Economic Valuation of Irrigation Water under a Major Irrigation Scheme (Gal Oya) in Eastern Sri Lanka

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Introduction

About three-fourths of Sri Lanka comes is within the dry-zone, in which water becomes a particularly limited resource during the dry '*yala*' season. Therefore, it is very important that a farmer in the dry zone uses water at an optimum level. Even though up to now irrigation water in Sri Lanka is unpriced, views have emerged that it has to be priced due to its scarcity and increasing demand for both farming and residential use. The Government of Sri Lanka has been investing large amounts of money in irrigation development and subsequent supply of water to farmers since national independence. The lack of participation of water users in system management and inadequate funds for operation and maintenance (O&M) activities have resulted in the inefficient use of water on the one hand, and the excess use of water on the other. As a result, farmers use water until the marginal productivity of water reaches zero (Seagraves and Easter1983) and overall water usage has become inefficient.

One way to achieve an efficient allocation of water is to price its consumption correctly. Pricing of water affects allocation considerations by various users. The prevailing pricing methods for irrigation water include volumetric pricing, non-volumetric pricing methods, and market-based methods. Volumetric pricing mechanisms charge for irrigation water based on the consumption of actual quantities of water (Easter and Welsch 1986; Small and Carruthers 1991; Bandaragoda 1998). Non-volumetric methods charge for irrigation water based on a per output basis, a per input basis, a per area basis, or based on land values (Easter and Welsch 1986; Easter et al. 1997).

Market-based mechanisms have recently arisen as a need to address water-pricing inefficiencies inherent in existing irrigation institutions. These mechanisms rely on market pressures and well-defined water rights to determine the irrigation water price. Area pricing is the most common method used for irrigation water pricing (Bos and Walters 1990). The rotational method combines elements of volumetric pricing with area pricing, for equitable allocation of irrigation water fixes flows by day, time, and duration of supply, proportionate to irrigated area (Bandaragoda 1998; Perry and Narayanamurthy 1998). Tiered pricing for irrigation water is common in the State of Israel (Yaron 1997b).

In Sri Lanka, the charges for irrigation water are not based on the amount of water used, but on the basis of the operation and maintenance value of irrigation water. There have been many studies in Sri Lanka to value irrigation water for agriculture. Upasena and Abeygunawardena (1993) estimated the value of irrigation water as Rs.750 per acre per rotation (season), using the productivity change method. They also identified that farmers were willing to pay Rs. 560 per acre/year for O&M with an expectation to receive an effective water supply to their land plots, and that that supply will be higher than the O & M costs of irrigation (Rs. 370 / acre/year). Piyasena (2000) estimated the value of irrigation water supplied under the Mahaweli Irrigation System using a Linear Programming model, and found that the value of water was Rs. 2,030/acre-feet in the '*yala'* season. Later, Renwick (2000), using a residual approach, found that the value of water under the Kirinda Oya Irrigation System was Rs.16,748 per hectare (Rs. 6,699.2 per acre) for paddy cultivation during the '*maha*' season. Whereas, Bandara and Weerahewa (2003) estimated the value of irrigation water used for paddy cultivation in five districts to be Rs. 5,727.63 acre^{-1} season^{-1} or Rs.1,272.8 per acre-feet. Meanwhile, Herath and Gichuki (2006) conducted a field study in the Lunuwewa in 'Mahaweli H' area to value irrigation water by using the 'Willingness-To-Pay' method, and found that the majority of farmers were willing to pay Rs. 300 per hectare/year for irrigation water.

The objective of this study was to estimate the economic value of irrigation water used in a crop farm (paddy and chilies) using a Linear Programming approach in the Senanayake Samudra (Gal-Oya Irrigation Scheme) Right Bank System area in the Ampara District.

