Irrigation Investment Trends in Sri Lanka: New Construction and Beyond

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P.B. Aluwihare
and
Masao Kikuchi

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE

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Please direct inquiries and comments to:

Sri Lanka Field Operations
International Irrigation Management Institute
107, Havelock Road
Colombo
Sri Lanka

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Contents

List of Figures

List of Tables

Foreword

THE PRIMARY MISSION of the International Irrigation Management Institute is to strengthen national efforts to improve and sustain the performance of existing irrigation systems in the developing world. Developing countries have made massive investments in irrigation construction during the past few decades. But it has been found that most irrigation systems are performing far below their potential. Most of the benefits of irrigation construction have stemmed not from efficient and productively managed systems but from the magnitude of the investment.

As the demand for irrigation continues to increase, we, as many others working in this sector, have recognized the need to improve the performance of irrigation systems and the importance of improved management to attain this objective. However, there has been a lack of clear evidence to prove that the economic potentials of investment in rehabilitation or modernization and improvement of management of existing irrigation systems are high. While many studies have been carried out on the economic performance of new irrigation construction projects, the economic viability of water management improvement programs has been rarely demonstrated in a way comparable to the other studies.

Mr. P. B. Aluwihare and Dr. Masao Kikuchi have tried to fill this gap through this study of the irrigation sector in Sri Lanka, in which they have made painstaking efforts to collect data and adopt a succinct analytical framework. I commend the authors for the important contribution they have made to our understanding of the economic potentials of irrigation investments and the profound need for more research in this field of irrigation management. I believe the study is timely for Sri Lanka where new policy formulation in the irrigation sector is going on, as well as supportive of the irrigation sector in the developing world in general to strengthen itself toward higher performance in the "management stage."

IIMI extends its gratitude to the Japan International Cooperation Agency for the support that has made possible this research project and the dissemination of its results and lessons in the form of this publication.

Roberto L. Lenton
Director General
International Irrigation Management Institute
April 1991

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The study was fostered by the International Irrigation Management Institute (IIMI), under the directorship of Dr. Roberto L. Lenton, in a mission-oriented atmosphere that made us conscious all the time of the need to direct our research to solving real problems that the irrigation sector in developing countries faces.

We are most indebted to Douglas J. Merrey, the Head of IIMI's Sri Lanka Field Operations for continuous encouragement and support without which this study would not have been undertaken and completed. Our special appreciation also goes to C. R. Panabokke who has, throughout this research, given us many helpful suggestions on various aspects of the issues related to irrigated agriculture and irrigation systems in Sri Lanka.

We have also benefited from comments and suggestions, at various stages of research, from J. Bandaragoda, A. Ekanayake, Y. Hayami, S. M. Miranda, H. Murray-Rust, K. Otsuka, F. E. Schulze, C. G. Thornstrom, H. Tsutsui, Y. Sano, R. T. Shand, A. Valera, and A. Widanapathirana. E. Vander Velde played a role as the Institute referee for this publication. His perusal of the manuscript, together with intensive editing by Nimal A. Fernando and Kingsley Kurukulasuriya of the Information Office, made this report more presentable and easier to read and understand.

We would also like to express our appreciation to the many officials of the Central Bank of Sri Lanka and of the irrigation related agencies of the Government of Sri Lanka for their enduring help in data collection. The strength of this study depends heavily on the quality of the records that they kindly looked for in piles of old documents. We alone are responsible for any errors and omissions in this publication.

P. B. Aluwihare

Masao Kikuchi

Executive Summary

IRRIGATION HAS BEEN the most important strategic factor in agricultural development in Sri Lanka and elsewhere in monsoonal Asia. Major government efforts for economic development in general and agricultural development in particular have been directed toward the development of the irrigation infrastructure. Now that such efforts, coupled with the diffusion of seed-fertilizer technology, have brought Sri Lanka to a state of near self-sufficiency in rice, the irrigation sector of the country is at a turning point. In which direction should the irrigation sector now proceed?

This paper tries to answer this question through the identification of changes in the growth momentum as revealed by the changing investment portfolio of the irrigation sector. To attain this goal, time-series data on irrigation investments by category are compiled for the four decades since independence, and cost-benefit analyses are conducted for three different types of irrigation investments: new imgation construction, major rehabilitation, and water management improvement projects.

Until the early 1980s, new irrigation construction investments had been by far the most important investment opportunity in the country, accounting for more than 90 percent of the total irrigation investment and 20 to 40 percent of the total public investment in the country; the irrigation sector was fully in its "construction stage." The decisions to promote this direction in investment made by the government and by international donor agencies, particularly in the past two decades, were fairly right; the economic potential for new irrigation development was large and it was preserved by the successive developments in rice seed-fertilizer technology.

However, as development proceeded, new construction shifted from small projects like the renovation of ancient abandoned tank systems to more difficult undertakings including major water resources development, resulting in a sharply increasing trend of the real construction cost per hectare of newly irrigated land. As a result of this trend and the long-term decreasing trend of the price of rice in the world market, new irrigation construction & no longer an economically viable investment opportunity.

Given the increasing trend of the real unit cost of construction, no major irrigation construction project can be economically justified even under extremely favorable conditions for new construction such as: a higher price of rice similar to the level experienced during the food crisis period in the 1970s, which is over 300 percent higher than that in the mid-1980s; or successful diversification of crops in rice-based irrigation systems with 100 percent of the *yala* (second) season crop area planted to high-value nonrice crops, resulting in incomes 300 to 700 percent higher than that for rice. The era of "major" irrigation construction in Sri Lanka is at an end.

Since the mid-1970s, a new investment trend has emerged in the irrigation Sector. Irrigation rehabilitation/modernization projects have appeared and their share of the total irrigation investment has been rapidly increasing since then. In addition to these rehabilitation projects, many others which aimed at improving water management in the existing irrigation systems have been initiated since the late 1970s. It is hypothesized that the diminishing returns from massive investments in new irrigation construction in the past have made the profitability of investments in improving and enhancing the quality of existing systems higher relative to that of new construction.

It is found that the rates of return on these new types of irrigation investment are indeed quite high. A major rehabilitation project completed in the mid-1980s showed an internal rate of return of 24 percent as compared to the rate of return on new construction of less than 10 percent in the 1980s. In the case of successful water management improvement projects, the internal rate of return is as high as 70 to 80 percent. Even in terms of the absolute value of the benefits to be generated, these rehabilitation/water management projects can compete with new construction projects.

All this clearly suggests that the investment portfolio of the irrigation sector has completely changed. Now that the irrigated land base has been well-established, the only economically feasible and viable option left for the irrigation sector in Sri Lanka is to go into a new stage: that is, the "management stage." Agricultural development is a necessity for the country's economic development. The development of the irrigation sector has been critical for agricultural development, and it continues to be so, with a different emphasis. Maintaining and upgrading the performance of existing irrigation systems in the most efficient manner would be consistent with the overall national development policy of heading toward a higher level of economic performance of the entire economy.

The experience in the irrigation sector in Sri Lanka could be typical of many other countries in the Asian tropics where land is the most scarce resource. Being a small island country, the change in the development momentum of the sector has been as clear as if observations were made in a laboratory. In other large countries consisting of many regions with diverse development stages, it may be more difficult to identify changes in the development momentum of the irrigation sector at the national aggregate level. However, as these countries also had a construction stage during the last few decades the irrigation sector in many of them should have reached a stage similar to that in Sri Lanka by the 1980s. The Sri Lankan experience revealed in this paper illustrates that the "management" orientation is inevitable in the irrigation sector in Asia and that the economic rewards for pursuing this direction are large.

CHAPTER 1

Introduction

IN SRI LANKA, as elsewhere in monsoonal Asia, irrigation has been the mainstay of agricultural development (Barker and Herdt 1985). Since independence, the major government efforts for economic development in general and agricultural development in particular have been directed at the development of the irrigation sector (Thorbecke and Svejnar 1987). Massive investments in irrigation coupled with the introduction of seed-fertilizer technology had brought Sri Lanka, which used to be a major rice-importing country, to a state of near self-sufficiency in rice by the mid-1980s.

Underlying this process has been the rationale that developing the irrigation infrastructure is the most basic and important strategy for increasing food production in Sri Lanka where more than two thirds of the country's total land area, which lies in the dry zone, is not a productive resource without the provision of irrigation water. Therefore. in the past, investments in irrigation have been concentrated on constructing new irrigation systems or restoring ancient tank systems in the dry zone that once supported the old Sinhalese. civilization.

Having reached a stage at which self-sufficiency in rice is within reach, a decision has to be made on whether the irrigation sector should continue in the present course or change direction: continue water resources development to deepen the existing irrigated land-base, or take other measures. There seems to have been a quiet revolution in the development of the irrigation sector among the policymakers in the government and in international donor agencies: the pendulum has swung from new irrigation system construction to irrigation system rehabilitation, and further, to irrigation system management improvement (e.g., Levine et al. 1982 and Abeywickrema 1983). Irrigation is still the mainstay of agricultural development, but with a different emphasis compared to the earlier stage.

What is the economic basis for this shift of emphasis? How far should the change in duection undergone by the irrigation sector in Sri Lanka be magnified? The answers to these questions appear to be obvious and the actions that have actually been taken in the sector are clear.

It is surprising, however, that in spite of the critical importance of irrigation investments in the development of the economy and the issue of investment alternatives in the irrigation sector in formulating or reformulating the development policies of the country, few attempts have been made to document the investments made in the past in an integrated manner and to demonstrate changing configurations of economic profitability among investment alternatives in the sector.[1]

The purpose of this paper is to fill this gap by compiling aggregate time-series data on different types of irrigation investments in Sri Lanka during the last four decades and by analyzing changes in the momentum of the process of irrigation development. In the following chapter, the process of rapid increase in rice production is documented and the role of irrigation development in this process is identified. In the third chapter, the past trends in irrigation investments will be looked into by type of investment and testable hypotheses as to the determinants of the investment trends will be presented. In chapters 4 and 5, changes in the momentum of irrigation sector development will be analyzed in terms of changes in the economic profitability of different types of irrigation investments. The last chapter will be devoted to discussing the implications of the findings of this study for the future direction of the irrigation sector.

[1] Shand et al. (1990), who try to give a future perspective for the irrigation sector in Sri Lanka, review the past trends in irrigation investments and their economic performance. In spite of many useful insights on many issues related lo the irrigation sector, their review of the past irrigation investments is, unfortunately. too brief, and lacks critical evaluation of the economic performance of these investments. The evidence they present in support of theu statement, 'bur review of past investments in irrigation, inside and outside the Mahaweli, shows that, with a few exceptions project economic internal rates of return are in excess of 10 percent, whether in new schemes or in rehabiliations" (ibid., xv) is mostly drawn from post-project evaluation reports without any critical assessment of their own. As pointed out elsewhere in this research paper. these reports often present evaluations based on assumptions which do not reflect the reality after completion of the projects. As a result, their conclusions as to the future direction of the irrigation sector in Sri Lanka are quite different from the one suggested in this paper, as far as investment opportunities are concerned. Judgement as to which is the more feasible direction is left to the reader.

CHAPTER 2

Increase in Rice Production

THE DRAMATIC INCREASE in rice. production in Sri Lanka during the last four decades is best illustrated by the changes in the rate of self-sufficiency in rice during this period (Table 1). Just after independence in 1948, the country produced only 40 percent of the total rice requirement and the remaining 60 percent was imported. By 1985, self-sufficiency in rice reached a level of more than 90 percent. Rice imports, which increased to over 0.7 million metric tons (mt) of rough rice in the mid-1960s, decreased to about 20 percent of the peak level by the mid-1980s. Between 1951 and 1985, domestic rice production increased almost sixfold at an annual compound growth rate as high as 5.3 percent. The total population of the country increased from the 7.6 million in 1951 to 15.8 million in 1985 at an annual growth rate of 2.2 percent; per capita rice production increased rapidly during this period at 3.1 percent per year. Sri Lanka has thus attained near self-sufficiency in rice within 40 years of independence, recording a remarkably high rate of increase in domestic rice production.

Table 1. 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.

Sources: See Appendix I. Table A1-1.

How did the country achieve such a rapid increase in rice production? The answer to this question and an explanation of the process of irrigation development in the country are almost identical.

The increase in rice production can be attributed to the increase in area planted to rice and the increase in the rice yield per hectare (ha) (Table 2). The 5.0 percent annual growth rate of total rice production for the period 1952-85 was brought about by a 2 percent increase in the area planted and a 3 percent increase in the yield per hectare, with percentage shares of 40 percent and 60 percent, respectively, in the total production growth. While the growth rate of area planted declined continuously from 3.1 percent in the 1950s to 0.4 percent in the early 1980s, that of yield per hectare declined from 4.1 percent in the 1950s to 2.2 percent in the 1970s. and again increased to 3.1 percent in the early 1980s. For all the subperiods shown in Table 2, the contribution of yield increase to the total production is more than that of the area increase. However, it should be noted that except for the last subperiod, the difference between the levels of contribution is about 10 percent 45 percent for the area increase and 55 percent for the yield increase, on the average. It is in the last subperiod that the contribution of yield increase. to the total production growth exceeds 90 percent.

Table 2. Annual compound growth rates of rice production, area planted, and yield per hectare, Sri Lanka.[a]

	Annual compound growth rate (%)		
	Rice production	Area planted	Yield per ha
1952-1960	7.2 (100)	3.1 (43)	4.1 (57)
1960-1970	5.0 (100)	2.3 (46)	2.7 (54)
1970-1980	3.9 (100)	1.7 (44)	2.2 (56)
1980-1985	3.5 (100)	0.4 (11)	3.1 (89)
1952-1985	5.0 (100)	2.0 (40)	3.0 (60)

[a] Growth rates are computed between the five-year avenges centering on the years shown. The percentage share of the rice production growth rate ia shown within parentheses.

Sources: See Appendix I, Tables A1-1 and A1-2

Concerning the process of agricultural development in east and southeast Asian countries, Kikuchi and Hayami (1978) postulate that the growth momentum shifts from the traditional pattern based on an extension of cultivation frontiers to the pattern based on land productivity growth or "internal land augmentation" as population and the agricultural labor force increase relative to a limited land resource, and irrigation development plays a key role in land productivity increases. Such a postulate is basically applicable to Sri Lanka as well, but in a slightly modified version. Unique features of rice fanning in Sri Lanka in terms of geographical as well as historical conditions make such a qualification necessary.

Sri Lanka is divided into two significantly different climatic zones: the wet zone and the dry zone (Figure 1). Although the island records an ancient civilization based on irrigated lowland agriculture which began several centuries before the Christian era, the dry zone had been abandoned from around the 13th century until the late 19th century during which period the population was concentrated in the wet zone (see for instance Farmer 1957. pp. 14-17). Before colonization of the dry zone recommenced around the turn of this century, the zone was no-man's-land except for some urban spots such as Jaffna. Even several decades after this, "the Dry Zone today, in spite of this new colonization, remains that rare phenomenon in Southern Asia, a region which makes up two-thirds of a country but is sparsely peopled" (Farmer 1957, p. 18).

In contrast, the wet zone, with a limited land area, had been far more densely populated. This zone was congested, with the peasant and plantation sectors forming a typical dual economy in Boeke's sense (Boeke 1953). The growing population pressure in this zone, as demonstrated by Farmer (1957, pp. 78-98). induced the dry-zone colonization in the early part of this century.

A distinct feature of the dry zone as an agricultural region is that land is not productive unless it is provided with water, the most scarce resource in the region. Without irrigation water, the only possible cultivation in the dry zone is very extensive chena, i.e., slash-and-bum shifting cultivation. In the wet zone, a sufficient amount of rainfall and its relatively even distribution between seasons make rain-fed rice production quite possible.[2] So, dry-zone colonization has taken place under projects in which land settlement is always coupled with irrigation development

The development of rice production in Sri Lanka has been brought about mainly through the development of the irrigation infrastructure in the dry zone. When viewed in a broader framework and taking chena cultivation into account, this process of dry-zone irrigation development is precisely a process of internal land augmentation.' When the rice farming sector alone is looked into, however, the impact of irrigation development is observed in the expansion of the area planted as well as in the increase in land productivity. As seen in Table 2, the expansion of area planted, though at declining growth rates, and the increase in yield per hectare have contributed to the growth of rice production.

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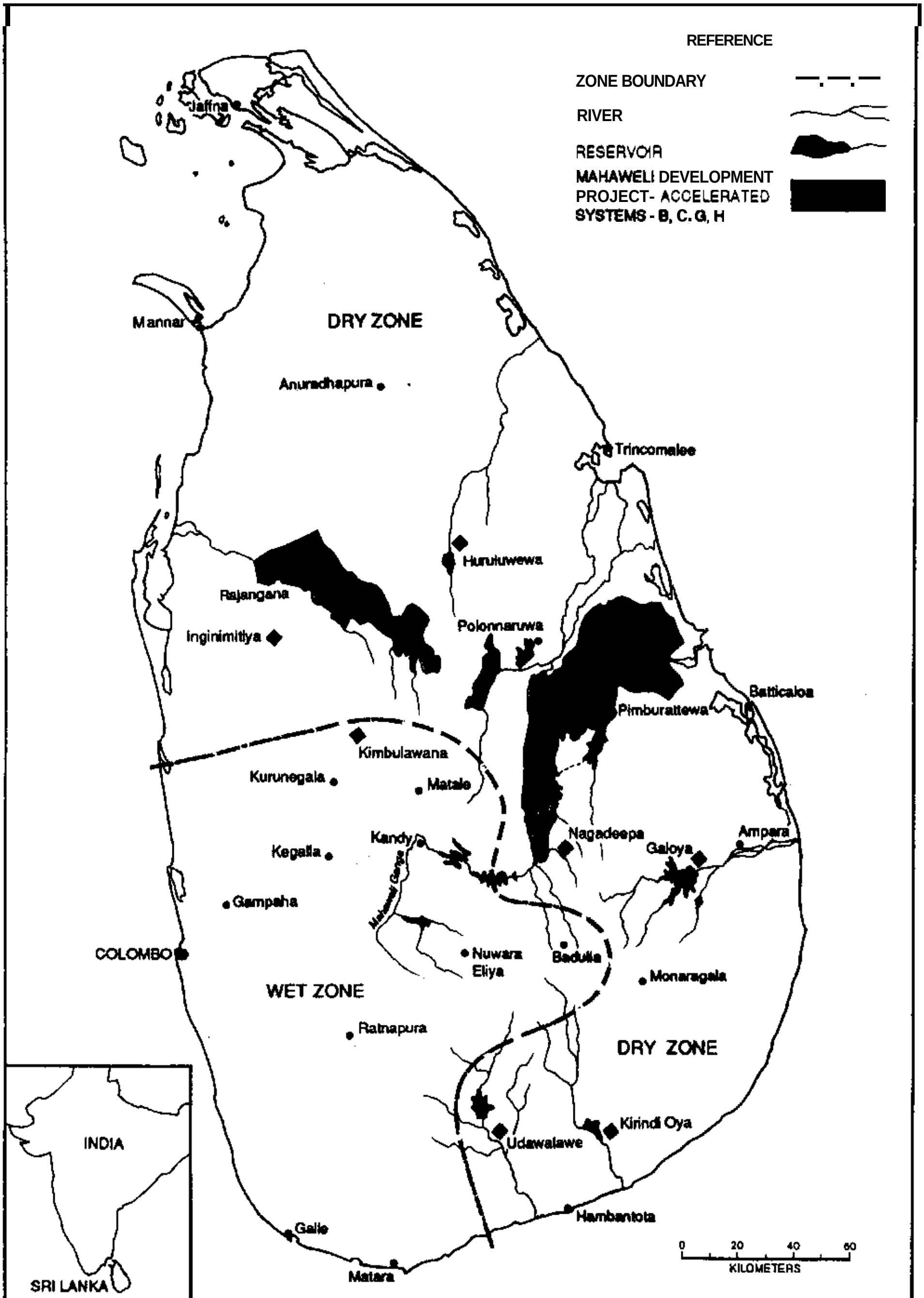
[2] Typically. rice fields in the wet zone an found in valley bottoms, watered by natural streams and by runoff and seepage from the slopes above. Under such an environment, irrigation of rice is a matter of tapping local perennial streams by simple means. Most of the rice fields in the wet zone are classified as "rain-fed," but many of them an provided with some means of irrigation.

[3] Except for a few sporadic monographs such as that by Leach (1961). information (the extent, regeneration, and changes over time) on chena cultivation in the dry zone is meager. The appraisal report of an irrigation construction project in the southeastern dry zone gives a cropping intensity of 20 percent for chena cultivation in the project area (ADB 1986, p. 73), but its changes over time are not known. Personal communications that one of the authors had with ex-chena farmers in Anuradhapura suggest that there has been a significant shortening of the fallow interval in chena cultivation over the past few decades.

Figure 1. The wet and dry zones, and major irrigation projects in Sri Lanka.



The role of irrigation development in increasing rice production can be seen more clearly if the national level annual data are disaggregated into zones and seasons. Table 3 shows where the area planted to rice has increased. Except for the areas 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 for all the periods under study. However, the most significant increases have occurred in the major irrigation systems in the dry zone. The annual growth rates of the areas planted to rice under major irrigation systems for the *maha* (wet) and *yala* (dry) seasons were as high as 4.4 percent and 3.4 percent, respectively, from 1952 to 1985. As a result, the share of the area planted to rice in the dry-zone major irrigation systems has increased from 20 percent in 1952 to 40 percent in 1985.

