PA-ABA-044

AGRICULTURAL POLICY ANALYSIS PROJECT, PHASE II

Under contract to the Agency for International Development, Bureau for Science and Technology, Office of Agriculture
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TRENDS AND POLICY DIRECTIONS FOR IRRIGATION INVESTMENT AND MANAGEMENT IN SRI LANKA

February 1992

APAP II
Collaborative Research
Report No. 323

Prepared for

Agricultural Policy Analysis Project, Phase II (APAP II)
A.I.D. Contract No. DAN-4084-Z-00-8034-00

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ACRONYMS

ARTI	Agrarian Research and Training Institute
c.i.f.	cost, insurance, and freight
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
ha	hectare
ID	Irrigation Department
IFPRI	International Food Policy Research Institute
IMPSA	Irrigation Management Policy Support Activity
IIMI	International Irrigation Management Institute
MW	megawatt
NIA	National Irrigation Administration
NIV	New Improved Varieties
OECD	Organization for Economic Cooperation and Development
O&M	operation and maintenance
OIV	Old Improved Varieties
Rs	rupees
SLFP	Sri Lanka Freedom Party
TIMP	Tank Irrigation Modernization Project
TV	Traditional Varieties
UNP	United National Party

ACKNOWLEDGEMENTS

This report was prepared under the Agricultural Policy Analysis Project, Phase II (APAP II), as part of a series of agricultural policy analysis studies for the U.S. Agency for International Development's Asia Near East Bureau. APAP II is managed and partly funded by the Bureau for Research and Development of A.I.D./Washington. Abt Associates Inc. implements APAP II in collaboration with Harvard Institute for International Development; the Food Research Institute, Stanford University; North Carolina State University; Abel, Daft & Earley; the International Science and Technology Institute; and the International Food Policy Research Institute.

This opinions expressed in this report relect the author's own, except where explicitly cited. In no way do they represent the views of the U.S. Agency for International Development or Abt Associates. A version of this report has been published as a research paper by the International Irrigation Management Institute.

EXECUTIVE SUMMARY

In Sri Lanka, as elsewhere in monsoonal Asia, irrigation has been the mainstay of agricultural development (Barker and Herdt, 1985). Such investment was essential to increase food production in Sri Lanka, where more than two thirds of the country's total land area lies in the dry zone and is not productive without the irrigation water. Massive investments in irrigation construction and restoration of ancient tank systems, coupled with the introduction of seed-fertilizer technology brought Sri Lanka from being a major rice importer, to near self-sufficiency in rice by the mid-1980s.

Having achieved near self-sufficiency in rice, a decision has to be made as to whether irrigation policy should continue to emphasize the expansion of the existing irrigated land-base, or take other measures to increase the returns to the existing irrigation investment. Policymakers in the government and in international donor agencies both appear to be shifting emphasis from new irrigation system construction to irrigation system rehabilitation and management improvement. In spite of the critical importance of irrigation investments to 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 past investments in an integrated manner or demonstrate changes in relative economic profitability among investment alternatives in the sector.

Trends in Rice Production

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 growing population pressure on a limited land resource was met by exploiting an even scarcer 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 is that the past development pattern of the agricultural sector in Sri Lanka, previously based on dry-zone colonization, has now reached a turning point.

Trends in Irrigation Investments

Public investments in the made over the post-independence period can be categorized as one of three basic types: new construction, rehabilitation, and operation and maintenance (O&M). Many of the new irrigation construction projects in the dry zone were based on the abandoned tank systems of the old Sinhala kingdoms. New irrigation construction, as used in this paper, includes both these restored systems and entirely new systems, whereas "rehabilitation" refers to projects which are meant to restore deteriorated, but functioning irrigation systems to their original capacity. "O&M" expenditures include investments in maintenance and ways to improve the operation and management of the system.

An examination of irrigation investment data for the 1950s through the 1980s reveals five major trends. First, irrigation in general, and new irrigation construction in particular, have been by far the most important investment opportunities in the country. In the 1950s, the percentage of irrigation investment in total public investment was close to 40%. After a decline in the mid-1970s, this figure jumped to an unprecedented level by 1980, bringing up the share of irrigation in total public investment to more than 20%.

