An Economic Analysis of Affordability of Irrigation Systems in LDCs: Evidence from a Field Study in the Hills of Nepal*

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The Nepalese government finds it increasingly difficult to sustain its irrigation systems, which is primarily caused by the absence of or negligible cost recovery from the systems. In this paper, farmers' ability to pay for irrigation services is examined based on information from a field study. Both a comparative analysis and the marginal value product (MVP) approach reveal that farmers under both government- and self-run irrigation systems are in the position to pay the operation and maintenance or O&M cost. However, charging capital as well as O&M costs is found to be difficult to justify.

I. Introduction

Irrigation is considered to be a costly but important investment in LDCs. It acts not only as an input but more importantly as a catalyst for advancing agricultural technology. Unfortunately, many irrigation systems, especially the publicly-funded ones, do not perform well [Sinclair, 1987]. Consequently, irrigation and irrigated areas are generally underused, which contributes to the food and income security problems in developing nations [Biswas, 1991].

As in other LDCs, the performance of irrigation systems in Nepal has failed to match prior expectations [World Bank, 1990]. Poor cost recovery is identified as one of the major causes of the failure. In essence, the issue of cost recovery relates to the

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sustainability of irrigation systems. To make such a system sustainable, it is necessary to attach certain values to irrigation water. By so doing, it will motivate farmers to use resources more efficiently. It could also compel them to look after the system. As argued by Carruthers and Clark [1981], charging irrigation water is of economic, financial and social significance. The revenue generated will facilitate capital formation and reinvestment in the further development of the system. In Nepal, however, only seven percent of operation and maintenance costs (O&M) is collected. This low recovery level poses serious threat to the sustainability of the irrigation systems. A solution to this problem is to seek contributions from farmers. The crucial question then becomes whether the farmers can afford to pay or not? If yes, should they bear the full cost or only the O&M?

To address these issues, a field study is undertaken. The study focuses on two medium-scale irrigation systems in Kaski District: the Arnapurna canal and the Chaurasi kulo. The former, abbreviated as GM, is funded and managed by a government agency while the latter, refereed to as FM, is established and managed by farmers. Both systems divert water from Yamdi river. Chaurasi kulo diverts water from the upper section of the Yamdi river which runs dry in winter. It serves about 200 hectares of land. The Arnapurna canal has its intake some two kilometres downstream of the FM and provides water throughout the year. The GM covers 300 hectares of land.

A stratified random sampling procedure was used to select 248 households: 75 under the FM, 138 under the GM and 35 who operate on unirrigated land. These numbers are proportional to the composition of farming families in the study area. Primary data on outputs, inputs, costs and some demographic materials were then collected through the use of standardised questionnaires. Twenty seven questionnaires were pretested in Bagar, just outside the studied area. Based on the pretesting results, slight modifications were made by reformulating some of the questions. The survey was implemented through personal interviews which are conducted by the senior author of the paper with two assistants. It took three months, June to September 1993, to complete the field study. The primary data, covering the 1991/92 agricultural year, are supplemented by information gathered from relevant government departments, research institutes and non-governmental organizations.

To assess farmers' ability to pay for irrigation, the marginal value product (MVP) approach of Ruttan (1965) will be used and supplemented by a comparative analysis based on the gross margin framework.

II. Marginal Value Productivity (MVP) Approach

This method involves determination of the difference in the marginal value products (MVPs) of irrigated and non-irrigated land. Irrigation is judged to be affordable if the difference exceeds the opportunity cost of land by no less than the O&M, or O&M plus capital costs [Ruttan, 1965]. Quantification of the MVPs may also provide information on the efficiency of resource allocation.

To find the MVPs. Cobb-Douglas production models are fitted to the survey data. The function is specified as follows :

$$Y = \alpha X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} e^{\mu}$$

where Y = value of output (NRs, 1 US $ = NRs 49), X_1 = sown area (ropani, 1 ha = 20 ropani), X_2 = labour (man-days), X_3 = chemical fertiliser (Kg), X_4 = manure (doko, 1 doko = 15 Kg), α and βs are parameters to be estimated and μ is the disturbance term.