Table 3. Total area planted to rice by zone and by type of irrigation, for selected years, Sri Lanka.

	Total	Dry zone						Wet zone
		Major irrigation			Minor irri-gation	Rain-fed	Total	
		Maha	Yala	Total				
	1,000 ha							
1952	451.1 (100)	53.6 (12)	48.3 (11)	101.9 (23)	66.6 (15)	82.2 (18)	250.7 (56)	200.4 (44)
1960	577.2 (100)	90.1 (16)	66.5 (11)	156.6 (27)	103.3 (18)	109.4 (19)	369.3 (64)	207.9 (36)
1970	721.4 (100)	133.8 (18)	86.5 (12)	220.3 (30)	126.1 (18)	135.0 (19)	481.5 (67)	239.9 (33)
1980	855.1 (100)	199.3 (23)	113.1 (13)	312.4 (36)	139.8 (16)	150.3 (18)	602.7 (70)	252.4 (30)
1985	873.6 (100)	222.4 (25)	147.9 (17)	370.3 (42)	130.3 (15)	133.3 (15)	633.9 (73)	239.7 (27)
Growth rate (%):								
1952-60	3.1	6.7	4.1	5.5	5.6	3.6	5.0	0.5
1960-70	2.2	4.0	2.7	3.5	2.0	2.1	2.1	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

Note: Five-year averages centering on the years shown. Figures within parentheses are percentages.

Sources: See Appendix I, Table A1-4.

Data on the total rice land (asweddumized land[4]) area by type of irrigation in the country, the irrigation ratio and the cropping intensity for the years 1950-1985 are summarized in Table 4. The total irrigated rice land area had increased from 253,000 ha in 1950 to nearly half a million ha in 1985; 90 percent of this increase was due to the increase in the irrigated land area under the major irrigation systems which are almost exclusively situated in the dry zone. The land area under major irrigation systems in the wet zone is only about 5 percent of the total land area under major irrigation. As a result, the share of the irrigated area (either in the total area of irrigated rice land or in the total area of rice land) under major irrigation systems has nearly doubled during the last three decades and a half. This rapid development of major irrigation systems in the dry zone was the main factor which has brought about the rapid increases in the area planted to rice during the maha and yala seasons.

Table 4. 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					
	Major irri-gation (i)	Minor irri-gation (ii)	Lift irri-gation (iii)	Total (iv)	(v)	(vi)	i/iv %	i/vi %	iv/vi %	Total %	Major irri-gation %
1950	90	163	-	253	157	410	36	22	62	107[d]	116[d]
1955	119	168	-	287	162	449	41	27	64	108	112
1960	136	171	-	307	171	478	44	28	64	120	126
1965	161	174	0	335	184	519	48	31	65	118	130
1970	193	187	2	382	201	583	51	33	66	124	127
1975	232	182	3	417	215	632	56	37	66	119	110
1980	272	184	4	460	221	681	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 far 1950-53.

Sources: See Appendix I. Table A1-3

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[4] The land which is ridged. bunded. and prepared for the cultivation of rice; in short, rice fields.

Equally important in increasing rice production were the conditions created by irrigation development for the introduction of new seed-fertilizer technology which was crucial to increasing the rice yield per unit of land area planted. As shown in Table 5, the fertilizer use per hectare of rice planted began to rise in the late 1950s as the Old Improved Varieties were being introduced by the farmers. By the mid-1960s just before the advent of New Improved Varieties, the area planted to the Old Improved Varieties had reached 50 percent of the total. and, by the mid-1980s. almost all the rice land area had been planted with New Improved Varieties.[5] Parallel with these changes, the fertilizer intensity increased tremendously, reaching a level of more than 100 kg/ha in the mid-1980s.

Table 5. Fertilizer input for rice production per hectare, irrigation ratw, 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.

Sources: See Appendix I, Tables A1-3, A1-4, and A1-5.

[5] Old Improved Varieties (OIV), also called the H series. were the results of the Rice Hybridization Programme launched in 1952. The common characteristic of these varieties are higher yield potential, higher fertilizer responsiveness. and tall plants. New Improved Varieties (NIV), also called the BG-series, are those which were bred primarily to overcome the easy-to-lodge characteristic of OIV and are therefore dwarf or semi-dwarf varieties. It should be noted *that* these improved varieties were made available through the research efforts of the Sri Lankan agricultural research institutes themselves; the first OIV, H-4, was released in 1957, and the first NIV, BG 11-11, in 1968. For details, see Senadhira et al. (1980).

One notable aspect of the "seed-fertilizer revolution" in Sri Lanka is that it began much earlier than in other countries of the Asian tropics. The first Old Improved Variety was introduced in Sri Lanka in 1957, more than ten years ahead of the advent of IR 8, the forerunner of the revolution in other countries. This could be explained partly by the fact that Sri Lanka, as compared to other countries, was endowed with a better irrigation infrastructure at independence. In 1950, the irrigation ratio was 62 percent in terms of cultivated rice fields (rice land area) (Table 4) and 48 percent in terms of the area planted to rice (Table 5).

On the one hand, a favorable irrigation infrastructure would have given a stronger incentive for national agricultural research institutions to develop improved rice varieties and make it possible for the farmers to adopt seed-fertilizer technology ahead of those in other developing Asian countries, and on the other, the successful development of seed-fertilizer technology, by increasing the pay-off of the investment in irrigation, would have provided a higher incentive for the government to further develop the irrigation infrastructure. Such dynamic interaction between irrigation infrastructure and seed-fertilizer technology should have been behind the rapid irrigation development in the dry zone resulting in further development of the country's irrigation infrastructure, and thereby, intensifying the interactive process further.

Since independence, irrigation development has played a pivotal role in increasing Sri Lanka's rice production by increasing the area planted and land productivity. This has been a Sri Lanka-specific process of agricultural development in which the economy counteracted a growing population pressure on a limited land resource by exploiting an even more scarce resource, water. However, it should be noted that the growth rate of the land area planted to rice has continuously declined in the last four decades and that the contribution of yield increase to the growth in rice production has exceeded 90 percent in the 1980s. All this may indicate that the past development pattern of the peasant agriculture sector in Sri Lanka, which has been based primarily on dry-zone colonization, has now reached a turning point.

CHAPTER 3

Trends of Irrigation Investments

THE DEVELOPMENT OF the irrigation sector in Sri Lanka has been carried out by the government through massive investments in the development of the irrigation infrastructure. In this chapter, data of a series of irrigation investments compiled from various government documents are presented and an attempt is made to derive testable hypotheses as to the determinants of the investments. Details of the compilation and the data used are given in Appendix I.

The public irrigation investments made during the postindependence period are summarized by type of investment in Table 6, and their trends in terms of five-year moving averages are shown in Figure 2. Irrigation investments are grouped into three categories: new construction, rehabilitation, and operation and maintenance (O&M).

The term, "new irrigation construction" is used here to refer to projects aimed at constructing modern irrigation systems. In the dry zone, there are still many abandoned tanks which were constructed during the time of ancient Sinhala kingdoms. Many new irrigation construction projects were based on these abandoned tanks. In some cases. a modern system came into being by the restoration of the ancient system utilizing the same catchment area, tank site, and sometimes even the old embankments or bunds. In other cases, a new reservoir with a new canal network and a new command area has been constructed. The former process may be called "restoration," and the latter "new construction."[6]

However, because these "new construction" projects usually encompass old small tank systems which have been maintained by the *purana* (old) villagers, it is difficult to find an entirely new irrigation construction project in the dry-zone setting. As used in this paper, "new irrigation construction" includes both "restoration" and 'hew construction" types of projects, whereas "rehabilitation" refers to projects which are meant to restore deteriorated but yet functioning irrigation systems to their original capacity, or improve them above their original capacity.

[6] *An* example of a "restoration" project is the Parakrama Samudra system, an irrigation system with a command area of about 7,000 ha which was originally constructed during the 12th century A.D. For the reasons stated above, it is rather difficult to give clear-cut examples of "new construction" projects, but systems such as Huruluwewa, Inginimitiya, and the systems under the Mahaweli Project could be classified as those coming under 'hew construction." For the nature of irrigation projects in Sri Lanka, see, for instance Arumugam (1969).

Table 6. 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 (96)	-	34 (4)	941 (100)	8	37
1955	859 (96)	-	38 (4)	897 (100)	6	29
1960	601 (83)	-	121 (17)	722 (100)	3	19
1965	619 (91)	-	62 (9)	681 (100)	3	15
1970	994 (93)	-	78 (7)	1,072 (100)	3	16
1975	1,116 (89)	5 (1)	127 (10)	1,248 (100)	2	13
1980	3,023 (89)	225 (7)	137 (4)	3,385 (100)	6	21
1985	2,770 (82)	451 (13)	154 (5)	3,375 (100)	6	18
1988	1,676 (80)	308 (15)	102 (5)	2,086 (100)	3	na

[a] Five-year averages centering on the years shown, except for 1988. Figures within parentheses are percentages.
na = data are not available.

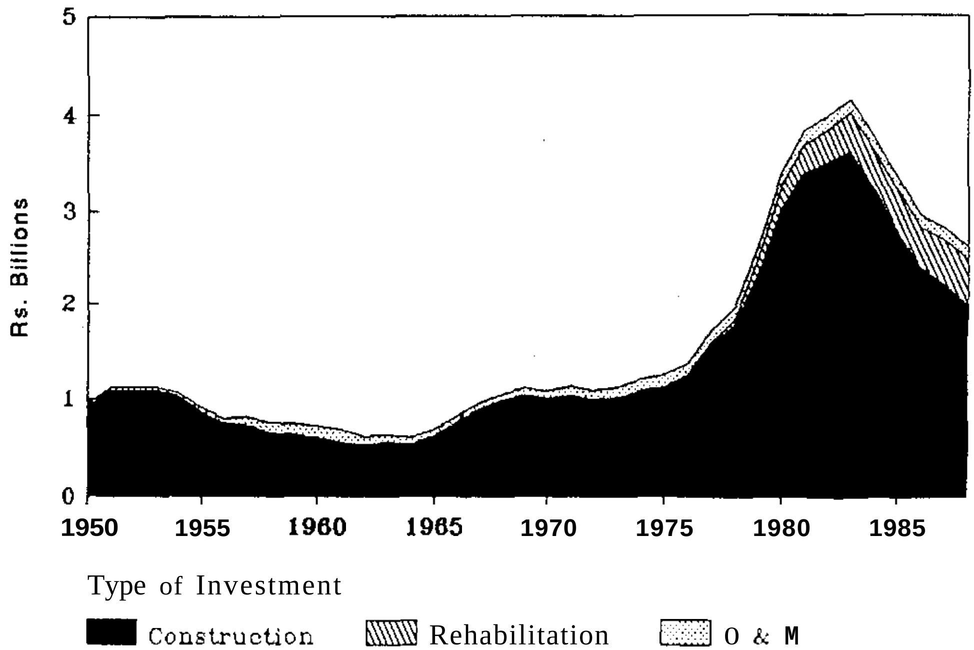
[b] Investments for constructing new systems or restoring old abandoned systems.
Only irrigation-infrastructure-related investments, such as tank and canal construction, are included.

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

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

Sources: See Appendix I, Tables A1-6 and A1-7.

Figure 2. Changes in irrigation investments in Sri Lanka, five-year moving averages, 1950-86, in 1986 prices.



It should be noted that the investments in new irrigation construction considered here include only those related to the development of the irrigation infrastructure such as the construction of reservoirs, canals, channels, and roads. New irrigation construction in the dry zone usually takes the form of a "colonization" project involving the settlement of farmers in the newly developed system areas. The settlement component of a project requires some investment for the provision of shelter, domestic water services, subsistence for the settlers during the initial period of settlement, etc., in addition to the investment for developing the irrigation infrastructure. The settlement-related investment, as well as overhead costs such as the emoluments of personnel at headquarters offices of the irrigation-construct related agencies, and general overhead costs are, in principle, not included in the new irrigation construction investment. Likewise. the rehabilitation investment and O&M expenditures, in principle, do not include general administrative overhead costs which are incurred outside or beyond the irrigation systems.

There have been several multipurpose projects aimed not only at irrigation development and settlement but also at hydroelectric power generation. Gal Oya, Udawalawe, and Mahaweli projects are some examples of these. For these projects, the investment cost of structures common to both purposes such as reservoirs is apportioned in the ratio of the benefits expected from each purpose according to the project appraisal reports. For example, the Mahaweli Project which is by far the largest government project in the country envisages the development of more than 300,000 ha of new irrigated land and the generation of 800 MW of hydropower at the completion of the project The project involves three major upstream headworks, the Kotmale. Victoria, and Randenigala reservoirs. The capital cost of the first two reservoirs is apportioned in the ratio of benefits and the share for irrigation benefits is included in new irrigation construction investments. The cost related to the Randenigala Reservoir is excluded because this reservoir plays little role in irrigation (Salzgitter Consult GMBH et al. 1979, pp. 10-27).

An examination of the irrigation investment data (Table 6 and Figure 2) reveals several interesting points in the investments made so far.

First, irrigation in general and new irrigation construction in particular have been by far the most important investment opportunities in the country. Major government efforts at developing the economy have been directed toward the agricultural sector, particularly toward developing irrigated agriculture. Even at the early stage of post-independence development, substantial amounts of investments were made in constructing new irrigation systems. The share of new construction in the total irrigation investment was as high as 96 percent in the early 1950s, and irrigation investments as a whole took nearly 40 percent of the total public investment or nearly 10 percent of the government budget during that period. As the economy developed, the share of the total irrigation investment in the total public investment declined toward the mid-1970s. However, the total irrigation investment jumped to an unprecedented high level in and around 1980, bringing up the share of irrigation investment in the total public investments to more than 20 percent.

Second, new irrigation construction has been dominant among the three types of irrigation investments (Figure 2), and from 1950 to the early 1980 the long-term trend of new construction investments has been upwards. Such a trend suggests that the major efforts in the irrigation sector have been directed toward attaining the national policy goal of self-sufficiency in rice through the expansion of the irrigated land base. As observed in the previous section, a mechanism could have been at work in Sri Lanka as well as in other countries in monsoonal Asia by which the growing population pressure against a limited land resource necessitated developments in agriculture to augment land internally through improvements in land quality. Within this broad framework, it can be hypothesized that a basic economic factor behind the heavy investments in irrigation construction was the high profitability of such investments. The successive introduction of improved seed-fertilizer technology would have played a critical role in maintaining and enhancing the profitability of irrigation construction.

Third, investments in new irrigation construction have experienced distinct short- to medium-tern fluctuations. Three peaks, or investment spurts, can be seen: the early 1950s, the late 1960s, and the late 1970s to the early 1980s. During the periods between these peaks, new construction investments decelerated. Major irrigation works of the first peak are, among others, the Gal Oya, Parakrama Samudra, and Huruluwewa projects. while those of the second peak include projects such as Nagadeepa, Udawalawe, and Rajangana. The third and the highest peak was created by the commencement of the Accelerated Mahaweli Development Project in the late 1970s. together with projects such as Inginimitiya and Kirindi Oya.

However, it should be noted that in the last peak the new construction investments begin to decline, rather sharply, after the mid-1980s. Why have the investments in new irrigation construction shown such fluctuations over the past 30 years? Were the three peaks created by the same factors, or will another peak appear in the future. after a certain period of investment deceleration as was the case before the last two peaks?

One may discern certain associations between the investment levels of new irrigation construction and the political regimes of the country. Thorbecke and Svejnar (1987) found close associations between agricultural performance and political regimes of Sri Lanka between 1960 and 1984. Being a critical factor in agricultural development, the investments in irrigation reveal a similar pattern. Since independence, the United National Party (UNP) which put strong emphasis on open-economic policies was in power for the periods 1947 to 1954.1965 to 1970, and 1977 to the present, while the Sri Lanka Freedom Party (SLFP) which strongly supported socialistic welfare policies was in power for the periods 1955 to 1965[7] and 1970 to 1977.

The three UNP regimes overlap the peak periods of investment in new irrigation construction, whereas the SLFP regimes correspond well with the periods when the imgation investment decelerated. It may seem quite likely that the different emphases given to the policies toward economic development by different political regimes have led to different stances in public investment policy, including irrigation investment. However, it should be noted again that after the mid-1980s (after the third peak) new construction investments begin to decline rather sharply under the same political regime.

Careful observers may point out that these investment peaks seem to be associated with food crises of the past or with the sharp increases in the world market price of rice resulting from food shortages. The first peak matches food shortages experienced immediately after World War II and during the Korean War; the second peak, the crisis due to the 1965-66 famine in the Indian subcontinent; and the third peak, the crisis triggered by worldwide poor harvests of the early and late 1970s. Such associations suggest that government decisions on imgation investments in particular, and agricultural policy in general,’ have been strongly affected and restricted by changing situations in the world rice market and/or by fluctuations in foreign currency reserves of the country, as demonstrated by Hayami and Kikuchi (1978) for the Philippines.

An overriding objective of the government agricultural policy in Sri Lanka has been to supply a sufficient amount of rice to the consumer through the food ration/food stamp system or at relatively low and stable prices in the open market, and at the same time providing decent prices to the producer through the Guaranteed Price Scheme.

Heavy government intervention has characterized the rice sector in Sri Lanka, especially on its distribution side. The policy of rice rationing adopted by the government for more than three decades until 1978, when it was replaced by the present food stamp scheme, has always been one of the hottest political issues in the country. For instance, the food riot that occurred in 1953 was triggered by a government attempt to reduce the rice subsidy to the consumer

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[7] There was an interruption in 1960 when the UNP came to power briefly, winning the first general election held that year. Later in the same year. the SLFP regained power after winning the second general election.

[8] Plantation crops such as tea, rubber, and coconut are important subsectors of agriculture in Sri Lanka. However, because these plantation subsectors are largely independent of the peasant food crop subsector in terms of agricultural/irrigation policy, they are set aside throughout this paper. And the term "agriculture," is used to mean the peasant food subsector. As for the performance of and government policy toward the plantation sector in Sri Lanka, see, for instance. Thorbecke and Svejnar (1987).

and it led to the resignation of the prime minister and a defeat for the ruling party at the subsequent election (Gavan and Chandrasekera 1979, pp. 29-30). In 1970, the SLFP which campaigned for higher subsidies for food and other basic consumer items won the general election. The extent of the government efforts to maintain the ration scheme was such that the level of the fiscal cost of food subsidies reached 17 percent of the total budget in the mid-1970s (Edirisinghe 1987, p. 30).

As Sri Lanka was a regular importer of rice and as the importation of rice and its dismbution were under the direct control of the government, it is reasonable to assume that government efforts to increase domestic rice production were strengthened when the cost of rice imports increased. Increases in the import cost imply increases in the incentive to invest in new irrigation systems as a means of increasing self-sufficiency in rice. The high premiums on government funds and the chronic shortage of foreign exchange would have made such a government response even more imperative.

In fact, the ups and downs in the food subsidy programs have been linked closely to the importprice of rice and the country's balance of payments. For instance, prior to the food riot in 1953 the government was compelled to reduce the rice subsidy because of the high world market price of rice due to the Korean War (Gavan and Chandrasekera 1979. p. 30). It was the drain of foreign exchange reserves and the heavy fiscal burden caused by unprecedented high prices in the world rice market in the mid-1970s that put an end, in 1978, to the food ration scheme and led to the present target-grouporiented food stamp scheme under which the share of the food subsidies in the total government expenditure declined to less than 3 percent (Edirisinghe 1987, p. 30).

Thus, it can be hypothesized that government decisions on irrigation investments have been heavily influenced by short-term fluctuations in the world market price of rice which, in turn, seriously affected the social pay-off of those investments as well as the country's foreign exchange reserves.

The fourth important point to be noticed in the irrigation investment trend (Table 6 and Figure 2) is that rehabilitation investments appear in the mid-1970s and rapidly increase their share in the total irrigation investment. As indicated in Table 6, this share rose to 15 percent of the total irrigation investment by the mid-1980s. Investment in rehabilitation represents a change in direction for irrigation development in Sri Lanka.

The fist modern irrigation rehabilitation project in Sri Lanka was the Tank Irrigation Modernization Project (TIMP) which started in 1976. It was soon followed by other major rehabilitation projects. It should be noted that these rehabilitation projects included water management improvement programs as an important component, as in the epochal case of the Gal Oya Water Management Project (ARTI and Cornell University n.d.); a clear shift in the design philosophy of irrigation projects and in the emphasis of their implementation has been observed in many of these projects, which is another important aspect of the change in direction for irrigation development

In addition to major rehabilitation projects, there are other projects which aim at improving water management in existing irrigation systems. The fust project of this type was the Minipe Water Management Project implemented during 1978-80 (de Silva 1985). It must be noted that although they are not shown here as independent irrigation investments because of their small size, there has been a proliferation of water management improvement projects in Sri Lanka since the late 1970s. The inauguration, in 1984, of the Irrigation Management

Division which deals with water management issues in 35 major irrigation systems is an example of the important institutional changes toward a new direction of irrigation development; and many water management improvement projects in systems outside these major systems constitute another.