Second, new irrigation construction has been dominant among the three types of irrigation investments. This dominance reflects its high profitability and key role the national food policy objectives.

A third trend is the short to medium-term fluctuations in new construction investment, with spurts occurring in the early 1950s, late 1960s, and late 1970s to early 1980s. The peaks correspond with construction of major irrigation systems. Other factors behind the pattern of irrigation investment include changes in the political regime of the country, short-term fluctuations in the world market price of rice and the foreign currency reserves of the Sri Lanka.

The beginning of major rehabilitation investments in the mid-1970s and the rapid increase in their share of total irrigation investment is the fourth major trend observed. This share rose to 15 percent of the total irrigation investment by the mid-1980s. The growth of the irrigation sector itself and its consequences induced this proliferation of irrigation rehabilitation and water management improvement projects. Capital costs per hectare of new irrigated land have increased as new construction moved from less expensive, simpler projects based on old tank systems in the early stages to more complex and costly systems. Also, as the irrigated land base enlarged, it became economically more rational to invest in improving and enhancing the quality of existing systems than to invest in the construction of new systems.

The fifth major trend has been the low share of expenditures for O&M as a percentage of total irrigation investment. In spite of the substantial increase in irrigated land area, the share of O&M in total irrigation investment failed to show any increase over time. This suggests that the maintenance of existing irrigation systems may have been inadequate, resulting in low performance of the systems and endangering their long-term sustainability.

New Irrigation Construction

The GOSL must consider many factors before making decisions on the allocation of funds for investment opportunities, including the development of the irrigation infrastructure. As irrigation infrastructure is one of the most important public goods in Sri Lanka, social, political and economic factors affect the government's investment decisions; however, the changes in economic conditions have been the principal causes of change in irrigation investment patterns.

Chapter 4 illustrates the extent to which the economic factors presented in Chapter 3 explain the changes in Sri Lanka's irrigation investment patterns. The benefit-cost ratio and internal rate of return are considered as the rates of return for irrigation investment. Using data for 49 of the new irrigation construction projects implemented since independence, analysis of the returns to irrigation investment reveals that fluctuations in the economic returns of these investments was the driving force behind changes in irrigation investment over the period.

On the cost side, as new construction moved from small-scale, simpler schemes to more difficult and larger-scale projects, the real cost of irrigation construction increased fourfold from the 1950s to the 1980s. In addition to the capital costs, the "desired level" of Rs 740 per hectare is taken as the annual O&M costs for new area brought under irrigation.

The benefit flow is measured as the increase in agricultural income or gross value added attributable to the new irrigation system. Three different levels of seed-fertilizer technology are used to reflect the technology available during each time period.

The results of analysis indicate that massive investments in new irrigation construction after independence were induced by the high economic potential of such investments. Profitability was high at the initial stage and was preserved until the 1980s by dynamic interaction between the irrigation infrastructure and seed-fertilizer technology. The data suggest that, given the present level of rice technology, the increasing real capital cost of construction, and the rice price structure in the mid-1980s, the irrigation sector in the country has come to a stage where the economic returns make further investment in new irrigation construction difficult to justify.

However, other economic considerations enter into the Government's irrigation investment decisions. In the short-run, changes in prices, and the price of rice in particular, have been a key factor in these decisions. Given the Government's heavy subsidy on rice consumption and domestic production, a high import price for rice increases the payoff to irrigation investment relative to other public investment opportunities. The availability of foreign funds for imported components of irrigation construction is also significant constraint. Nevertheless, the allocation of government funds for irrigation construction was primarily guided by the economic returns to the investment.

An unprecedented increase in the price of rice, or diversification into high-value, non-rice crops such as chili, onion, and gherkin would have improved the rate of return during the 1980s slightly. By the end of the decade, however, the B/C ratio would fall beneath one.

The trend in increasing construction costs has been the basic cause of the increasingly unfavorable returns to new irrigation construction. There may still be some spots in Sri Lanka where new irrigation systems can be built at lower capital costs, although such projects would most likely be small-scale. Any spillover effects in terms of employment creation are incorporated in the estimate of the returns to investment. Also, there is no reason to assume that any income multiplier and linkage effects of irrigation construction projects are higher than other kinds of investment projects. It is clear that little economic justification remains for investment in new irrigation construction.