Three functions describing paddy production, respectively for the households under the

GM, FM and unirrigated, are estimated. Since wheat is not irrigated under FM due to unavailability of water in winter, two wheat production equations are obtained: one for irrigated wheat crop under GM system and the other under the FM system which serves as a proxy of unirrigated land. Only paddy and wheat are considered in this paper as they are the two major crops which are irrigated.

The regression results are presented in Table 1. Given the use of cross-sectional data, the production functions seem to be estimated quite successfully, with a minimum R^2 of 0.55 for wheat cropping without irrigation. The F values show that the parameter estimates as a whole in every equation are significant at the one percent level. As is expected, all significant estimates are positive. The elasticities of irrigated land are higher than that of the non-irrigated counterpart for paddy production. With wheat, output appears to be less responsive to sown area under irrigation than to that without irrigation. This may be caused by the omission of weather and land quality variables in the equations. It is interesting to note that the elasticity under FM (0.726) is higher than that under GM (0.628). As indicated by the sum of elasticities, paddy production displays constant returns to scale in the hills of Nepal, while decreasing returns to scale prevail in wheat cultivation (Table 1). In passing, we point out that scale economies are difficult to achieve in Nepalese agriculture given the hilly geographic condition and extensive land fragmentation.

[Table 1 near here]

Marginal value product (MVP) under multiple inputs is a crucial concept in production theory [Yotopoulos and Nugent, 1976]. With Cobb-Douglas specification, the most accurate estimate of MVP of factor i can be obtained when all inputs are held at their geometric means [Heady and Dillon, 1961]. That is, for i=1, 2, 3, 4,

$$MVP_i = b_i \, (y/x_i)$$

where b_i = regression estimate of β_i, y = geometric mean of output Y, x_i = geometric mean of factor X_i. The MVPs so computed are tabulated in Table 2.

[Table 2 near here]

It is obvious that, relative to non-irrigated area, the MVPs of land under GM and FM are higher for both paddy and wheat crops. In other words, the economic effect of irrigation is shown to be positive. Taking the difference between the MVPs of the irrigated and non-irrigated land, an estimate of MVP of irrigation is obtained [Madariaga and McConnell, 1984]. This estimate, as mentioned earlier, is needed for evaluating farmers' ability to pay for irrigation.

As for other inputs, the variations in MVPs across columns in Table 2 are largely dependent on their marginal productivities as well as levels of usage. Consider chemical fertiliser. With paddy under the GM as an exception, MVPs of fertiliser on both irrigated and rainfed land exceed its market price, which is about NRs 10 per kilogram. This finding confirms the authors' speculation that chemical fertiliser in Nepal is underused. Shortage of cash for purchasing chemical fertiliser is a serious problem in Nepal. Consequently, there is a need of establishing efficient credit service to assist rural household in purchasing inputs, which will lead to increased productivity and financial gains to farmers. This clearly will help improve farmers' affordability of irrigation. The MVPs of labour used in paddy and wheat production under both GM and FM are less than the prevailing wage rate of NRs 50 per day. This is not surprising given the existence of seasonal surplus of labour and general underemployment in the Nepalese farming sector.

With the estimates of MVPs so obtained, attention is now turned to the cost side. The investment cost vary with the type as well as size of irrigation systems. The Master Plan for Irrigation Development in Nepal [HMGN, 1990] indicates that new construction in the hills requires a capital cost amounting NRs 5880 to 11760 per ropani (US $2,400 to 4,800 per hectare) and an annual O&M cost of NRs 47 to 154 per ropani (US $19 to 63 per hectare) . For the Arnapurna Irrigation Project, the total investment cost was NRs 11,710,350 [HMGN, 1986]. An interview with the District Irrigation Engineer Department revealed that the cost had risen to NRs 5,000,000 by the time it was completed. At the present exchange rate, this is equivalent to US $1,020 per hectare. It is obvious that the actual capital cost is lower than the projections made in the Master Plan.