This proliferation of irrigation rehabilitation and water management improvement projects should have been induced by the growth of the irrigation sector itself and its consequences. As new irrigation development progressed, construction shifted from relatively easier projects to more difficult ones and the nature and scale of irrigation construction projects also changed from smaller "renovation" type activities in earlier years to larger "new construction" in more recent years. These were finally followed by the Mahaweli Project, a large, sophisticated transbasin irrigation development project begun in the late 1970s. Implied in this development sequence are increases in the marginal cost of creating a unit of irrigated land.

As this process continues. while the irrigated land base is enlarged, a stage should be. reached when it becomes economically more feasible to invest in improving and enhancing the quality of existing irrigation systems than to invest in the construction of new systems. It is hypothesized that, since the late 1970s. Sri Lanka has been at the crossroads where the marginal rates of return on irrigation investments that deepen the existing irrigated land base through rehabilitation and water management improvement become relatively higher than those on investment in new irrigation construction.

Lastly, it can be observed from Figure 2 that expenditures for irrigation system option and maintenance (O&M) have been a minor component of the total irrigation investment and, more significantly, the share of O&M expenditures in the total irrigation investment has not shown any steady increase over time. In spite of the large increase in irrigated land area under major irrigation systems, which is the result of huge investments in new construction in the past 35 years, the share of O&M in the total irrigation investment remained as low as 5 percent in the 1980s (Table 6).[9] This fact suggests that the maintenance of the existing irrigation systems may have been inadequate resulting in low performance of the systems and endangering their long-term sustainability.

Indicative of low performance of the major irrigation systems in the dry zone are their low cropping intensities as shown in Table 4. Another indication is the fact that when rehabilitation investments started in the late 1970s, almost all systems which came under rehabilitation were those constructed less than 30 years before (some were not even 20 years old), even though they were planned to operate. for much longer periods without rehabilitation.

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[9] Around 1960, O&M expenditures increased substantially due to the expenditures for major repairs in many systems following flood damage in 1959.

CHAPTER 4

New Irrigation Construction

MANY FACTORS HAVE to be considered by the government before decisions are made on the allocation of funds for investment opportunities including the development of the irrigation infrastructure. The irrigation infrastructure being one of the most important public goods, political, social, as well as economic factors affect the decision-making process of the government in regard to irrigation investments. However, in the long run, economic factors will have a far-reaching impact on irrigation investment trends; government decisions on the irrigation sector cannot be made without considering the changing economic environments. Some economic factors which were hypothesized as the causes of change of irrigation investments in the previous chapter, are examined here and in Chapter 5.

LONG-TERM TREND

As observed in the previous chapter, investments in new irrigation construction increased tremendously until the early 1980s. Such a trend should have been induced by high economic returns from such investments. On the other hand, it was postulated that the cost of creating a unit of irrigated land would have increased as new construction progressed from relatively easier projects to more difficult ones. It was hypothesized that a dynamic development process in which the irrigation infrastructure and seed-fertilizer technology reinforced each other to increase the productivity of irrigated agriculture worked as a mechanism to maintain and enhance the profitability of new construction investments while counteracting increasing construction costs. This hypothesis could be tested by estimating the rates of return on the investments in new irrigation construction during the last four decades, as detailed below.

On the project-cost side, the trend of the capital cost to create a unit of irrigated land can be identified by using the capital investment data for 49 of the new irrigation construction projects implemented after independence. These 49 projects/systems are listed in Table A1-8 (Appendix II) with the basic data. The aggregate time-series data on new irrigation construction investments are not used for the cost-benefit analysis because: i) "disaggregation" of the series into individual projects is not possible for many of the new construction projects; ii) data on the command area newly brought under cultivation are not available for many of the projects; and iii) many construction works under the Mahaweli Project are ongoing.

The capital cost per hectare of these 49 projects are plotted in Figure 3 after incorporating capital interest during the construction period assuming an interest rate of 10 percent and converting it into a real term by the GDP implicit deflator for the investment in construction. The unit capital cost series in Figure 3 is constructed by: i) identifying the capital cost per hectare of each project [inclusive of capital interest. i.e., $(1+i)^m K$, where K is the capital investment per hectare, m is the average gestation period of the investment and $i = 10\%$] in 1986 prices; ii) recording it against the year when the project reached 90 percent completion; and iii) taking the weighted average over the projects for each year using the system command area as weight.

As defined earlier, the capital cost includes only irrigation-infrastructure-related investments, such as for the construction of reservoirs, canals, and channels, and the development of rice land; costs related to settlement are not included.[10]

Figure 3 shows an increasing trend in the unit cost and this increasing trend is more evident from the early 1970s. This is because new irrigation construction project, shifted from the small-scale "restoration" type to large-scale transbasin ones, such as the Mahaweli Project.[11] All this supports the postulate that the new irrigation construction in the post-independence period started with relatively easier projects and moved to more difficult ones. As a result, the construction cost per hectare increased more than fivefold from the 1950s to the late 1980s (i.e., from Rs 70,000 to Rs 360,000, in 1986 prices).

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 1,000) in 1986 prices,
t = time (48 to 89),
R^2 = coefficient of determination, and
the figures in parentheses are t-ratios.

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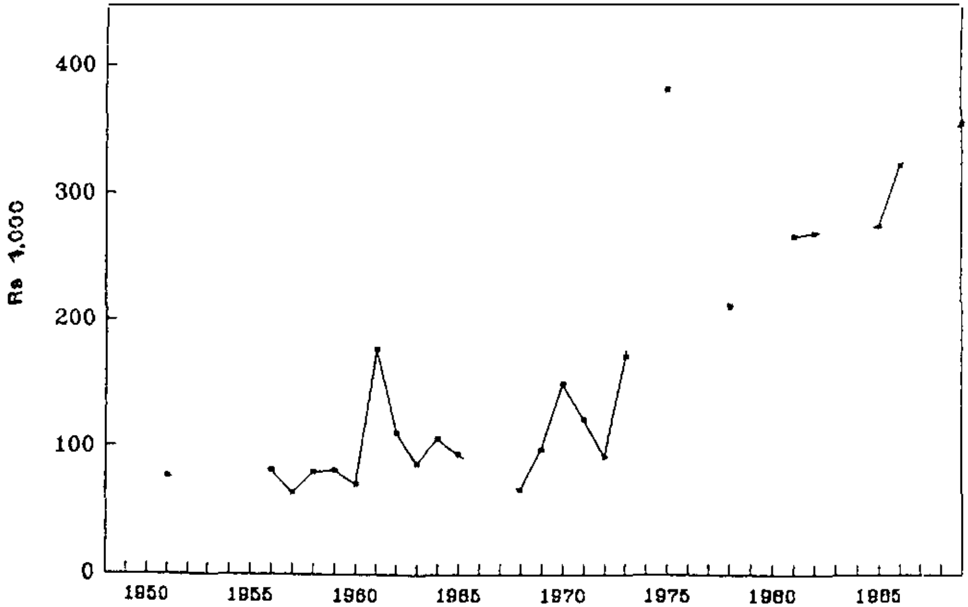
[10] Of the Mahaweli Systems, only System C is included in this analysis because of the lack of reliable data on the others. It must be noted that the cost of the Mahaweli upstream headwork developments is not included in the capital cost of System C which includes the construction cost of the irrigation infrastructure of the Minipe Anicut and below. It should also be noted that among the 49 projects studied, the Mahaweli System C and the Kirindi Oya projects are ongoing. By the time of this study, 90 percent of construction works was completed in the case of System C. and the first of the two construction phases was completed in the case of Kirindi Oya. For System C. the actual capital expenditures until 1989 and the expected capital costs for 1990-1992 are taken into account as the total capital cost of construction, and the designed command area is assumed to have been realized. For Kirindi Oya, such casts as those for the reservoir and the main canal which are common to the entire system are apportioned according to the share of the completed part of the command area in the total designed command area.

[11] For two years. 1961 and 1975, the unit cost is apparently far above the trend level (Figure 3). In 1961. it was due to the Gal Oya construction project which was the first multipurpose large-scale irrigation project of the country. In 1975, it was due to the Uda Walawe construction project which, at that time, was the second largest irrigation project in the country. and which took 17 years to complete.

Figure 3. 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.



It is estimated that the capital cost has increased at a growth rate of about 5 percent per year during the last four decades. For the cost-benefit analysis, the unit capital cost estimated by this trend curve is taken as the capital cost of irrigation construction.

On the project-benefit side, rice is assumed to be the crop to be grown in the newly created irrigation systems. In order to analyze the complementary relation between irrigation and seed-fertilizer technology, three different seed-fertilizer-technology levels are assumed 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 as estimated by Kikuchi and Aluwihare (1990).

The benefit flow is measured as an increase in agricultural income (gross value added). The increase (gross value added) is estimated by subtracting the current input cost, (seed, fertilizer, chemicals, fuel, etc.) from the value of produce of the newly created irrigated land. Increases in labor cost for crop production due to inigation were not subtracted, assuming that labor was available at zero opportunity cost. As explained earlier, almost all new irrigation construction projects in Sri Lanka have been "colonization" projects in which farm families were brought into newly constructed irrigation systems as settlers from other rural areas in the wet and dry zones. Because the settlers in these irrigation systems were those who had difficulty in finding productive employment in their locations, their opportunity cost, if not zero, would have been quite low.

The rice output is valued at the average domestic market price for 1985-87. An alternative way of valuing the rice output for estimating the benefit would be to use the import price of rice, and it will be adopted in the next section. During the base period (1985-1987), there was little difference in the price of rice between the farm gate and the port of entry: while the domestic market price was Rs 4.10/kg, the import price (Colombo c.i.f.; in rough rice equivalent) was Rs 3.90/kg. The total current input into rice production is estimated by multiplying the cost of nitrogen by a factor of 2.5.[12]

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. Cropping intensity varies considerably across systems as well as over time for a particular system. The rationale behind this assumption is the fact that although all major irrigation systems are designed for much higher levels, cropping intensity in these systems in the long run are, almost universally, close to this average level. This suggests that there exist certain systematic gaps between the design and the reality in the technical parameters (total water resources available, reservoir and canal capacity, seepage and percolation rates, and crop water requirement) and management parameters (operation and maintenance). In the cost-benefit analysis for new irrigation construction it is assumed that no specific management effort is made to overcome these gaps over and above the level that has been made in the past. This assumption will be relaxed in the last part of this section.

It is assumed that 100 percent of the command area of newly constructed irrigation systems was brought under new cultivation, and did not include "old" cultivated areas. There could have been some very extensive chena cultivation in the project area in the dry zone before system construction. As compared to the value of the rice output in the new area, however, the output value of chena cultivation, if any, would be quite low. Another problem associated with this assumption is that many new irrigation systems include old smaller systems. For those overlapping areas, only increases in the value output due to the project over and above the previous output level must be taken into account. However, because of the nonavailability of data, this adjustment cannot be made. This leads to an overestimation of the benefit, but in many systems the share of such an old area in the new command area is not so large (less than 10 percent). The degree of overestimation due to this, if any, is reasonably small.

The annual operation and maintenance costs per hectare of new area brought under irrigation are assumed to be Rs 740, in 1986 prices. This is the level that the Irrigation Department set as the "desired level" of operation and maintenance for the major irrigation systems (IIMI 1989). It is assumed that with this level of operation and maintenance, irrigation systems can sustain their operations for 50 years.

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[12] This ratio is obtained from the rice production cost surveys conducted by the Sri Lanka Department of Agriculture (various issues).

The benefit-cost ratio and the internal rate of return are considered as the rates of retum The benefit-cost (B/C) ratio is estimated using the formula:

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

where: R = annual increase in income due to the project,
c = annual operation and maintenance 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, and
i = interest/discount rate (assumed to be 10%).

The first term of the numerator on the right hand side of the formula. which is defined if, and only if, $\ell \geq 2$, is introduced to take into account cases where a part of the benefits start accruing before project completion, assuming linear increases in benefits from zero to the full benefit level. Such adjustments are necessary because the construction periods of many projects were quite long, more than 10 years in many cases, and the command area in such cases was often developed step by step. The settlement and cultivation of a pan of the command area usually commenced much earlier than project completion. For ℓ and m, weighted averages by period using the command area of the sample projects as weight are adopted in the estimation.

The internal rate of retum is estimated as r which satisfies the following equation:

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

The estimated rates of return are summarized by period in Table 7, and the B/C ratio series estimated by level of seed-fertilizer technology are shown in Figure 4. The rates of retum estimated on the basis of the actual capital cost of construction projects are also presented in Table 7 in order to check whether the series based on the estimated capital cost reproduces the changes in actual levels of the rates of retum. As these two sets of estimates give essentially the same results in terms of level and trend, the discussion which follows will focus on the series based on the estimated capital cost.

Just after independence, irrigation construction was a lucrative investment opportunity. The B/C ratio in the late 1940s was as high as 2.3 (Figure 4). F a the 1950s. it was 1.7 on the average (Table 7). However, reflecting the increasing trend in the unit construction cost, the B/C ratio under traditional rice technology (represented as "TV N=0") declined rapidly. and went below 1.0 by the early 1960s. Had there been **no** progress in the technology from the traditional level, the economic potential **of** imgation construction would have been exhausted within a decade and a half after independence.

The progress in seed-fertilizer technology compensated for the increases in the construction cost to a large extent, and preserved the profitability **of** new construction investments. The introduction of improved rice varieties and the associated increases in fertilizer application resulted in the upward shift from the previous technology level of the B/C ratio curves in Figure **4. In** terms of time (horizontal axis), the degree **of** the shift is about 10 **years** for both Old Improved Varieties and New Improved Varieties.

Table 7. Benefit-cost *ratios* and *internal rates of return* on *investments* in new irrigation construction. based on *1986* prices."

	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 + 0.047 t; 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.

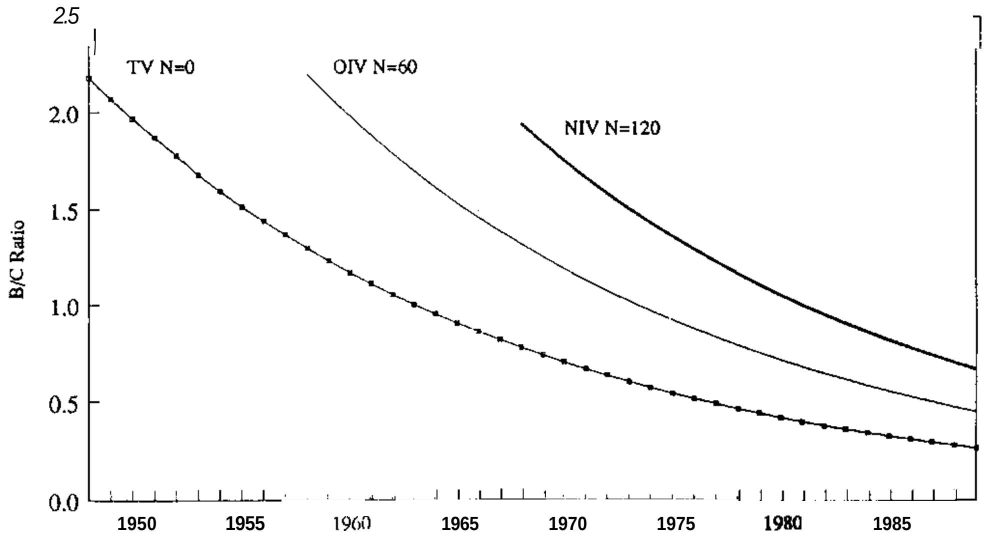
[d] Technology levels assumed for measuring the benefits from newly created irrigated land based on the following rice production function? under irrigated conditions:

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.***

Figure 4. Changes in tk benefit-cost ratio of new irrigatwn construction investments, 1948-89, by level of seed-fertilizer technology, based on 1986 prices.



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

It is interesting to observe that a new technology was introduced before the B/C ratio of the previous technology level reached the 1.0 level, as if to compensate for the sharply declining trend in the rate of return under the previous technology level. In 1958 when the B/C ratio wentbelow 1.5, the introduction of the Old Improved Varieties restored it to a level greater than 2.0, and again in 1968 the process was repeated with the introduction of the New Improved Varieties.

The results of the foregoing analysis support the hypothesis that massive investments in new irrigation consrmction after independence were induced by the high economic potential of such investments. Profitability was high at the initial stage and was preserved thereafter by dynamic interaction between the irrigation infrastructure and seed-fertilizer technology.

However, it should be noted, that this analysis does not explain the trend acceleration observed in Figure 2 (p.13). Although successive developments in seed-fertilizer technology preserved the high profitability of new construction to a great extent, it did not raise the rates of return beyond the highest level attained under the previous technology. The B/C ratio in 1968 under the technology level "NIV N=120" is lower than that in 1958 under "OIV N=60" (Figure 4). On the other hand, of the three peaks of new construction investments in Figure 2, the third one is incomparably high.

Moreover. 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.[13]

The data suggest that, given the present level of rice technology, the increasing real capital cost of construction, and the price structure in the mid-1980s. the. irrigation sector in the country has come to a stage at which further investment in new irrigation construction cannot be. economically justified.

SHORT-TERM FLUCTUATIONS

The level of the B/C ratio (Figure 4) depends critically on technology and prices, both in agriculture and in irrigation construction. While the impact of the technology is long-run in nature, changes in the prices, particularly the price of rice, have an immediate short-run impact on the rates of return. How change in the price of rice has affected the investments should be studied before the factors that brought about the trend acceleration and future prospects of new irrigation construction investments are examined.

Figure 5 shows changes in the index of the import price of rice (Colombo c.i.f.) deflated by the GDP implicit deflator for investments in construction for 1948-89. The impact of the four food crises in the past on the import price of rice is clearly visible as four distinct peaks. It should also be pointed out that the import price of rice was at a historic low level in 1986.

As mentioned earlier (p15), these peaks in the import price of rice clearly correspond to the peaks of the investments in new irrigation construction, with a certain time-lag particularly in the case of the third investment spurt. It was hypothesized that government decisions on irrigation investments had been guided by the profitability of the investments which had in turn been determined largely by the import price of rice.

As a test of this hypothesis, the benefit-cost ratios of the investments in new irrigation construction were reestimated by evaluating the costs and benefits at current prices, while incorporating the effects of improvements in rice varieties and fertilizer applications. On the

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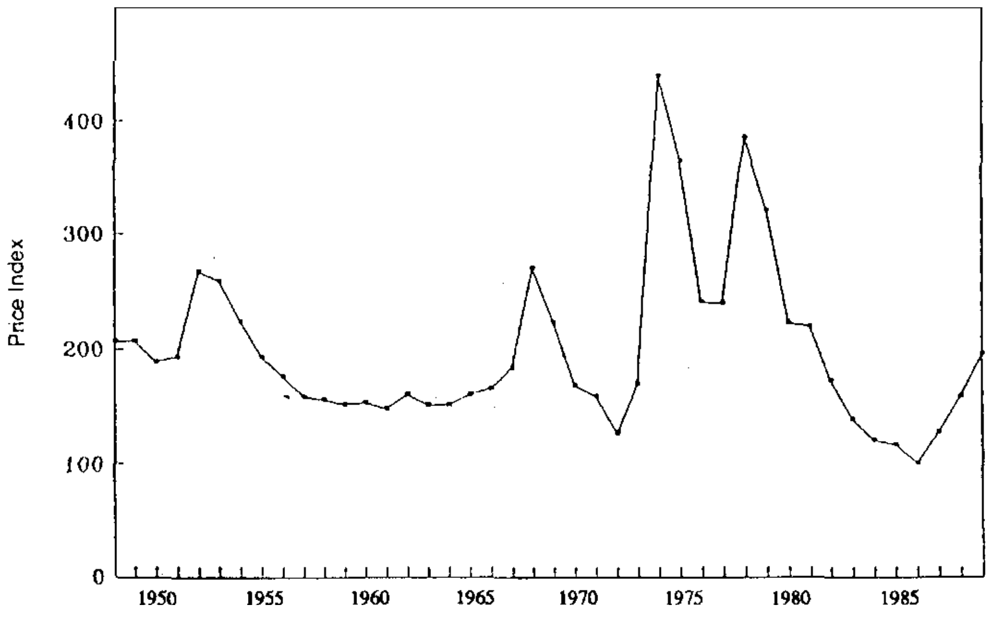
[13] As explained earlier, it was assumed that all the newly created systems would generate the same level of benefits, which is based on the national average. Such an assumption was made to focus on the overall trend in the rates of return on the construction investments. Of course, variations in the benefits could be large across the projects. but it is expected that such variations are canceled by taking averages over a reasonable number of projects in each period. Project-specific estimation of the rates of return made for some recent projects, such as the Kirindi Oya and Mahaweli System C (these two projects are in sharp contrast, for instance, in terms of cropping intensity; less than 1.3 for the former and nearly 2.0 for the latter), does not alter the estimated results based on the average. Some readers may wish to estimate project-specific rates of return with their own estimates of the benefits specific to certain projects. The necessary data on the cost side are provided in Appendix I. Table A-8.

