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IRRIGATION IN ASIA AND THE NEAR EAST IN THE 1990S: PROBLEMS AND PROSPECTS

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EXECUTIVE SUMMARY

Food grain production has grown at a rate of about three percent per year in Asia and the Near East for the past two decades. At the present time there is a sharp difference of opinion as to what the future holds for agriculture in this region. This difference of opinion is closely linked to uncertainties associated with the development of irrigation, which has played a central role in the achievement of rapid output growth.

Trends in New Irrigation and in Irrigation Investments

In order to better understand the current situation with respect to irrigation, we assembled data on the rate of change in new area irrigated and on trends in irrigation investment by major international lenders (World Bank, Asian Development Bank, U.S. Agency for International Development, and the Japanese Overseas Economic Cooperation Fund). New irrigated area grew fairly steadily at a rate of about 2 percent world wide and in

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Asia from the mid 1960s to 1980, but this growth rate fell to less than 1 percent in the 1980s.

Following the sharp rise in food grain prices in 1973, investments in irrigation by the major lenders rose sharply in the mid 1970s. But as food grain supplies have increased and prices have fallen in the 1980s, investments in irrigation and in agriculture also have declined. Other factors which undoubtedly have contributed to this decline include the large public and foreign debt load carried by most of the agriculturally-based economies in the region, the decline in share of unexploited irrigation development and rising per-hectare costs, and the stiffening political resistance from environmental interests and those displaced or otherwise negatively affected by irrigation development.

The apparent cyclical fluctuation in irrigation investment raises questions about the appropriateness of benefit/cost or internal rate of return as the basis for project justification. The major lenders, dealing on a project by project basis, apparently do not see *themselves* as endogenous actors in the system, capable through their investment decisions of creating cyclical fluctuation in agricultural production. Given the long-term nature of irrigation investments, would it be more appropriate to treat irrigation in the manner of a utility or basic national infrastructure such as roads and power?

Issues Related to the Performance of Existing Systems

The decline in irrigation investments raises a number of important issues, particularly regarding the performance and potential productivity of existing systems, which we have explored only briefly. First, and perhaps most obvious, as investments in new systems decline and there is a shift toward rehabilitation and qualitative improvements in existing systems, there is a need for more adequate ways to characterize and quantify irrigation services. Failure to develop such standards and techniques will leave us unable to measure the impacts of our investments. Very little information exists at present on the potential for developing new irrigation or for raising the productivity of existing systems.

Developing countries have been accused by international lenders of not properly maintaining their irrigation systems. How can efficiency in the operation of systems be improved? There is a growing consensus that farmers should have more direct participation in the design, operation, and maintenance of systems.

Due to the extreme budget constraints that many governments are facing, there is a major interest in devising ways to obtain additional resources from farmers for O & M. The transfer of operation and maintenance responsibility to users, particulary at the tertiary or field channel level, is gaining popularity. There is a feeling, partially supported by research, that water user group operation of portions of the system is more efficient than government operation. Relatively successful techniques for assisting farmers in organizing water user groups have been tested in the Philippines, Sri Lanka, and Nepal.

The relatively low prices for rice and wheat, and the increasing costs for new irrigated land have stimulated interest in the production of other crops. Diversification implies greater ability to respond to spatial and temporal variations in water need associated with diversified cropping patterns. There is a need to improve our understanding of the requirements of flexibility and of procedures for obtaining it.

Implications for USAID Policy and Programs

The uncertainties in predicting the future of an important and complex sector makes the identification of appropriate investment activities difficult. Nevertheless, there are indications from past trends and in more recent experience that have implications for USAID's irrigation portfolio. These are summarized as follows:

. There are sufficient differences among countries of the region in terms of both irrigation potential and in the stage of irrigation development that a single pattern to the development of irrigation activity is unlikely to be appropriate.

. It is clear that, notwithstanding significant development of understanding of the irrigation sector and irrigation organizations during the past 15 years, there is still much that is not adequately known. Opinions differ widely as to the most appropriate investment strategies in different circumstances. The fact that these differences in opinion exist suggests that increased study would be not only appropriate but urgent.

. There is a great need for better data even to define the different qualities of irrigation so that one can access the impact of investments on productivity. USAID should consider the fostering of increased capability in data collection and problem analysis to assist in significant policy, operations, and design decisions.

. There is a need to examine more carefully the shifts in investment priorities which have occurred recently within the irrigation sector and the potential impacts of the downward trends in investments in new area irrigated documented in this paper.

. One specific component of the sector where there is an obvious need for better understanding is the role of the private sector at both the water course and systems level.

. In most of the countries, increased emphasis on effective farmer participation in the irrigation sector would be valuable.

. In most countries increased attention to the structure and operation of irrigation organizations would be beneficial.

. We need a greater understanding of the rehabilitation process and of the tradeoff between rehabilitation and maintenance.

. We need to understand how systems can be managed more flexibly to enhance the potentials for crop diversification.

. While it is anticipated that much of USAID's programs will emphasize the "software" aspects of the irrigation sector, in countries with significant underdeveloped potential for expansion of irrigated area, support for development of physical infrastructure might be appropriate.

The foregoing suggests that USAID has significant opportunities for major contribution to irrigation development in the region, but the appropriate country irrigation portfolios are likely to be complex and often different mixes of activities - physical infrastructure development, support of organizational and institutional change, and sponsorship of field studies, research, and training. This represents a major challenge for USAID.