Methodology

The Linear Programming approach is used to identify the optimal farm plan for the farmer in the Gal Oya Irrigation Scheme, given the limited (constraints) land, labor, water and capital available for cultivation of crops in the '*yala*' season. A farmer needs two pieces of information in deciding whether he should add a little more input to his crop or not. First, he needs to know the cost associated with adding one extra unit of the input and second, he needs to estimate how much more income his crop would generate as a result of the added input. Hence, if the added income to the crop is larger than the added cost, a farmer interested in increasing profits will add more of the input for production activity. At the point of profit maximization, the Marginal Value of Product (MVP) is equal to the price of the productive input used. Therefore, the farmer can use water until the point is reached whereby the last Rupee spent on water, returns exactly its incremental cost.

It is assumed that farmers tend to maximize profits from each activity (production) on the farm land owned. Thus, the maximization model of LP is used to identify the maximum profits attainable and the shadow prices of inputs used in production.

The maximization model used in this study is as follows:

Maximize: $N = PI * X + Py * Y$

Where X and Y are two different commodities (Example: paddy and chilies)

PI - Price of paddy per unit of X

Py - Price of chilies per unit of Y

N - Net profit from all activities

The LINDO (2002) software package was used to solve the linear programming problem. By using the LINDO program the shadow price of the constraints (resources) of the optimal farm plan can be found. The LINDO solution report also gives a 'Dual Price' figure for each constraint. The 'Dual Price' (Shadow Price) can be interpreted as the amount by which the objective would improve given a unit of increase in the right-hand side of the constraint. Dual Prices/ Shadow Prices indicate how much a person should be willing to pay for additional units of a resource.

The crops cultivated (paddy and chilies), duration of crops and their net returns per acre, on an average 2-acre farm are shown in Table 1. The net returns were estimated from survey data collected.

Table 1. Crops and net returns (1 acre).

Crops	Abbreviations	Net Return (Rs./Acre)
1. Paddy (4.5 months)	P1	37,080
2. Paddy (3.5 months)	P2	26,380
3. Chilies	C	68,550

Technical crop water requirements for paddy 1 (4.5 months), paddy 2 (3.5 months) and chilies were found by using the software package CROPWAT. CROPWAT is a computer program used to calculate the crop water requirement and irrigation requirements from crop and climate data. The output, which is the crop water requirement for one acre land crop cultivation, is used for modeling the matrix formulation of linear programming. The CROPWAT program also generated the water co-efficient (irrigation requirement).

Constraints and co-efficients for the model were estimated from data collected through the survey (net returns from selected crops are shown in Table 1). Water constraint was identified through the information obtained from District Irrigation Engineers. Water co-efficient was identified through secondary information collected and with the help of the CROPWAT program. Taking into consideration the land (2 acres), labor (50 man-days), water (4.1 acre-feet) and capital (Rs. 50,000) constraints, the matrix was formulated to solve the problem of profit-maximization by linear programming (Table 2).

Table 2. LP Matrix formulated for profit maximization.

Limit			Paddy 1 (P)	Paddy 2 (S)	Chilies (C)
Objective	N	-	37.08	26.38	68.55
Land	L	2.00	1.00	1.00	1.00
Labor	L	50.00	15.00	15.00	70.00
Water	L	4.10	4.37	3.54	3.43
Cash Rs.	L	50,000	31.8	35.6	45.9

LP Model formulated and used is as follows:

Maximize $N = 37.08P + 26.38S + 68.55C$

Subject to;

1. Land: $P + S + C <= 2$,
2. Labor: $15P + 15S + 70C <= 50$,
3. Water: $4.7P + 3.54S + 3.43C <= 4.1$;
4. Cash: $31.8P + 35.6S + 45.9C <= 50$.

Where P, S, C and N => 0.

Method of Data Collection and Analysis

Data needed for this study were collected from three sources: 1) sample farm survey; 2) secondary data from records; and 3) publications and reports, along with use of the CROPWAT Program (FAO1998) to estimate the crop water requirements for the crops.