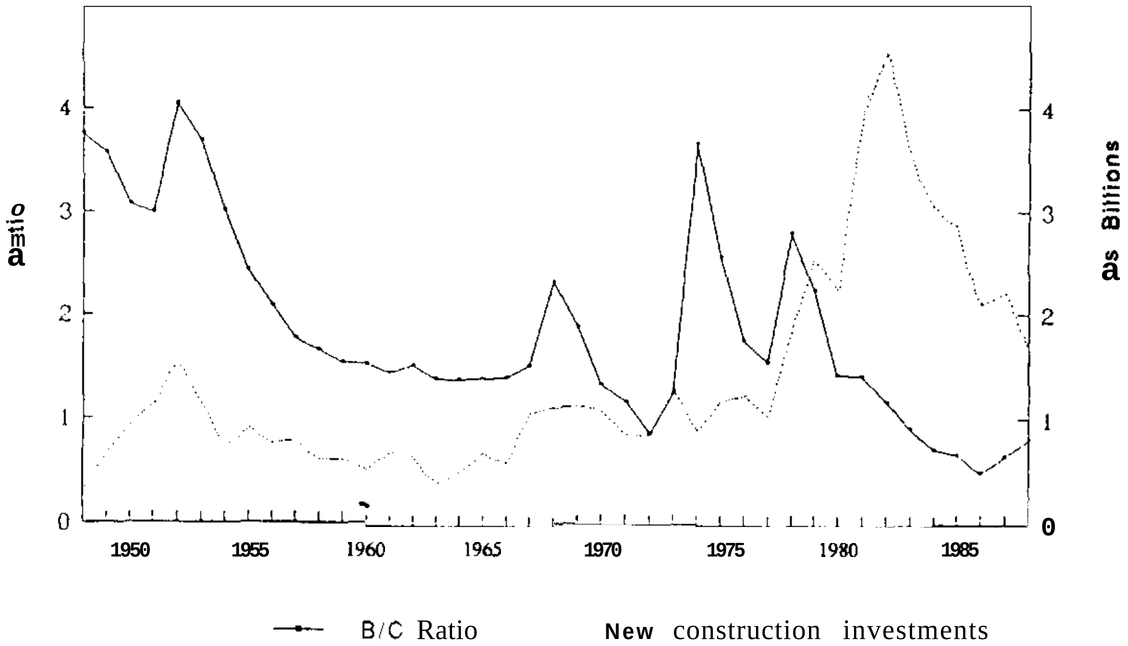
benefit side, the rice output was evaluated by the current Colombo c.i.f. price of rice (in rough rice equivalent) and production inputs by the respective current prices. Changes in seed-fertilizer technology were incorporated by first taking the three technology levels assumed in the constant price calculation and then aggregating the income (gross value added) 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 as weight. On the capital cost side, the unit cost, at current prices, of creating 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 in the previous section (p.20).

Figure 5. Changes in the rice import price index (Colombo c.i.f.) deflated by the GDP implicit deflator for construction investment, 1948-89 (1986=100).



The Series of B/C ratios thus estimated is shown in Figure 6, together with the annual investments in new construction. A few points are worth noting: First, although shon-term

Figure 6. 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 in 1986 prices, 1948-88.



fluctuations in the B/C ratio are large, the long-term trend of the investment performance is downward, as identified by the constant price evaluation, basically reflecting the increase over time in the capital cost to create a unit of irrigated land.

Second, close associations between the changes in the B/C ratio and the construction investments are discernible. The first investment spurt in the 1950s corresponds to a B/C ratio as high as 4.0 during the same period. The period of rather long stagnation in investments from the mid-1950s to the mid-1960s, which occurred when the B/C ratio of the investments went down to and remained at a level barely above 1.0, was followed by the second investment spurt in the late 1960s during which the B/C ratio of the investments went above 2.0 because of price increases in the world rice market. After a four-year period of price stagnation around 1970, the B/C ratio again jumped to a level close to 4.0 in 1974, and after a short period of price decline moved up again in 1979. The third investment spurt began in 1978 and reached an unprecedented high peak in 1982.

Thus, the data strongly support the hypothesis that the social payoff of the investments, which is largely determined by the import price of rice, has been a prime factor behind government decisions to invest in irrigation construction. It is suggested that, while the government response to the changes in the payoff was rather quick until the late 1960s, the process began to involve substantial time-lags after 1970. This could be explained by the fact that, whereas in earlier years there were many sites where construction projects could be initiated rather easily, site selection and project preparation/implementation have become much more difficult and time-consuming in recent years. It was in the 1970s that the Mahaweli Project, the largest irrigation construction project in the country with huge upstream head-work developments, was initiated and accelerated, and other major construction projects, such as the Uda Walawe and Kirindi Oya projects, were undertaken side by side with the Mahaweli Project. With such large projects, time-lags would have occurred between the making of the investment decisions and the actual investment disbursements.

A high import price of rice has a direct impact on government decisions on irrigation construction investment through the increase in the payoff of the investment relative to other public investment opportunities. This implies the reallocation of government funds to irrigation construction projects from other public investment opportunities and/or from recurrent expenditures such as those for rice imports. As investible funds have always been scarce, their availability would have constrained this reallocation process to a great extent. To the extent that irrigation construction investments involve import components, the country's limited foreign exchange reserves would have worked as an even more critical constraint to the investments. As another important determinant of short-term changes in irrigation construction investments, the availability of funds should be examined, in addition to the changes in the social payoff of the investments due to fluctuations in the price of rice.

How the availability of investible funds affects investment in irrigation construction could he understood by studying changes in the foreign fund availability index in comparison with the trend of new irrigation construction investments. The foreign fund availability index is the ratio of the total official foreign assislance consisting of foreign loans and grants, to the total budget of the government. Changes in this index are shown in Figure 7, together with the trend of new irrigation construction investments. Sri Lanka started receiving foreign assistance in 1952, but its level relative to the government budget was less than 5 percent in the 1950s, except in 1954. The index increased toward the late 1960s reaching 10 percent in 1969. It began to rise sharply after 1973, finally reaching a level of more than 20 percent in the 1980s.

More significant is the close association between this index and the new construction investments. This association is quite strong after the early 1960s: the investment spurt in the late 1960s coincides with the increase in the index during the same period: the unprecedented high investment spurt that began in the late 1970s is closely preceded by the rapid increase in the availability of foreign funds; and the investments begin to decline in this third spurt after the index hit the peak in 1981. All these indicate that the government decision to invest in irrigation construction was seriously constrained by the availability of funds, particularly of foreign origin.

Almost all of Sri Lanka's irrigation construction projects after 1970, including the Mahaweli Project, have been funded, at least partially, by donor countries and/or by international lending agencies such as the World Bank and the Asian Development Bank. Given this fact, it may not be surprising to observe a close correlation between the two series (Figure 7). It should be noted, however, that the foreign'fund availability index shown in

Figure 7. Changes in the foreign fund availability index in comparison with changes in the new irrigation construction investments in 1986 prices, 1948-1988.

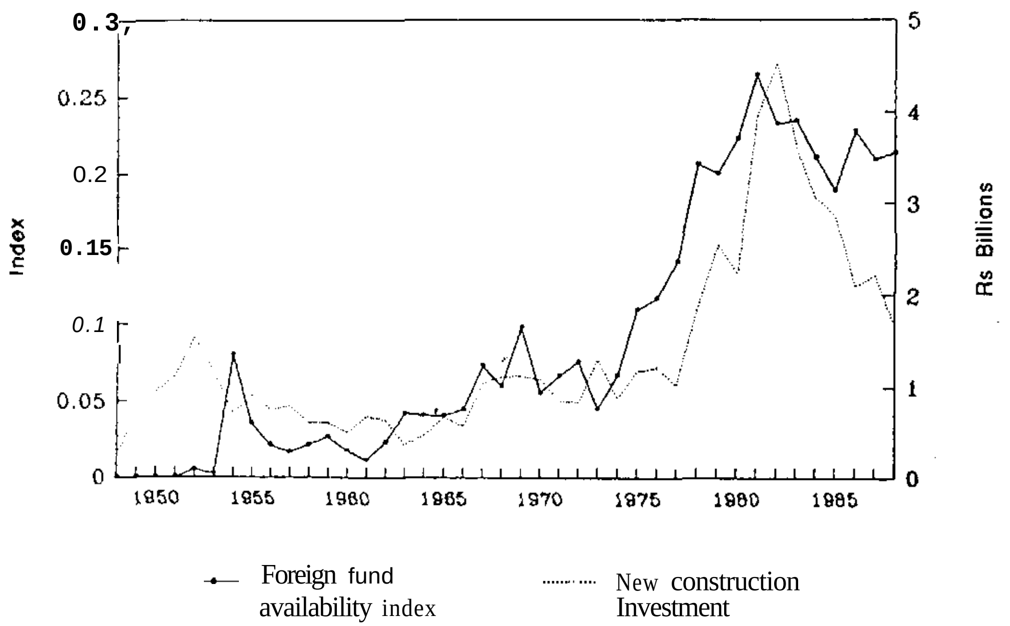


Figure 7 refers to all the official assistance the government received. To a significant extent, the foreign assistance specifically aimed at developing irrigation systems would have contributed to the increasing trend of the irrigation investments. At the same time, the availability of foreign funds for nonirrigation projects would have allowed the government to divert its own funds from other purposes to irrigation construction projects when the investment prospects of these projects were better.

It is this increasing foreign fund availability that explains the trend of acceleration in irrigation construction investments. As shown in Figure 6, the peaks of the B/C ratio estimated using the rice import price, correspond well to the investment peaks; but these two series move in opposite directions. While the third peak of construction investments climbs to a high in **1982,** the B/C ratio peaks in the **1970s.** Though this B/C ratio peak is quite high, funds, rough estimates obtained from various Administration Reports and Vote Ledgers of related agencies are given in Table 8.

Table 8. Weights of foreign assistance in irrigation projects.'

	Foreign funds directed to irrigation projects:	
	As % of total irrigation investments	As % of total foreign assistance
1967-70	59	3
1971-74		22
1975-78	22	4
1981-85	68	22
1986-88	63	11

'Data for 1979 and 1980 are incomplete.

The following observations can be made from Table 8: First, the level of foreign funds directed to irrigation development fluctuated significantly over time: until 1970, the percentage share of the foreign funds for irrigation, both in the total irrigation investments and in the total foreign assistance receivedby the government, was negligible. The share in the total irrigation investments and in the total foreign assistance rose to 59 percent and 22 percent, respectively, during the early 1970s, declined to 22 percent and 4 percent in the mid-1970s. rose again to high levels in the early 1980s, and declined again in the late 1980s. It is obvious that donor agencies reacted quite responsively to the high world market prices of rice; foreign aid for irrigation increased sharply after the food crises in the late 1960s and the mid-1970s, but decreased once the crises were over, with three- to five-year time-lags.

Second, the share of foreign aid in the total irrigation investment was particularly high for the third investment peak in the early 1980s; nearly 70 percent of the investment was financed by foreign funds. The donor-driven nature of irrigation projects was outstanding in this peak.

These data support the hypothesis that the rates of return and the foreign fund availability are major determinants of the government investments in new irrigation construction.[14] It is

[14] The following estimate of the investment function for new irrigation construction with Koyck-Nerlove distributed-lag specification. using annual time-series data for 1948-88, gives statistical support for the hypothesis:

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

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

where L_n =natural log; I_t = new construction investment in year t, in 1986 prices; $(B/C)_t$ =benefit-cost ratio of the investments in year t, evaluated at current prices (for rice prices, Colombo c.i.f.); AID = foreign fund availability index; R^2 (adj.) = the coefficient of determination adjusted for the degree of freedom: D.W. stat. = Durbin-Watson statistic; and the figures within parentheses are t-ratios.

worth emphasizing that the government did respond to changes in the social profitability 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 exercised undue influence (e.g., Mendis 1989; Nijman forthcoming). Nevertheless, the allocation of government funds for irrigation construction while being constrained by the lack of investible funds and foreign exchange reserves, has been guided by economic considerations, i.e., the economic returns on the investment.

OUTLOOK FOR NEW IRRIGATION CONSTRUCTION

Figure 6 (p.28) reveals that the B/C ratio of the investments in irrigation construction went down sharply beginning in the early 1980s and hit an unprecedented low in 1986. Such a drastic decline was due partly to the increased construction costs per unit of irrigated land and partly to the historic low prices in the world rice market. Although the B/C ratio showed an upward mend after 1986 as the world market price of rice rebounded and exceeded the level experienced in the early 1960s (Figure 5), its level in 1988 was still below 1.0. Irrigation construction investments have been under a typical phase of diminishing returns. It could be said that the era of "major" irrigation construction in Sri Lanka is at an end, unless major breakthroughs in construction or agricultural technology are forthcoming.

A few qualifications need to be made in this regard. First, the rates of return to the investments depend heavily on the price of rice. For example, if the world market price of rice increases in the near future to the level experienced during the food crisis period in the 1970s the rates of return on irrigation construction investment will increase, with the B/C ratio going slightly above 1.0 at the present level of construction costs (Table 9). This could be checked by estimating the rates of return for three years of the last decade of this century assuming the import price of rice to be that experienced from 1974 to 1979 which is more than 300 percent higher than that in 1986 in terms of the price of rice relative to construction cost. The capital cost of construction is estimated from the trend curve, explained earlier. However, even with such a high price of rice, the B/C ratio will go down quickly lo a level less than 1.0 by the end of this decade."

The second qualification is the effect of crop diversification on the rates of return. Since the mid-1980s when Sri Lanka attained a state of near self-sufficiency in rice, serious efforts have been made to diversify the cropping pattern of the rice-based irrigation systems. Could the benefits from irrigation construction be increased drastically by switching from rice to

" his always hazardous to predict future food prices. It may be worth noting. however. that the World Bank predicts a declining trend in the world market price of rice after 1989. Its prediction made in January 1990 is as follows: 1989=100.0, 1990=84.5, 1995=75.1 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.

high-value nonrice crops? Studies on crop diversification[16] have shown the need to introduce high-value, high-performance nonrice crops, if crop diversification is to be an economically viable option for rice-based irrigation systems.

To check how crop diversification with high-value nonrice crops affects the profitability of construction investments, reestimations of the rates of return can be done in a manner similar to the case of high world market price of rice. It is assumed that the entire cultivated area in the yala (dry) season (with a cropping intensity of 0.5) is planted with high-value nonrice crops, such as chili, onion, and gherkin.

At least four sets of estimates are available for cropping intensities of the major irrigation systems in Sri Lanka depending on the data source and definition. For "irrigated paddy land area" (stock term), two slightly different sets of data are available; one from the Irrigation Department (ID) and the other from the Department of Census and Statistics. For "cropped area" (flow term), either the rice planted area or the rice harvested area (the data available from the Department of Census and Statistics) can be used in computing the cropping intensity. Long-term averages of these sets are shown in Table 10. Note that the cropping intensities in the maha season are less than 1.0. Since crop yields are defined in terms of harvested area, more consistent with the context here are the cropping intensities based on rice harvested areas, which range from 1.20 to 1.32 for the total (yearly) cropping intensity, or from 0.48 to 0.53 for the yala cropping intensity. Here an average cropping intensity of *0.50* is adopted for the yala season.

Table 9. 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.

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[16] See, for example, Miranda (1989), Panabokke (1989), Kikuchi (1990), and, in particular, IIMI (1990a) and Shand et al. (1990).

[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 craps is assumed to be Rs 72,000/ha, in 1989 prices.

It should be noted, that there are many difficulties and constraints to face in promoting crop diversification in rice-based irrigation systems on a wide scale (Kikuchi 1990, IIMI 1990a, pp. 168-178): it is difficult to identify economically viable nonrice crops which can replace rice; some high-value nonrice crops available for farmers to adopt usually require higher input intensity as well as more deliberate water management than does rice; 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 for rice. Therefore, the same level of cropping intensity as for the case of rice monoculture is assumed in the estimation here. Replacing rice with nonrice crops could cause a system to save water so that the cropping intensity of the system can be increased. Without deliberate management efforts to make better use of this saved water, however, crop diversification does not necessarily result in an increase in cropping intensity.

Table 10. Cropping intensities of rice (asweddumized) land areas under major irrigation

ID data (1950-87)						Census and Statistics data (1960-87)					
Planted area base			Harvested area base			Planted area base			Harvested area base		
Maha	Yala	Total	Maha	Yala	Total	Maha	Yala	Total	Maha	Yala	Total
0.75	0.50	1.25	0.72	0.48	1.20	0.83	0.54	1.37	0.79	0.53	1.32

Based on a 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 Colombo c.i.f. price of rice is at the 1986 level, or 310 percent higher if it is at the 1989 level. For valuing the rice output, the world market prices of rice predicted by the World Bank are used after linking them with the Colombo c.i.f. price.

The results shown in Table 9 indicate that the full conversion of yala season extent from rice to high-value nonrice crops increases the rates of return slightly. With the unit capital cost in 1990, the B/C ratio will be raised to 1.5, but it soon goes below 1.0. Given the present conditions of the construction costs and the level of system management as related to the cropping intensity, the impact of crop diversification on the rates of return is marginal, even if it is with high-value nonrice crops and with 100 percent of the cropped area in the yala season.

A basic assumption in the cost-benefit analyses made so far for new irrigation construction is that the newly created **systems are operated at a cropping intensity of** 1.3. The conclusions obtained here will not be changed even if this assumption is relaxed. Suppose a newly created irrigation system has a cropping intensity of 2.0 (although it is quite difficult to attain this level in the dry-zone setting except for a few systems which are endowed with exceptionally favorable water resources, such as the Parakrama Samudra system and the Mahaweli System C), the benefits will be increased by about 50 percent over the case with the cropping intensity **of** 1.3. Such an increase in the benefits is well within the magnitude assumed for the cases of high world market price of rice and crop diversification.

All analyses in this section, including the two exercises above, pinpoint the rapidly increasing construction costs as the basic cause **of** a dim prospect for irrigation construction. This trend, as already mentioned, has been due mainly to the fact that construction projects have shifted **from** relatively small-scale simple ones to large-scale sophisticated ones including the transbasin type.[17] This leads to the fourth qualification; the analyses done here are applicable mainly to major irrigation construction projects which require massive construction efforts. There may be some **spots** left in the country where new irrigation systems can be set up at reasonably low capital costs. Such potentials must not be overlooked, though possible projects may be small-scale.

The last qualification is the impact of new irrigation construction on employment creation. Many people involved in irrigation construction in Sri Lanka seem to believe that the prime objective of irrigation construction projects is to create productive employment opportunities, **benefits of which are beyond a narrow economic calculation**. This view often leads them to conclude that economic rates of return miss this important objective. It may be worthwhile to point out again that in the cost-benefit analysis the benefits of the irrigation construction project are measured by the increase in gross value added in agricultural production, of which the returns to labor are a major component. As far as the employment created in agriculture is concerned, it is fully counted in. Therefore, low rates of return to the investments mean that irrigation construction is not a cost-effective means of creating employment.

The following example illustrates this point more clearly. If rice is the crop to be planted on the newly irrigated area, around 150 person days/ha/season of employment are Created. Labor absorption of rice farming in the dry-zone setting rarely exceeds this level. With a cropping intensity **of** 1.3, the total employment created with rice farming is about 200 person days/ha/year. The *capital* cost **of** creating this level **of** employment is about Rs 350,000/ha (with capital interest) in 1986 prices. Suppose the government has the option of earning interest by depositing this fund in the Central Bank at an interest rate **of** 10 percent per year (the actual rate is higher than this), the government can earn an interest of Rs 35,000/year. Suppose the minimum wage rate for unskilled labor in 1986 prices is Rs 50/day the government can create 700 person-days of employment from the interest. (Laborers

[17] The increasing trend in irrigation construction costs might have been due partly to a capital intensive [illegible] projects. Though this [illegible] has not been ex[illegible] it seems that serious attention should be paid to the question whether [illegible] adopted i[illegible] tion is "[illegible]iate" under [illegible] *prices* prevailing in the country.

employed can be used for whatever work; e.g., for maintenance work in irrigation systems.) The employment created by constructing an irrigation system is less than 30 percent of this option.

This situation will not change, even if the employment created by the construction project itself is taken into account. Suppose 30 percent (a generously overestimated figure) of the construction cost (Rs 200,000/ha without capital interest) is for hiring unskilled laborers, then 1,200 person days/ha of labor are employed for the construction. "Annualizing" this by applying a 10 percent discount rate, the *total* employment generated by the project is estimated to be 320 (i.e., 200+120) person days/ha/year, which is still far less than 700 person days/ha/year. It should be clear enough that irrigation construction under the present conditions cannot be justified even from the perspective of employment creation."

[18] Advocates of irrigation construction often go further, claiming that spillover effects of employment created hy irrigation projects which are usually not taken into account in a cost-benefit analysis must not be overlooked. It is true that any income generated by a certain project has income multiplier and linkage effects; it induces income generation outside the project. There seems, however, no reason to assume that the income multiplier and linkage effects of irrigation construction projects are higher than other kinds of investment projects (e.g., an investment project to create an industrial zone for labor-intensive light industries).

CHAPTER 5

Rehabilitation and Water Management Improvement

AS OBSERVED IN Chapter 3, a new trend in irrigation investments emergedin the late 1970s: investment in irrigation system rehabilitation[19] rapidly increased its share of the total irrigation investment. Then, after a short time-lag came water management improvement projects. It was hypothesized that irrigation development in Sri Lanka has come to a stage where, with the enlarged irrigated land base resulting from the massive investments in irrigation construction in the past, the profitability of investments in improving and enhancing the quality of existing systems becomes higher relative to that of new construction. This hypothesis can be examined by estimating the rates of return of selected rehabilitation and water management projects.

