CHAPTER 1

Irrigation Investment Trends in Sri Lanka: Implications for Policy and Research in Irrigation Management

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EVERYONE AT IIMI is firmly confident of the importance of improving irrigation management and so, to a lesser extent, are the policymakers associated with the irrigation sector in Sri Lanka and elsewhere in the third world. On what grounds is this confidence based? All of us strongly believe that irrigation management improvement will have a high economic payoff, but how large is the economic potential for such improvements? No one doubts the need for research to improve irrigation management, but how profitable is it to invest in such research?

Our confidence stems mainly from the fact that the existing irrigation schemes in the third world, many of which have been constructed in the last few decades with huge capital investments, perform below expectations. The answers to the questions above therefore hinge upon the size of the gap between actual performance and expected, or maximum attainable, performance. We believe this gap to be substantial rather than marginal and, using the irrigation sector in Sri Lanka as an empirical example, we try in this paper to substantiate a "material" basis for this belief.

Some qualifications need to be made. The first concerns the dimension or domain of the issue. Any research in irrigation management begins with the belief that such research is important, and looks into the process of irrigation management with a view to enhancing the performance of irrigation systems. The issue dealt with in this paper precedes this process, having nothing to do with "management" per se. In terms of IIMI's strategy, it is related to the component of "Objectives/National Irrigation Policies," and not with the "Process" components. However, since this study tries to evaluate the investment performance of different types of irrigation projects, its findings give not only direct support, but, to a certain extent, direction for irrigation management research.

The second concerns the shift of the irrigation sector in Sri Lanka, as in many other countries in the Asian tropics, from a "construction" phase to a "management" phase. This shift has had to occur simply because the management side of irrigation projects has been grossly neglected or forgotten during the "construction" phase in Asia, leaving huge potentials to be exploited by management improvements. In other words, these two phases are not necessarily mutually exclusive. Such a dichotomy in phasing could be misleading in some countries, such as some parts of Africa, where potentials for irrigation construction still exist. In such cases, these two phases must go together.

In what follows, we first summarize the major findings of our research and then spell out some implications for policy and research on irrigation management. This paper draws heavily on Aluwihare and Kikuchi (1991).

RICE PRODUCTION AND IRRIGATION DEVELOPMENT IN SRI LANKA

Irrigation is a critical input in rice-based agriculture in monsoonal Asia. This is the case in Sri Lanka, even though the climatic conditions and historical background specific to the country make the process of irrigated agriculture development somewhat unique. First, let us briefly observe the history of rice production and irrigation development in Sri Lanka and identify the stage that irrigated agriculture has reached there.

Sri Lanka is divided into two significantly different climatic zones; the wet and dry zones. A distinctive feature of the dry zone as an agricultural region is that land is not a productive resource unless it is provided with water. Without irrigation water, the only possible cultivation is very extensive *chena*, i.e., slash-and-burn or shifting cultivation. In the wet zone, the adequate rainfall and its relatively even distribution between seasons make rain-fed rice production quite possible. Despite an ancient civilization based on irrigated lowland agriculture, the dry zone had been nearly deserted for centuries until the late 19th century, the population being concentrated in the wet zone. The process of irrigation development in Sri Lanka in the last several decades has consisted of major colonization (settlement) projects, mainly in the dry zone.[1]

Changes in the total rice land area by type of irrigation in the country are summarized in Table 1.1. The total irrigated rice land area increased from 253,000 ha in 1950 to nearly half a million ha in 1985; 90 percent of this was brought about by an increase in the irrigated land area under the major irrigation systems which are situated almost exclusively in the dry zone. As a result, the proportion of irrigated area under major irrigation systems, either in the total irrigated rice land or in the total rice land, has virtually doubled in the last 35 years. Since newly created irrigated lowland areas have been almost exclusively devoted to rice production, this rapid development of dry-zone major irrigation systems has resulted in rapid increases in the area planted to rice in the *maha* (wet) and *yala* (dry) seasons in the dry zone (Table 1.2). Excluding the

[1] This is a unique feature of irrigation development in Sri Lanka. In other densely populated Asian countries, irrigation development has mainly consisted of providing existing rain-fed lowland with irrigation facilities.

area under minor irrigation systems and rain-fed areas in the dry zone for the period 1980 to 1985, the area planted to rice has increased regardless of zone, type of irrigation, or season. However, the most significant increases have been in the major irrigation systems in the dry zone.

Table 1.1. Rice land area by type of irrigation, irrigation ratios, and cropping intensity for selected years, Sri Lanka.[a]

	Rice land area (1,000 ha)						Irrigation ratio			Cropping intensity[c]	
	Irrigated[b]				Rain-fed	Total				Total	Major irrigation
	Major irrigation (i)	Minor irrigation (ii)	Lift irrigation (iii)	Total (iv)	(v)	(vi)	i/iv %	i/vi %	iv/vi %	%	%
1950	90	163	-	253	157	411	36	22	62	107[d]	118[d]
1955	119	168	-	287	162	449	41	27	64	108	112
1960	136	171	-	308	171	479	44	28	64	120	126
1965	161	174	0	336	184	520	48	31	65	118	130
1970	193	187	2	382	201	583	51	33	66	124	127
1975	232	182	3	417	215	630	56	37	66	119	110
1980	272	184	4	460	221	682	59	40	67	125	123
1985	305	186	4	495	220	715	62	43	69	123	129

[a] Five-year averages centering on the years shown.

[b] Irrigated asweddumized land area. Major irrigation refers to the irrigation systems with a command area of 81 ha (200 acres) or more, and minor irrigation to those with less than 81 ha of command area.

[c] Yearly cropping intensity = total area planted per year divided by the asweddumized area. The total cropping intensity includes lands in all the categories.

[d] Three-year average for 1950-53.

Source: Aluwihare and Kikuchi (1991)

This development in irrigation infrastructure paved the way for the successful introduction of seed-fertilizer technology in rice production. As shown in Table 1.3, the fertilizer use per hectare of rice planted began to rise in the late-1950s as the Old Improved Varieties were being adopted by rice farmers. By the mid-1980s, virtually all rice planted consisted of improved varieties. Parallel to this, fertilizer intensity increased tremendously, reaching a level more than 100 kg/ha. It is noteworthy that the process of "seed-fertilizer revolution" began much earlier in Sri Lanka than in other countries in the Asian tropics. This can be partly explained by the fact that Sri Lanka

Table 1.2. Total area planted to rice by zone and by type of irrigation, for selected years, Sri Lanka.[a]

	Total	Dry Zone						Wet Zone
		Major irrigation			Minor irri gation	Rain-fed	Total	
		Maha	Yala	Total				
	----	----	----	----	1,000 ha	----	----	----
1952	451.1	53.6	48.3	101.9	66.6	82.2	250.7	200.4
	(100)	(12)	(11)	(23)	(15)	(18)	(56)	(44)
1960	577.2	90.1	66.5	156.6	103.3	109.4	369.3	207.9
	(100)	(16)	(11)	(27)	(18)	(19)	(64)	(36)
1970	721.4	133.8	86.5	220.3	126.1	135.0	481.5	239.9
	(100)	(18)	(12)	(30)	(17)	(19)	(67)	(33)
1980	855.1	199.3	113.13	12.4	139.8	150.3	602.7	252.4
	(100)	(23)	(13)	(35)	(16)	(17)	(70)	(30)
1985	874.6	222.4	147.9	370.8	130.3	133.3	634.9	239.7
	(100)	(25)	(17)	(42)	(15)	(15)	(73)	(27)
Growth Rate (%) :								
1952-60	3.1	6.7	4.1	5.5	5.6	6	5.0	0.5
1960-70	2.3	4.0	2.7	3.5	2.0	2.1	2.7	1.4
1970-80	1.7	4.1	2.7	3.5	1.0	1.1	2.3	0.5
1980-85	0.4	2.2	5.5	3.5	-1.4	-2.4	1.0	1.0
1952-85	2.0	4.4	3.4	4.0	2.0	1.5	2.9	0.5

[a] Five-year averages centering on the years shown. Figures within parentheses are percentages.

Source: Aluwihare and Kikuchi (1991)

was endowed with a better irrigation infrastructure at the onset of agricultural development after independence; the irrigation ratio in 1950 was as high as 62 percent for cultivated rice fields (Table 1.1) and 48 percent for rice cropped area (Table 1.3).[2] On the one hand, such a favorable initial irrigation infrastructure provided a strong incentive for national agricultural research institutions to develop improved rice varieties. On the other hand, the successful development of seed-fertilizer technology, by raising the payoff to investments in irrigation, increased the incentive for the government to develop the irrigation infrastructure further. Such a dynamic interaction between the irrigation infrastructure and the seed-fertilizer technology may well have fuelled the rapid development of irrigation in the dry zone.

[2] Such high irrigation ratios at the start of agricultural development after independence are another unique feature of irrigation development in Sri Lanka when compared with other countries in the Asian tropics.