Rehabilitation and Water Management Improvement

As observed above, investment in irrigation system rehabilitation rapidly increased its share of the total irrigation investment beginning in the late 1970s. Water management improvement projects soon followed. Irrigation development in Sri Lanka has come to a stage where the profitability of investments in improving and enhancing the quality of existing systems becomes higher relative to that of new construction.

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 costs and benefits are valued at 1986 prices, and the benefits are measured by the increases in agricultural income attributable to the rehabilitation or water management project. The cases selected for analysis include two of the four major rehabilitation projects, the Tank Irrigation Modernization Project (TIMP) and the Gal Oya Water Management Project; and water management improvement projects implemented in the Kimbulwana, Pimburettawa, and Nagadeepa systems.

This study only takes two sources of possible project benefits into account: changes in cropping intensity (including irrigable area increase) and reductions in yield gaps between the head and tail-end 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.

Rice yields are identified by system, based on the average level attained in each system after the project. The cost of O&M to sustain the benefits of rehabilitation and water management improvement projects is assumed to be 740 Rs per hectare, and the benefit streams are assumed to have lifetimes of 20 and 15 years, respectively. Both types of projects are treated independently of the initial construction projects. Thus the projects do not include the sunk costs of system construction, and the project benefits are measured over and above what has been generated by the construction projects.

Both rehabilitation projects showed rates of return higher than those for new construction. While the Gal Oya project's level of profitability was extremely high, that for TIMP was only marginally above that for new construction. It should be noted, however, that TIMP's relative success was hampered by its status as the first major rehabilitation project in Sri Lanka. The project encountered many management and implementation difficulties, which served as useful lessons to future rehabilitation projects. In particular, Gal Oya is said to have benefitted from such lessons, making it a more accurate indicator of rehabilitation's potential profitability, providing adequate attention is given to management and implementation.

More striking are the high levels of overall economic performance that some water management improvement projects achieved (Table 9). 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. Poor management of water in the main season and maintenance of physical structures results in the rapid deterioration of irrigation performance. Programs to rectify these defects do not require much financial investment and result in substantial improvements in system performance.

Costs of the Nagadeepa system water management improvement project, however, were much greater than its benefits. The difference between Nagadeepa and the two others, however, is that management improvements in the Kimbulwana and Pimburettawa projects were enhanced by physical structure rehabilitation and modernization, which was not part of the Nagadeepa project.

The limited number of sample projects, both for major rehabilitation and for water management improvement, restricts a more complete test of this hypothesis. The evidence at hand, however, is sufficient to conclude that as long as rehabilitation and management improvement programs 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 increases in the relatively profitability of these investments.

Implications for the Future

There are many unknowns still 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 successful 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. There has also been substantial criticism of the sustainability of the success stories. Questions remain as to why rehabilitation and management improvement in other systems failed.

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 area. The large potential benefits for irrigation management improvement can be tapped with an appropriate combination of action research and effective implementation.

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 brought Sri Lanka, which used to be a major rice-importing country, to near self-sufficiency in rice by the mid-1980s.

The rationale for this policy has been that development of the irrigation infrastructure is the fundamental 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 productive 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 achieved near self-sufficiency in rice, a decision has to be made as to whether irrigation policy should continue to emphasize the deepening of the existing irrigated land-base, or take other measures. Policymakers in the government and in international donor agencies both appear to be shifting emphasis 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 direction undergone by the irrigation sector in Sri Lanka be magnified? 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 changes in relative economic profitability among investment alternatives in the sector.

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 process of irrigation development. In the next section, the process of rapid increase in rice production is documented and the role of irrigation development in this process is identified. In the third part, past trends in irrigation investments will be examined by type of investment and determinants of the investment trends will be assessed. In the succeeding sections, trends in the economic profitability of different types of irrigation investments will be analyzed. Finally, the implications of this study for the future direction of the irrigation sector will be discussed.