There have been four major rehabilitation projects in Sri Lanka, of which two are ongoing. The two completed projects, the Tank Irrigation Modernization Project (TIMP) covering five tank irrigation systems, and the Gal Oya Water Management Project (Gal Oya) are selected for the post-project cost-benefit analysis of this study.[20] Among water management improvement projects, three are chosen for which detailed data on project-costs as well as changes before and after the projects are available; these are the water management improvement projects implemented in the Kimbulwana, Pimburettawa, and Nagadeepa systems. Detailed descriptions of these projects, together with the data used, are given in Appendix II.

The same method of cost-benefit analysis used in the constant price estimation of new construction investments is applied to these chosen projects: both the capital cost and benefits are valued at 1986 prices, and the benefits are measured by the increases in agricultural income (gross value added) due to the projects. As the sources of the benefits are numerous and often elusive in the case of rehabilitation/water management projects, it is more difficult to estimate the benefits accruing from the investments. In this study, only two sources of possible project benefits are taken into account, changes in cropping intensity (including imgable area increase) and reductions in yield gaps between the head-end and tail-end

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[19] Irrigation system rehabiliation projects usually intend not only to bring up deteriorated physical structures to the original design levels but also to modernize them. In this sense, it is better that these projects are called irrigation system modernization projects. Here, the conventional term of rehabilitation is used to represent these projects.

[20] The two ongoing projects are the Major Irrigation Rehabilitation Project (MIRP), and the Irrigation System Management Project (ISMP).

sections due to better water distribution after the project. General yield increases due to better water availability/management after the rehabilitation/water management improvement projects are not taken into account because it is rather difficult to isolate such an impact on yield from "autonomous" yield increases over time. In many irrigation project appraisal/ evaluation reports, this kind of "autonomous" increases in rice yield are assumed to be a part of the project benefits. It is difficult to understand why such increases in yield are treated as a benefit of the projects without verifying whether the projects really contributed to the increases. They must not be included in the project benefits, unless they are clearly due to the projects.

Rice is assumed to be the crop grown and its unit yield is identified by system. based on the average level attained in each system after the project, except for TIMP in which the technology level "New Improved Varieties: N=120kg" is assumed. as it was for new construction.The average rice production functions used to estimate rice yield for the new construction projects can be applied for all the rehabilitation and water management projects; the yield level of each system is well-represented by these functions if the variety mix is taken into consideration. Since the data on variety shares are not available for some systems, the actual post-project yield levels are used to avoid any overestimation of the benefits. A general principle adopted here is to take the lower bound in estimating benefits from the rehabilitation/water management projects. The gross value added ratio of the rice production is assumed to be 80 percent.

As tq the operation and maintenance (O&M) cost, it is assumed that an amount of Rs 740 per hectare, the same as for new construction projects, is necessary to sustain the benefits of major rehabilitation as well as water management projects. There is little information available on the "maintenance" needs of water management projects. particularly of their "software" side. As mentioned later, the real difficulty in this respect is that it is not known how to sustain the benefits of water management projects and therefore it is not known what costs are specifically involved. By assuming a rather high level, it is expected that maintenance requirements, if any, are well within this assumed level.

A 20-year lifetime of project benefits is adopted for major rehabilitation projects, following the conventional assumption made in this kind of project. F a the water management improvement projects the lifetime is assumed to be 15 years. Just as for the "O&M requirements" little information is available on the durability of water management projects. The rationale behind the assumption of a 15-year lifetime is that the benefits can be sustained if appropriate O&M is carried out after the project. Considering the highly volatile nature of the projects. the results of alternative estimations made under different assumptions are presented in Appendix II. It is mentioned there that alternative assumptions on the lifetime do not change the conclusions made here.

It should be mentioned that the projects are treated as independent of the construction projects that preceded the rehabilitation/water management projects. The capital costs are specific to the project, and do not include the "sunk" costs of system construction, and the project benefits are measured over and above what have been generated by the construction projects. It is necessary to treat these projects in this way as the purpose of analysis here is to compare the economic performance of these projects with that of irrigation construction.

The results of the estimations are summarized in Table 11. The rates of return on new construction investments in the 1980s are also given for comparison.

As expected, both the major rehabilitation projects studied show rates of return higher than those for new construction. In particular, the Gal Oya Project reveals high rates of return on the rehabilitation investments. It is interesting to notice that the level of profitability of this project is almost the same as that of the investments in new irrigation construction 40 years ago when the irrigation sector started its construction phase, just after independence. The Gal Oya case gives clear support to the hypothesis that rehabilitation is a more lucrative investment opportunity than new construction at the present stage of irrigation development in Sri Lanka. The result of this Gal Oya case when compared with the new construction case gives statistical support, in the Sri Lankan context, to a statement ma& as early as in 1976 ".... the cheapest way to increase production by 1 ton/ha/year of paddy is .... (irrigation rehabilitation), ... In general, all (irrigation development) methods involving new land .... are not advisable, because they cost more and take longer time than others, which further deteriorates their economic returns" (Okita and Takase 1976, pp. 7-8; words within parentheses were added by the authors).

Table 11. 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 he technology level "New Improved Varieties; N=120kg" and the estimated construction costs (From Table 7).

[b] The rate of return of the Tank Irrigation Modernization Project is 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.

However, a major rehabilitation project is not necessarily as successful as the Gal Oya Project, as illustrated by TIMP. The difference in the rates of return between TIMP and new construction is marginal. It must be noted that, unlike for other rehabilitation/water management projects studied here, the rate of return for TIMP is the "higher bound" estimate; for this project, the assumed change in cropping intensity. the largest source of the project benefits, is not based on the actual data but on the project appraisal report data. The actual internal rate of return of this project could be lower than 10 percent (see Vithanage 1982).

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 toward engineering and capital-intensive activities while giving little attention to the fanner-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 was that it provided many useful lessons to the rehabilitation projects that followed it. It is suggested that the Gal Oya Project, said to have absorbed many useful lessons from TIMP (Merrey and Murray-Rust 1987), had a far better economic performance than its predecessor. The potential of irrigation rehabilitation projects can be more effectively realized when due attention is given to the institutional and management aspects of the project

More striking are the very high levels of economic performance that some water management improvement projects achieved (Table 11). Even with conservative assumptions made in evaluating the project benefits, the Kimbulwana and Pimburettawa projects yielded internal rates of return as high as 70 to 80 percent, implying that such projects have been severely underinvested.[21]

It is not surprising at all, however, to see such results for water management projects if one looks into the present state in which many of the major irrigation systems in Sri Lanka rue being operated and maintained resulting in inequitable water distribution, considerable wastage of water by head-end farmers, poor management of water in the maha (main) season that leads to water shortage in the yala (secondary) season, and poor maintenance of physical structures that results in the rapid deterioration of irrigation performance. Programs to rectify these defects, on the one hand, result in substantial improvements in system performance, and on the other, do not require much financial investment.

However, it must be pointed out that not all water management projects are successful. Of the three projects studied, any systematic improvement in system performance, after the project, was not detected for the Nagadeepa project. At best, assuming no O&M costs, the B/C ratio of this project was 0.4; it generated benefits which were much less than the investment costs. An important difference between this and the other two projects can be. observed in their components related to physical structure improvements; rehabilitation and/or modernization components, howsoever minor. accompanied institution building and water management improvement activities in the Kimbulwana and the Pimburettawa

[21] Such high levels of internal rates of return may not be common in the irrigation sector where the economic feasibility of construction or major rehabilitation projects is usually argued as revolving around the break-even rate of 10 percent. But, it is not uncommon in the public sector where large economic potentials are often left unexploited because of market failures. A typical example of such a case can be found in agricultural research for peasant crops, where it is not rare to find internal rates of return as high as 50-100 percent because of underinvestments (see, e.g., Evenson and Kislev 1975).

projects whereas they were largely absent in Nagadeepa. The capital cost per hectare of these water management projects, in 1986 prices, can be roughly broken down as follows:[22]

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

It should be noted that the amount spent for physical improvements in Nagadeepa was less than the assumed 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.

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 fanners' participation and cooperation. The two success cases suggest that relatively modest investments in rehabilitation are sufficient to provide the basis for significant improvements in water management.

Although the limited number of sample projects, both for major rehabilitation and for water management improvement, restricts a more complete test of this hypothesis. evidence at hand is sufficient to conclude. that as long as they are properly designed and implemented the economic performance of these projects is far better than that of new construction. The rapid increase in rehabilitation investments and proliferation of water management projects in and after the late 1970s must have been induced by such changes in the relative profitability of these investments.

One may argue that even if the rates of return are higher for rehabilitation and water management projects the absolute value of benefits generated from such projects would be far less than that from new construction projects. If that is the case, considering the overhead and other transaction costs involved in project preparation and implementation which were not taken into account in the cost-benefit analysis in this paper, might it not be worth pursuing the opportunities for rehabilitation and water management improvement? A comparison of the Net Present Value of the projects gives a clear answer to this question. The Net Resent Value, defined as the present value of the total project benefits less the present value of the total project capital investments. is estimated for new construction and rehabilitation/water management improvement for three systems and the results are compared in Table 12.

In the case of the Gal Oya system, the Net Present Value of the new construction project in 1986 prices is Rs 1.459 million while that of the rehabilitation project is Rs 1,055 million; the benefits generated by the latter are as much as 72 percent of that of the former. 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 is even larger than that of the new construction project.

[22] For details of the data, see Appendix II.

Similar results are obtained for the water management projects. For the Kimbulwana system, the absolute value of the benefits generated by the water management project is only 20 percent less than that generated by the new construction project. Among the three new consauction projects, the Pimburettawa one had the best internal rate of return, resulting in a relatively high Net Present Value of the construction project. Even for Pimburettawa, the Net Present Value of the water management project is nearly 50 percent of the new consauction project.

Table 12. Comparison of the Net Present Values of new construction and rehabilitation/water management improvement projects of selected irrigation systems m Sri Lanka, in 1986 prices.

	New construction (1)	Rehabilitation/ water management (2)	(2)/(1)
Gal Oya			
Construction period'	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 Resent Value' (Rs million)	1,459 (960)[d]	1,055	0.72 (1.10)
Kimbulwana			
Construction period'	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 Resent Value' (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 Resent 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 coats) minus total capital investment costs. Costs and benefits a n compounded/discounted by an interest rate of 10 percent.

[d] For the Left Bank only.

[e] The command area after the project.

Thus, it can be concluded that investment in rehabilitation and water management improvement represents a valuable economic opportunity not only in terms of the rates of return but also in terms of the absolute value of the benefits to society.

CHAPTER 6

Implications for the Future

THE MOST IMPORTANT general conclusion of the analysis of the investment trends in the irrigation sector in Sri Lanka since independence is that the emphasis in the development of the irrigation sector has shifted markedly from the construction of new irrigation systems to rehabilitation/modernization, coupled with institutional improvements in the management of the existing systems.

Despite several gaps in the data it should be reasonably clear from this analysis that, given the state of irrigation development in the country and present levels of technology in agriculture and in construction engineering, little economic potential is left to be exploited by new irrigation construction. This does not deny the fact that there may yet be some few potential for developing small- to medium-sized new irrigation systems at a few locations in the country. Generally speaking, however, the era of major irrigation construction in Sri Lanka is at an end.

With the irrigation infrastructure and the land base now well-established, investment in Sri Lanka's irrigation sector should be directed to and focused upon system rehabilitation or modernization and improvement of the management of existing inigation systems. The potential for maintaining growth in agricultural output and income through these activities is high, with improved irrigation management representing an opportunity to be more fully exploited.

Within the range of economic conditions likely to be encountered by the irrigation sector in the near future (e.g., higher prices in the world rice market due to food shortages, the potential of crop diversification with high-value nonrice crops in rice-based irrigation systems), this new direction for irrigation sector investment, firmly established by the late 1980s, will continue to outperform construction-oriented investment.[23] Through such a change in irrigation sector investment, Sri Lanka can go into the "management" phase of irrigation development, putting an end to the "construction bias" built up during four decades of the "construction" phase.

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[23] The results of the sensitivity analyses of the rehabilitation and water management projects were not presented because the alternative scenarios assumed for new construction projects affect the rates of return for these projects equally, or even more strongly, and therefore, do not alter the conclusions. For example, the internal rate of retum of the Gal Oya rehabilitation project of 24 percent will be brought up to 53 percent with the higher price of rice, and to 63 percent with the crop diversification scenario assumed in the sensitivity analyses.

The potential provided by the new direction is limited by the irrigated land base now in place. A rough idea of this limit may be given as follows: The total irrigated land area at present is around 520,000 ha with a cropping intensity of 1.3. If the cropping intensity can be increased to 2.0 by rehabilitation and/or better water management, 364,000 ha of additional crop area can be brought in. This is equivalent to creating new irrigation systems with a total command area of 280,000 ha (almost equivalent to the total command area envisaged by the entire. Mahaweli Project upon completion, or more than 50 percent of the present total irrigated land area) at the present cropping intensity of 1.3.

Agricultural development is a necessity for Sri Lanka's economic growth. The major development efforts of the government since independence have been directed at the agricultural sector in general and toward irrigation development in particular. Countries which neglected agriculture at the early stages of their economic development have paid a heavy price in terms of lost development. Sri Lanka seems to have avoided this trap. The development of irrigation has been critical for the agricultural development of Sri Lanka, and it continues to be so, with a different emphasis. Maintaining and upgrading the performance would be consistent with the overall national development policy of attaining a higher level of performance of the entire economy.

The economy of the country as a whole needs to be diversified. An important role of agriculture in development is to supply resources to the. rest of the economy. So far, thii role has been played in Sri Lanka by the tree plantation sector (tea, rubber, and coconut); the resources that the rice sector has been absorbing from the rest of the economy, the major part of which has been for irrigation construction, are roughly comparable to the "agricultural surpluses" that the tree sector has been generating. Thorbecke and Svejnar (1987) have established the total net tax and levies from the tree plantation and the total producer and consumer subsidies to the rice sector (except irrigation investments) for 1960-1982, and it is found that the ratio between the total subsidies to the rice sector (total producer and consumer subsidies to the rice sector plus public irrigation investments) and the total net tax and levies from the tree sector is around 1.0 for most of the years during this period.

The shift from the construction to the management stage in the irrigation sector will release the bulk of these resources to the other sectors of the economy, in addition to providing foreign exchange savings/earnings if the sector is successful in crop diversification with import substituting and/or export promoting nonrice crops.

The resources that will be released from the irrigation sector by the shift from the construction stage to the management stage could be roughly assessed by assuming that: 1) the irrigated land area of the country remains at the present level of about 0.5 million 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 of rehabilitation/modernization are at the level needed for the Gal Oya rehabilitation project (about Rs 25,000/ha in 1986 prices — the "rehabilitation" needs for the water management improvement projects in Kimbulwana and Pimburettawa were one-fifth of this level); and 4) O&M needs are Rs 740/ha in 1986 prices for the entire irrigated area (the actual government O&M expenditures were about Rs 300/ha for the major irrigation systems and no expenditure was incurred by the government for the minor irrigation systems of about 180,000 ha). Based on these assumptions, the annual investment needs are estimated to be around Rs 995 million, which is less than 30 percent of the average annual total irrigation investments for the period

1978 to 1988 (the third investment peak period). At least 70 percent of the funds which have been invested in irrigation development could be released for other development purposes.

During the four decades since independence, the government. together with international donor agencies, has been responding rationally to the economic opportunities that have been provided by the irrigation sector, by developing the irrigation infrastructure. It is reasonable to expect that the government will respond positively to the new opportunities as well. In fact, though after a certain time-lag, many steps have been taken in the new direction. Many major rehabilitation as well as water management projects have been initiated and more are forthcoming. Some important principles that these projects must follow have been already established on the experiences of the recent past. The necessity for a major rehabilitation project to put heavy emphasis on institutional aspects of project implementation and system O&M is an example of such a principle.

Changes in the government policy toward the irrigation sector are clearly visible (see, for example, IIMI 1986 and 1990b). Above all, the Irrigation Management Policy Support Activity (IMF'SA), which is a new policy formulation process launched in 1990 for the transition from the construction to the management stage, represents a conscious government and donor response to the changing emphasis in the sector (IMPSA 1990).

However, there are many unknowns to be faced in guiding the irrigation sector to the new direction. The economic potentials of new opportunities are large and realizable, as exemplified by the "success" cases of major rehabilitation and water management projects studied in this paper, but the conditions necessary and sufficient to realize the potentials, particularly of the latter, are not fully known. In the case of Kimbulwana, a success story of a water management improvement project, the Technical Assistant attached to the system played a key role in the project; without him there might have been no success (Gunadasa 1989). The question then arises as to why those in other systems failed. Even for this project, there has been some criticism of the mode and sustainability of the project (Weeramunda 1985). Athukorala and Athukorala (1990) raise the same question of sustainability for the Pimburettawa case.

What are the decisive factors that made certain projects successes and certain others failures? How can a successful water management project be sustained? No systematic answers seem to have been given to the fundamental questions, and the replicability of these "success" cases is not assured without the answers. More research is needed in this field; the profitability is firmly insured by the huge economic potential of the water management improvement projects themselves.

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

Even if there are some potentials left to be exploited for new irrigation construction in some regions of some countries, the "management" orientation must accompany the development efforts. In fact, the "construction" and "management" stages are not mutually exclusive; the potentials for irrigation management per se, aside from the rehabilitation/ modernization, would not have emerged if the two had gone together. The fact that huge potentials exist for irrigation management improvement means that this has not been the case in Sri Lanka or in other developing countries of Asia.

APPENDIX I

Basic statistics used in the study and their original data sources

Data related to area and weight are expressed in the metric system. The following conversion factors are used throughout:

1 hectare	=	2.471 acres
1 bushel (rough rice)	=	20.86 kg
1 kg of rough rice	=	0.671 kg of milled rice

In the statistical tabla that follow, na stands for "data are not available."

Table A1-1. Domestic production, imports, and domestic and import prices of rice. 1949-89, Sri Lanka.

	Domestic rice production[a] (1)	Rice imports[b] (2)	Self-sufficiency in rice (%) (1)/(1)+(2)	Price of rice[c] Market (Rs/kg) (3)	Colombo c.i.f. (Rs/kg) (4)
	1,000 mt				
1949	317	602	34	na	0.38
1950	303	744	29	na	0.37
1951	459	600	43	na	0.39
1952	603	606	50	na	0.54
1953	457	612	43	0.68	0.53
1954	649	601	52	056	0.46
1955	745	575	56	054	0.39
1956	561	734	43	055	0.36
1957	653	781	46	054	0.33
1958	764	720	51	0.55	0.33
1959	759	871	47	055	0.32
1960	897	189	53	0.55	031
1961	899	700	56	055	0.31
1962	1.002	613	62	0.51	0.32
1963	1,026	602	63	0.51	0.32
1964	1,065	983	52	0.51	0.33
1965	756	419	64	0.54	0.35
1966	955	1.035	48	053	036
1967	1,145	511	69	0.65	0.40
1968	1,346	552	71	0.73	0.62
1969	1,374	461	75	0.73	056
1970	1.616	716	69	0.71	0.44
1971	1396	440	76	0.69	0.44
1972	1,312	446	75	0.70	036
1973	1.312	507	72	1.28	0.53
1974	1,602	444	78	1.96	1.63
1975	1.154	693	63	1.99	1.48
1976	1353	563	69	1.79	1.06
1977	1,677	803	68	1.69	1.14
1978	1,890	278	87	1.95	2.48
1979	1,917	315	86	2.04	2.80
1980	2,133	251	89	2.46	3.01
1981	2,229	250	90	3.31	3.87
1982	2.143	259	89	3.45	3.54
1983	2,484	219	92	357	3.49
1984	2,413	57	98	3.54	3.43
1985	2.661	314	89	3.98	3.46
1986	2,588	344	88	4.03	3.06
1987	2,128	168	92	4.27	4.08
1988	2,477	313	89	4.13	5.77
1989	2,063	471	81	5.66	731

[a] In rough rice.
[b] In rough rice equivalent.
[c] Rough rice.

Sources: (1) For 1949-51, Central Bank of Sri Lanka, *Review of Economy*, various issues; for 1952-87, Sri Lanka, Department of Census and Statistics (1988); for 1988-89, Central Bank of Sri Lanka (1989b).

(2) Central Bank of Sri Lanka, *Review of Economy*, various issues.

(3) For 1953-80, International Rice Research Institute (1988); for 1981-84, Sri Lanka, Department of Census and Statistics, *Statistical Abstract*, various issues; for 1985-87, Central Bank of Sri Lanka (1989a).

(4) Central Bank of Sri Lanka, *Review of Economy*, various issues.

Table AI-2. Area planted to rice and rice yield. 1950-88. Sri Lanka.