Table 1.3. Fertilizer input for rice production per hectare, irrigation ratio, and rice variety ratio, for selected years, Sri Lanka.[a]

	Fertilizer input		Irrigation ratio[c]	Variety ratio[d]		
	Total[b] (N+P+K) (kg/ha)	Nitrogen (kg/ha)	(%)	Traditional Varieties (%)	Old Improved Varieties (%)	New Improved Varieties (%)
1952	2.6	1.7	48	100	-	-
1960	13.8	8.3	57	87	13	-
1970	53.2	32.9	60	32	59	9
1980	85.2	57.2	62	13	15	72
1985	111.8	75.5	66	2	6	92

[a] Five-year averages centering on the years shown.
[b] Nutrient content (three major elements) of the fertilizer.
[c] Irrigated area planted to rice/total area planted to rice.
[d] Percentage of rice variety planted

Source: Aluwihare and Kikuchi (1991)

As a result, the country has experienced dramatic increases in rice production during the last four decades (Table 1.5). Immediately after independence, the country was producing only 40 percent of its total rice requirements, and the remaining 60 percent was imported. By 1985, the rate of self-sufficiency in rice had reached a level of more than 90 percent. Self-sufficiency in rice is now within sight for Sri Lanka.

Table 1.4. Rice production, rice imports, and rate of self-sufficiency in rice for selected years, Sri Lanka.[a]

	Domestic rice production[b] (x)	Rice imports[b] (y)	Self-sufficiency in rice (%) $\frac{x}{x+y}$
	------ 1,000 metric tons ------		
1951	428	633	40
1955	613	661	48
1960	864	739	54
1965	989	710	58
1970	1,409	523	73
1975	1,400	602	70
1980	2,062	271	88
1985	2,455	220	92

[a] Five-year averages centering on the years shown.
[b] In rough rice equivalent

Source: Aluwihare and Kikuchi (1991)

Using the rice fertilizer response functions by variety and irrigation condition, we arrive at the following rough breakdown of the rice production increase between 1952 and 1985 into the three major contributing factors:

		(1,000 mt)	(%)
Total rice production increase		2,087	100
Increase due to:	Variety	861	41
	Fertilizer	561	27
	Irrigation	665	32

Irrigation development since independence has thus played a pivotal role in increasing the total rice production through increasing both the area planted and the land productivity. Now that the longstanding national policy target of self-sufficiency in rice is almost attained, the development pattern of the peasant agriculture sector in Sri Lanka, which has primarily been based on the dry-zone colonization, has reached a turning point.

TRENDS IN IRRIGATION INVESTMENTS

As outlined above, irrigation development in Sri Lanka has been attained through massive investments. Public investments in the post-independence period are summarized by type in Table 1.5, and their trends in terms of five-year moving averages are shown in Figure 1.1. Irrigation investments are grouped into three categories: new construction, rehabilitation, and operation and maintenance (O&M).

"New irrigation construction" refers to projects aimed at the construction of modern irrigation systems. In the dry zone, there are still many abandoned tanks dating from the time of the ancient Sinhalese kingdoms. In some cases, a modern system was created just by restoring the ancient system. In other cases, a new reservoir, together with new canal networks and new command areas, was constructed. The former may be called "restoration," and the latter "new construction." However, since even "new construction" projects usually include in their new command areas some old small tank systems, it is rather rare to find an entirely "new" irrigation construction project in the dry-zone setting. Included in the "new" construction are all those projects that are not categorized as "rehabilitation," which is defined as the restoration of deteriorated, but still functioning, irrigation systems to their original capacity, or their modernization.

The investments for new irrigation construction here include only those related to the development of the irrigation infrastructure, such as reservoir, canal, rice field, and road construction. Settlement-related investments, as well as such overhead costs as the personnel emoluments at the headquarters of the irrigation construction related

Table 1.5. Irrigation investments in Sri Lanka, in 1986 prices, by type of investment, and their share in the government budget and the total public investment, 1950-88.[a]

	Irrigation investments				Share of the total irrigation investment in	
	New construction[b]	Rehabilitation[c]	Operation and maintenance[d]	Total	Government budget	Total public investment
	Rs million in 1986 prices				%	
1950	907	-	34	941	8	37
	(96)	-	(4)	(100)		
1955	859	-	38	897	6	29
	(96)	-	(4)	(100)		
1960	601	-	121	723	3	19
	(83)	(17)	(100)			
1965	619	-	62	681	3	15
	(91)		(9)	(100)		
1970	994	-	78	1,071	3	16
	(93)		(7)	(100)		
1975	1,116	5	127	1,248	2	13
	(89)	(1)	(10)	(100)		
1980	3,023	225	137	3,385	6	21
	(89)	(7)	(4)	(100)		
1985	2,770	451	154	3,375	6	18
	(82)	(13)	(5)	(100)		
1988	1,676	308	102	2,086	3	na
	(80)	(15)	(5)	(100)		

[a] Five-year averages centering on the years shown. Figures within parentheses are percentages. na = data are not available.

[b] Investments for constructing new systems or restoring old abandoned systems. Only irrigation-infrastructure-related investments, such as tank and canal construction, are included.

[c] Investments for major rehabilitation and modernization of existing systems.

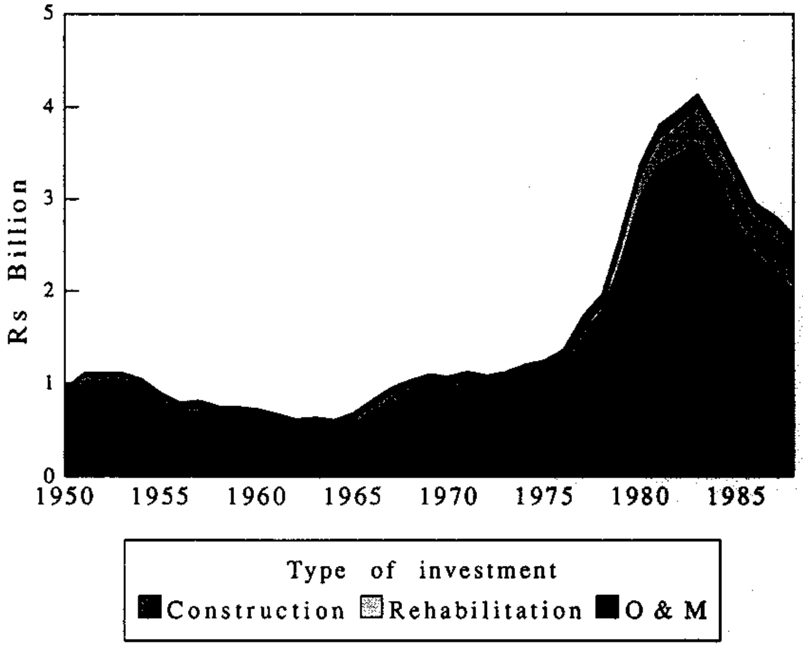
[d] Not including overhead costs such as personnel emoluments or administrative expenditures.

Source: Aluwihare and Kikuchi (1991)

agencies, are not included in the new irrigation construction investment.[3] Likewise, the rehabilitation investment and O&M expenditures are defined as not including general and administrative overhead costs.

[3] There have been several multipurpose projects concerning not only irrigation but also hydroelectric power generation. For these projects, the investment costs common to both purposes, such as the reservoirs, are apportioned to each purpose in the ratio of the benefits expected from each purpose according to the project appraisal reports.

Figure 1.1. Changes in irrigation investments in Sri Lanka, five-year moving averages, 1950-86, in 1986 prices.



Source: Aluwihare and Kikuchi (1991)

Several points are to be noted in Table 1.5 and Figure 1.1. First, irrigation, and particularly new irrigation construction, have been by far the most important investment opportunity in the country. New construction investment accounted for 96 percent of the total irrigation investments in the early-1950s, and irrigation investments as a whole took nearly 40 percent of the total public investments or nearly 10 percent of the government budget during that period. As the economy developed, the share of total irrigation investments in the total public investments declined towards the mid-1970s. However, around 1980, the total irrigation investments suddenly rose again to constitute more than 20 percent of the total public investments.

Second, new irrigation construction has been the dominant type of irrigation investment, and the long-term trend of new construction investments has been upwards. Third, however, this type of investment has experienced distinct short- to medium-term fluctuations. Three peaks, or investment spurts, can be discerned. During the periods between these peaks, new construction investment decelerated. The third peak was particularly high, but new construction investment began to decline sharply after this peak.

Fourth, rehabilitation investments began in the mid-1970s and have rapidly increased their share in the total irrigation investments since then. The share rose to more than 10 percent of the total irrigation investments by the mid-1980s. The first modern irrigation rehabilitation project in Sri Lanka was the Tank Irrigation Modernization Project (TIMP), started in 1976, which was followed by several other major rehabilitation projects. In addition to these, many water management improvement projects have been initiated since the late 1970s.

Last, expenditures for irrigation system O&M have been a minor component of the total irrigation investment. More importantly, the share of O&M expenditures in the total irrigation investments has not shown any steady increase over time. In spite of the large increase in the irrigated land area under major irrigation systems, its share in the total irrigation investments remained as low as 4 percent in the 1980s.[4] This suggests that the maintenance of the existing irrigation systems has remained inadequate, resulting in the low performance of the systems and endangering their long-term sustainability.

These observations on past investment trends in irrigation raise some interesting questions. Why have such huge investments been made for new irrigation construction? What were the factors that caused the fluctuations in new construction investments? Will there be a fourth peak in new construction investments after the third one in the 1980s? Why have rehabilitation/water management improvement projects become important since the late 1970s? Answers to these questions reveal a basic change in emphasis in the development of the irrigation sector in Sri Lanka — the shift from the construction phase to the management phase.