2. TRENDS IN RICE PRODUCTION

Between 1952 and 1985, domestic rice production increased at a rapid annual growth rate of 5 percent (Table 1). The 5 percent annual growth rate of total rice production for the period 1952-85 was brought about by a 2 percent annual increase in area planted and a 3 percent increase in the yield per hectare with percentage shares in productin growth of 40 and 60 percent, respectively. 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 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 each subperiod shown in Table 1, the contribution of yield increase to the increase in 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 modest. It is in the last subperiod that the contribution of yield increase to the total production growth exceeds 90 percent.

The process of growth in rice production can be better understood by looking at the unique features of rice farming in Sri Lanka in terms of geographical as well as historical conditions. Sri Lanka is divided into two significantly different climatic zones: the wet zone and the dry zone. Although the island had 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, 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 the rare phenomenon in Southern Asia, a region which makes up two-thirds of a country but is sparsely peopled" (Farmer 1957, 18).

In contrast, the wet zone, with a limited land area, has 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, 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 extensive slash-and-burn shifting cultivation. In the wet zone, a sufficient amount of rainfall and its relatively even distribution between seasons make rainfed rice production feasible. So, dry zone colonization has taken place under projects in which land settlement is coupled with irrigation development.

The development of rice production in Sri Lanka has been brought about mainly through the development of irrigation infrastructure in the dry zone. When viewed in a broader framework, this process of dry zone irrigation development is 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 1, 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.

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 2 shows where the area planted to rice has increased. Except for the areas under minor irrigation systems and rainfed 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.

Data on the total rice land area by type of irrigation in the country, the irrigation ratio and the cropping intensity from the years 1950-85 are summarized in Table 3. The total irrigated rice land area increased from 253,000 ha in 1950 to nearly half a million ha in 1985; 90 percent of this 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 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.

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 4, the fertilizer use per hectare of rice planted began to rise in the late 1950s as the Old Improved Varieties developed by the Sri Lankan agricultural research institutes were being adopted by the farmers. By the mid-1960s, just before the advent of New Improved Varieties based on IRRI germ plasm, 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. Parallel with these changes, fertilizer use increased rapidly, reaching a level of more than 100 kg/ha in the mid-1980s.

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) and 48 percent in terms of the area planted to rice (Table 3).

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 growing population pressure on a limited land resource was met by exploiting an even scarcer 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 agricultural sector in Sri Lanka, which has been based primarily on dry zone colonization, has now reached a turning point.

3. TRENDS IN 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 section, data on irrigation investments compiled from various government documents are presented, and an attempt is made to assess the determinants of the investments.

The public irrigation investments made during the post-independence period are summarized by type of investment in Table 5. 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."

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 "new construction" types of projects, whereas "rehabilitation" refers to projects which are meant to restore deteriorated but functioning irrigation systems to their original capacity, or to improve them above their original capacity.

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-construction-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, Victori, and Randenigala reservoirs. The capital cost of the first two reservoirs is apportioned according to 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 (Saltzgitter Consult GMBH, et al, 1979, 10-27).

An examination of the irrigation investment data (Table 5) reveals several interesting points. 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 and nearly 10 percent of the government budget during that period. As the economy developed, the share of total irrigation investment in the total public investment declined toward the mid-1970s. However, the total irrigation investment jumped to an unprecedented level in and around 1980, bringing up the share of irrigation investment in the total public investment to more than 20 percent.

Second, new irrigation construction has been dominant among the three types of irrigation investments, and from 1950 to the early 1980s the long-term trend of new construction investments has been upward. 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. Within this broad objective, 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 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-term 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. 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 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 irrigation 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 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 shortage. 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 irrigation investments in particular, and agricultural policy in general, have been strongly affected 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 at relatively low and stable prices in the open market, while at the same time providing reasonable 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 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, 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, 30).

As Sri Lanka was a regular importer of rice and as the importation of rice and its distribution 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 import price 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, 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-group-oriented food stamp scheme under which the share of the food subsidies in the total government expenditure declined to less than 3 percent (Edirisinghe 1987, 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 is that rehabilitation investments begin in the mid-1970s and rapidly increase their share in the total irrigation investment. As indicated in Table 5, 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 first 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 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 first 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 was 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 shifted 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 is 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 Table 5 that expenditures for irrigation system operation 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 5). 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 was shown in Table 3. 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.