Chapter I INTRODUCTION

Food grain production has grown at a rate of about three percent per year in Asia and the Near East for the past two decades. During this period an increasing proportion of the growth in production has come from the increase in yield per unit area. The close association between high yields, use of modern varieties, higher levels of fertilizer application, and irrigation is well documented[1]. The advent of high yielding varieties was accompanied by a rapid increase in irrigation investment throughout the region, with irrigated area increasing at more than two percent per year[2].

As a result of the energy crisis and a period of unfavorable weather, food prices rose sharply in the mid-1970s. However, since that time, the rapid adoption of new technologies in both the developed and the developing countries, accompanied by large subsidies, particularly in the developed countries, has led to a decline in world prices of rice and wheat (see Fig. 1). In real terms, there has been a long-term secular downtrend in grain prices (Figure 2).

At the present time there is a sharp difference of opinion as to what the future holds for Asian agriculture. There are three general scenarios:

The most optimistic scenario is based on the assumption that growth in food grain production can be sustained easily through normal technological improvements. Advocates of this position argue that we should reduce the rate of investment in irrigation and look for more profitable investment opportunities[3]. Among the latter, diversification of agriculture is considered to be a strong candidate; this would include production of non-grain crops on irrigated areas which have been devoted almost exclusively to the production of wheat and rice.

In a second scenario, the problem is viewed as cyclical. Just as the high prices in the mid-1970s led to an overinvestment in food grain crop production, now the extremely low prices coupled with increasing foreign debts may have led to under-investment. Any rise in food grain prices will bring forth more investment and the long term growth in food grain production will be sustained.

The third and most pessimistic scenario is based on the uncertain outlook for new technology and for irrigation. The argument is that in many areas, such as parts of China and Java, the potential of new technology has to a large extent been realized and no significant technological breakthroughs are on the horizon. In addition, it is argued that most of the land suitable for irrigation has been developed and that new irrigation development will have much higher per hectare costs. While increased attention can be paid to improvement in system operation and maintenance, the potentials for yield and production increases as a result of system improvement are not well understood.

From the foregoing, understanding the problems and prospects for Asian agriculture, and developing the appropriate strategies to deal with those problems depends heavily on an understanding of the role and potential for irrigation. We consider that the task of this paper, therefore, is threefold:

(1) to document the trends in area irrigated and in irrigation investment for the region as a whole. Among the questions to be addressed are: What are the patterns of irrigation investment? Can causal factors be determined or reasonably inferred? Is there a discernible time lag between change in investment rate and change in growth of irrigated area and/or production?

(2) to identify the problems and issues relating to the irrigation sector that are emerging in part as a consequence of the observed trends. Questions to be considered include: What are the potentials for increases in irrigated area and yield? To what degree should irrigation systems be treated as basic development infrastructure or as public utilities by contrast to

a production project? How can agricultural and irrigation policies be coordinated more effectively?

(3) to suggest implications for future USAID activities to support the irrigated agriculture sector. Among these implications we can anticipate issues relating to the balance between development of physical infrastructure and the improvement of existing systems, to the role of the private sector both within existing government systems and as a substitute for those systems, and to the appropriate emphasis on research and human resource development in USAID irrigation related programs.

Although this paper deals broadly with irrigation issues, limitations of time and data prevent a full exploration. Primary emphasis will be on public sector surface irrigation even though in many countries the area irrigated by farmer and community managed systems and by privately operated tubewells is as large as the area served by national government systems. These latter types of irrigation activity often are under-reported in official statistics, and while much has been learned of them in recent years, much still is unknown, especially in quantitative terms. Even confining the discussion largely to the government sector, the inadequacies of data and the limitations of time prevent a comprehensive analysis at this time. We hope, however, that the issues raised will stimulate more critical attention to this important topic.

Chapter II TRENDS IN IRRIGATED AREA AND IN IRRIGATION INVESTMENT

This chapter is divided into two major sections, the first dealing with trends in new area irrigated, and the second dealing with trends in irrigation investment by the major international lenders (World Bank, Asian Development Bank, U.S. Agency for International Development, and Japanese Overseas Economic Cooperation Fund). One purpose is to ascertain whether there is an apparent relationship between these trends and the trend in international grain prices. As shown in Fig. 1, rice and wheat prices rose sharply in the mid-1970s, and then declined in the 1980s. In real terms grain prices continued a long secular down trend (Figure 2). Given the fact that investment decisions are influenced by estimated internal rates of return, lower grain prices should be expected to influence investments in irrigation.

Extension of Irrigated Area

In 1984, the world's net irrigated area[4] was 219.7 M hectares. Of this amount, 137.0 M hectares were in Asia, 62.3% of the worldwide total (Table 1).

Over the preceding 20 years, the Asia total grew at this level from a base of around 100 M hectares, an overall increase of 36%. Interestingly, however, the share of the world's irrigation contributed by Asia declined over that period by nearly three percentage points, from 65.3% to 62.5 (Table 2).[5] Over the same period, by contrast, African irrigation, starting from a much smaller base, expanded by 67%, and its share of the world total increased from 4.1% to 4.5%. The bulk of the change, however, was caused by the extremely rapid growth in the Soviet Union, and, to a lesser extent, Europe. Europe's share grew from 6.2% to 7.2%, while irrigated area in the Other category (Australia, New Zealand, and the Soviet Union) nearly doubled, expanding its share from 7.3% to 9.8%. A modest share decrease for North and Central America (1.1%) and no change for South America round out the picture.