	Area		Rice yield					
					Yield by zone and by season			
			Based on	Based on	Wet zone		Dry zone	
	Planted (ha)	Harvested (ha)	planted area	harvested area	Maha	Yala	Maha	Yala
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			(mt/ha)					
1950	432	396	0.70	0.76	na	na	na	na
1951	435	402	1.06	1.14	na	na	na	na
1952	470	446	1.28	1.35	1.48	1.31	1.67	1.90
1953	424	384	1.08	1.19	1.35	1.22	1.37	1.76
1954	508	486	1.28	1.33	1.40	1.35	1.63	1.70
1955	545	520	1.37	1A3	1.65	1.50	1.59	1.51
1956	473	426	1.19	1.32	1.68	1.28	1A7	1.72
1957	488	460	1.34	1.42	1.91	1.41	1.61	1.95
1958	560	501	1.36	1.52	1.75	1.52	1.75	1.95
1959	530	497	1.43	1.52	1.82	1.67	1.66	2.05
1960	594	564	1.51	1.59	1.91	1.75	1.84	2.00
1961	580	569	1.55	1.58	1.80	1.73	1.80	2.04
1962	622	604	1.61	1.66	2.01	1.70	2.00	2.11
1963	632	617	1.58	1.67	1.99	1.83	1.95	2.12
19M	542	621	1.96	1.71	2.04	1.86	1.99	2.13
1965	589	503	1.28	1.50	1.89	1.65	1.71	1.93
1966	653	612	1A6	1.56	1.89	1.63	1.96	2.00
1967	663	634	1.73	1.81	1.95	1.91	2.18	2.41
1968	705	662	1.90	2.04	2.33	2.06	2.51	2.52
1969	693	623	1.98	2.21	2.58	2.23	2.69	2.70
1970	759	718	2.13	2.25	2.59	2.17	2.72	2.86
1971	725	694	1.92	2.01	2.22	2.06	2.37	2.74
1972	724	639	1.81	2.05	2.39	2.12	2.55	2.48
1973	726	672	1.80	1.95	1.98	2.01	2.47	2.42
1974	805	797	1.99	2.01	2.36	1.68	2.56	2.23
1975	687	597	1.68	1.93	2.21	1.91	2.55	2.33
1976	717	635	1.75	1.97	2.15	1.68	2.57	2.36
1977	824	782	2.03	2.14	2.13	1.95	2.89	2.51
1978	871	839	2.17	2.25	2.19	2.29	2.91	2.56
1979	839	789	2.28	2.43	2.39	2.11	2.97	2.99
1980	845	821	2.52	2.60	2.46	2.34	2.97	3.10
1981	876	842	2.54	2.64	2.61	2.38	3.10	3.35
1982	844	746	2.54	2.89	2.90	2.60	3.33	3.84
1983	824	778	3.01	3.19	3.01	2.85	3.97	4.03
1984	990	886	2.44	2.73	2.94	2.56	3.04	3.16
1985	881	864	3.02	3.08	3.06	2.59	3.67	3.77
1986	896	835	2.89	3.10	2.96	2.64	3.81	3.68
1987	782	679	2.72	3.13	3.12	2.95	3.88	3.83
1988	868	725	2.85	3.42	3.05	na	3.60	na

Sources: (1) and (2) Sri Lanka, Department of Census and Statistics, *Statistical Abstract*, various issues.
(3) and (4) from column (1) of Table A1-1 and columns (1) and (2) of this table.
(5) through (8) Sri Lanka, Department of Census and Statistics, *Statistical Abstract*, various issues.

Table AI-3. Rice land area by type of irrigation, irrigation ratio, and cropping intensity, 1948-87, Sri Lanka.

	Rice land area[a]						Irrigation ratio			Cropping intensity[c]	
	Irrigated[b]				Rain-fed	Total				Total	Major irrigation
	Major irrigation	Minor irrigation	Lift irrigation	Total							
	(1)	(2)	(3)	(4)	(5)	(6)	(1)/(4)	(1)/(6)	(4)/(6)		
	1,000 ha										
1948	81.4	159.7	0.0	241.1	162.1	403.2	34	20	60	na	na
1949	84.6	160.7	0.0	245.3	162.1	407.4	34	21	60	na	na
1950	88.2	163.7	0.0	251.9	159.2	411.1	35	21	61	105	113
1951	94.5	164.7	0.0	259.2	155.1	414.3	36	23	63	105	113
1952	102.8	166.2	0.0	269.0	148.9	417.9	38	25	64	112	122
1953	109.9	166.9	0.0	276.8	157.2	434.0	40	25	64	98	100
1954	116.3	167.5	0.0	283.8	164.5	448.3	41	26	63	113	118
1955	120.1	168.3	0.0	288.4	165.5	453.9	42	26	64	120	127
1956	123.1	169.3	0.0	292.4	162.0	454.4	42	27	64	104	99
1957	124.8	169.6	0.0	294.4	160.8	455.2	42	27	65	107	115
1958	129.1	170.0	0.0	299.1	166.0	465.1	43	28	64	120	119
1959	133.4	170.8	0.0	304.2	171.5	475.7	44	28	64	111	110
1960	135.6	171.1	0.0	306.7	169.4	476.1	44	[illegible]	64	125	136
1961	140.0	171.6	0.0	311.6	172.9	484.5	45		64	120	127
1962	144.0	172.1	0.0	316.1	175.9	492.0	46	29	64	126	136
1963	147.3	172.6	0.0	319.9	178.4	498.3	46	30	64	127	140
1964	151.7	172.9	0.3	324.9	179.2	504.1	47	30	64	107	138
1965	158.0	174.6	0.3	332.9	182.8	515.7	47	31	65	114	119
1966	162.7	175.5	0.7	338.9	182.6	521.5	48	31	65	125	138
1967	186.1	176.2	1.1	363.4	197.7	561.1	51	33	65	118	116
1968	190.5	186.3	1.4	378.2	199.9	578.1	50	33	65	122	124
1969	192.6	186.5	1.6	380.7	199.4	580.1	51	33	66	119	116
1970	193.6	188.0	2.1	383.7	199.7	583.4	50	33	66	130	136
1971	194.0	188.0	2.3	384.3	200.0	584.3	50	33	66	124	131
1972	194.4	188.0	2.5	384.9	205.2	590.1	51	33	65	123	126
1973	195.8	188.0	2.8	386.6	210.5	597.1	51	33	65	122	126
1974	197.0	188.0	3.7	388.7	208.5	597.2	51	33	65	134	139
1975	253.2	173.0	3.7	429.9	210.6	640.5	59	[illegible]	67	107	84
1976	253.2	178.0	3.7	434.9	219.5	654.4	58		66	110	93
1977	258.6	181.0	3.7	443.3	223.9	667.2	58	39	66	123	110
1978	261.4	184.3	3.7	449.4	222.4	671.8	58	39	67	130	122
1979	267.2	184.3	3.7	455.2	222.4	677.6	59	39	67	124	123
1980	269.2	184.3	3.7	457.2	224.1	681.3	59	40	67	124	123
1981	277.0	184.3	3.7	465.0	217.1	682.1	60	41	68	128	126
1982	285.8	184.3	3.7	473.8	221.3	695.1	60	41	68	121	121
1983	288.7	184.3	3.7	476.7	219.9	696.6	61	41	68	118	129
1984	294.0	184.3	3.7	482.0	219.9	701.9	61	42	69	141	145
1985	296.2	186.7	3.7	486.6	219.9	706.5	61	42	69	125	133
1986	320.2	186.7	3.7	510.6	219.9	730.5	63	44	70	123	127
1987	326.9	186.7	3.7	517.3	219.9	131.2	63	44	70	106	113

Table A1-4. Land area (in 1,000 ha) planted to rice, by zone, by type of irrigation, and by season, 1950-87, Sri Lanka.

	Drv wne						Wet m e					
	Major		Minor		Rain-fed		Major		Minor		Rain-fed	
	Maha	Yala	Maha	Yala	Maha	Yala	Maha	Yala	Maha	Yala	Maha	Yala
1950	46.0	40.5	42.6	14.0	71.2	10.1	7.1	6.0	14.3	12.3	90.9	64.1
1951	44.1	48.3	29.4	26.0	72.6	12.0	7.6	7.0	17.1	13.8	86.6	70.1
1952	59.4	52.1	57.1	21.2	73.1	8.6	7.3	6.8	20.0	14.4	82.0	68.4
1953	51.5	44.5	37.4	15.6	68.7	8.6	7.4	7.0	19.9	12.9	80.2	70.3
1954	67.0	56.2	58.0	31.9	73.2	12.7	7.7	6.3	22.0	16.2	84.0	72.5
1955	76.8	61.8	61.7	37.7	79.1	17.1	8.0	6.3	22.8	16.9	85.5	71.6
1956	77.6	30.1	58.4	12.3	81.9	9.3	7.7	6.2	24.2	15.8	83.6	65.6
1957	73.8	54.9	44.5	19.7	80.9	11.1	8.4	5.9	26.9	18.8	81.0	62.3
1958	79.4	59.6	64.6	42.1	87.7	20.9	8.0	6.4	27.5	21.1	73.1	69.2
1959	78.4	53.3	54.6	28.0	89.1	17.2	8.8	6.5	29.8	22.6	77.0	64.9
1960	95.6	72.8	68.1	34.1	93.3	18.5	8.9	6.7	28.8	22.8	78.1	66.8
1961	97.7	65.3	73.6	30.4	93.2	13.4	8.5	6.2	29.0	23.7	76.3	63.1
1962	99.6	81.6	78.3	42.7	95.8	17.7	8.1	6.5	29.0	22.3	77.0	63.0
1963	109.3	81.5	81.2	39.3	99.9	15.7	8.8	5.9	29.8	22.4	76.1	62.5
1964	108.7	84.3	84.9	33.6	102.9	17.5	8.8	7.2	29.6	23.8	75.5	65.0
1965	107.0	65.0	71.3	28.2	103.6	14.4	9.7	6.0	31.5	23.0	75.6	54.0
1966	116.4	90.2	82.9	34.0	107.4	165	11.1	6.5	32.0	22.8	75.4	57.5
1967	114.9	81.0	85.8	30.7	106.3	20.9	11.5	8.0	31.8	26.0	76.3	70.2
1968	127.3	86.9	94.5	24.4	117.7	17.7	12.6	9.1	32.3	25.8	79.9	77.1
1969	132.7	65.1	100.2	22.5	116.3	16.7	12.9	11.8	33.6	25.5	83.6	71.8
1970	134.3	105.2	102.5	39.1	115.1	20.7	12.8	11.1	33.2	26.6	84.0	74.3
1971	133.5	96.2	90.7	33.9	110.3	21.8	12.8	11.7	33.6	26.3	83.1	71.5
1972	141.1	79.3	90.0	32.9	114.3	24.5	13.9	11.7	33.1	26.1	85.7	71.7
1973	144.5	74.1	91.0	29.2	108.6	25.9	14.4	12.9	33.3	27.8	85.6	78.2
1974	156.0	95.0	98.8	38.3	119.3	27.7	11.5	11.0	35.1	31.3	91.2	88.2
1975	122.1	67.9	64.2	24.9	105.8	24.6	11.3	10.8	35A	31.4	97.2	91.9
1976	131.2	84.9	76.1	28.5	106.2	25.9	11.6	8.7	34.7	26.4	97.9	85.3
1977	169.2	92.4	103.2	37.1	118.6	28.4	11.7	10.1	34.1	28.7	97.8	92.6
1978	182.4	115.5	123.6	32.7	122.2	28.5	11.5	10.3	33.5	26.3	97.7	87.2
1979	193.7	114.6	119.8	22.5	128.3	19.8	11.0	9.0	31.1	21.2	94.1	73.5
1980	195.6	112.5	116.8	25.6	125.0	24.6	12.1	10.2	30.5	21.7	93.7	76.7
1981	208.9	116.8	118.9	24.3	131.6	21.5	12.7	10.6	32.0	23.8	92.3	83.0
1982	216.3	106.4	88.6	26.5	124.8	25.3	13.0	11.3	32.2	24.8	92.3	82.6
1983	221.4	129.1	94.2	20.2	128.1	20.5	13.2	9.3	32.8	18.2	93.2	44.0
1984	228.7	174.2	112.6	62.4	127.9	29.4	12.7	10.8	32.6	24.4	92.0	82.5
1985	224.6	145.3	100.0	30.0	109.2	21.4	12.5	10.6	33.8	26.6	88.9	78.1
1986	225.8	159.6	99.2	39.2	96.1	25.6	12.5	10.5	34.1	27.1	88.2	78.4
1987	216.6	131.5	72.7	21.1	86.2	22.2	12.6	10.0	34.4	25.4	85.5	63.6

Compilation: The dry zone includes the districts in the intermediate zone. The districts included in the wet zone are Colombo, Kalutara, Gampaha, Galle, Matara, Kegalle, Kandy, Nuwara Eliya, and Ratnapura.

Sources: For 1950-84, Sri Lanka, Department of Census and Statistics, *Statistical Abstract*, various issues; for 1985-88, Sri Lanka, Department of Census and Statistics, *Paddy Statistics*, various issues.

Table A1-5. Fertilizer use, nitrogen price, and modern variety ratio, 1950-87, Sri Lanka.

	Fertilizer[a]				Modem variety ratio[c]		
	Total fertilizer consumption (1)	Fertilizer for rice only (2)	Fertilizer use per unit area sown[b] (3)	Nitrogen price (4)	New Improved Varieties (5)	Old Improved Varieties (6)	Total (7)
	— (1,000 mt) —		(kg/ha)	(Rs/kg N)	— — —(%)— — —		
1950	31	0.3	1	na	0	0	0
1951	33	0.6	1	na	0	0	0
1952	29	0.8	2	na	0	0	0
1953	45	1.7	4	na	0	0	0
1954	48	2.3	5	na	0	0	0
1955	53	3.0	6	na	0	0	0
1956	81	5.3	11	na	0	0	0
1957	50	3.8	8	na	0	0	0
1958	47	4.0	7	1.95	0	2	2
1959	68	7.4	13	1.53	0	7	7
1960	70	5.5	9	1.20	0	15	15
1961	75	7.7	13	0.62	0	18	18
1962	79	10.2	16	0.61	0	22	22
1963	84	12.2	19	0.64	0	30	30
1964	92	15.8	25	0.76	0	41	41
1965	87	11.4	18	0.93	0	42	42
1966	91	13.9	21	0.88	0	48	48
1967	94	24.5	35	0.88	0	51	51
1968	107	29.7	41	0.94	2	60	62
1969	102	29.2	42	0.89	4	67	71
1970	105	31.9	43	0.89	9	62	71
1971	112	38.8	52	0.89	12	54	66
1972	100	38.8	54	0.97	18	51	69
1973	111	53.1	70	1.17	39	34	73
1974	110	42.9	59	2.23	55	25	80
1975	72	22.7	32	4.40	49	32	81
1976	95	33.3	42	2.19	60	22	82
1977	112	54.6	63	3.86	63	21	84
1978	140	61.5	71	2.90	63	22	85
1979	137	58.3	70	2.13	65	18	83
1980	169	84.9	98	4.65	69	15	84
1981	144	70.5	83	4.65	74	13	87
1982	155	77.1	90	6.05	89	9	98
1983	162	74.9	88	6.20	92	7	99
1984	188	86.6	91	6.62	93	6	99
1985	195	94.6	109	6.62	93	6	99
1986	200	108.9	128	6.80	na	na	na
1987	201	101.7	124	6.58	na	na	na

[a] Total nutrients (N + P + K).
[b] Total nutrients used for rice divided by area planted with rice.
[c] Ratio of area planted with modem varieties to total area planted with rice.

Compilation: On fertilizer use for 1950-60 for which the National Fertilizer Secretariat data (A) are not available, the data from IRRI's ***World Rice Statistics*** (B) are used after the following adjustments: i) since the A series gives consistently higher estimates for the total N+P+K consumption than the B series for the years for which data are commonly available, the latter series is adjusted upward by applying the average gap ratio between the two series for 1961-65 to the former series; and ii) the total N+P+K for rice during this period is estimated by applying to the total N+P+K the percentage ratio of N+P+K for rice that is obtained from the trend after 1960.

Source: (1) and (2) For 1950-60, International Rice Research Institute (1988); for 1961-87, National Fertilizer Secretariat, *The Review of Fertilizer*, various issues. (4) For 1957-84, International Rice Research Institute (1988); for 1985-87, Central Bank of Sri Lanka (1989a). (5)-(7) Rice Breeding Center of the Department of Agriculture.

Table A1-6. ***Irrigation investments by type of investment and the GDP implicit deflator for construc-lion. 1948-88, Sri Lanka.***

	Current prices				GDP	1986 constant prices			
	New con-snuction	Rehabili-tation	O&M	Total	deflator	New con-snuction	Rehabili-tation	O&M	Total
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	————Rs million			————	(1986=100)	———— Rs million			————
1948	16.07	0	2.04	18.11	0.060	267.91	0	34.08	301.98
1949	40.71	0	2.13	42.84	0.060	680.35	0	35.65	716.W
1950	60.08	0	2.00	62.08	0.064	941.77	0	31.42	973.19
1951	72.93	0	2.14	75.07	0.066	1,106.63	0	32.41	1,139.04
1952	101.25	0	2.49	103.74	0.066	1,536.31	0	37.81	1,574.12
1953	76.34	0	2.18	78.52	0.067	1,140.15	0	32.62	1,172.77
1954	47.58	0	2.37	49.95	0.067	714.14	0	35.50	749.64
1955	59.98	0	2.48	62.46	0.066	905.54	0	37.37	942.91
1956	50.77	0	2.99	53.76	0.067	753.83	0	44.37	798.20
1957	52.97	0	2.83	55.80	0.068	781.92	0	41.81	823.73
1958	41.99	0	2.96	44.95	0.069	606.79	0	42.74	649.53
1959	41.77	0	17.20	58.97	0.069	602.51	0	248.09	850.60
1960	32.84	0	9.97	42.81	0.066	494.37	0	150.07	644.44
1961	45.98	0	6.18	52.16	0.068	671.47	0	90.18	761.65
1962	41.21	0	4.99	46.20	0.065	630.91	0	76.33	707.24
1963	25.52	0	4.54	30.06	0.069	368.75	0	65.67	434.42
1964	32.98	0	4.95	37.93	0.071	462.86	0	69.48	532.34
1965	47.19	0	5.17	52.36	0.071	664.56	0	72.84	737.40
1966	40.16	0	3.63	43.79	0.071	563.22	0	50.88	614.10
1967	73.81	0	3.82	77.63	0.071	1,033.30	0	53.49	1,086.79
1968	82.95	0	4.44	87.39	0.075	1,103.22	0	59.00	1,162.22
1969	91.27	0	5.51	96.78	0.082	1,114.08	0	67.24	1,181.32
1970	91.68	0	5.58	97.26	0.085	1,079.25	0	65.70	1,144.95
1971	75.84	0	6.35	82.18	0.090	841.85	0	70.43	912.30
1972	76.95	0	11.74	88.69	0.093	829.18	0	126.54	955.72
1973	134.02	0	12.68	146.70	0.102	1,308.77	0	123.84	1,432.61
1974	104.82	0	14.69	119.51	0.121	869.36	0	121.81	991.17
1975	155.77	0	17.43	173.20	0.133	1,168.80	0	130.76	1,299.56
1976	175.87	0.41	17.71	193.99	0.144	1,218.32	2.83	122.65	1,343.80
1977	158.01	3.83	21.27	183.11	0.155	1,016.19	24.64	136.79	1,177.62
1978	387.19	11.27	22.75	421.21	0.210	1,841.68	53.62	108.22	2,003.52
1979	726.12	19.25	42.38	787.75	0.285	2,549.93	67.62	148.84	2,766.39
1980	987.12	59.89	70.84	1,117.85	0.442	2,231.08	135.37	160.10	2,526.55
1981	2,269.50	312.40	78.28	2,660.18	0.575	3,945.72	543.13	136.09	4,624.94
1982	3,033.98	218.46	89.27	3,341.71	0.667	4,545.67	327.30	133.74	5,006.71
1983	2,928.72	332.46	110.47	3,371.65	0.814	3,596.85	408.31	135.68	4,140.84
1984	2,842.68	266.33	142.66	3,251.67	0.929	3,056.00	286.59	153.51	3,499.10
1985	2,766.26	412.90	138.31	3,317.47	0.963	2,873.37	428.89	143.67	3,445.93
1986	2,100.91	524.34	169.09	2,794.34	1.000	2,100.91	524.34	169.09	2,794.34
1987	2,312.08	634.46	177.10	3,123.64	1.042	2,218.89	608.89	169.96	2,997.74
1988	1,975.46	363.01	119.75	2.458.22	1.179	1,675.54	307.90	101.57	2,085.01

Compilation: (1) New construction investments refer to the capital expenditures on construction of new systems and restoration of old abandoned systems. Included are the expenditures related to irrigation infrastructure development, such as the construction of reservoirs, dams, canals, and roads. Settlement-related costs and such overhead costs as salaries of the supervision staff are, in principle, not included. For the multipurpose projects with hydroelectric power generation, the capital costs common to both purposes, such as for reservoirs, are apportioned to each purpose in the ratio of the benefits expected from each purpose in the project appraisal reports. For the Mahaweli Project, the costs of the major upstream developments are attributed to irrigation as follows: Victoria (26%), Kotmale (25%) Randenigala (0%) and Polgolla (100%). Data are collected separately from various agencies involved in irrigation construction and aggregated into a single series. These agencies are the Irrigation Department (ID), the Territorial Civil Engineering Organization (TCEO), the River Valleys Development Board (RVDB), the Mahaweli Development Board (MDB), and the Mahaweli Engineering and Construction Agency (MECA).