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 have a far-reaching impact on irrigation investment trends; government decisions on the irrigation sector cannot be made without considering the changing economic environment. Some economic factors which were hypothesized as the causes of change of irrigation investments in the previous chapter, are examined here and in the next section.

4.1 Long-Term Trends in Costs and Returns

As observed in the previous section, investments in new irrigation construction increased rapidly until the early 1980s. Such a trend should have been induced by high economic returns from such investments. On the other hand, it is 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 is further 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 can be tested by estimating the rates of return on the investments in new irrigation construction during the last four decades, as detailed below.

4.1.1 Costs of Construction

On the project-cost side, the trend in capital costs 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. The capital cost per hectare of these 49 projects are computed after incorporating capital interest during the construction period, assuming an interest rate of 10 percent and converting it into real terms by using the GDP implicit deflator for the investment in construction.

The results, summarized in Table 6, show an increasing trend in the unit cost of irrigation, with particularly dramatic increases in costs beginning in the 1980s. The real cost of irrigation construction increased fourfold from the 1950s to the 1980s. If capital interest during construction is included, irrigation construction cost per hectare increased more than fivefold from the 1950s to the late 1980s, from Rs 70,000 to Rs 360,000 in 1986 prices. This increase is due to the shift in new irrigation construction projects from the small-scale "restoration" type to large-scale transbasin ones, such as the Mahaweli Project. The results support the hypothesis that the new irrigation construction in the post-independence period started with relatively easier projects and moved to more difficult ones.

The rate of increase over time in per unit cost of irrigation construction can be estimated by fitting an exponential time-trend curve to the data:

$$K^* = 1.637 + 0.047t, \; R^2 = 0.685,$$

$$(3.411) \; (6.763)$$

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

The results show that the capital cost has increased at a growth rate of about 5 percent per year during the last four decades.

4.1.2 Benefits of Irrigation Investment

In order to estimate project benefits, 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 estimated by Kikuchi and Aluwihare (1990).

The benefit flow is measured as an increase in agricultural income or gross value added. The increase is estimated by subtracting the current input costs, such as 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 irrigation 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 form 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 this 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

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 close to this average level. This suggests that there exist 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 slash and burn 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 slash and burn 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 large (less than 10 percent). The degree of overestimation due to this assumption, if any, is 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 at the "desired level" of operation and maintenance for the major irrigation systems (IIMI, 1989). It is assumed that with these level of operation and maintenance, irrigation systems can sustain their operations for 50 years.

The benefit-cost ratio and the internal rate of return are considered as the rates of return. 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
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 part 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 return 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 and the B/C ratio series estimated by level of seed-fertilizer technology are shown in Table 7. The rates of return 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 return. 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, and for 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 irrigation 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 ratios.

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 went below 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 construction 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, 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. The data suggest that, given the present level of rice technology, the increasing real capital cost of construction, and the rice 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 is difficult to justify economically.

4.2 Determinants of Irrigation Investment

The level of the B/C ratio 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 prices particularly the price of rice, have an immediate short-run impact on the rates of return. It is hypothesized that government decisions on irrigation investments had been guided by the profitability of the investments, which have in turn been determined largely by the import price of rice.

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. The availability of foreign funds for irrigation is therefore hypothesized to be another important determinant of short-term changes in irrigation construction investments.

In order to test of these hypotheses, 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 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 previous section.

To measure the impact of the availability of foreign funds on irrigation investment, a foreign fund availability index was computed. This index was defined as the ratio of total foreign assistance, consisting of foreign loans and grants, to the total budget of the government. The hypothesis that the rates of return and the foreign fund availability are major determinants of the government investments in new irrigation construction was then tested by estimating a public irrigation investment function. 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:

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

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

where,

Ln	=	natural log
I_t	=	new construction investment in year t, in 1986 prices
$(B/C)_t$	=	benefit-cost ratio of the investments in year 5, 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
DW stat.	=	Durbin-Watson statistic

Figures within parentheses are t-ratios.

It is 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.