CONSTRUCTION PHASE

Long-Term Trend

Investments in new irrigation construction increased greatly until the early-1980s, and the reason for this lies in the high economic returns on such investments. On the one hand, the cost of creating a unit of irrigated land has increased over the last four decades, as new construction progressed from relatively easy projects to more difficult ones. On the other hand, the irrigation infrastructure and the seed-fertilizer technology reinforced each other to increase the productivity of irrigated agriculture, thereby maintaining the profitability of new construction investments and counteracting increased construction costs. Taking these factors into account, the rates of return on new irrigation construction investments in the last four decades are estimated, based on 1986 constant prices.

We first identify the trend in the capital costs of creating a unit of irrigated land. Historical changes in the real capital costs of creating one hectare of irrigated land are

[4] Around 1960, the share of O&M expenditures increased substantially. This was due to the expenditures required for major repairs in many systems following flood damage in 1959.

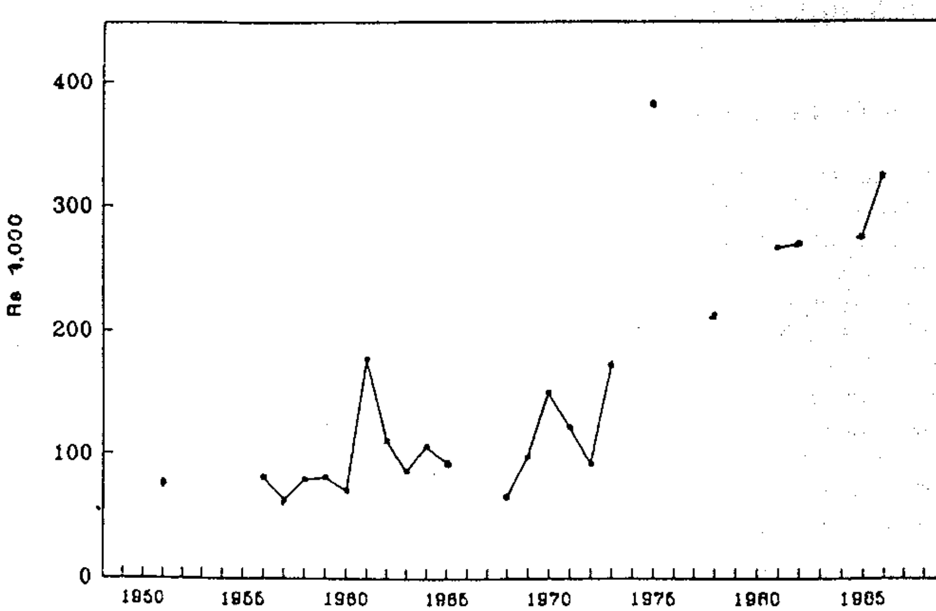
shown in Figure 1.2, based on 49 new irrigation construction projects for which detailed capital investment data are available. As defined earlier, the capital costs include only investments related to irrigation infrastructure. An increasing trend in the unit cost is apparent. The cost escalation has become more apparent since the early 1970s as irrigation construction projects shifted from small-scale "restoration" type to large-scale transbasin ones, such as the Mahaweli Project. This trend suggests that new irrigation construction in the post-independence period began in relatively easy projects and moved to more difficult ones. As a result, the construction cost per hectare in the late 1980s was more than five times that in the 1950s, in real terms.

The following result is obtained when the exponential time-trend curve is fitted to the data:

$$K^{*} = 1.637 + 0.047t, \quad R^2 = 0.685,$$
$$(3.411) \quad (6.763)$$

where: K^{*} = capital cost per hectare including capital interest (in Rs 1000) in 1986 prices,
t = time (48 to 89),
R^2 = coefficient of determination, and
the figures in parentheses are t-ratios.

Figure 1.2. Changes in the real capital cost per hectare (including capital interest evaluated at 10% per annum) of new irrigation construction, 1951-89, in 1986 prices.



Source: Aluwihare and Kikuchi (1991)

For the benefit side, we assume rice is the crop to be grown in the newly created irrigation systems. In order to analyze the complementary relationship between irrigation and seed-fertilizer technology, three different seed-fertilizer technology levels are considered: 1) Traditional Varieties (TV) with 0 kg/ha of nitrogen application; 2) Old Improved Varieties (OIV) with 60 kg/ha of nitrogen; and 3) New Improved Varieties (NIV) with 120 kg/ha of nitrogen. The rice output for each variety group at each nitrogen level is estimated by using the national average fertilizer response function for each group (Kikuchi and Aluwihare 1990a).

Both the benefit-cost (B/C) ratio and the internal rate of return were estimated. The formula used to calculate the B/C ratios is as follows:

$$\frac{B}{C} = \frac{\sum_{k=0}^{l-1}(1+i)^k (l-k) [(R-c)/l] + \sum_{j=1}^{n}[(R-c)/(1+i)^j]}{(1+i)^m K}$$

where; R = annual increase in income due to the project, C = annual O&M cost to maintain the benefit stream, K = capital cost, n = lifetime during which the benefit stream continues to accrue, l = time in years from the commencement of the accruing of benefits to the completion of the project m = average gestation period of the capital investment, i = interest/discount rate (assumed to be 10 percent). The first term of the numerator in the right hand side of the formula, which is defined if and only if $l \geq 2$, is introduced to take into account the cases where part of the benefits starts accruing before the project completion, assuming linear increases in benefits from zero to the full benefit level. The internal rate of return is estimated as r that satisfies the following equation:

$$(1+r)^m K = \sum_{k=0}^{l-1} (1+r)^k (l-k) [(R-c)/l] + \sum_{j=1}^{n}[(R-c)/(1+r)^j]$$

The benefit flow is measured by an increase in agricultural income (gross value added). The increase is estimated by subtracting the current input cost (seed, fertilizer, chemicals, fuel, etc.) from the value of produce from the newly created irrigated land.[5] Rice output is valued by the average domestic market price for 1985-1987. The cropping intensity of the systems is assumed to be 1.3, which is the average for all the major irrigation systems for the entire study period (see Table 1.1).[6] The annual O&M

[5] Increases in labour costs for crop production due to irrigation were not subtracted. This assumes that the additional labor is available at zero opportunity cost. As explained earlier, almost all new irrigation construction projects in Sri Lanka have been settlement schemes. Since the settlers in these irrigation systems were those who had difficulty in finding productive employment in their prior locations, their opportunity cost, if not zero, would have been quite low.

[6] More detailed analysis of the cropping intensity of the dry-zone major irrigation systems will be given later.

Table 1.6. Benefit-cost ratios and internal rates of return on investments in new irrigation construction, based on 1986 prices.[a]

	Based on estimated construction cost[b]			Based on actual construction cost[c]		
	Technology level[d]			Technology level[d]		
	Traditional Varieties N=0kg	Old Improved Varieties N=60kg	New Improved Varieties N=120kg	Traditional Varieties N=0kg	Old Improved Varieties N=60kg	New Improved Varieties N=120kg
1948-49	2.3 (20)			na		
1950-59	1.7 (15)			1.7 (15)		
1960-69	1.0 (10)	1.6 (15)		1.0 (10)	1.5 (14)	
1970-74	0.7 (7)	1.1 (11)	1.6 (15)	0.9 (9)	1.4 (14)	2.1 (20)
1975-79	0.5 (6)	0.9 (9)	1.3 (12)	0.5 (5)	0.8 (8)	1.1 (11)
1980-84	0.4 (4)	0.6 (7)	0.9 (10)	0.4 (3)	0.5 (5)	0.8 (8)
1985-89	0.3 (3)	0.5 (5)	0.7 (8)	0.3 (3)	0.5 (5)	0.7 (7)

[a] Internal rates of return are shown within parentheses. na = data are not available.
[b] The capital investment cost per hectare of new irrigation construction is estimated by the following equation: $K = 1.637 + 0.047t$; where K = capital investment per hectare with interest and t = time (48, 49,..., 89).
[c] The actual capital investment cost of new irrigation construction projects; weighted averages for the projects completed in the periods shown, using the command area as weights.
[d] Technology levels assumed for measuring the benefits from newly created irrigated land based on the following rice production functions under irrigated conditions:

Traditional Varieties	$Y = 1500 + 10N - 0.09N^2$
Old Improved Varieties	$Y = 1900 + 14N - 0.06N^2$
New Improved Varieties	$Y = 2400 + 21N - 0.08N^2$

where Y = rice yield (kg/ha) and N = nitrogen input (kg/ha).

The benefits are measured by the increase in agricultural income (gross value added). The opportunity cost of labor is assumed to be zero. The total current input cost is estimated assuming the ratio between the total current input and the nitrogen cost to be 2.5.

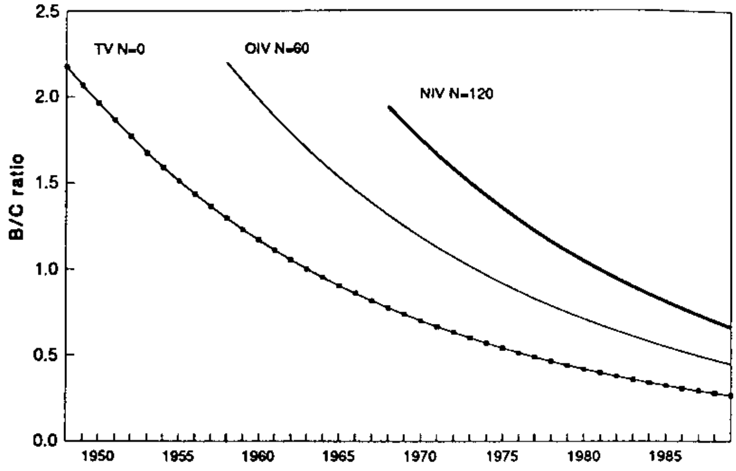
Source: Aluwihare and Kikuchi (1991)

cost of new areas brought under irrigation are assumed to be Rs 740/ha at 1986 prices.[7] It is assumed that with this level of O&M, irrigation systems can sustain their operation for 50 years.