(2) Rehabilitation investments cover the major irrigation rehabilitation/modernization projects, including Tank Irrigation Modernization Project (TIMP), Gal Oya, Major Irrigation Rehabilitation Project (MIRP), Irrigation System Management Project (ISMP), Integrated Rural Development Project (IRDP), and Village Irrigation Rehabilitation Project (VIRP). General administrative costs and salaries of the supervision staff are not included.

(3) O&M expenditures are defined as not including overhead costs and salaries of the agency personnel not specific to the systems.

(5) The deflator used is the GDP implicit deflator for the investments in construction. The indices for the different base-years are linked to each other without any adjustment.

Sources: (1) For 1948-59, Sri Lanka, ID, *Administration Report* (major and minor irrigation works), various issues. For 1960-88, Sri Lanka, Ministry of Finance, *Government Appropriation Accounts (vote 7)*, various issues. TCEO, *Budget Estimates* (project 101). Gal Oya Project Evaluation Committee (1970); for Uda Walawe, RVDB, *Annual Report*, various issues. For 1969-82, MDB, data of the Accounts Department. For 1983-88, MECA, data of the Accounts Department.

(2) Sri Lanka, ID, *Budget Estimates*, various issues; Sri Lanka, Department of Agrarian Services (DAS), *Administration Report*. various issues.

(3) For 1948-59, Sri Lanka, ID. *Administration Report*, various issues. For 1960-88, TCEO. *Budget Estimates*, various issues. Sri Lanka, DAS. *Budget Estimates*, various issues. Mahaweli Economic Agency (MEA), data of the Accounts Department.

(5) Central Bank of Sri Lanka, *Review of Economy*, various issues.

Table A1-7. Government budget, public investments, and foreign assistance, 1948-88 (current prices), Sri Lanka.

	Total government budget	Total public investments	Public investment in agriculture	Irrigation investments[a]	Foriegn assistance' Grants	Loans	Total
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	——— Rs Million ———						
1948	593	128	45	18	0	0	0
1949	691	164	75	43	0	0	0
1950	796	161	75	62	0	0	0
1951	969	187	93	75	0	0	0
1952	1,242	268	131	104	65	0	6.5
1953	1.200	246	116	78	33	0	3.3
1954	1,021	204	93	50	19.1	633	82.4
1955	1,068	247	120	62	26.0	12.1	38.1
1956	1,323	256	131	54	23.2	52	28.4
1957	1.506	257	125	56	10.5	15.1	25.6
1958	1.553	303	149	45	13.1	203	33.4
1959	1,773	321	179	59	18.2	29.6	47.8
1960	1,862	333	175	43	9.3	23.7	33.0
1961	2,005	362	185	52	13.3	10.4	23.7
1962	2,268	375	188	46	18.1	34.8	52.9
1963	2.185	374	168	30	31.1	60.9	92.0
1964	2,305	358	179	38	31.9	63.5	95.4
1965	2,432	428	228	52	24.1	75.6	99.7
1966	2,609	488	251	44	41.3	76.5	117.8
1967	2.825	569	310	78	19.3	189.3	208.6
1968	3.153	655	350	87	29.0	161.2	190.2
1969	3,573	729	454	97	19.5	334.1	353.6
1970	3,928	698	456	97	56.9	163.7	220.6
1971	4,143	631	416	82	59.7	220.6	280.3
1972	4.647	836	554	89	59.7	293.8	353.5
1973	5,459	864	547	147	46.6	202.0	248.6
1974	6386	927	644	119	2524	179.1	431.5
1975	7.783	1.581	638	173	404.2	454.8	859.0
1976	9,314	2.053	747	194	366.3	730.5	1,096.8
1977	9.760	1,721	657	183	500.5	880.7	1,381.2
1978	18.853	3,890	693	421	660.7	3,215.3	3,876.0
1979	21.251	5,505	938	788	1,390.4	2,846.5	4,236.9
1980	30,343	8,977	1,082	1.118	2,619.5	4,116.0	6,735.5
1981	31,094	9,350	5,095	2.660	2,721.3	4,486.8	8,208.1
1982	37.900	13,455	9,063	3.342	3,376.1	5,418.0	8,794.1
1983	46.815	13.827	8,414	3,372	3,472.7	7,477.5	10,950.2
1984	53,592	18,109	9.566	3,252	3,293.1	7,957.5	11,250.6
1985	64,685	18,950	9,478	3.317	3.306.6	8,898.3	12,204.9
1986	69.715	21.547	8.440	2,794	3.752.7	12081.3	15,834.0
1987	72,242	20,834	8,728	3,124	4,676.8	10,406.5	15,083.3
1988	88,916	na	na	2,458	6,588.2	12,336.8	18,925.0

[a] From Table A1-6.
[b] Foreign assistance received by the government.

Sources: (1) to (7), except (4) Central Bank of Sri Lanka, *Review of Economy*, various issues.
(4) Table A1-6.

Table A1-8. Selected new irrigation construction projects used in the cost-benefit analysis.

Scheme	Year construction commenced	Year construction completed[a] (90%)	Year construction completed[b] (100%)	Year settlement commenced	Command area[c] (ha)	Average gestation period[d]	Construction cost current prices (Rs/ha)	Construction cost 1986 prices (Rs/ha)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Muhathan Kulam	52	57	57	54	324	4.5	926	15,000
Dewahuwa	47	51	58	49	946	9.6	3.277	52,600
Huruluwewa	49	56	59	52	3.515	6.8	2,731	39300
Katupotha	53	56		55	202	5.2	7,921	114,600
Kandalawa Tank	52	59	60	55	842	6.3	5.107	77.100
Periya Madu	52		60	56	304	5.4	3.289	48,900
Chemamadu	54	60	60	57	243	3.8	1,235	20.699
Parakrama Samudra	46	57	61	50	7,368	11.0	1,466	22,900
Badagiriya	52	60	61	57	486	6.0	3.292	47,500
Hattota Amuna	52		61	58	202	5.9	2,970	43300
Thannimurappu	52	60	61	56	957	5.5	1,958	20.400
Horiwila	54	60	62	57	206	5.6	971	16.100
Kapakada Wewa	52	61		55	374	6.0	6,952	103,400
Akkarayan Kulam	52	61	62	62	1215	6,1	1.399	21.00
Handapangala Wewa	53	60	62	57	405	5.6	2963	44.200
Kalmadu Kulam	53	61	62	57	182	6.0	1.648	22,300
Mahawillachciya	55	60	62	55	1.079	5.3	4.819	71,000
Gal Oya	49	61	65	52	37,760	12.0	3.816	58,000
Diul Wewa	53	63	65	58	162	7.6	3.086	40,400
Pavatkulam	58	62	65	57	1,674	8.4	3.584	53,100
Usga Siyambalngamuwa	56	64	65	58	636	5.8	4,874	69,100
Mahakandarawa	57	63	65	61	2,429	4.6	3.746	55.700
Karawita Yoda Ela	56	65	66	60	444	6.9	2928	42,500
Ettimole Wewa	56	64	66	57	405	6.0	6.173	89.100
Mora Wewa	56	64	65	60	1,215	4.9	3.457	50.800
Padaviya	53	62	67	57	5,263	9.4	3.002	44.500
Kimbulwana	53	62	67	55	560	10.6	2,679	39,000
Vavunikulam	54		67	59	2,429	8.3	2,305	33,600
Hakwatuna	56	65	67	62	1.74 1	6.0	4,710	69,200
Kaudulla	59	69	69	66	1.862	6.4	3.169	47200
Kurai	57			62	215	7.6	3,256	47,200
Mahatotilla	60	68	69	64	283	6.5	2,473	35.100
Muthuiyankaddu Kulma	58	70	70	68	2,429	4.7	3,952	48.300
Visvamadukulam	60	71	71	64	327	4.8	4.893	61,400
Ambelaperumal	60	71	72	65	252	6.4	6349	82.700
Koddal Kaddina	61	70	72	65	162	6.9	3.086	37,800
Kariyali Nagapanduwa	60	72	72	63	608	7.8	3.783	51,000
Vdayarkaddu Kulam	63	72	73	63	486	6.8	2,881	37,600
Muruthawela	67	73	73	68	1310	4.2	10,992	129,400
Rajangana	57	70		57	5.523	8.8	5,812	79.200
Nagadeepa	67		73	68	1.619	4.4	8,338	99.900

Table A1-8 (Continued).

Scheme	Year construction commenced (1)	Year construction completed[a] (90%) (2)	Year construction completed[b] (100%) (3)	Year settlement commenced (4)	Command area[c] (ha) (5)	Average gestation period[d] (6)	Construction cost current prices (Rs/ha) (7)	Construction cost 1986 prices (Rs/ha) (8)
Pimburattawa	69	75	75	68	1.619	4.2	7,597	55,000
Wahalkada	73	78	79	74	810	4 2	24.074	141.100
Uda Walawe	64	75	81	64	17,600	12.0	11.852	130,500
Mahadivulwewa	76	81	82	80	486	3.6	69.136	188,900
Muthukandiya	79	82	83	80	810	4.2	76.296	180,100
Inginimitiya	79	85	87	81	2,644	5.1	130,408	168.800
Kirindioya Phase 1	78	86	88	86	8,951	5.9	142,224	184,100
Mahaweli System-C	78	87		80	26,500	6.0	172351	200,700

[a] The year 90% of the total expenditure incurred.

[b] The year 100% of the total expenditure incurred.

[c] The command area after the completion of the construction project.

[d] Average gestation period of the captial investments.

Compilation: (6) Average gestation period of the capital investments is obtained as the weighted average of gestation years of the capital investments made each year during the construction period, using the value of the investment in constant prices as weights.

(7) Construction cost includes capital expenditures related to irrigation infrastructure development of each new construction project. Costs related to settlement, supervision and general administration are, in principle, not included

Sources: (1) (3), and (6) (7) Sri Lanka, ID *Administration Report*, various issues; Sri Lanka, Ministry of Finance, *Government Appropriation Accounts*, various issues; and other various unpublished accounts data from ID, MEA, and RVDB.

(4) Land Commissioner's Department.

(5) For the systems completed before the mid-1960s except Gal Oya, Arumugam (1969); for Gal Oya (new construction), Gal Oya Project Evaluation Committee (1970); for the rest, data from ID and MEA.

APPENDIX II

Data and estimations of the costs and benefits of sample major irrigation rehabilitation and water management improvement projects, and estimated rates of return for different assumptions on the crucial parameters.

Benefits of the Projects

As in the new construction projects, the returns to the rehabilitation/water management improvement projects are defined as the increase in income (gross value added) in agricultural production attributable to the projects.

The benefits so defined include the returns on the labor used in additional agricultural production due to the projects. As long as the opportunity cost of such labor is zero all of the increase in value added is considered as benefits. However, if the labor has a positive opportunity cost, the income forgone because of the transfer of labor from previous employment to this additional agricultural production must be deducted from the gross value added. In reality, the opportunity cost of labor in major irrigation schemes in the dry zone, particularly that during off-fanning seasons (e.g., a yala season without cultivation because of lack of water), could be quite low, if not zero. Here, the estimation of the benefits is made for two polar cases of labor opportunity cost: zero opportunity cost, and positive opportunity cast evaluated at the wage rate in agriculture.

The benefits of rehabilitation/water management improvement projects are numerous. Among them are increases in the command (irrigable) area, increases in cropping intensity, and increases in crop yield due to better water adequacy. More equitable water distribution within a system is expected to reduce productivity differences between tail- and head-end sections, a chronic problem of mismanaged systems. particularly in the case of water management improvement projects. In addition to these direct benefits, there could be indirect ones. For example, well-rehabilitated/better-managed systems may cost less for O&M than what it was before the project. Well-organized water-used groups, which usually constitute the central component of water management improvement projects, would be instrumental in achieving more effective maintenance. less damage to the physical structure, better water distribution, less wastage of water and more cropping intensity, better crisis management in times of drought, etc.

In this study, only two possible project benefits are taken into account increase in cropping intensity (including increase in the imgable area), and reduction in yield gaps between head- and tail-end sections due to better water distribution after the project. Other benefits, including yield increases not specifically related to rehabilitation/water management, will be discarded.

The crop to be grown for additional agricultural production is assumed to be rice, with a gross value added ratio of 80 percent. The level of rice yield is identified by system whenever possible. In addition, the yield level derived from thence-fertilizerrse function of New Improved Varieties, reported by Kikuchi and Aluwihare (1990), will be adopted wherever appropriate.

Evaluation of Cost and Returns

The costs of a project and its returns are evaluated at 1986 prices. The GDP implicit deflator for construction is used as a deflator. The prices of rice and nitrogen are fixed at the averages of the domestic market prices for 1985-87. It should be noted that the domestic price of rice during this period was almost at the same level as the Colombo c.i.f. price. For a positive opportunity cost of labor, the factor share. of labor in rice production is assumed to be. 25 percent, based on the production cost surveys of the Sri Lanka Department of Agriculture (various issues).

TANK IRRIGATION MODERNIZATION PROJECT

The system of the projecf. The Tank Irrigation Modernization Project (TIMP) was the first major irrigation rehabilitation project in Sri Lanka, under which five tank systems, Mahawilachchiya (1,053 ha), Mahakandarawa (2,429 ha), Padaviya (5,061 ha), Pavatukulam (1.781 ha), and Vavunikulam (2,429 ha), all situated in the northern dry zone, were rehabilitated.

The project had the following objectives: i) increasing the cropping intensity through crop diversification in the dry season: ii) early land preparation for wet-season rice, based on mechanization and dry seeding, to use early rainfall and conserve tank water for the following dry season: iii) use of short-duration rice varieties in the wet season; iv) improving equity of water distribution through the introduction of a strict rotational delivery schedule: and v) redesigning of the conveyance system, lining distributary and field channels, introducing water measurement capacity within the systems, and constructing cross-regulators in the main canals (World Bank 1976, Murray-Rust and Rao 1987). The project commenced in 1976 and was completed in 1984. As pointed out by Murray-Rust and Rao (1987), emphasis was given to the engineering aspects and little attention was paid to the institutional aspects of the rehabilitation process and water management after the projecr

Cost of the project. The capital investments of the project are summarized in Table A2-1. The average gestation period of the investments is estimated to be 4.0 years.

Benefits of the projecf. Although Abeysekera (1984) and Murray-Rust and Rao (1987) report some positive effects in selected systems included in the project, no definite observation as to the changes in cropping intensity and rice yield after project completion can be derived from these reports as the available data on the impact of this project on the actual performance of the systems involved are inadequate. For example, Murray-Rust and Rao, while appreciating the positive impact the project bad on the reliability and equity of water distribution (due mainly to the introduction of parallel, Lied channels), failed to find out any systematic change in the cropping intensity attributable to the project.

Table A2-1. Capital investments in the Tank Irrigation Modernization Project.

	Current prices (Rs 1,000)	Deflator[a]	1986 prices (Rs 1,000)
1976	408	0.144	2,838
1977	3,831	0.155	24.714
1978	12,038	0.210	57,323
1979	47,050	0.285	165,090
1980	83355	0.442	188,587
1981	49,086	0.575	85,367
1982	53.924	0.667	80,845
1983	36,870	0.814	45.295
1984	1,263	0.929	1360
Total	287,825		651,419
Total command area (ha)			12,753
Cost per ha (Rs)			51,080

[a] GDP implicit deflator for construction.

Source: Irrigation Department

Here, it is assumed that the cropping intensity of the five systems increased from the pre-project level of 1.02 to 1.56 as projected in the appraisal report (World Bank 1976, pp. 40 and 105). In addition, as in the Gal Oya Water Management Project, a yield increase of 377 kg/ha due to more equitable water distribution is assumed. The yield level of New Improved Varieties with N=120 kg is assumed to be the rice yield. Since the rehabilitation of the first three tanks was completed by the end of 1982, it is assumed that a part of the benefits accrued from 1983. These assumptions me highly optimistic, and do not necessarily represent the reality. They are made here so as to estimate the best possible benefits from the project, unlike in the other projects analyzed in this appendix where project benefits me estimated as conservatively as possible using the actual data.

GAL OYA WATER MANAGEMENT PROJECT

The system of the project. The Gal Oya Scheme, situated in the eastern dry zone, is the first multipurpose, large-scale irrigation scheme in Sri Lanka. Construction commenced in 1949 and the main reservoir of 950 million cubic-meter capacity was completed by 1955. The entire construction project including the downstream developments was completed in the early 1960s. The reservoir serves its command area through the Left Bank. the Right Bank. and the river diversion. In 1981. the service areas were estimated to be about 25,000 ha, 11,200 ha, and 11,400 ha, respectively. Except for an area of 4,000 ha under the Right Bank where sugar cane is planted, the system service areas are planted to rice.

In 1979, a major rehabilitation and improvement project aimed at enhancing the conveyance, control and measurement capacities/efficiencies of the system was undertaken on its Left Bank. The major components of physical rehabilitation were: a) the removal of silt and rehabilitation of eroded embankments including the Left Bank main canal, the branch canal and distributary and field channels; b) the repair and replacement of control gates, and repair or construction of regulators and other structures in the canal-channel system; and c) the repair and installation of measuring devices and the recalibration of measurement structures. The project started in 1980, and the major part of the rehabilitation was completed by the end of 1985, though some of the downstream works continued until 1988.

An innovative feature of this rehabilitation project was its strong emphasis on farmers' participation in the project itself and in O&M after completion of the project. Substantial efforts were made to mobilize farmers' knowledge in the design process and to form effective farmers' organizations. Further, intensive training programs for the farmers as well as for the officers in the managing agencies were carried out under the project (Merrey and Murray-Rust 1987, Uphoff 1986, Wijayarame 1986b).

Cost of the project. The capital investments of this project are summarized in Table A2-2. It is difficult to obtain a reliable figure for the command area (irrigable area) under the Left Bank of the system. And there are no accurate estimates for the pre-project and post-project situations. The Project Appraisal Report assumes command areas of 21,000 ha and 23,000 ha before and after the project, respectively, while the Final Evaluation Report assumes that the command area increases from 17,000 ha to 21,500 ha because. of the project (ISTI n.d.). In 1981, the Irrigation Department estimated the Left Bank rice land area to be 30,500 ha (Svendsen and Wijayaratne 1982, p. 78). In this study, based on the Agrarian Research and Training Institute (ARTI) and Cornell University (n.d.), the irrigable area under the Left Bank is assumed to be 25,000 ha both before and after the project. Assuming that the full benefits of the project started to be realized after 1985, the average gestation period of the capital investments is estimated to be 3.1 years. It is assumed that a part of the benefits started accruing in 1984.

Benefits of the project. As was the case in the command area. it is difficult to accurately estimate the change in the cropping intensity due to the project Of the available estimates. the one by ARTI and Cornell University (n.d.), regarded as the most conservative, is adopted here. According to this estimate the cropping intensity increased from the pre-project level of 1.21 to a post-project level of 1.65.

There have also been various estimates of the rice yield per ha before and after the project. The best estimate for the average rice yield in the system can be obtained from the water response functions estimated by Wijayaratne (1986a, p. 166) using data of the 1980/81 maha to 1982 yala seasons; $Y = -297+41 * WAI$, where Y=rice yield (kg/ha) and WAI=water availability index. The water availability indices of these four seasons are summarized in Table A2-3. Since the impact of the project on water distribution became apparent in and after the third year of the project (ARTI and Cornell University n.d., pp. 93-99), these four seasons represent the pre-project situation of water availability in the system. Assuming that the water availability after the project reaches the level that the three head-end sections enjoyed before the project, the average rice yield after the project is estimated to be 3,188 kg/ha. This level of yield is fairly consistent with the actual yield obtained from the farm-record-keeping survey conducted in the scheme by ARTI and Cornell University (n.d., p. 107).

Table A2-2. *Capital investments of the Gal Oya Water Management Project, 1980-87.*[a]

	1980	1981	1982	1983	1984	1985	1986	1987	Total[b]	
	Rs 1.000									
1. Physical rehabilitation	2,375	6,989	17.810	42,654	54,423	82,614	7,271	9,960	224,096	(SO)
2. Machinery and equipment	22,803	29,297	7,919	3,013	5,609	8,498	2,716	3,720	83,575	(18)
3. Master plan and on-farm research	29	139	137	103	0	0	0	0	408	(0)
4. Central support	2,749	14,590	19,395	15,525	22,508	8,772	2,935	4,020	90,494	(20)
5. Training	1	658	5,025	3.705	7,695	3.138	715	980	21,917	(5)
6. Research	2.100	1,511	3,436	11,048	3,989	2323	861	1.180	26,448	(6)
7. Contingencies	133	1,713	131	172	857	5	102	140	3,253	(1)
Total	30,190	54.897	53,853	76,220	95,081	105350	14,600	20,000	450.191	(100)
(Deflator)[c]	(0.442)	(0.575)	(0.667)	(0.814)	(0.929)	(0.963)	(1.000)	(1.080)		
Total in 1986 prices	68303	95,473	80,739	93.636	102348	109398	14,600	18519	583.016	

[a] Figures for 1986 and 1987 are provisional.
[b] The percentage share of the total investment is given within parentheses.
[c] GDP implicit deflator for construction.

Source: Irrigation Department.

If the distribution of water was indeed improved and more equitable distribution within the system was achieved after the project, there should have been an increase in rice yield in the tail-end sections over the pre-project level. A possible magnitude of such an increase would be obtained by assuming an increase in the water availability index from the overall average of the Left Bank of 75.8 to the average of head-end subsections of 85.0. Inserting the difference into the water-yield response function given above, a 377 kg/ha of yield increase per crop due to better water management is obtained. Note that the yield increase due to the reduction in yield gaps is applicable only for the crop area before the project. It is also assumed that no additional current input is required for this increase.