4.3 Outlook for New Irrigation Construction

As was shown above, the B/C ratio of 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 trend after 1986 as the world market price of rice rebounded and exceeded the level experienced in the early 1960s, 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 significant 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 8). 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. However, even with such a high price of rice, the B/C ratio will go down quickly to 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 high-value nonrice crops? Studies on crop diversification, see, for example, Miranda, 1989; Panabokke, 1989; Kikuchi, 1990; and in particular, IIMI, 1990a; and Shand, et al., 1990, 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 8. Note that the cropping intensities in the maha season are less than one. 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.

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, 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 soils 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.

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 8 indicate that the full conversion of yala season extent from rice to high-value nonrice crops increases the rates of return only slightly. With the unit capital cost in 1990, the B/C ratio will be raised to 1.5, but it soon goes below one. 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 change even if this assumption is relaxed. Assuming a newly created irrigation system has a cropping intensity of 2.0, the benefits will increase 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. The increasing trend in irrigation construction costs might also have been due partly to a capital intensive bias in the construction technology adopted in the recent irrigation construction projects. Though this issue has not been examined, it seems that serious attention should be paid to the question whether the technology adopted in irrigation construction is "appropriate" under the factor prices prevailing in the country. 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 built 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. Cost-benefit analysis fully accounts for the employment created in agriculture. Therefore, low rates of return to the investments mean that irrigation construction is not a cost-effective means of creating employment.

Advocates of irrigation construction often go further, claiming that spillover effects of employment created by 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).

5. REHABILITATION AND WATER MANAGEMENT IMPROVEMENT

As observed above, investment in irrigation system rehabilitation rapidly increased its share of the total irrigation investment beginning in the late 1970s. Water management improvement projects followed after a short time-lag. It is 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. 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.

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 irrigable area increase, and reductions in yield gaps between the head-end and tail-end 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" increase 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=120 kg" 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 is not available for some systems, actual post-project yield level is used to avoid any overestimation of 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 rice production is assumed to be 80 percent.

Operation and maintenance (O&M) cost is assumed to be Rs 740 per hectare, the same as for new construction projects, which 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. 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 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. For 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. Alternative assumptions on the lifetime of projects 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.

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 (Table 9). It is interesting to note 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.

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 farmer-beneficiaries in the design and O&M processes (e.g., Murray-Rust and Rao, 1987). It is said that the most valuable contribution made by TIMP 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 that 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 9). 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. It is not surprising 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 are being operated and maintained. Current practices result 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, 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 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:

	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.

A lesson that can be derived from these experiences is the importance of physical structure improvements as a precondition to achieving better water management through farmers' participation and cooperation. The two success cases suggest that 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 relatively profitability of these investments.

6. IMPLICATIONS FOR THE FUTURE

The most important general conclusion of the analysis of 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 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 irrigation 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,[1] this new direction for irrigation sector investment, firmly established by the late 1980s, will continue to outperform construction-oriented investment. 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.

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 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

[1]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.

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, this 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 estimated 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.

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, 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 (IMPSA), which is a new policy formulation process launched in 1990 for the transition form the construction to the management stage, represents 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 successful 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 successful 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 area. The large potential benefits for irrigation management improvement can be tapped with an appropriate combination of action research and effective implementation.

TABLES

Table 1 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 averages centering on the years shown. The percentage share of the rice production growth rate is shown within parentheses.

Sources: 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).

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

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).

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

Table 2 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	53.6	48.3	101.9	66.6	82.2	250.7	200.4
	(100)	(12)	(11)	(23)	(15)	(18)	(56)	(44)
1960	577.2	90.1	66.5	156.6	103.3	109.4	369.3	207.9
	(100)	(16)	(11)	(27)	(18)	(19)	(64)	(36)
1970	721.4	133.8	86.5	220.3	126.1	135.0	481.5	239.9
	(100)	(18)	(12)	(30)	(18)	(19)	(67)	(33)
1980	855.1	199.3	113.1	312.4	139.8	150.3	602.7	252.4
	(100)	(23)	(13)	(36)	(16)	(18)	(70)	(30)
1985	873.6	222.4	147.9	370.3	130.3	133.3	633.9	239.7
	(100)	(25)	(17)	(42)	(15)	(15)	(73)	(27)
Growth rate (%):								
1952-60	3.1	6.7	4.1	5.5	5.6	3.6	5.0	0.5
1960-70	2.2	4.0	2.7	3.5	2.0	2.1	2.7	1.4
1970-80	1.7	4.1	2.7	3.5	1.0	1.1	2.3	0.5
1980-85	0.4	2.2	5.5	3.5	-1.4	-2.4	1.0	1.0
1952-85	2.0	4.4	3.4	4.0	2.0	1.5	2.9	0.5

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

Sources: 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).