The estimated rates of return are summarized in Table 1.6 by period, and the estimated B/C ratio series are shown in Figure 1.3 by level of seed-fertilizer technology. Several points should be noted. First, irrigation construction was a lucrative investment

[7] This is the level that the Irrigation Department set as the "desired level" of O&M for the major irrigation systems (IIMI 1989).

Figure 1.3. Changes in the benefit-cost ratio of new irrigation construction investments, 1948-89, by level of seed-fertilizer technology, in 1986 prices.



Note: TV = Traditional Varieties
OIV = Old Improved Varieties
NIV = New Improved Varieties

Source: Aluwihare and Kikuchi (1991)

opportunity just after independence. The B/C ratios in the late 1940s were as high as 2.3 (Figure 1.3). For the 1950s, it was 1.7 on the average (table 1.5). Reflecting the increasing trend in the unit construction cost, however, the B/C ratio under the traditional rice technology (represented as "TV N=0") declined rapidly, and it went below 1.0 in the early 1960s. Had there been no progress in the technology from the traditional level, the economic potential of irrigation construction would have been exhausted within fifteen years after independence.

Second, the progress in seed-fertilizer technology compensated for the increases in construction costs to a large extent, and preserved the profitability of new construction investments. The introduction of improved rice varieties and the associated increase in fertilizer application resulted in successive upward shifts of B/C ratio curves from the previous technology levels; in terms of the horizontal axis, the degree of the upward shift was about 10 years for both Old Improved Varieties and New Improved Varieties.

Third, the rates of return on construction investments continued to decline even with the highest level of technology, cutting across the B/C ratio = 1.0 line by the early 1980s. This suggests that, given the present level of rice technology, the increasing real capital cost for construction, and the price structure in the mid-1980s, the irrigation sector in the country has come to a stage at which the investments in new irrigation construction cannot be economically justified.

The analysis above gives clear evidence for the following statements:

1) The massive investments in irrigation new construction after independence were induced by the high economic potentials of such investments; the profitability was high at the initial stage and was then preserved by dynamic interactions between irrigation infrastructure and seed-fertilizer technology.
2) The economic potential for new irrigation construction had been exhausted by the mid-1980s.

Short-Term Fluctuations

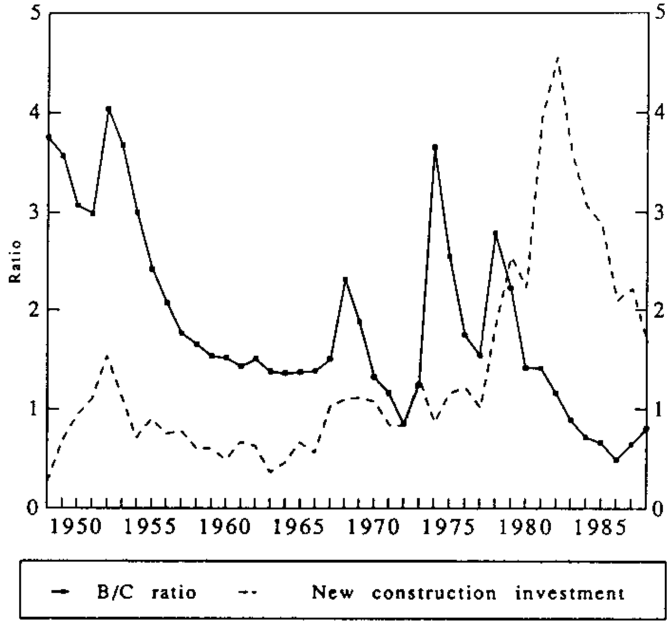
The new irrigation construction investments have experienced large short-run to medium-run fluctuations in the past. If new irrigation construction was always a lucrative investment opportunity, as the long-term analysis above indicates, why did the government not make a continuous effort to invest in it? The answer can be sought in two areas: fluctuations in rice prices, and the availability of investible funds.

The rates of return on construction investments depend critically on the price of rice. For a government making decisions on irrigation investments, the import price of rice is of particular importance. An overriding factor in the food policy of the Government of Sri Lanka has been the need to supply a sufficient amount of rice to the consumers, through the food ration/food stamp system or at relatively low and stable prices in the open market. It is therefore reasonable to suppose that the government, as an importer of rice, strengthened its efforts to increase domestic rice production in response to rising world rice prices. It can therefore be hypothesized that, besides pursuing the long-term objective of attaining self-sufficiency in rice, government decisions on irrigation investments have been strongly influenced by short-term fluctuations in world rice prices and their effects upon the social payoff from irrigation investments as well as the country's foreign exchange reserve.

As a test of this hypothesis, the benefit-cost ratios of investment in new construction were re-estimated by evaluating the costs and benefits at current prices. On the benefit side, the rice output was evaluated by the current Colombo c.i.f. price of rice. Changes in seed-fertilizer technology were incorporated by aggregating the income generated under each technology level into a single series, using the percentage shares of area planted with each type of rice variety in each year. On the capital cost side, the unit cost at current prices of constructing one hectare of new irrigated land was obtained by applying the GDP implicit deflator to the real unit cost estimated from the trend line presented earlier.

The series of B/C ratios thus estimated are shown in Figure 1.4, together with the series of annual investments in new construction. Close associations between changes in the B/C ratio and construction investments are discernible. While the government response to the changes in the payoff was rather quick until the 1960s, the process began to involve substantial time lags after around 1970. This could be explained by the fact that, whereas in earlier years there were many sites where construction projects could be initiated easily, project preparation and implementation have become more difficult and time-consuming in recent years.

Figure 1.4. Changes in the benefit-cost ratio of new construction (evaluated at current import price of rice) in comparison with changes in the new construction investments, 1948-88, in 1986 prices.

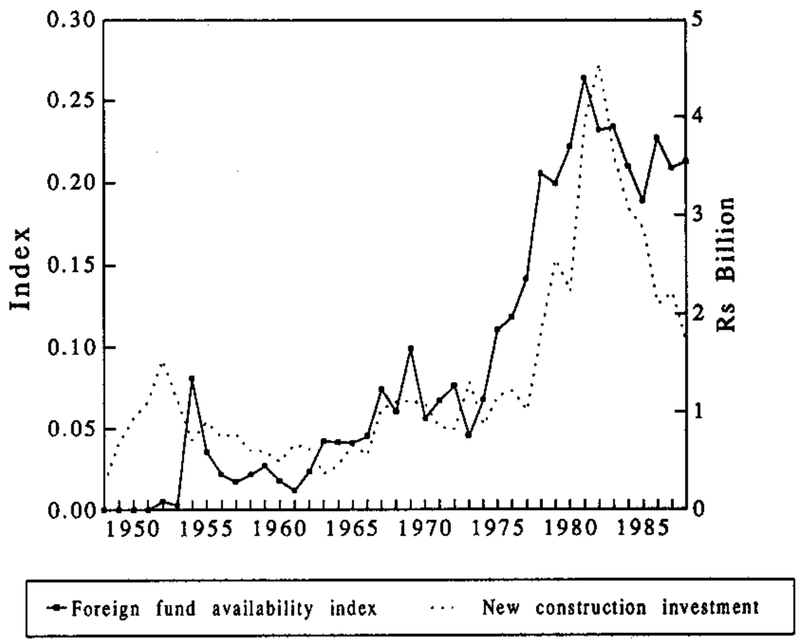


Source: Aluwihare and Kikuchi (1991)

A high rice import price clearly has a direct impact on government decisions in irrigation construction, through raising the payoff of the investments relative to other public investment opportunities. This implies the reallocation of government funds from other public investment opportunities and/or from recurrent expenditures such as those for importing rice for the food ration program. Since the government's investible funds have always been scarce, their availability would have constrained this reallocation process to a great extent. To identify how the availability of funds affects investment in irrigation construction, we prepared a foreign fund availability index which is defined as the ratio of the total foreign official assistance, consisting of the foreign loans and grants, to the total government budget. Historical changes in this index are shown in Figure 1.5, together with the trend of new irrigation construction investments.

A close association is apparent between this index and new construction investments. In particular, the association is quite strong after the early 1960s. The investment spurt in the late 1960s coincided with an increase in the index during the same period. The unprecedented high investment spurt that began in the late 1970s was narrowly preceded by a rapid increase in the availability of foreign funds, and the investments began to decline after the index hit a peak in 1981. All this indicates that

Figure 1.5. Changes in the foreign fund availability index in comparison with changes in the new irrigation construction investments, 1948-88, in 1986 prices.



Source: Aluwihare and Kikuchi (1991)

the government decision to invest in irrigation construction was seriously constrained by the availability of funds, particularly those of foreign origin. It could be said that the last two peaks in construction investment, particularly the third one, were largely created by donor countries and international lending agencies; they too reacted to the high profitability of investments in irrigation construction.