Worldwide, net irrigated area grew at a moderate compound rate of 2.0% over the two decades between 1965 to 1984 (Table 3). In Asia the rate was a slightly lower 1.6%. When the period is broken down into quinquennia, however, a more interesting picture emerges. As seen in Table 3, the 20-year average merges relatively stronger worldwide growth rates during the first three 5-year periods with sharply diminished growth during the last period indicating a *distinct* slowing in the pace of irrigation expansion. For Asia, the same pattern is repeated, though with a more consistent and steady decline in rates of expansion. Growth there slowed from 2.5% during the first period to 0.7% in the last.

It is interesting to look at what happened over the same period to the total land area employed in crop agriculture. Between 1965 and 1984, net arable and permanently cropped land increased by about 57 M hectares or 4.0% (Table 4). However, this yields a compound annual growth rate of just one-quarter of one percent. For Asia, the rate was less than one-tenth of one percent. As a result, the fraction of the world's agriculture land that is irrigated increased from 10.8% to 14.9 over the period. For Asia the increase was from 22.1% to 30.0%.

Asia

Examining regions within Asia,[6] provides additional insight. Regions are as shown in Figure 3. Twenty-year growth rates range from Southeast Asia's (SE Asia) 2.5% to China's 1.2% (Table 5). South Asia (S. Asia) is intermediate at 2.1%. In terms of shares, however, the region of strongest growth, SE Asia contributes only 10.7% of the region's net irrigated area, while S. Asia provides nearly half (49.9%) and China another 38.3% (Table 6). As might be expected, this distribution of shares and growth rates has led to a 2.7 percentage point increase in the S. Asia share, a 1.2 point increase in the SE Asia share and a 4.1 point drop in China's share. Data for individual countries is included in an annex.

In SE Asia, after peaking at 4.0% in the first half of the 1970s, growth has slowed steadily -- to 3.0% in the second half of the decade and to 2.1% during 1980-84. Growth remains, however, the strongest of the three regions.

In South Asia, although tendencies during the first three periods are mixed, the trend is generally downward and the figure of 1.0% for the most recent period is clearly the lowest of the two decades.

In China, growth ceased after 1975. During the first two 5-year periods, expansion occurred at a compound annual rate of 2.9% in each period. During the last two periods, growth has been nil (0.0%).

In South Korea also, growth has fallen in recent years to less than 1% from a brisk earlier pace, but S. Korea contributes only 1.0% of the Asian irrigated total.

Near East

Irrigated area in selected countries[7] in the Near East declined slightly over the 20-year period, the annual compound rate being -0.3%. Trends in this region are dominated by Egypt, and net irrigated areas in Egypt and in the region as a whole, peaked in the early 1970s before declining to their 1984 values. Quinquennial rates of growth are shown in Table 5.

Data

It is important to remember that the trends noted above refer only to net irrigated area -- that is, land irrigated at some point during a calendar year. The data collected by the FAO on which they are based do not take into account the frequency of land use; hence irrigated area which produces two or more crops in a twelve month period is counted only once. Moreover, the quality of irrigation service provided is not reflected in any way in such figures. Thus, a hectare at the tail end of an ancient diversion scheme is exactly equivalent in the data to a hectare irrigated by a private shallow tubewell, even though the output of the latter may be several times that of the former.

This points to a critical deficiency in routine data collection in most developing countries, and many developed ones. This deficiency is the absence of standards for or description of the quality of irrigation service that is claimed. Such criteria could establish minimum standards for service areas to be termed "irrigated," take into account the irrigation intensity of land cropped more than once during the year or land in long season or perennial crops, and ultimately, take into consideration the degree to which irrigation meets the "demand" for water, however defined.

Trends in Lending for Irrigation by International Donors

A number of observers have noted that irrigation investment in the Asia region appears to have declined over the past few years. This trend, if real, would stem from several root causes: (a) the relatively favorable food security situation in the region as a whole and the corresponding low level of rice and other foodgrain prices, (b) the large public and foreign debt loads carried by most of the agriculturally-based economies in the region, (c) the declining share of unexploited irrigation development potential in many countries in the region and the correspondingly increasing per hectare cost of development, and (d) stiffening political resistance from the environmental interests and those displaced or otherwise negatively affected by irrigation development.

In this section of the paper we examine the extent to which this apparent decline in irrigation investment is real. The analysis assesses the trend in irrigation investment in South Asia, Southeast Asia, and the Middle East/North Africa by four major donors, the World Bank, Asian Development Bank (ADB), the United States Agency for International Development (USAID), and the Japanese Overseas Economic Cooperation (OECF). The countries included in this assessment are as follows: The South Asia region is composed of Bangladesh, Burma, India, Nepal, Pakistan, and Sri Lanka. The countries in Southeast Asia are Indonesia, Malaysia, Papua New Guinea, Philippines, and Thailand. The Middle East/North Africa region consists of Afghanistan, Algeria, Cyprus, Egypt, Jordan, Morocco, Syria, Tunisia, Turkey, Yemen, Arab Republic, and Democratic Republic of Yemen.