The survey was carried out at the Right Bank System in the Gal Oya Irrigation Project. The sample consisted of 30 farmers. These farmers were selected using the 'Multiple Stage Sampling' technique. The area of the Right Bank System of the Gal Oya Project was selected as a cluster of the Senanayake Samudra, and a few distributory channels in the 'Right Bank System' were selected randomly. Data was collected through a sample survey using a pre-tested questionnaire from farmers residing along three irrigation channel (Distributory Channel) areas. For the analysis, climatic data such as mean monthly temperature ranges, type of soil, elevation, average rainfall, rainfall pattern, rainfall distribution, and crop pattern, were collected from the Meteorological Department Sub-station at Ampara, and the Land and Water Management Centre of the Department of Agriculture. Data on water issues from the Right Bank system of the Senanayake Samudra for each month in the '*yala*' season were also obtained from the Irrigation Engineer's Office, Ampara.

Results and Discussion

The results indicated the objective function value and the Dual or Shadow Prices, along with the slack or surplus of the inputs used on the 2-acre farm. It was found that the farmer can obtain a maximum profit of Rs. 59,127.88 per season by cultivating paddy and chilies on 2 acres of land. The output also indicated that paddy 1 (4.5 months) and chilies had zero Reduced/ Shadow Costs, while paddy 2 (3.5 months) had a Shadow Cost greater than zero. This implies that it is not economical to include paddy 1 in the farm plan activity.

The results also showed that the farmer could cultivate 0.4539 acres of long-aged paddy (4.5 months), and chilies on 0.617 acres of land, while short-aged paddy (3.5 months) is not selected to be cultivated (Table 3).

Shadow or Dual Price is the maximum price that management is willing to pay for an extra unit of a given limited resource. Shadow prices, which reflect the social value of goods, replace the market prices that are used in private calculation. In a perfectly competitive economy,

Table 3. Level of activities and reduced cost.

Variable	Value	Reduced Cost
1. Paddy 1 (P)	0.453920	0.000000
2. Paddy 2 (S)	0.000000	5.587403
3. Chilies (C)	0.617017	0.000000

market prices and shadow prices will coincide (Smith 1985). As shown in Table 4, the water constraint has a Dual/Shadow Price of Rs. 6,159.76, which implies that the farmer can increase his net profits by this amount by using additional acre-feet of irrigation water in his optimal farm plan. Water has such a high Shadow/Dual Price due to its limited availability. Therefore, it's profitable for the farmer in the area to purchase water at a price close to or less than Rs. 6,159.75 per two acre-feet. These results are close to the findings of Renwick (2000), who valued irrigation water as Rs. 6,699.2 per acre-feet, and that of the figure projected by Bandara and Weerahewa (2003) at Rs. 5,727.6 per acre.

Table 4. Slack and dual prices of constraints/inputs.

Row	Slack or Surplus	Dual Prices
2) Land	0.929063	0.000000
3) Labor	0.000000	0.677458
4) Water	0.000000	6.159756
5) Capital	7.244252	0.000000

Conclusions and Policy Implications

The study estimated the value of irrigation water using the principle of Marginal Value Product in a Linear Programming approach that maximizes net returns for a specific farm plan. The Shadow or Dual Price of water was used to estimate the economic value of irrigation water. The results indicated that the economic value of irrigation water was Rs. 6,699.2; the amount by which the net returns could be increased by its additional usage. This indicates the likely importance of water in crop cultivation under irrigation schemes. Thus, it is economically rational for the farmer to pay at least Rs. 6,699.2 for acre-feet of irrigation water, as long as its benefits (returns) are also more.

However, the water management and cost recovery mechanisms should be developed according to the farm size and season of cultivation, as both have significant impacts on farmers in irrigation schemes. The productivity of land, cropping intensity, water availability, and market prices should be considered in recommending a price for irrigation water. It is also important to communicate the need to, and encourage the farmers in the irrigation scheme to contribute to the development and maintenance of existing irrigation systems in a sustainable manner.

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