Our analysis thus indicates that rates of return and foreign fund availability are major determinants of government investment in new irrigation construction.[8] It is worth emphasizing that the government also responded to changes in the social profitability

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[8] The following estimate of the investment function gives statistical support for the determinants of new construction investments:

$$\ln I_t = \underset{(4.01)}{1.265} + \underset{(2.26)}{0.221 \ln (B/C)_t} + \underset{(3.77)}{1.541\ AID} + \underset{(4.67)}{0.527 \ln I_{t-1}}$$

$$R^2\ (\text{adj.}) = 0.819,\ \text{D.W. stat.} = 2.001,$$

where; I_t = irrigation construction investments in year t; $(B/C)_t$ = B/C ratio in year t evaluated at current prices; AID = foreign fund availability index; and figures in parentheses are t-ratios. It should be noted that a very similar relationship between irrigation construction investments and world rice prices/foreign fund availability is observed in the Philippines (see Hayami and Kikuchi 1978 and Svendsen and Ramirez 1990).

of the investment. It is often said that irrigation-settlement projects in Sri Lanka have always been a hot social issue in which political and social factors exercise undue influence (e.g., Mendis 1989; Nijman forthcoming). Nevertheless, the allocation of government funds for irrigation construction has been guided by economic considerations, i.e., by the economic returns on the investment, while being constrained by the scarcity of investible funds and foreign exchange reserves.

FUTURE PROSPECTS FOR NEW IRRIGATION CONSTRUCTION

Figure 1.4 reveals that the B/C ratio of the investments in irrigation construction went down sharply from the late 1970s and hit an unprecedented low in 1986. Such a drastic decline was due partly to the increased construction costs and partly to the historic low price in the world rice market. Although the B/C ratio shows an upward trend after 1986 as the world rice price rebounded, its level in 1988 was still below 1.0. Irrigation construction investment at present represents the classical case of diminishing returns. It could be said that the era of "major" irrigation construction in Sri Lanka has ended, unless major breakthroughs in technology are forthcoming either in construction or in agriculture, or in both.

This statement raises two questions. First, what would the level of the rates of return for irrigation construction be if the world rice price rose in the near future to the level experienced during the food crisis period in the 1970s? To check this, the rates of return are estimated for three years in the last decade of this century assuming the average rice import price experienced during the period from 1974 to 1979, which is more than 300 percent higher than in 1986 in terms of the price of rice relative to construction cost. The results show that the high rice price raises the B/C ratio to slightly more than 1.0 with the present level of construction costs (Table 1.7). However, even with such a high rice price, it will go down quickly to a level below 1.0 by the end of this decade.[9]

Second, since the mid-1980s when Sri Lanka attained near self-sufficiency in rice, efforts have been made to diversify the cropping pattern on rice-based irrigation systems. Could the benefits from irrigation construction be drastically increased by switching the crops to be grown in the systems from rice to high value nonrice crops? To check this, re-estimations of the rates of return were attempted, assuming that the entire planted area in the yala season with a cropping intensity of 0.3 is planted with high value nonrice crops, such as chili, onion, and gherkin. Based on our recent study (IIMI 1990a), the gross value added of these high value crops is assumed to be at a level 740 percent higher than that of rice if the rice c.i.f. price is at the 1986 level. For valuing rice output, the World Bank predictions are used after linking with the

[9] It is worth noting that the World Bank predicts a declining trend in the world rice price after 1989. Its latest prediction at January 1990 is as follows: 1989=100.0, 1990=84.5, 1995=72.1, and 2000=71.2. The predicted level for the year 2000 is not only less than the level assumed here but less than the 1986 level.

Table 1.7. Rates of return on the irrigation construction investment for different assumptions on the world market price of rice and crops grown.[a]

	Rates of return[b]					
	1990		1995		2000	
High world market price: Import price of rice (Colombo c.i.f.) relative to the construction cost index; average for 1974-79[c]	1.43	(13)	1.13	(11)	0.89	(9)
Crop diversification: Complete diversification in the yala season with high performance nonrice crops[d]	1.47	(14)	1.11	(11)	0.88	(9)

[a] For all cases, the technology level of "New Improved Varieties; N=120kg" for rice is assumed. The capital cost of construction is estimated on the basis of the trend curve.

[b] The benefit-cost ratio. The internal rates of return are shown within parentheses.

[c] The average relative price of rice for 1974-79 is assumed. The same assumption is adopted in estimating the benefit, except that the nitrogen price is evaluated by using the price with the subsidy added, instead of the farm-gate price.

[d] It is assumed that the entire cultivated area in the yala (dry) season with a cropping intensity of 0.5 can be planted with the high performance nonrice crops. The gross value added of the nonrice crops is assumed to be Rs 72,000/ha, in 1989 prices.

Source: Aluwihare and Kikuchi (1991)

Colombo c.i.f. price. The results shown in Table 1.7 indicate that, with the unit capital cost in 1990, the B/C ratio will be raised to 1.2, but it soon declines to below 1.0.[10]

Our conclusion that the era of "major" irrigation construction has ended is thus maintained under these two extremely favorable cases for new construction, cases

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[10] It should be noted that in reality there are many difficulties and constraints in promoting crop diversification in rice-based irrigation systems on a wide-scale (IIMI 1990a; 168-178): it is difficult to identify economically viable nonrice crops which can replace rice; some high value nonrice crops are available for farmers to adopt, but usually these crops require higher input intensity as well as more deliberate water management than rice does; not all soil types found in the irrigation systems are fit for growing nonrice crops; the markets, both for outputs and for inputs, are not well-developed; etc. There is no doubt that needs as well as potentials exist for crop diversification, but there are many prerequisites to attaining it, including the capability to manage water better than is necessary for rice.

which are hardly likely to occur.[11] The conclusion is further reinforced when compared to other types of irrigation investments which have emerged in the management phase.

MANAGEMENT PHASE: REHABILITATION AND WATER MANAGEMENT IMPROVEMENT PROJECTS

A new trend in irrigation investments emerged in the mid-1970s; investment in irrigation system rehabilitation appeared and has rapidly increased its share in the total irrigation investments. Following this, with a short time-lag, has been a spate of water management improvement projects. Why? It is natural to hypothesize that the diminishing returns on new irrigation construction, due to massive investments in the past, have increased the relative profitability of the investments in improving and enhancing the quality of existing systems.

Let us examine this hypothesis by estimating the rates of return on selected rehabilitation and water management projects. Two completed major rehabilitation projects — the Tank Irrigation Modernization Project (TIMP) and the Gal Oya Water Management Project (Gal Oya) — and three water management improvement projects, implemented in the Kimbulwana, Pimburettawa, and Nagadeepa systems, are selected for post-project cost-benefit analysis.

The same cost-benefit analysis framework as for the constant price estimation for new construction investments is applied; both the capital costs and benefits are valued at 1986 prices, and the benefits are measured by the increases in agricultural income due to the projects. There could be various possible sources of benefits from rehabilitation/water management projects. In this study, we take into account only two sources of possible benefits: changes in the cropping intensity, and reduction in yield gaps between the head- and tail-end sections due to better water distribution after the project. Rice is assumed to be the crop grown, with yields identified by system, except TIMP for which the technology level "NIV; N=120" is assumed. The gross value added ratio of rice production is assumed to be 80 percent. O&M cost is assumed to be Rs 740 per ha. The lifetime of project benefits is assumed to be 20 years for major rehabilitation projects and 15 years for the water management projects.

[11] Note the magnitudes of changes assumed in our sensitivity analyses. Unlike appraisal reports for this kind of irrigation project in which sensitivity analyses are made assuming 10-20% changes in crucial parameters in cost-benefit analyses, ours are in the order of several hundred percent. Any possible changes in the parameters other than those treated here will be within these magnitudes. For instance, a basic assumption in the cost-benefit analysis made thus far for irrigation construction is that the newly created systems are operated at a cropping intensity of 1.3. What if it is 2.0? The benefits then will be increased by about 50% over the 1.3 case. Such an increase in benefits is well within the magnitudes.

The results of the estimations are summarized in Table 1.8, together with the rates of return of new construction investments in the 1980s for comparison. As expected, the two major rehabilitation projects both show rates of return higher than new construction. In particular, the Gal Oya Project reveals high rates of return for rehabilitation investments. It is interesting to notice that the level of profitability of this project is almost at the same level that investments in irrigation construction enjoyed forty years ago, when the irrigation sector started its construction phase after independence. The Gal Oya case thus gives clear support to the hypothesis that rehabilitation is a more lucrative investment opportunity than new construction at the present stage of irrigation development.

However, not all major rehabilitation projects are necessarily as successful as the Gal Oya project, as illustrated by the TIMP case. The difference in the rates of return between TIMP and new construction is marginal. It has been pointed out that TIMP, as the first major rehabilitation project in the country, encountered many difficulties in implementation; particularly serious was its strong bias towards engineering and capital intensive directions while giving little attention to the farmer-beneficiaries in the design and O&M processes (e.g., Murray-Rust and Rao 1987). It is said that the most valuable contribution made by TIMP is that it has given many useful lessons to the rehabilitation projects that followed it. It is noteworthy that the Gal Oya project, which is said to have absorbed many useful lessons offered by TIMP (Merrey and Murray-Rust 1987), showed far better economic performance than its predecessor. Improving water management through introducing institutional changes, including farmers organizations, became a central feature of the Gal Oya project; it thus included elements of both rehabilitation and water management improvement projects.