The capital cost for the rehabilitation of old FM is estimated to be NRs 434 per ropani or US $177 per hectare. This figure represents the amortization cost in 1993 assuming an interest rate of 12 percent with a future life of 10 years. Using the same rate of interest but assuming a life of 40 years for the new GM system, the capital cost is computed to be NRs 303 per ropani or US $123.67 per hectare. For GM, it is further assumed that 80 percent of the capital cost is borne by the summer paddy crop. This is because paddy uses much more water than other crops and major maintenance is usually required during the summer season. The remaining 20 percent is assumed to be borne by the winter wheat crop.

O&M costs also vary widely with the size, location, type, topography, technology, management and organisation of an irrigation system. Information provided by the District Irrigation Engineer Department reveals that O&M of the Arnapurna Irrigation System is around NRs 50 per ropani, which is close to the costs estimated in the Master Plan. The actual cost of O&M for the old, farmer managed system was not available since no data had ever been recorded. However, little difference in O&M cost exists between the two systems. Again, the O&M cost under the GM is allocated among rice and wheat with shares of 80 and 20 percent, respectively.

The opportunity cost of land is estimated in two ways: one based on the MVP of unirrigated land computed above; another based on the rent of the irrigated land, mainly in the form of crop shares paid to the landlord which is about one-third of the total product. The information on costs are summarised in Table 3.

[Table 3 near here]

In drawing the final conclusion, two scenarios are considered. The first scrutinises whether farmers can afford to pay the O&M cost or not. The second determines whether or not farmers can afford to pay the O&M plus capital costs. From Table 3, the sums of opportunity cost of land and O&M are lower than the marginal value products of irrigated land for both wheat and rice production. This indicates that farmers are in the position to pay for the O&M. When capital cost is added, however, the affordability of irrigation in Nepal becomes questionable. If rent is used to estimate the opportunity costs of unirrigated land, farmers are unable to pay for O&M and the capital costs. The contrary can be said when opportunity costs based on MVPs of unirrigated land are used. In the latter case, nevertheless, charging both O&M and capital would leave farmers with little incentive to irrigate. Given the need to promote irrigation in the hills of Nepal, it is suggested that farmers should only bear the cost of O&M, not O&M plus capital cost. These are consistent with Small et al. [1989] and Nathan [1989] who strongly advocate that capital cost recovery ought to be postponed to some later date while the O&M cost may be collected from water users now.

III. Comparative Study

Gross margin analyses are undertaken in this section to implement the comparative study, which involves comparison of farming income from irrigated and non-irrigated agriculture based on the survey data. Table 4 shows the gross and net returns from paddy and wheat cropping. The results indicate that there are substantial benefits derived from both the irrigation systems. Incremental income from irrigation per ropani is then computed and presented in Table 5. Since the FM operates only during the monsoon period, only paddy crop is considered. For the GM, both paddy and wheat are taken into account.

[Table 4 near here]

Converting values in Table 5 onto a per household basis, the scope for the payment of O&M from the incremental value of production under irrigation can be clearly seen (Table 6). If the full O&M is to be charged, which are NRs 50 per ropani or NRs 1,000 per hectare, it would cost some 17 to 19 percent of farmers' incremental net income. At present, farmers under the GM do not pay any water charges. Even in cases where an irrigation fee is charged, amounts range from NRs 60 to 200 per hectare, with the most common rate of NRs 100 per hectare. This is merely one-tenth of the fee required to defray O&M costs. At NRs 100 per hectare per crop, the annual irrigation service fee accounts for about two percent of the net income. This clearly indicates that farmers can afford to pay for the O&M of their irrigation systems, which reinforce our earlier conclusion.

[Table 5 near here]

IV. Consideration of External Factors

In this section, government input and output pricing and taxation policies are examined, which may also affect farmers' affordability of irrigation service. Intervention in the product market is unlikely to be relevant here as majority of farmers only produces for home consumption. Moreover, the government usually cannot guarantee the purchase of all output when market prices fall below the floor price set by the government [Wallace, 1987; Small et al., 1989]. Even if there were some production response to government-supported prices, implementation of such a price policy is problematic in the hilly districts because of the fragmented markets.

