data for the Kurunagala district was based on a small sample. However, the coefficient does not reflect the differences among districts. Therefore, the results of these two estimations should be interpreted cautiously.

These results show that returns to water are quite small when water is used in paddy cultivation. Previous estimates show that returns to water are higher than what is revealed in this study, when it is used in the cultivation of other field crops (Piyasena 2000; Kumara 2003). If the water usage in paddy is considered to be 4.5 acre-feet season^{-1} (Department of Agriculture), the results of this study show that the value of water is Rs. 1,272.80 acre-feet^{-1} when Rs. 5,723.63 acre^{-1} season^{-1} was considered as the value of water. According to Piyasena (2000), who used a linear programming model, the value of water is Rs. 2,030.00 acre-feet^{-1}; which was not purely used for paddy. Renwick (2000), who used a residual approach in calculating the value of water for paddy cultivation in the Kirindi Oya irrigation system in the 1999 *Maha* season found that it was Rs. 1,488.71 acre-feet^{-1}. If it is compared with the values estimated by Kumara (2003), which varied between Rs.18.81 m^{-3} to Rs. 33.06 per m^{-3} for chilli and Rs. 19.76 m^{-3} to Rs 29.99 m^{-3} for Red Onion, the equivalent values are around Rs. 24,000.00 acre^{-1} (Table 7).

Table 7. **Summary results of studies on valuing of irrigation water.**

Author	Year	Region	Crop	Value of water	Equivalent value of water (Rs/acre-ft)
Piyasena	2000	Galnewa Mahaweli H area	Number of crops at a farm	2,030.00 Rs/acre-feet	2,030.00
Renwick	2000	*KirindiOya* Irrigation system	Paddy	6,999.20 Rs/acre	1,488.71
Kumara	2003	Northwestern Province (Irrigated by Agro wells)	Chilli*	18.81. Rs/m^3	23,136.30
This Study	1979-2001	National level	Paddy	5,727.63/acre	1,272.80
This Study	1979-2001	Kurunegala district	Paddy	3,964.75/acre	881.05

*One acre-foot is approximately 1,230 m^3

The value of water obtained above should not be interpreted as the price of irrigation water to be charged from farmers. As Gunatilake and Gopalakrishnan (2002) clearly indicate, given the current economic environment, farmers are in a desperate situation. Unequal bargaining power against middlemen, open-market policies and regional trade agreements have made their situation worse. Until the agricultural sector undergoes a major transformation, any proposal to collect a water management fee will be ineffective and highly disruptive. Rather, the value of irrigation water obtained above should be considered as the loss incurred by the farmers, if irrigation water is not provided free of charge.

CONCLUSIONS

This study estimates the value of water using three methods: residual approach, with and without comparisons, and production function approach. The latter, which shows the marginal increment in yield due to the provision of irrigation water, provides the best approximation for the value of irrigation water. The results show some important policy implications. First, they indicate the importance of water in determining profitability of paddy cultivation. A large portion of profits (Rs. 5,727.63 $acre^{-1}$) is attributable to returns to water, and any change in irrigation water may have a significant impact on the income of paddy farmers. Second, they show the marginal benefit of water when it is used in paddy cultivation. According to Shilpi (1995), operation and maintenance costs of irrigation were Rs. 5420.32 ha^{-1} in 1994 and it is equivalent to Rs. 2,168 $acre^{-1}$ $season^{-1}$ for that year. The value of irrigation water would be Rs. 3,614.13 $acre^{-1}$ $season^{-1}$ in 1994 according to the results of this study, if the price of paddy is considered to be Rs. 8.02 kg^{-1}. These numbers indicate that the marginal cost of providing irrigation water does not exceed the marginal benefit of water when it is used in paddy cultivation, and in that regard it is not an inefficient allocation.

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