The investment data utilized are the total amount of loans and assistance in the year those loans and assistance are approved. Time series data on actual disbursements of the loans and assistance are not available. The data is presented in real terms, with current loans and assistance deflated by the Industry Price Deflator published in the World Tables 1987. For those countries where the Industry Price Deflator was not available, an alternative price index was utilized, chosen from the following, in order of the preference when available: implicit GDP deflator, agricultural price index, wholesale price index, and consumer price index.

Irrigation Investment Trends

The data for loans and assistance to irrigation are presented in tables and figures. Tables 7-10 present the average annual lending and assistance for irrigation by period, 1969-84, by the four donors for the total of the three regions and for each of the three regions separately. Figure 4 traces the summation of loans from World Bank, ADB, and OECF on an annual basis, 1974-87, and Figure 5 shows the summation including USAID, for the years 1979-87. The two separate summations are given because the first provides a longer-term perspective due to the more limited number of years of data from USAID.

As shown in Table 7, the World Bank has been the largest lending institution for irrigation in the three regions. Of the total lending by the World Bank, ADB and OECF, the World Bank provided 90% in 1974-76 and 75-80% in subsequent periods. With USAID included in the summation, the World Bank accounted for about 70% of the total lending and assistance in the last three periods. ADB is the second largest lender for irrigation, accounting for about 17% of total loans since 1977. ADB is particularly significant in Southeast Asia where it accounts for about one-third of total irrigation loans and assistance. USAID and OECF together account for a little over 10% of total for irrigation.

Table 7 shows that there has been a large decline in real lending and assistance for irrigation from the four donors since the peak period of 1977-79. Lending has declined in each period since 1977-79, and by 1986-87 total lending was just over 50% of the 1977-79 level. The decline was the sharpest after the 1980-82 period, with a drop in lending and assistance from the four donors of 40% through 1986-87.

The pattern of investment over time varied somewhat by donor. Lending by the World Bank peaked in 1977-79 at an annual average of $1.19 billion, before declining by half to an average of $589 million in 1986-87. ADB lending showed strong growth through 1980-82 to an annual average of $253 million before dropping to an average of $144 million in 1986-87, a decline of 43%. OECF lending increase rapidly from a low base level to an average of $75 billion in 1983-85 before declining to an average of $22 billion in 1986-87. Lending and assistance from USAID dropped from an average of $93 million in 1980-82 to $75 million in 1986-87.

Average lending and assistance for irrigation in South Asia was highest in 1980-82, at $820 million, before declining by more than one-half to $397 million in 1986-87 (Table 8). The largest decline from peak investment levels, however, has been in Southeast Asia. Lending for irrigation from World Bank, ADB, and OECF declined from an annual average of $630 million in 1977-79 to $202 million in 1986-87, a decline of two-thirds (Table 9). World Bank average lending for irrigation in Southeast Asia in 1986-87 was only one-fifth of the level in 1977-79. In the Middle East/North Africa, irrigation lending in 1986-87 was about 40% less than peak levels of 1974-76, but significantly higher than the lower years of 1980-82 (Table 10).

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Irrigation Lending as a Proportion of Total Lending

The results presented above establish that there has been a dramatic decline in total lending and assistance for irrigation in South and Southeast Asia and the Middle East/North Africa over the past decade. The question can also be asked whether this decline has been part of a general decline in investment by donors, or whether irrigation investment has in fact declined more rapidly than other types of investment. Data is available for the World Bank, ADB, and USAID to provide a partial answer to this question.

Tables 11-14 show average annual total lending, agricultural lending, and irrigation lending by the World Bank, 1975-87, for the summation of the three regions and for the three regions separately. As shown in Table 11, for the three regions as a whole, total lending and agricultural and irrigation lending all peaked in 1977-79, with a continuous decline thereafter. However, the decline in agricultural and irrigation lending was proportionately faster than the decline in total lending. As a result, agricultural lending dropped from one-third of total lending in 1977-79 to about one-fifth in 1986-87, and irrigation lending dropped from 19% to 14% of total lending. Irrigation as a percentage of agriculture varied only modestly over the period.

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The relative decline in lending for agriculture and irrigation is even more dramatic for South and Southeast Asia. In South Asia, peak lending in all three categories was 1980-82, but average total lending declined by only 7% thereafter, while agricultural lending declined by 39% and irrigation by over 50% (Table 12). In 1986-87, agricultural lending was 23% of total lending, compared to a high of 39%. Irrigation fell from 27% of the total in 1980-82 to 14% in 1986-87. In the latter period, irrigation was also at its lowest proportion relative to agricultural lending.

The largest drop in relative importance of irrigation investment by the World Bank has been in Southeast Asia. Irrigation lending in 1986-87 was 80% lower than peak levels reached in 1977-79, while total lending dropped by 40% and agricultural lending by 74% over the same period (Table 13). Agricultural lending therefore declined from 40% of total lending in 1977-79 to 18% in 1986-87. Irrigation lending dropped from 22% of the total in 1977-79 to just 7% in 1986-87. Irrigation lending also declined as a proportion of agricultural lending, from about 60% of agricultural lending in the first two sub-periods to 40% in later years.

The Middle East/North Africa experienced sharp declines in total and agricultural lending, with smaller cuts in irrigation lending. As a result, agriculture remained roughly constant as a percentage of total lending (with the exception of 1980-82), while irrigation lending increased relative to both total and agricultural lending (Table 13).