Being the most important input, chemical fertiliser is heavily subsidised in Nepal. Depending on the types of fertiliser, the subsidy ranged from 35 to 62 percent of the total cost of supply in the years 1984/85 [Small et al., 1989]. Theoretically, subsidising fertilisers will enhance the farmers' ability to pay for irrigation service. However, this is true only if fertiliser supply is on time and in sufficient quantity. Timing and quantity of supply have long been problems in Nepal. Further, a subsidy is ineffective if elasticity of demand is low, which is the case, especially in the hills of Nepal [Wallace, 1986]. Despite these facts, the role of chemical fertiliser remains essential in irrigated agriculture.

As far as taxation is concerned, very little revenue is generated from the agricultural sector through taxes in Nepal. The only tax farmers have to pay is the land tax which is levied at different rates according to land classification. Although the government has not heavily taxed the agricultural sector, it has not protected farmers from the all-pervasive dominance by the Indian market either,. There is no import tax levied on any agricultural food products from India.

V. Summary and Policy Implications

Sustainability of irrigation systems is very important from both farmers' and government perspective. Conversely, developing countries like Nepal are facing tremendous budgetary pressure arising from the need to defray irrigation costs. Quite often, farmers do not receive adequate service due to insufficient O&M budget. This undoubtedly affects crop productivity and farming income. It is therefore important to decrease the budgetary burdens of governments through local control and support. The evidence assembled from the Philippines suggests that there are significant financial, economic and social benefits generated from irrigation charges. If the charging system is appropriate, it will result in improved irrigation performance [Svendsen, 1993].

Pricing water is important not only for generating revenues but also for promoting efficient use of water resource [IIMI, 1988; Takase, 1987]. Lusk and Parlin [1991] stress that free or very low water charge encourages overuse, reduces the incentive for farmers to cooperate or participate in irrigation organisations, and may result in low system productivity and poor conservation. The charges could also bring an ownership feeling to the farmers [Uphoff, 1986; IIMI, 1988; Vincent, 1990], which will ultimately lead to better use of available water and increased crop production.

Of course, collecting irrigation fees should not create any disincentive for farmers to irrigate, which means that the cost recovery mechanism should be compatible with resource use. This can be achieved if the fees are treated as a payment for service, not a tax. One way to do so is to link the charges to the quality of the service in terms of timing and quantity of water supply. Alternatively, the charges can be related to the value of crop income.

It should be mentioned that irrigation fee need not be paid entirely in cash. Since opportunity cost of labour is lower than the local wage rate in Nepal, as in many LDCs, farmers may prefer to pay the affordable O&M in the form of providing labour for maintenance tasks. In fact, mobilisation of resources of low opportunity cost, especially labour in the rural sector, for the construction of social overhead capital has long been identified as a key to the development of low-income societies [Kikuchi, Dozina, Jr. and Hayami, 1978]. Further, any payment in the form of labour contribution are used directly for irrigation services, whereas cash collected from farmers is deposited in the general treasury and may not be spent in the system from which it was collected.

Capital cost recovery may be gradually introduced with the improvement in the management of irrigation systems and as production shifts from subsistence agriculture to commercial farming. This would require substantial efforts from the government as well as from the farmers. At present, capital cost recovery will yield a negative impact on agricultural production and management of irrigation systems. Moreover, the recovery of capital cost through an irrigation service charge is not recommended because the two kinds of charges differ in the methods of assessment, means of collection and primary beneficiaries [Nathan Associates, 1989].

Experience from Taiwan suggests the need of institutional mechanism for promoting managerial performance of irrigation systems [Moore, 1989]. A water users association may be such a mechanism under which farmers assume significant managerial roles not only in an advisory capacity but also through delegating to them full responsibility for overall O&M functions, including O&M planning and irrigation service fee assessment. It could also play the leading role in water allocation, system maintenance, conflict resolution and fee collection.