Table A2-3. Water availability index of the Gal Oya Left Bank during the four seasons of the pre-rehabilitation stage.

	Left Bank average[a]	Head-end sections[b]	Best[c] section	Tail-end sections[d]	Worst[e] section
1980/81 maha	76.1	84.8	88.3	69.8	665
1981 yala	73.0	85.1	87.9	61.2	65.9
1981/82 maha	78.1	85.5	89.6	72.6	60.9
1982 *yala*	76.0	84.4	85.1	70.6	675
Average	75.8	85.0	81.7	70.1	65.2

[a] Weighted averages of nine sections under the Left Bank using the rice areas as weights.
[b] Weighted averages of the three sections which had the best, second best, and third best water availability indices.
[c] The water availability index of the best section.
[d] Weighted averages of the three sections which had the worst, second wont. and third worst water availability indices.
[e] The water availability index of the worst section.

Source: Wijayaratne (1986a, pp. 155-158).

KIMBULWANA WATER MANAGEMENT PROJECT

The system *of the* project. The Kimbulwana Scheme, situated in the Kurunegala District of the North-Central Province, is a medium-sized irrigation system, with a command area of 666 ha at present. The Kimbulwana tank, whose origin can be traced back to the third century A.D., was restored in 1957. Later in 1965, the tank capacity was increased to 629 hectare meters by raising the spillway level by 1.22 meters. This brought about an increase in the command area from about 400 ha to 560 ha (Gunadasa 1989). The system has two main canals. At present, the Right Bank canal irrigates 564 ha of mainly settlement land, while the Left Bank canal irrigates 102 ha of *purana* (old) land.

By 1979, the physical structure of the system had deteriorated to a considerable extent due to insufficient maintenance: the canals had damaged bunds, scoured profiles, and eroded embankments. As a consequence, the capacity of the canals to carry discharges was far below design, and the maximum designed discharge could not be released through the channels without overtopping and/or breaching the tank. Even in the maha season, the tail-end farmers failed to cultivate the land because of water shortages. Yield gaps between the head- and tail-end sections were large due to inequitable water distribution. Quite often, the yala season crop failed partially or completely due to lack of water in the tank.

In order to bring the system's physical capacity back to the designed level, the rehabilitation of the system was undertaken in 1979-80. What was intended initially was "physical" rehabilitation of dilapidated channels, embankments, and concrete structures. A Technical Assistant was assigned to the system to oversee the rehabilitation project. He organized the project in such a way that the farmers in the system were highly involved in the rehabilitation work through work groups which they themselves formed. These work pups later became the farmers' groups that performed O&M functions of the system, by themselves. under the supervision of the Technical Assistant After the rehabilitation, with the help of farmer groups, the Technical Assistant introduced a strict water rotation system to insure, an equitable distribution of irrigation water within the system.

Cost of the project. The capital investment cost of this rehabilitation-cum-watermanagement project was Rs 1 million in current prices (Gunadasa 1989). The rehabilitation works were split into two seasons; first, April-September 1979 for the head-end part and second, April-September 1980 for the tail-end part. Assuming a uniform disbursement pattern in the two seasons, the total capital cost in 1986 prices is estimated as shown in Table A2-4.

Table A2-4. Investments in the Kimbulwana Water Management Project.

Year	Current price.	Deflator (1986=1.000)	1986 price
1979	Rs 500,000	0.285	Rs 1,754,000
1980	Rs 500,000	0.442	Rs 1,131,000
Total			Rs 2,885,000
Capital cost per ha of command area (666 ha)			Rs 4,332/ha

The mean gestation period of the capital investments is assumed to be 1.5 years. It is assumed that no benefits accrued before project completion. It should be noted that the capital investment cost here covers only physical costs; the services devoted by the Technical Assistant are difficult to value and are not taken into account.

Benefits of the project. The rehabilitation and subsequent improvements in water management first brought about an increase. in the irrigable area from 560 ha to 666 ha. Second, it brought about a Substantial increase in the cropping intensity. Before the rehabilitation, crops in the tail-end sections often failed even during the maha season. The farmers could plant crops during the yala season, at best, once every two years. An overestimated cropping intensity of 1.5 is assumed here for the pre-project situation, which is equivalent to 1.26 in terms of the new command area. The cropping intensity improved significantly after the completion of the project and a third crop became possible for some years; the cropping intensity was as high as 2.21 in 1983 and 2.04 in 1985. For the rest of the post-project years, the intensity was 2.0, except in 1987 when it declined to 1.3 due to a serious drought. On the average, for 1981-1989, the cropping intensity of the scheme was 1.95.

The rice yield per ha in the system for 1977-1978 is given in Table A2-5. The average yield increased substantially after the project; for the system as a whole, the average yield per Season increased by nearly 50 percent. Reflecting more equitable water distribution after the project, the increases in yield have been much more distinct in the tail-end sections of the Right Bank and the Left Bank. As a result, the yield gaps of these sections relative to the head-end section have been reduced.

Table A2-5. Rice yield per hectare (mt/ha) in the Kimbulwana system, by season and by location in the system.

	Right Bank (564 ha)				Left Bank (102 ha)	
	Head (271 ha) FC 1-20		Tail (293 ha) FC 21-50 & BC2			
	Maha	Yala	Maha	Yala	Maha	Yala
1978	2.73	2.78	2.22	2.22	n.a.	0.77
1979	3.25	Rehab.	237	2.22	0.93	0.88
1980	3.50	3.35	2.22	Rehab.	1.03	1.13
1981	3.50	356	3.25	3.40	1.29	1.19
1982	3.61	3.81	350	3.76	155	2.37
1983	3.81	3.81	3.71	3.71	2.42	2.32
1984	3.81	3.97	3.26	3.92	232	2.63
1985	4.02	3.76	3.76	356	2.99	258
1986	4.07	356	4.02	3.45	2.47	2.42
1987	3.50	n.a.	3.40	n.a.	2.27	n.a.
Average[a]:						
Before project (a)	2.99	2.78	2.27	2.22	0.98	0.93
After project (b)	3.73	3.69	3.56	3.63	2.19	2.25
(b)/(a)	(1.25)	(1.33)	(1.57)	(1.63)	(2.23)	(2.42)
Yield differential relative to the head-end yield (ratio):						
Before project			0.76	0.80	0.33	0.33
After project			0.95	0.98	0.59	0.61
Average yield for the system as a whole and for maha and yala:[b]						
Before project (a)		2.31				
After project (b)		3.44				
(b)/(a)		(1.49)				

[a] Yields before and after the project are demarcated by a line in each column.
[b] Weighted average using the area of each location as weight. For the maha and yala seasons, 1:1 weights are assumed.

Source: Gunadasa (1989).

The impact of this reduction on the average yield of the system as a whole can be derived as follows: Let Y and Y_h be the average yield of the system as a whole and that of the head-end section of the Right Bank, respectively. Then, $Y = (\alpha_h + \alpha_t \beta_t + \alpha_l \beta_l) Y_h = \delta Y_h$, where α_h, α_t, and α_l are the percentage share of area in the total command area of the head-end, tail-end, and Left Bank sections, respectively, and β_t and β_l are the yield ratios of the tail-end and Left Bank sections relative to the head-end section. Assuming that there has been no change in yield in the head-end section before and after the project, and distinguishing the pre-project and post-project states by the subscripts 0 and 1, respectively, the change in the average yield for the scheme as a whole due to the yield gap reductions is expressed as: $Y_1 - Y_0 = (1 - \delta_0 / \delta_1) Y_1$. The data give a 14 percent increase in the average yield.

The average post-project rice yield per ha was 3.44 mt. (A survey on the 1988/89 maha crop in the system gives 84 percent of value-added ratio with a yield of 3.8 mt/ha.) In the yala season about 20 percent of the command area has been planted with various nonrice crops. Assuming that the income-generating capacity of these nonrice crops is 50 percent of that for rice, the average yield per ha for the scheme as a whole in terms of rice equivalent is about 3.2 mt/ha.

PIMBURETTAWA WATER MANAGEMENT PROJECT

The system of the project. The Pimburettawa System, located in Polonnaruwa, is a part of Mahaweli System B, consisting of 9 tracts with a total command area of 2,150 ha. The construction of the system started in 1969 and was completed in 1975. From the commencement of operations, the system had been operated and maintained by the Irrigation Department until 1982 when the management was handed over to the Mahaweli Economic Agency.

The full storage capacity of 40,000 acre-feet of the F'imburettawa tank is sufficient to provide an adequate water supply to the entire system, if water is equally distributed among the sections in the scheme without substantial losses. In reality, however, because of lavish water use by the head enders, many tail enders of the scheme were not able to receive water. In order to attain more equitable water distribution, a water management project was begun in mid-1986. It had two components, minor hardware rehabilitation and building of farmer organizations. Under the rehabilitation component, deteriorated canal systems were improved and a few new distributary channels added to facilitate water distribution to the tail-end sections. Under the farmer-organization building component, a nongovernmental organization played a role as change agent, The project continued for three years until mid-1989.

Cost of the project. The investment cost of this pilot project is shown in Table A2-6. It is assumed that the average gestation period of the investments is 0.5 years.

Table A2-6. Investments in the Pimburettawa Water Management Proiect. in 1986 orices.

	(Rs 1,000)	(%)
1. Rehabilitation of structures	9.870	(81)
2. Institution building		
a. USAID[a]	1,805	(15)
b. NBA[b]	89	(1)
3. Farmers' labor contribution	370	(3)
Total	12,134	(100)
Unit cost per hectare (Rs)	5,636[c]	

[a] USAID = United States Agency for International Development.
[b] NBA = Nation Builders' Association (nongovernment organization).
[c] Assuming a total command area of 2.153 ha.

Source: Athukorala and Athukorala (1990).

Benefits of the project. Since this project aimed at distributing water to the tail-end sections which received no water either in the yala or the maha season, the major benefit of the pmject was the increase in the cropping intensity. Table A2-7 shows the changes in the cropping intensity from the 1985 yala to the 1989 yala. The benefits of the project started to be realized one to two years after the project had begun. It should be noted that such increases in the cropping intensity were brought about in spite of the lower water availability in the tank during this period (Athukorala and Athukorala 1990). Based on these data, the change in the cropping intensity was estimated by dividing the data series into two periods. With an assumed total command area of 2,153 ha, the cropping intensity increased from 1.25 to 1.88. The rice yield per hectare is also given in Table A2-7. There has been no appreciable change in the yield before and after the project for either season. The 1988-1989 average yala season yield of the tail-end sections 3,138 kg/ha, is assumed to be the yield for the system as a whole.

NAGADEEPA WATER MANAGEMENT PROJECT

The system of the project. The Nagadeepa Scheme is situated in Badulla District. The Nagadeepa tank, which receives water from the Hepola Oya River, a tributary of the

Table A2-7. Extent planted to rice and nonrice crops and rice yield per hectare in the Pimburettawa system. 1980-89.

	Planted area							Rice yield			
	Rice		Nonrice		Total			Head end		Tail end	
	Maha	Yala	Maha	Yala	Maha	Yala	Total	Maha	Yala	Maha	Yala
	ha							kg/ha			
1980	na	na	na	na	na	na	na	na	2.319	na	3,236
1981	na	na	na	na	na	na	na	3.658	3,009	2,741	3,241
1982	na	na	na	na	na	na	na	3,550	3.024	3,895	3,272
1983	na	na	na	na	na	na	na	3.648	3.128	3,890	3,962
1984	na	na	na	na	na	na	na	3.751	3.210	3.612	3,447
1985	na	859	na	55	na	914	na	3,751	3,246	4.199	3.318
1986	974	1.567	144	181	1,118	1.748	2,866	3.720	3,205	4.323	3.395
1987	1.705	941	128	66	1,833	1,007	2.840	3,643	3,627	4,323	3.328
1988	1,834	1.867	122	199	1,956	2,066	4.022	3.888	3,560	4.204	2,782
1989	1,889	1.737	264	202	2,153	1,939	4,092	3,875	3,565	4,199	3,493
Average:											
1980-1987					1,476	1.223	2,699	3,674	3,096	3,855	3,400
(Cropping intensiiy)							(1.25)*				
1988-1989					2.055	2.003	4.058	3.878	3.563	4,202	3,138
(Cropping intensity)							(1.88)*				

* Assuming a total command area of 2,153 ha.

Source: Athukorala and Athukorala (forthcoming)

Mahaweli River, was constructed during **1967-1970.** The system was originally planned to irrigate 1,680 ha of rice fields and **650** ha of upland fields through pump irrigation (JICA 1986). However, the upland irrigation had to be abandoned because of insufficient water and the high cost of pumps. At present, the system serves about 2,640 ha of the command area which is planted to rice as well as to nonrice crops, even in the *maha* season. Because of water shortages the system generally allows rice cultivation in the *yala* season to a limited extent, and nonrice crops can be grown in a very small part of the system. A water management improvement project similar to the one in Pimburettawa was implemented in this scheme in 1986-1989. As to institution building, the project has the same structure as in Pimburettawa, with the difference that in the case of Nagadeepa, the physical rehabilitation component was less-pronounced than in Pimburettawa.

The cost of the project. The total cost of the project is shown in Table **A2-8.** Note that the amount spent for physical rehabilitation was about Rs 500/ha, which is less than the assumed level of O&M cost per ha.

Table A2-8. *Investments in the Nagadeepa Water Management Project,* in *1986 prices.*

	(Rs 1,000)	(%)
1. Rehabilitation of structures	1,345	(42)
2. Institution building		
a. USAID	1,556	(48)
b. NBA	88	(3)
3. Farmers' labor contribution	225	(7)
Total	3,214	(100)
Unit cost per hectare (Rs)	1.217[a]	

[a] Assuming a total command area of 2,640 ha.

Source: Athukorala and Athukorala (1990)

Table A2-9. Extent planted to rice and nonrice crops and rice yield per hectare in the Nagadeepa system, 1980-89.

	Planted area							Rice yield			
	Rice		Nonrice		Total			Head end		Tail end	
	Maha	Yala	Maha	Yala	Maha	Yala	Total	Maha	Yala	Maha	Yala
	ha							kg/ha			
1980	na	na	na	na	na	na	na	na	2.061	na	1.030
1981	na	na	na	na	na	na	na	2,581	1,649	2,205	3,777
1982	na	na	na	na	na	na	na	2,916	2.061	2,391	3.349
1983	na	na	na	na	na	na	na	2,597	2.061	2,277	4,380
1984	2,028	0	0	315	2.028	315	2,343	2,355	na	2.334	1,417
1985	na	na	na	na	na	na	na	2,746	na	2.339	3,607
1986	1.869	664	430	955	2,299	1,619	3,918	2,540	1,711	2.422	3.731
1987	1,869	0	518	532	2,387	532	2,919	2,813	2,009	2,782	1,298
1988	1,840	615	801	623	2,641	1.238	3.879	2,885	1.479	3,808	1,556
1989	1,809	31	343	254	2,152	285	2,437	2.695	2,690	2,123	2664
Average:											
1980-1987					2,238	823	3,061	2,650	1.925	2,393	3,080
(Cropping intensity)							(1.16)[a]				
1988-1989					2.397	762	3.159	2,790	2.085	2.966	2,110
(Cropping intensity)							(1.21).				

[a] Assuming a total command area of 2,640 ha.

Source: Athukorala and Athukorala (1990).

The benefits of the project. The changes in the cultivated areas and rice yield in the scheme are shown in Table A2-9. Variations in cultivated area across years were very large in the yala as well as in the maha seasons. It is also difficult to detect any positive impact of the project on rice yield. Though doubtful, it is assumed that the benefits of the project came only from an increase in the cropping intensity from 1.16 to 1.21, with a constant rice yield of 2.7 kg/ha.

Results of Estimations for Different Assumptions

The results of the estimation of benefit-cost ratios and internal rates of return for the sample rehabilitation/water management projects for some of the assumed parameters are summarized in Table A2-10.

The internal rate of return for the Tank Irrigation Modernization Project (TIMP) is estimated to be 11 percent with zero opportunity cost of labor. For this project the best possible benefits, which were not actually supported by the real data, were assumed. The

Table A2-10. Benefit-cost ratios and internal rates of return of the sample rehabilitation and water management improvement projects for alternative assumptions.

	Assumption					B/C ratio	Internal rate of return
	Opportunity cost of labor	Yield level	Yield-*gap* reduction	Life-time (n) (years)	O&M cost (c) (Rs/ha)		(%)
I. Major rehabilitation projects							
TIMP	off	NIV	on	20	740	1.1	11
	on	NIV	on	20	740	0.8	8
Gal Oya	off	NIV	on	20	740	2.3	24
	off	3.2t	on	20	740	1.9	20
	off	3.2t	off	20	740	1.3	14
	on	NIV	on	20	740	1.8	18
	on	3.2t	on	20	740	1.4	15
II. Water management projects with minor rehabilitation							
Kimbulwana	off	3.21	on	15	740	13.4	83
	off	3.2t	off	15	740	9.9	69
	off	3.21	off	9	740	7.5	68
	on	3.2t	on	15	740	10.7	72
	on	3.2t	off	9	160	6.1	60
Pimburettawa	off	3.1t	off	15	740	7.4	77
	off	3.1t	off	2	0	1.9	53
	on	3.1t	off	15	740	5.3	58
	on	3.1t	off	2	0	1A	32
Nagadeepa	off	2.7t	off	2	0	0.4	6

[a] Labor employed in additional agricultural production due to the projects is assumed to have no opportunity cost if "off," and to have an opportunity cost evaluated at the average wage rate in the rim labor market if "on."

[b] The assumed rice yield level per ha. NIV stands for the yield level estimated by the rim fertilizer response function at the nitrogen input of 120 kg/ha. In all cases. no yield change before and after the projects is assumed. except the yield *gap* reduction.

[c] The reduction in yield gaps between head- and tail-end sections due to better water distribution within the system after the project is taken into account as a part of the project benefits if "on," and not taken into account if "off."

would-be yield-gap reduction due to better water management after the project is "on" for TIMP and the Gal Oya rehabilitation project. Even at that benefit level, TIMP yields an internal rate of return barely above 10 percent, which is usually used as the break-even rate of return for the project appraisals of this kind. The assumption of a positive opportunity cost of labor, evaluated at the wage rate in the rural labor market, reduces the rate of return to 8 percent.

For the Gal Oya Water Management Project, the internal rate of return with zero opportunity cost of labor is estimated to be 20-24 percent depending on the rice yield level assumed. If the gain derived from the productivity increases in the tail-end sections due to better water management after the project is excluded, the rate is still 14 percent, far above that of TIMP. Even with a positive opportunity cost of labor the rate of return is estimated to be 15 percent or more.

For this project, at least three different sets of estimates of the internal rate of return have been made: 23.2 percent of the Project Appraisal Report, 47.4 percent of the Final Evaluation Report (ISTI n.d.), and 17 percent of the End-of-project Impact Report by the Agrarian Research and Training Institute (ARTI) (ARTI and Cornell University n.d., p. 157). Of these estimates, 17 percent (i.e., the estimate by ARTI) is the closest to the estimate of this research study. However, it should be noted that there are large differences between these two estimates in terms of the assumptions made. First, cost data of this research study are more accurate since data were gathered after the entire project had been completed. Second, unlike the other estimates, they are based on 1986 constant prices. Thud, any arbitrary yield increase after the project was not assumed, whereas the ARTI study assumes, without specifying any ground, that the yield increases from the initial level of 3.1 t to 4.9 t. Similar assumptions are made in the other two estimates. In particular, the assumptions made in the International Science and Technology Institute (ISTI n.d.) study on yield increases (from 3.8 t to 4.5 t) and the cropping intensity increases (from 1.29 to 2.20, including an increase in irrigable area) are so different from the reality that the resulting rate of return is unduly overestimated.

For the water management improvement-cum-minor rehabilitation projects, the economic performance is astonishingly high compared to the major rehabilitation projects. In the case of Kimbulwana, the internal rate of return is estimated to be 60-83 percent. The highest estimate is obtained for the case in which the increases in income due to the cropping intensity improvements and the yield-gap reductions are both "on" with no labor opportunity cost. The lowest estimate is for the case where the life span of the project benefits is assumed to be the nine years that have already been attained, while assuming a positive opportunity cost of labor and no gain from the yield-gap reduction. In this case, the O&M cost is assumed to be Rs 160/ha which was the actual O&M expenditure level in 1986 prices for 1985-87 in this system (IIMI 1989, 2.34).

Similarly, the Pimburettawa Project shows very high internal rates of return. With a rather modest assumption made on the rice yield of the scheme, if the project benefits are kept accruing for 15 years, it is expected that the project investments will bear a rate of return as high as 77 percent with zero opportunity cost of labor, or 58 percent with positive opportunity cost of labor. Even if it is assumed that the benefits accrued only for two years and "evaporated" soon after the change agent for institution building had left the system, the project generated benefits worth 32-53 percent of the internal rate of return.

In the case of the Nagadeepa system, where without any substantial improvements in the physical structure little benefit due to the water management improvement project could be detected, the internal rate of return is estimated to be 6 percent with the assumption that the benefits accrued for two years without O&M cost.

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