Table 14 shows total, agricultural lending, and irrigation lending by ADB for the three regions combined. Further regional breakdown is not currently available. Total lending by ADB increased sharply from 1974-76 to 1977-79, and has remained nearly constant since then. Similarly, agricultural lending increased continuously through 1977-79, and then has stayed about the same level. Irrigation lending, however, has dropped sharply from the highs in 1980-82. As a result of these trends, the share of agriculture in total lending has remained roughly the same since 1974-76. However, the share of irrigation in total lending has dropped from 21% in 1980-82 to 11% in 1986-87. Irrigation has also declined as a share of agriculture, from a high of 53% in 1980-82 to 32% in 1986-87. Irrigation investment has therefore declined as a share of total lending for both the World Bank and ADB.

USAID lending and assistance for agriculture and irrigation to the three regions combined is summarized in Table 15. The data subdivided into Development Assistance (DA) and Economic Support Funds (ESF). DA is the regularly programmed funds designed to achieve economic development objectives, while ESF is programmed primarily to achieve strategic and political objectives. Irrigation lending and assistance under DA has declined sharply as a share of agriculture, from 27% in 1983-85 to 12% in 1988-89. However, there has been an offsetting increase in the share of irrigation under ESF, so the total share of irrigation in agriculture has increased over time.

Summary

From the mid-1960s to 1980 new irrigated area grew at over 2 percent per annum world wide and in Asia, the growth rate being fairly constant throughout the period. Records on irrigation investments by major lenders do not cover the period of the 1960s. Investments increased very sharply in the mid-1970s following the sharp rise in world grain prices in 1973.

During the 1980s, the picture has changed dramatically. Total lending has changed very little, with a decline in World Bank lending being offset by an increase in lending by the Asian Development Bank. But particularly since 1983 lending for agriculture and for irrigation as a percent of total lending have dropped significantly. Also the annual increase in new area irrigated has dropped from 2 percent to less than 1 percent in the 1980s. The sharpest decline in irrigation investment has been in Southeast Asia, but the annual growth in new irrigated area is still about 2 percent while it has fallen to 1 percent in South Asia.

If the expansion of irrigation facilities continues to slow and investments shift increasingly to rehabilitation and qualitative improvement of existing area, the need for more adequate ways to characterize and quantify irrigation services will also grow. Failure to develop such standards and techniques will make it impossible to measure the impacts of our irrigation investments or to attribute future gains in agricultural production to the appropriate causative factors.

Whether or not the observed trends will be lasting ones is impossible to predict without a much more detailed analysis of underlying factors. This probably could be achieved most effectively through a series of country level studies. Sorting out the reasons for the decline become vital, however, given the importance of irrigated agriculture in the Asian food supply/-demand equation and the long lead time, often measured in decades, between the decisions to invest in irrigation and the realization of outputs.

Chapter -II SECTORAL ISSUES

The data presented in Chapter II, fragmented and incomplete as they are, suggest a need to consider future investments in irrigated agriculture with increased depth and comprehensiveness. Critical to this more in-depth analysis are the answers to three sector-level questions:

-- what are the potentials for area and/or yield and/or economic return increases associated with improvement of existing systems vis a vis development of new systems?

-- to what extent should irrigation be considered like a public utility, a basic national or state infrastructure rather than production infrastructure dependent upon project benefit/-cost evaluations?

-- How can agricultural sector policies and irrigation sector policies be more effectively coordinated to maintain the economic utility of the irrigation investment?

This section will explore these questions briefly, but definitive statements must await more detailed analysis.

Potential for New Systems vs. Improvement of Existing Systems

Area Potential:

The expansion of the area served by existing systems can be considered in two dimensions -- spatial and temporal. Spatial expansion often means the extension of physical infrastructure to command new areas, coupled with either increased efficiency of water use or the augmentation of the existing water resources. Expansion of area in the temporal dimension is illustrated by increased cropping intensities and implies increased use of the existing water resource in an additional time period, or the ability to shift the time availability of the water.

Spatial expansion:

Water use efficiencies in many systems appear to vary between 30 and 40 percent, suggesting relatively large opportunities for significant increases in the effectiveness of existing water supplies. However. many of these data are derived from individual system evaluations rather than from hydrologic watershed measurements. Unmeasured downstream recovery of 'waste' surface water and extractions and recharge of groundwater can result in actual efficiencies substantially greater than the nominal values. For example, estimates of individual system water use efficiencies in Egypt are as low as 30 percent, but the overall efficiency for the entire Nile system in Egypt is estimated at approximately 70 percent. Given this efficiency, and the need to prevent upstream migration of the salt front at the mouth of the river, the feasibility of significant additional 'savings' of water for application to other agricultural land is not obvious. Similar observations can be made for the Mahaweli Project in Sri Lanka. The runoff from System H, resulting in low water efficiency for that system, represents 40 percent of the supply for the system downstream, but outside of the official Mahaweli Project area.

In Maharashtra, India, many hardrock dug wells have been installed, privately, within government irrigation systems; these obviously are recharged by seepage from the surface systems, but the extent of this recharge is unknown and area served by the wells is not included in evaluations of the performance of the government systems.

Definitive estimates of the potential for increasing the effective water supply to apply to expanded areas would require site specific analyses, both to evaluate the real potential for increasing the supply and to identify the extent of irrigable land that could be served economically with the saved water. However, it seems reasonable to suggest that there is <u>less potential</u> for expansion of existing systems than the nominal water use efficiencies imply.