Table 1.8. Rates of return on irrigation investments in the 1980s: Comparison of B/C ratios and internal rates of return of new construction, major rehabilitation, and water management improvement projects, based on 1986 price estimates.

	B/C ratio	Internal rate of return (%)
I. New construction Projects:		
The average for the 1980s[a]	0.8	9
II. Major Rehabilitation Projects:		
TIMP[b]	1.1	11
Gal Oya	2.3	24
III. Water Management Projects:		
Kimbulwana	13.4	83
Pimburettawa	7.4	77
Nagadeepa	0.4	6

[a] For the technology level "New Improved Varieties; N=120kg" and the estimated construction costs (From Table 1.6).

[b] The rates of return for the Tank Irrigation Modernization Project are based on "would-be" benefits assumed in the project appraisal report. For all other rehabilitation and water management projects, the project benefits are based on the data that show changes before and after the projects.

Source: Aluwihare and Kikuchi (1991)

More striking results in Table 1.8 are the very high economic performanc that some water management improvement projects reveal. The Kimbulwana and Pimburettawa Projects yielded internal rates of return as high as 70 to 80 percent, implying that such projects have been terribly underinvested. It is not surprising at all, however, to see such results for water management projects, if one examines the present level at which many major irrigation systems in Sri Lanka are being operated and maintained: inequitable water distribution, considerable wastage of water by head-end farmers, poor management of water in the maha season leading to water shortage in the yala season, poor maintenance of physical structures, etc. Rectifying these defects results in substantial increases in system performance, while requiring little financial investment.

However, not all water management projects are successful. Among the three projects studied, we failed to detect any systematic improvement in system performance after the intervention in Nagadeepa. There are two important differences between this and the other two projects. One lies in the inadequate follow-up to consolidate the water management improvements by the managing agency at Nagadeepa. The other lies in the components related to physical structure improvements; the rehabilitation and/or modernization components, however minor they were, accompanied the institution-building and water management improvement components in Kimbulwana and Pimburettawa, whereas they were almost nonexistent in Nagadeepa.

An important lesson that could be derived from these experiences is the importance of physical structure improvements as a precondition to achieving better water management through farmers' participation and cooperation. The two success cases suggest that very modest investments in rehabilitation are sufficient to provide the basis for water management improvement.[12] A second lesson is the importance of sustained effort to achieve the full potential of improvements over the long term.

The available evidence thus indicates that, given proper design and implementation, the economic performance of rehabilitation and water management improvement projects is far better than that of new construction. The rapid increase in rehabilitation

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[12] The capital cost per hectare of these water management projects, in 1986 prices, can be roughly broken down as follows (Kikuchi and Aluwihare 1990b):

	Kimbulwana	Pimburettawa	Nagadeepa
	Rs/ha		
Rehabilitation of physical structures	4,332	4,734	596
Institution building	0	902	621

Note that the amount spent for physical improvements in Nagadeepa was less than the assumed level of O&M cost per hectare, and that the rehabilitation component was quite similar for Kimbulwana and Pimburettawa, i.e., US$ 160/ha (using the average exchange rate of US$ 1.00 = Rs 28.00 in 1986).

investments and the proliferation of water management improvement projects in and after the late 1970s must have been induced by such changes in the relative profitability of these investments.

One may think that, even if their rates of return are higher, the absolute amount of benefits to be generated from such projects would be far less than the benefits obtained from new construction projects. If that were the case, considering the overhead and other transaction costs involved in project preparation and implementation (which are not taken into account in our cost-benefit analysis), it might not be worth pursuing the opportunities for rehabilitation and water management improvement. To answer this question, the project net present value, defined as the present value of the total project benefits less the present value of the total project capital

Table 1.9. Comparison of the Net Present Values of new construction and rehabilitation/water management improvement projects of selected irrigation systems in Sri Lanka, in 1986 prices.

	New construction (1)	Rehabilitation/ water management (2)	(2)/(1)
Gal Oya			
Construction period[a]	1949-61	1980-87	
Command area (ha)	38,000	25,000[d]	
Total capital cost[b] (Rs million)	2,190	450	0.21
Internal rate of return (%)	12	24	2.00
Net Present Value[c] (Rs million)	1,459	1,055	0.72
	(960)[d]		(1.10)
Kimbulwana			
Construction period[a]	1953-62	1979-80	
Command area (ha)	560	666[e]	
Total capital cost[b] (Rs million)	21.8	2.9	0.13
Internal rate of return (%)	16	83	5.19
Net Present Value[c] (Rs million)	53.3	41.3	0.77
Pimburettawa			
Construction period[a]	1969-75	1986-89	
Command area (ha)	1,619	2,153[e]	
Total capital cost[b] (Rs million)	89.0	12.1	0.14
Internal rate of return (%)	25	77	3.08
Net Present Value[c] (Rs million)	168.2	81.3	0.48

[a] For the new construction projects, the end-year is defined as the year by which time 90 percent of the total capital investment was made.

[b] Capital interest during the gestation period is not included.

[c] Net Present Value of project = total capitalized benefits (net of O&M costs) minus total capital investment costs. Costs and benefits are compounded/discounted by an interest rate of 10 percent.

[d] For the Left Bank only.

[e] The command area after the project.

Source: Aluwihare and Kikuchi (1991)

investments, are estimated and compared between new construction and rehabilitation/water management improvement for three systems (Table 1.9).

In the case of the Gal Oya system, the net present value of the new construction project in 1986 prices was Rs 1,459 million while that of the rehabilitation project was Rs 1,055 million. If the benefits of the new construction project are prorated, according to its command area share, to the Left Bank to which the rehabilitation project was confined, the net present value of the rehabilitation project was even larger than that of the new construction project. Similar results are obtained for the water management projects. We conclude that investments in rehabilitation and water management improvement are valuable economic opportunities in terms not only of the rates of return but also of the absolute size of the benefits to society.

IMPLICATIONS FOR POLICY AND RESEARCH IN IRRIGATION MANAGEMENT

Policy Implications

Future direction of the irrigation sector. The most important general implication of our study is that development of the irrigation sector in Sri Lanka has shifted from the construction of new irrigation systems to rehabilitation/modernization, coupled with an improvement in water management, of the existing systems. It is clear that, given the present state of irrigation development in the country and the present levels of technology in agriculture and construction engineering, little economic potential is left to be exploited by new irrigation construction. This is not to deny that there could still be some potential for developing new irrigation systems in some parts of the country, most likely small- to medium-sized. Generally speaking, however, the era of major irrigation construction in Sri Lanka is at an end.

Instead, now that the irrigated land base has been well-established, attention in the irrigation sector should be directed towards, and concentrated on, rehabilitation and modernization, and improvement in water management, including crop diversification, of the existing systems. The potential for increasing agricultural income through these means is high. In particular, water management improvement is unduly under-invested, leaving huge potentials to be exploited from now on. It is the uncontested, inexorable direction for the irrigation sector in Sri Lanka to go into the "management" stage, while getting out of the ingrained "construction bias" that has become built in over the last four decades.

The experience in the irrigation sector in Sri Lanka could be typical of many other countries in the Asian tropics where land is scarce. Being a small island country, the change in emphasis in the development of the sector has been as clear as if observations had been made in a laboratory. In larger countries, consisting of many regions with diverse development stages, it may be more difficult to identify such a change at the national aggregate level. However, having had a construction stage during the last few decades, in common with Sri Lanka, the irrigation sector in many of these countries should have reached a similar stage by the 1980s. Sri Lanka's experience illustrates that the management orientation is inevitable in the irrigation sector in Asia, and that the economic potentials in this direction are large.

Macro-economic context. Agricultural development is a necessity for the country's economic development. The major efforts of the government since independence have been directed towards the agricultural sector in general and the irrigation sector in particular. This direction has been correct: countries that have underfunded agriculture have paid a high price in terms of foregone development, and Sri Lanka seems to have avoided this trap. The development of the irrigation sector has been critical for the agricultural development in this country, and it continues to be so, though with a different emphasis. Keeping and upgrading the performance of the existing irrigation systems in the most efficient manner would be consistent with the overall national development policy, leading towards a higher level of economic performance of the entire economy.

With a well-established base for food production, not only the irrigation sector but also the economy as a whole needs to be diversified. As stated in any text book on development economics, an important role of agriculture in economic development is to supply resources, financial as well as human, to the rest of the economy. So far, in Sri Lanka, this role has been played by the tree plantation sector. As Table 1.10 indicates, the order of resources that the rice sector has been absorbing from the rest of the economy, the major part of which has been for irrigation development, is roughly comparable to the "agricultural surpluses" that the tree sector has been generating. The shift from the construction to the management stage in the irrigation sector will release the bulk of these resources to other sectors of the economy, in addition to foreign exchange savings/earnings that will be forthcoming if the sector is successful in crop diversification with import-substituting, and/or exportable, nonrice crops.[13]

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[13] The following rule of thumb calculation gives indicative orders of the resources to be released from the irrigation sector by the shift from the construction to the management phase. Assume: 1) the irrigated land area of the country remains at the present level of about 500,000 ha (major and minor irrigation); 2) this existing irrigated land-base requires rehabilitation or modernization every 20 years so that 25,000 ha need rehabilitation each year; 3) capital costs for rehabilitation/modernization are at the level needed for the Gal Oya rehabilitation project (about Rs 25,000/ha in 1986 prices; note that the "rehabilitation" needs for the water management projects in Kimbulwana and Pimburettawa were one-fifth of this level); and 4) O&M needs are Rs 740/ha at 1986 prices for the entire irrigated area (note that the actual government O&M expenditures are about Rs 300/ha for the major irrigation systems and that no expenditure was incurred by the government for the minor irrigation systems of about 180,000 ha). The annual investment needs are then estimated to be around Rs 995 million, which is less than 30 percent of the average annual total irrigation investments for the period from 1978 to 1988. At least 70 percent of the funds which have been invested in irrigation development could be released for other development purposes. If O&M costs were borne by the farmers, instead of using scarce government resources, this release rate would increase to more than 80 percent.