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Table 1: Estimation Results of Production Functions

	Paddy			Wheat	
	FM	GM	Unirrigated	Unirrigated	GM
Elasticity Estimates					
Sown area	0.726	0.628	0.471	0.615	0.544
	(4.458)**	(7.635)**	(3.422)**	(4.117)**	(6.160)**
Labor	0.209	0.265	0.448	0.279	0.161
	(1.304)	(2.798)**	(2.714)**	(2.587)**	(2.049)**
Chemical fertiliser	0.023	0.010	0.022	0.02	0.025
	(2.463)**	(1.162)	(1.270)	(1.223)	(2.899)**
Manure	0.159	0.078	0.071	n.a.	n.a.
	(1.986)**	(2.258)**	(1.025)		
Constant	2.775	2.840	2.588	2.599	2.782
	(14.582)**	(27.253)**	(18.257)**	(25.444)**	(42.411)**
Sum of elasticities	1.117	0.981	1.012	0.914	0.73
R^2	0.77	0.85	0.89	0.55	0.62
F-value	56.24***	188.21***	61.39***	17.08***	47.05***
Sample size	75	138	35	66	127

Notes: (1) Figures in parentheses are t-ratios.
(2) ** and * indicate parameter being significant at 1% and 5% levels.
(3) n.a. = not applied in cropping.

Source: Estimated by the authors.

Table 2: Estimates of Marginal Value Products

	Paddy			Wheat	
	FM	GM	Unirrigated	Unirrigated	GM
Sample Geometric Means					
Output (NRs)	7273.33	8705.28	6482.08	1376.9	1872.84
Sown area (_ropani_)	4.45	6.08	5.77	2.97	3.27
Labor (Man-days)	39.12	50.94	39.16	9.59	11.77
Chemical fertiliser (Kg)	5.55	9.05	6.98	1.26	1.91
Manure (_doko_)	60.33	89.62	66.51		
Marginal Value Products (NRs)					
Sown area	1186.62	899.16	529.13	285.12	311.57
Labor	38.86	45.29	74.16	40.06	25.62
Chemical fertiliser	30.14	9.62	20.43	21.85	24.51
Manure	19.17	7.58	6.92	n.a.	n.a.

Note: n.a. = not applied in cropping.

Source: Computed by the authors.

Table 3: Affordability of Irrigation Services (NRs/ropani)

Crop	Irrigation System	Opportunity Cost of Land		O&M Cost	MVP of Irrigation	Capital Cost	O&M plus Capital Cost
Paddy	FM	529[a]	723[b]	50	1186.62	434	484
	GM	529[a]	620[b]	40	899.16	242	282
Wheat	GM	285[a]	253[b]	10	311.57	61	71

Notes: [a] Opportunity cost is based on the MVP of unirrigated land (cf. Table 2).
[b] Opportunity cost is based on the rent of unirrigated land.

Source: Calculated by the authors. See text for details.

Table 4: Returns from Irrigated and Non-irrigated Crop Production (NRs/ropani)

Return	Crop	FM	GM	Unirrigated
Gross Return[a]				
	Paddy	1117.65	890.1	634.25
	Wheat	236.1	355.2	162.20
Net Return[b]				
	Paddy	835.15	567.6	395.50
	Wheat	133.6	206.45	69.70

Notes: [a] Family labor is not included as factor cost.
[b] Family labor is calculated as part of production costs.

Source: Calculated from survey data.

Table 5: Incremental Income Attributable to Irrigation (NRs/ropani)

Irrigation System		With Irrigation			Without Irrigation			Incremental Income
		Paddy	Wheat	Total	Paddy	Wheat	Total	
FM	Yield (Kg/ropani)	145		n.a.	98			
	Net Return	835		835	396		396	439
GM	Yield (Kg/ropani)	124	70	n.a.	98	43		
	Net Return	569	206	775	396	70	466	309

Source: Calculated based on survey data.

Table 6: Incremental Income Attributable to Irrigation (NRs/household)

Irrigation System		With Irrigation			Without Irrigationm			Incremental Income	O&M/Incremental Income
		Paddy	Wheat	Total	Paddy	Wheat	Total		
FM	Area (ropani)	5.06			7.24				
	Net Return	4226			2863			1363	0.19
GM	Area (ropani)	7.79	3.57		7.24	3.59			
	Net Return	4422	737	5159	2863	250	3113	2046	0.17

Source: Calculated based on survey data.