Three sets of factors determine the potentials for area expansion for new systems -- the characteristics of the water resources that are available or can be developed, the characteristics of the land resources, the technologies which can economically be utilized to link the water and land. Estimates of 'ultimate potential' are difficult to make because of the inadequacies of the basic soil and water data, and because of the influence of the level of technology on the efficiency with which the water can be used. A recent World Bank paper[8] suggests a rapid assessment methodology which probably results in reasonably conservative estimates, though still limited by the adequacy of the data.

It is probable that estimates made for the humid and the arid regions are more accurate than those for semi-arid areas. In the humid regions, the land potentially suitable for irrigation is likely to be the limiting factor, and techniques for identifying irrigable land (in both qualitative and quantitative terms) are reasonably established. In the case of arid areas, water supply almost invariably is the limiting factor; in many, if not most of the arid areas with potential for irrigation, the amount and distribution of the water supply has been evaluated over time. In addition, the alternatives for economically viable technologies are relatively easily identified.

For the semi-arid regions, however, estimates of water amounts and temporal and spatial distribution are much more difficult; this is combined with greater difficulties in assessing technological appropriateness, introduce greater uncertainty in the determination of irrigation potential. Thus, although a number of estimates of ultimate potential have been made for countries in Asia and the Near East regions, their accuracy is questionable.

Temporal expansion:

Increasing cropping intensity usually is one of the most economic methods for expanding effective irrigated area since it takes advantage of the existing irrigation and agricultural infrastructure. However, cropping intensity, customarily defined in terms of number of harvests per year from the same area of land, is a very crude index of effective irrigated area. A more definitive index, in tropical and sub-tropical areas, would be the number of days during which a crop was actively growing. This would eliminate the problem of differential characterization of long-season and short-season crops, and reflect the fact that the <u>capture and utilization of sunlight</u> is the basis for successful agriculture. <u>Effective</u> irrigated area could then be defined not only in terms of the area but also include the proportion of the year during which a crop could be actively growing; this could be expressed as <u>hectare-days</u> of irrigation. This would be a relatively simple way to incorporate an irrigation quality component to the estimate of irrigation capability. Crop intensity efficiency would then be the ratio of this index to the number of hectare-days during which production was not prevented by uncontrollable factors, particularly water[9].

This type of "hectare-days" index would provide a better measure of the potential for both temporal and spacial expansion than commanded area, especially in those areas where systems have been designed to provide less than the full irrigation 'requirement', a common practice in South Asia and other semi-arid areas. Thus, a system with a water supply of 10,000 hectare-meters and a potential E-T of 5 mm/day, would have 2,000,000 hectare-days of irrigation supply. If the system had a command area of 30,000 hectares, and the water was applied to 10,000 hectares, it could meet crop needs for 200 days. If a 100 day crop were grown, crop intensity efficiency would be 50%, with a corresponding potential for temporal expansion. If the water was applied to 20,000 hectares, with a 100 day crop, cropping intensity efficiency would be 100%, with no opportunity for expansion. If the water was used on 30,000 hectares with a 100 day crop, cropping intensity would be 150%, suggesting production of a crop with less than the maximum yield potential per hectare, but, perhaps maximum yield per unit water.

In situations where water is the limiting factor, yield per unit water clearly is the most useful index of technical efficiency, but data on this are essentially non-existent at the project level. This lack makes it extremely difficult to make accurate judgments about system performance and opportunities for effective expansion in most of the semi-arid areas of the region. However, the combination of actual limitations of supply in relation to commanded area and unmeasured reuse suggest that the potentials for irrigated area expansion probably are significantly less than the nominal figures suggest. However, this does not mean that there are no opportunities for such expansion.

Yield Potential:

Area yield potentials for adequately irrigated rice and wheat, in irrigation system in the region range from 4 to 7 tons per hectare depending on soils, temperature, solar energy, length of growing season etc. The wheat yield potentials are usually about a ton below those of rice). These potential yields under field conditions may not be economically optimal in specific situations, and do not necessarily represent ultimate potentials, as indicated by significantly higher experiment station yields, but may represent practical limits[10] The influence of the other production factors and the lack of information on yields per unit water make it difficult to assess the true potential for increased yields in many parts of the region. Undoubtedly, there is significant opportunity, though, again, less than nominal differences between actual and theoretical would suggest.

Economic Return:

The potentials for increases in economic returns are at least as difficult to assess as the potentials for area and yield increases since the assessment must consider not only the physical aspects of irrigated agriculture and the on-farm economics, but also the broader aspects of the agricultural sector. Rapid, private investment in groundwater utilization in many areas, with changes in cropping practice and patterns suggests that there is potential for increases in the economic returns from irrigated areas. To the extent that these investments have been made in areas nominally served by government systems, as in the Maharashtra example cited earlier, and in the Punjabs of India and Pakistan, there is an implication that the service provided by these systems is inadequate in amount, timing or reliability, or some combination of these.

Even in systems with reputations for excellent service, e.g. those of the Taiwan Irrigation Associations, incompatible irrigation operational policies have resulted in individual farmers making private investments for irrigation capability to permit them to grow higher value crops. This suggests that there are situations where higher returns from irrigated areas are possible. Where market factors encourage and hydrologic situations permit private investment for irrigation development, there are opportunities for relatively higher returns. Where hydrologic conditions, or government policies do not permit private development, there probably are areas where existing government systems can generate higher economic returns, though changes in system operation may be necessary.