Table 1.10. Total net tax and levies from the tree plantation sector and total subsidies to the rice sector including irrigation investments, 1960-1982, in current prices.

	Total net tax and levies from tea, rubber and coconut (1)	Total producer and consumer subsidies to the rice sector[a] (2)	(2)/(1)
	------------Rs million	---------	
1960	386	322	0.83
1965	493	407	0.83
1970	499	652	1.31
1975	806	824	1.02
1980	4,428	1,179 [b]	0.27
1982	3,357	3,498 [b]	1.04

[a] Includes the public expenditures on irrigation

[b] Only the public expenditures on irrigation.

Source: Thorbeck and Svejnar (1987), and Aluwihare and Kikuchi (1990).

Government and donor responses to the change in emphasis. During the four decades since independence, the government, together with international donor agencies, has been responding fairly reasonably to the economic opportunities that have been provided by the irrigation sector through the development of the irrigation infrastructure. It is reasonable to expect that the government will respond to the new opportunities. In fact, though there has been a certain time lag, many steps have been taken in the new direction since the early 1980s, some of which are well-documented in the literature (e.g., IIMI 1986 and 1990b).

Notably, government efforts in the irrigation sector towards management orientation have borne fruit in the form of the Irrigation Management Policy Support Activity (IMPSA), launched in April 1990 with an 18-month project period. IMPSA, which is financed by USAID and assisted by the Irrigation Support Project for Asia and the Near East and IIMI, aims:

> to develop specific policy statements and suggest implementation strategies to expand on and fill the gaps in the broad policy framework on "participatory management in irrigation schemes" as outlined in the Cabinet Paper on this subject approved in late 1988. ..... IMPSA provides an opportunity for a fresh synthesis of experience and the refinement of policy to ensure the continued and timely transition to a new participatory management system (IMPSA 1990; 1).

In short, IMPSA is a policy formulation process in transition from the construction phase to the management phase, which represents a conscious government response to the changing momentum in the sector.

Guidelines for irrigation construction/rehabilitation projects. The cost-benefit analyses in this study were based on the performance of irrigation projects implemented in the past. This process of reviewing the investment performance revealed certain ranges for crucial parameters in determining performance. Referring to these ranges, a rough estimate can be made for the "reasonable" level of unit capital cost in order for new irrigation construction/rehabilitation projects to be economically viable.

Crucial parameters in determining investment performance are: 1) rice price, 2) rice yield, 3) cropping intensity, 4) the extent of crop diversification with nonrice crops which generate higher income than rice, and 5) the gestation period of a project (construction period in the case of new construction). It can be said, at least in the Sri Lankan context, that all other factors, such as agricultural input prices and project life span, are of minor importance in the benefit determination under normal circumstances. As illustrations, unit capital costs that make the B/C ratio equal to 2.0 under certain levels of performance in terms of the crucial parameters are presented in Tables 1.11 and 1.12 for new irrigation construction and major rehabilitation projects, respectively. The level of B/C ratio = 2.0 is chosen as the minimum level of rate of return for this kind of investment.[14]

It is indicated that unit capital cost should be, at the highest, about US$5,000 for new construction projects and US$2,500 for major rehabilitation projects, if these projects are to be economically viable. We have to remember that the majority of the past projects, while envisaging some performance level in the second category in these tables ("reasonable expectation"), ended up in the first category ("reality"). It requires considerable management and institutional efforts, after the project as well as during project implementation, to attain the target levels for the crucial parameters in this second category.

It should be noted that, although classified under "reasonable expectation," it is actually quite difficult to meet all the assumed levels for option II-5. For any project proposal with a capital cost of more than US$3,000 for new construction and US$1,500 for major rehabilitation, the assumptions need checking; there may well be unrealistic assumptions for some crucial parameters. Appraisal reports of capital intensive projects would make third category ("highly heroic") type assumptions as a last resort in order to raise the internal rate of return above a certain break-even level. Such a high level of performance has never been attained in Sri Lanka, though it may

[14] The Gal Oya rehabilitation project had a B/C ratio about this level and the level is much higher for some water management improvement projects. Any new projects should have a rate of return at this level or higher to be economically viable. At the order of cost and benefit in our examples with a discount rate of 10 percent per year, the B/C ratio of 2.0 roughly corresponds to an internal rate of return of 20 percent.

Table 1.11. Capital investments costs per hectare that make B/C ratio = 2.0 in 1990 prices: new irrigation construction.[1]

	Assumed parameters			Unit capital cost[2] Rs 1,000/ha(US$/ha)	
	Yield[3] mt/ha	Cropping intensity[4]	Crop diversification[5]	m=4	m=6
I. Reality[6]					
1.	4.0	1.3	0%	73 (1,900)	605 (1,500)
II. "Reasonable" expectation[7]					
2.	4.0	1.5	0%	85 (2,100)	70 (1,800)
3.	5.0	1.5	0%	106 (2,700)	87 (2,200)
4	6.0	1.5	0%	127 (3,200)	195 (2,700)
5.	4.0	1.5	30%	113 (2,800)	93 (2,300)
6.	5.0	1.5	30%	132 (3,300)	109 (2,700)
7.	6.0	1.5	30%	151 (3,800)	125 (3,100)
III. "Highly heroic" assumptions[8]					
8.	6.0	1.8	30%	191 (4,800)	158 (3,900)

[1] Basic assumptions: a) the entire command area to be created in new, not including any old cultivated areas; b) no opportunity cost for labor is used in the new system; c) the rice output is valued at Rs 5.20/kg (in paddy) which is the Colombo c.i.f. price linked with the World Bank projected rice price for the year 2000; and d) a gross value added ratio of rice production of 80 percent.

[2] Capital costs per hectare of the new command area which make B/C ratio = 2.0. Two different average gestation periods (m) of the project investments are assumed; four years and six years. The exchange rate assumed is US$1.0 = Rs40.00.

[3] Rice yield per ha to be realized after the project.

[4] The cropping intensity to be realized after the project.

[5] The percentage of the yala season crop area planted to high-value nonrice crops, the gross value added of which is assumed to be Rs 72,000/ha in 1990 prices.

[6] Assumes the average performance level attained by the irrigation new construction projects in the past.

[7] Assumes performance levels that could be attained with reasonable efforts in management aspects to ensure better O&M after the project than in the past.

[8] The performance levels which irrigation engineers-designers may wish to have in their desk work, but which have never been achieved in reality under the Sri Lankan setting.

Table 1.12. Capital investments costs per hectare that make B/C ratio = 2.0 in 1990 prices: major irrigation rehabilitation.[1]

	Assumed parameters			Unit capital cost[2] Rs 1,000/ha(US$/ha)	
	Yield[3] mt/ha	Cropping intensity[4]	Crop diversification[5]	m=3	m=5
I. Reality					
1.	4.0	+0.3	0%	25 (600)	21 (500)
II. "Reasonable" expectation[6]					
2.	4.0	+0.5	0%	36 (900)	29 (700)
3.	5.0	+0.5	0%	44 (1,100)	37 (900)
4.	6.0	+0.5	0%	53 (1,300)	44 (1,100)
5.	4.0	+0.5	30%	62 (1,600)	51 (1,300)
6.	5.0	+0.5	30%	69 (1,700)	57 (1,400)
7.	6.0	+0.5	30%	76 (1,900)	62 (1,600)
III. "Highly heroic" assumptions[7]					
8.	6.0	+0.7	30%	101 (2,500)	83 (2,100)

1 Basic assumptions: a) two sources of benefits from rehabilitation, i) increase in the cropping intensity (including an increase in the command area after the project), and ii) 10 percent increase in the system's average rice yield due to the yield-gap reduction between the head- and tail-end sections resulted from better water management; b) no opportunity cost for labor is additionally required for agricultural production; c) the rice output is valued at Rs.5.20/kg which is the Colombo c.i.f. price linked with the World Bank projected rice price for the year 2000; and d) the gross value added ratio of rice production of 80 percent for newly added planted area (for the yield increase due to yield gap reduction, no additional current inputs are assumed to be necessary)

2 Capital costs per hectare of the benefited area which make B/C ratio = 2.0. Two different average gestation periods (m) of the project investments, three years and five years, are assumed.

3 Rice yield per ha to be realized after the project (assumed to be the same as the yield attained in the head-end section before the project).

4 The increase in the cropping intensity due to the project. Assumes that the intensity before the project is 1.3 (the average for the major irrigation schemes at present).