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

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).

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

Table 3 Rice land area by type of irrigation, irrigation ratios, and cropping intensity, for selected years, Sri Lanka[a]

	Rice land area (1,000 ha)						Irrigation ratio			Cropping intensity[c]	
	Irrigated[b]				Rain-fed	Total				Total	Major irrigation
	Major irrigation (i)	Minor irrigation (ii)	Lift irrigation (iii)	Total (iv)	(v)	(vi)	i/iv %	i/vi %	iv/vi %	%	%
1950	90	163	-	253	157	410	36	22	52	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 land area. Major irrigation refers to the irrigation systems with a command area of 81 ha (200 acres) or more, and minor irrigation to those with less than 81 ha of command area.

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

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

Sources: 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).
Central Bank of Sri Lanka, *Review of Economy*, various issues.
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).
Central Bank of Sri Lanka, *Review of Economy*, various issues.

Table 4 **Fertilizer inputs for rice production per hectare, irrigation ratio, and rice variety ratio, for selected years, Sri Lanka[a]**

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

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

[b] Nutrient content (three major elements) of the fertilizer.

[c] Irrigated area planted to rice/total area planted to rice.

[d] Percentage of rice variety planted.

Sources: Sri Lanka, Irrigation Department, *Administration Report*, various issues.
Sri Lanka, Department of Census and Statistics, *Statistical Abstract*, various issues.
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.
For 1950-60, International Rice Research Institute (1988); for 1961-87, National Fertilizer Secretariat, *The Review of Fertilizer*, various issues. For 1957-84, International Rice Research Institute (1988); for 1985-87, Central Bank of Sri Lanka (1989a). Rice Breeding Center of the Department of Agriculture.

Table 5 Irrigation investments in Sri Lanka, in 1986 prices, by type of investment, and their share in the government budget and the total public investment, 1950-88[a]

	Irrigation Investments				Share of the total irrigation investment in	
	New construction[b]	Rehabilitation[c]	Operation and maintenance[d]	Total	Government budget	Total public investment
	-------- Rs million in 1986 prices			---------	--------- %	--------
1950	907 (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: 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.
Sri Lanka, ID, *Budget Estimates*, various issues; Sri Lanka, Department of Agrarian Services (DAS), *Administration Report*, various issues.
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.
Central Bank of Sri Lanka, *Review of Economy*, various issues.

Table 6 **Average real construction costs of new irrigation projects in Sri Lanka, by period, with construction costs per project weighted by command area**

Period	Number of Systems Completed	Weighted Average Construction Cost (1986 prices) (Rs/ha)
1950-59	4	43,294
1960-69	28	51,007
1970-79	11	78,287
1980-89	6	174,540

Sources:

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).

Central Bank of Sri Lanka, Review of Economy, various issues.

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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.

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

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.

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

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.

Central Bank of Sri Lanka, Review of Economy, various issues.

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.

Land Commissioner's Department.

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.

Table 7 **Benefit-cost ratios and internal rates of return on investments in new irrigation construction, based on 1986 prices**[a]

	Based on estimated construction cost[b]			Based on actual construction cost[c]		
	Technology Level[d]			Technology Level[d]		
	Traditional Varieties	Old Improved Varieties	New Improved Varieties	Traditional Varieties	Old Improved Varieties	New Improved Varieties
	N=0 kg	N=60 kg	N=120 kg	N=0 kg	N=60 kg	N=120 kg
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 functions under irrigated conditions:

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

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

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

Table 8 **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 = 120 kg" 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.

Table 9 **Rates of return on irrigation investments in the 1980s: Comparison of B/C ratios and internal rates of return of new construction, major rehabilitation, and water management improvement projects, based on 1986 price estimates**

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

[a] For the technology level "New Improved Varieties; N=120 kg" 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.

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