Treating Irrigation as a Utility

Decisions to invest in irrigation infrastructure are made in a climate of conflicting perspectives. At a basic level, there is the difficulty of predicting the pace and direction of technological development, as expressed in the three scenarios of Chapter I. At the present time, this prediction is more in the nature of a Delphic statement than an analysis with reasonable probability estimates. Thus, the fundamental strategy for irrigation development, may, in fact, be guided as much by "feelings" as analysis.

Even within a broad strategy of irrigation development, annual decisions frequently are inconsistent. As relatively long-term investments, with 25 to 35 year operating lives and substantial salvage value, it might be assumed that the decisions would be strongly influenced by long-time trends of need and potential benefit, with less influence of short-time circumstances. Thus, one might expect the decisions to be made in a manner similar to that for other basic utilities, such as roads and power, which would permit reasonably steady development, relatively stable employment pattern for irrigation related skills and a somewhat predictable impact. In those countries with formal development plans, e.g. India's Five-Year plans, irrigation sector planning does have a development infrastructure approach. However, individual projects associated with the plans are subject to benefit/cost evaluation (as well as political calculus) which frequently alters the pace of implementation, and usually introduces a shorter time perspective in the decision-making.

While careful benefit/cost analysis tries to place the estimation of benefits and costs in the appropriate time frame, the difficulties of predicting the future and the pressure of present circumstances tend to introduce a bias to the shorter term conditions. As a result, there is more irregularity to irrigation infrastructure development than is suggested by the longer term perspective. This probably tends to be more true of the larger projects that are dependent upon external funding than of the smaller projects which are constructed with national and/or state and local funds, though this latter may be changing as the external lenders move toward program and sector funding that includes minor irrigation, although at sharply lower investment levels.

Among the consequences of decisions based on shorter time perspectives are difficulties in making institutional and organizational adjustments, including appropriate modifications in budget allocations and relatively large variations in demand for irrigation development skills with shortages at construction time, significant problems relating to quality of construction skill, crash programs of training and then relatively long periods of employment stagnation. Illustrative of this latter situation are the cases of Bihar and Uttar Pradhesh, in India, where there was a major spurt of hiring during a major construction effort, with no hiring of engineers by the irrigation departments in the past five years. The boom/bust cycle prevents development of appropriate educational responses to needs

The need to be economic and reasonably efficient in allocation of development resources is obvious. Whether traditional benefit/cost is the most appropriate mechanism for making these types of decisions is arguable. In the case of projects utilizing external funding, the reality is that the external funds are not really buying the identified project, but are buying the <u>last project the government will build with the money released by the availability of the external funds</u>. Thus, the <u>real</u> benefit/cost ratio for the loan, even assuming accuracy of the estimates, is likely to be very different from that calculated for the project. And, as has been stated before, the ability to accurately predict the course of a project's costs and benefits is difficult, especially for the larger projects.

An approach that places greater emphasis on the factors that will lead to the best projects for the money, i.e. the best system for the amount one wants to spend or a 'value engineering approach', should be evaluated. This, combined with a more stable pace of sector development, would lead to easier assimilation of the new capability and more appropriate human resource development, within the agencies and in the support sectors.

Finally, although it may be useful to consider alternatives to benefit/cost analysis, there also are dangers in treating irrigation as a utility. Most developed countries, including the United States, Western Europe, and Japan, tend to treat the agricultural sector as a utility. As a result the developed countries have vastly overexpanded agricultural capacity, contributing to worldwide surpluses of food grains. While in years of unfavorable weather like the present we may be thankful for these surpluses, the burden that this places on both developed and developing countries in normal years is very large. (Parenthetically, utilities in New York State and in many other parts of the country have constructed generating capacity at very high cost well in excess of demand much to the consternation of consumers who must pay for this unwanted capacity). The dangers of this type of overinvesting in the developing countries are much less, since agriculture represents a much larger segment of the total economy.

Policy Coordination

The lack of coordination among the various government agencies involved in the irrigation sector has been identified as a significant factor in the inadequate performance of the sector. This problem has been addressed in a variety of ways in the different countries of the region, but usually at the scheme or project level. Illustrative are the inter-agency committee approach, e.g the Command Area Development Authorities in India and the Command Water Management program in Pakistan and the area authority approach, e.g. the Mahaweli Economic Authority and the Muda Agricultural Development Authority.

These approaches are focused on improving the coordination of the agencies as they relate to the actions of the agencies in the individual projects; they usually do not address the problem of coordinating the policies of the different agencies at the sector level, policies which at times can be in relatively direct conflict. For example, in Sri Lanka, the agriculture ministry policy of stabilizing rice prices and maintaining a ceiling on the price of chilies and similar crops resulted in production of rice on land in the Mahaweli project that was neither designed for rice, nor physically appropriate for rice. The results were excessive water use, disputes among the farmers and between the farmers and system personnel. A variety of technical solutions -- underground pipe, controlled outlets, etc. -- were considered, but a shift in government policy to maintain a reasonably profitable price for chilies essentially resolved the problem.

When severe problems of policy conflict between ministries become apparent, they can be addressed at the Cabinet level, but this frequently is a difficult and inefficient venue; other mechanisms to minimize and avoid development of problems are desirable.