5 The percentage of the yala season crop area planted to high-value nonrice crops, the gross value added of which is assumed to be Rs.72,000/ha in 1990 prices.

6 Assumes performance levels that could be attained with reasonable efforts in management aspects to ensure better O&M after the project than in the past.

7 The performance levels which irrigation engineers-designers may wish to have in their desk work, but which have never been achieved in reality under the Sri Lankan setting.

become feasible if irrigation management research can successfully identify how to attain such a high performance.[15]

Research Implications

The irrigation sector has reached the management stage. However, there are many unknowns in pursuing this new direction. The economic potentials of new opportunities are large and realizable, as exemplified by the "success" cases of major rehabilitation and smaller water management improvement projects studied in our research, but necessary and sufficient conditions for realizing the potentials are not fully known. In the case of Kimbulwana, a successful water management improvement project, the Technical Assistant (TA) attached to the system played a key role in the project; without him there might have been no success. The question then arises as to why those in other systems failed. Even for this project, certain criticisms exist (Weeramunda 1985). Athukorala and Athukorala (1990) raise the same sustainability question for the Pimburettawa case. What are the decisive factors that made certain projects successful and certain others failures? How can a successful water management project be sustained? We have hypotheses but no systematic answers to these fundamental questions, and the replicability of these success cases is not assured without the answers. More research is definitely needed in this field, the profitability of which is firmly ensured by the huge economic potentials of the object itself.

Complementarity between physical and institutional improvements. Our study on rehabilitation/water management improvement projects found particular complementarity between the physical infrastructure and institutional improvements; for all the success cases, these two went hand in hand. It is clear that physical improvement alone cannot solve the problem of irrigation management and that institutional/organizational aspects are critical. The kinds of physical improvements that complement institutional improvements, and the conditions under which these two components best interact for cumulative improvements in system performance, are important areas of water management research suggested by this study.

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[15] The levels of unit capital cost referred to here should not be taken to mean that one can spend up to those levels in construction or rehabilitation projects. Every effort must be made to attain the best investment performance under the specific conditions and realities that each project faces. For instance, in the case of rehabilitation, a unit capital cost of US$1,500 at 1990 prices is referred to as a "reasonable" level. This does not mean that every rehabilitation project should aim at this level of unit capital cost. Given a certain level of performance, the unit cost of a project should always be minimized. In the case of the Irrigation System Management Project (an on-going major rehabilitation project which pursues cost-effective methods of system rehabilitation and modernization under "Essential Structural Improvement" "Pragmatic Rehabilitation" with a heavy emphasis on farmer organizations), the level of unit capital cost envisaged is 60-70 percent of the Gal Oya rehabilitation project, or about US$400-US$500/ha at 1990 prices. As we suggest, an important area of irrigation management research is to find the best balance/interactions between physical and institutional improvements in pursuit of better performance with the lowest cost combination.

Where does the potential lie? In conducting cost-benefit analyses for rehabilitation and water management projects, there are difficulties in identifying the benefits, since the sources of these benefits are numerous and often elusive. In addition to the two direct benefits (an increase in the cropping intensity and reduction in the yield gap between the head end and tail end due to better water management), which are taken into account in our cost-benefit analyses, there could be indirect ones. For example, well-rehabilitated and better-managed systems may lower O&M costs. Well-organized water users' groups, which are usually the central component of water management improvement projects, would be instrumental in making maintenance more effective, reducing damages to the physical structures, improving water distribution, reducing wastage of water, and achieving a higher cropping intensity and better crisis management in times of drought, etc. To the extent that they are identifiable, these indirect benefits should be included in our analysis, and research efforts should be made to identify the impacts of water management improvement upon these sources of benefit.

However, our data clearly show that the two direct sources of benefits are by far the major ones. It is particularly the increase in the cropping intensity that determines the level of the rate of return on investments in these projects. In the cases of the Gal Oya rehabilitation project and Kimbulwana water management project, 75 percent of the total benefits came from the increase in the cropping intensity and the remaining 25 percent from the reduction in the yield gap. In the case of Pimburettawa, the share was 100 percent. Among the indirect sources, we have some data for possible cost reduction in O&M due to better management. The level of O&M cost assumed in our analysis is Rs 740/ha in 1986 prices, whereas the actual government expenditure for this has been less than Rs 300/ha. Even if this "full" cost (Rs 740) is borne by the farmers so that the government can save scarce resources,[16] the resulting cost reduction is less than 40 percent of the benefit due to the reduction in the yield gap in the two cases above.

All this implies that the largest economic potential in water management improvement lies in the possibility of increasing the cropping intensity, followed by reduction in the yield gap through more equitable water distribution. If the potentials are to be realized effectively, efforts in water management research should be strategically directed to areas where the results of the research bring about an increase in the cropping intensity and more equitable water distribution to reduce the yield gap in irrigation systems.[17] Indicators of system performance should be related in some way with these two parameters. As far as economic performance is concerned, indicators that are unrelated to these parameters would be meaningless.

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[16] Our study in the Kimbulwana system indicates that the nonlabor O&M expenditures of high opportunity cost in this well-maintained system, through well-organized farmers' groups, are almost negligible (IIMI 1989).

[17] Crop diversification with high-value nonrice crops, if promoted successfully, could be another source of significant benefits. Note also that in this paper we do not deal with the issue of "institutional change" (in the sense of the IIMI Strategy), which would have a potential benefit.

How big is big? The potential or challenge ahead. We conclude that irrigation management improvement has a big economic potential. The size of this potential depends critically on how far system performance can be improved in terms of the two parameters discussed above — the cropping intensity and the yield gap reduction.

Figure 6 shows annual changes in the cropping intensity (rice harvested area base) of the major irrigation systems in the dry zone by season for 1960-87. In the last three decades, the cropping intensity has never reached 0.9 in the maha season or 0.7 in the yala season, the averages for the period being 0.79 and 0.51, respectively. How far can it be raised on a secular basis through water management improvement? Factors affecting it being many, it is difficult to predict a possible level. However, the following regression equations may give indicative figures:

$$CI_{maha} = \underset{(0.716)}{0.099} + \underset{(4.736)}{1.306}\, Rain_{maha} - \underset{(-4.514)}{0.612}\, (Rain_{maha})^2 + \underset{(4.100)}{0.083}\, D$$

$$R^2\ (adj.) = 0.534$$

$$CI_{yala} = \underset{(7.329)}{0.969} - \underset{(-6.985)}{0.243}(Rain_{maha})^{-1} + \underset{(1.566)}{0.219} Rain_{yala} + \underset{(2.185}{0.072}\, D - \underset{(-1.696)}{0.003}\, t$$

$$R^2\ (adj.) = 0.710$$

where; CI = the cropping intensity, Rain = total rainfall during the season in meters (in the case of the yala function, $Rain_{maha}$ = total rainfall during the maha preceding the yala season), D = dummy variable for the period after the Mahaweli water diversion to the dry zone (D=1 for 1978-87)[18], t = time trend (60, 61, ..., 87), and the figures in parentheses are t-ratios. The effects of rain on the cropping intensity could be interpreted as follows: in the maha season, rain during the season affects the cropping intensity positively, but too much rain reduces it; in the yala season, rain in the previous maha season, which determines the water storage of the tank at the beginning of the season, has a decisive impact on the cropping intensity with a certain maximum ceiling for it.

The maha function gives a maximum cropping intensity of around 90 percent for the period D=1, and the yala function yields the cropping intensity ceiling of around 80 percent for the late-1980s with average yala season rainfall. Thus, the past cropping intensity performance reveals the yearly cropping intensity of 1.7 on dry-zone major irrigation systems as attainable under the best conditions with rice as the crop grown. If good management could be a substitute for these best conditions, this would be the level of the cropping intensity attainable with rice. This is an increase over the present level by about 0.4. It may not be impossible to increase it further to a level of 2.0, an increase of 0.6 to 0.7 over the present level, if nonrice crops requiring less water can

[18] Note that the Mahaweli dummy has a positive significant coefficient for both the maha and yala functions.

be successfully introduced in the rice-based systems.[19] An increase of 0.6 for the existing irrigation systems in the dry zone (from 1.3 to 1.9 for major irrigation and from 0.8 to 1.4 for minor irrigation) is equivalent to constructing new irrigation systems, with the present level of the cropping intensity, of a total command area of 200,000 ha, which is more than 65 percent of the present total command area of the dry-zone major irrigation systems.

As for the yield gap reduction, available data indicate that an increase of some 10 percent in the average unit rice yield for the system as a whole can be attained by this reduction due to water management improvements. If this is applicable to all dry-zone irrigation systems with an average rice yield of 4 mt/ha for major irrigation and 3 mt/ha for minor irrigation, together with the increase in the cropping intensity of 0.6, a rule of thumb calculation suggests that the expected income increase in real terms would amount to about 60 percent of the income presently generated in these systems, assuming that rice, and/or nonrice crops which give an income as high as rice, are grown. To the extent that nonrice crops giving an income higher than rice can be planted, an expected rate of income increase could be even higher than this level. It is no doubt hard to attain these targets, but this is the order of economic potential that irrigation management, and research therein, is challenged to realize in Sri Lanka.

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[19] The Kimbulwana case gives the best example in this respect; by implementing a strict water rotation system, the cropping intensity was increased from less than 1.3 to nearly 2.0 on an average basis, with a third crop in some years (Gunadasa 1989).

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