CHAPTER IV IMPROVING SYSTEMS

Over the years, concern for improved performance of irrigation systems in the developing countries has been expressed through specific types of remedial efforts, the nature of which has changed over time. Early efforts focused on system technological improvements, with introductions of new technologies as well as improved application of existing methods. Later, this focus was overlain by concern for the improvement in the irrigation governmental organizations. To this was added increased attention to the problems of maintenance and the associated need to involve the farmers. Problems of financing focused even greater attention on the farmers, and 'privatizing' became a catchword. Most recently, low prices of basic staple crops and increasing opportunities for economic returns from other crops has given impetus to incorporating 'flexibility' into system operations to permit 'diversification'. At the present time, programs for the improvement of irrigation system performance frequently include combinations of this set of approaches, but it is not clear that the designs of these programs reflect adequate analysis of the problems of performance or of the prerequisites for effective application of proposed solutions.

In this chapter, we will consider three performance problems that are perceived as being critical in many systems in Asia and the Near East and will attempt to analyze the approaches to dealing with these problems. The analysis is intended to be indicative, rather than comprehensive, and should illustrate some of the complexity associated with irrigation problems.

Performance problems that are of general concern throughout the region include 1) failure of governments to obtain and/or to allocate sufficient funds for adequate operation and maintenance of the systems; 2) inefficiency in the use of the irrigation infrastructure and water resource; 3) inability of systems to meet the needs of farmers with diversified crops.

Funds for Operation and Maintenance

In most, but not all systems in the region, there is sense that the systems deteriorate too rapidly because of inadequate maintenance and that at least part of the reason systems do not meet the needs of farmers is that there is too little money for appropriate operation. Appropriate operation often is considered to be operation that is 'responsive' to farmer needs. Two basic approaches to dealing with these O&M problems are emphasized, frequently with pressure from the lending/donor community: to increase funding, with all, or a major proportion to come from the water users; to turn over all, or major portions of systems to the water users.

The problem of deterioration has a number of ambiguities. In certain situations, such as a the highly erosive environments of the middle hills of Nepal, any substantial inadequacy in system maintenance results in rapid failure of the system. The need for adequate maintenance resources obviously is critical. In many, and probably most other systems in the region, however, deterioration to the point of necessary rehabilitation occurs over an extended period -- 20 to 30 years -- and it is not obvious that this deterioration period can, or should be reduced significantly. The nature and pace of the deterioration, the impact on performance of that deterioration and the influence of relatively high discount rates in developing countries combine to suggest that 'deferred maintenance' and periodic 'rehabilitation' may be reasonably efficient, economically, though not without problems of maintaining equity[11].

The argument of lack of responsiveness of systems also has difficulties. The evidence to suggest that the systems are inadequately responsive to the needs of the farmers and that this lack of responsiveness is significantly related to the lack of financial resources for the irrigation system is not strong. Systems, such as the Warabandi[12] in the Punjab of India and Pakistan, are designed to be non-responsive, but the evidence is that the farmers are able to introduce significant variation in their cropping and agricultural practice, at least in part because the systems are predictable. In a very different context

Table 1. Net Irrigated Area - World ('000 Ha).

YEAR	WORLD	ASIA[a]	AFRICA	NORTH & CENTRAL AMERICA	SOUTH AMERICA	EUROPE	OTHER[b]
1964	149,697	97,532	5,938	20,455	5,486	9,335	10,951
1965	153,697	100,540	6,222	20,697	5,555	9,406	11,277
1966	155,335	101,574	6,465	20,374	5,712	9,767	11,443
1967	159,193	106,038	6,619	20,023	5,309	9,837	11,367
1968	162,634	108,184	6,953	20,366	5,403	10,266	11,462
1969	167,648	110,465	7,287	21,475	5,922	10,760	11,739
1970	167,399	109,727	7,620	20,955	5,681	10,728	12,688
1971	175,471	115,652	7,116	21,769	6,154	11,497	13,283
1972	176,608	116,604	7,275	21,820	5,879	11,438	13,592
1973	181,445	119,189	7,449	22,169	6,228	12,058	14,352
1974	184,320	120,041	7,652	22,554	6,406	12,385	15,282
1975	188,048	121,578	8,169	22,853	6,587	12,765	16,096
1976	193,763	125,941	7,775	23,234	6,755	13,118	16,940
1977	196,633	127,132	7,975	23,514	6,931	13,435	17,646
1978	204,132	129,583	7,888	27,514	7,090	13,811	18,246
1979	207,720	131,546	7,076	27,857	7,213	14,571	19,457
1980	210,974	132,563	9,325	27,871	7,386	14,658	19,171
1981	210,905	132,434	8,070	28,102	7,541	14,873	19,885
1982	215,454	134,907	10,014	27,299	7,692	15,070	20,472
1983	213,376	133,395	8,227	27,485	7,835	15,307	21,127
1984	219,715	136,962	10,390	27,414	7,979	15,616	21,354
1985	220,312	138,279	10,625	25,361	8,131	16,093	21,823

Source: FAO Production Year Books, 1965-86.
[a] Corrected using China data from the Annex.
[b] Other includes Oceania and the Soviet Union.

Table 2. Shares[a] of Net Irrigated Area - World

YEAR	ASIA	AFRICA	NORTH & CENTRAL AMERICA	SOUTH AMERICA	EUROPE	OTHER[b]
1965	0.653	0.041	0.134	0.037	0.062	0.073
1966	0.658	0.041	0.130	0.035	0.062	0.073
1967	0.662	0.042	0.127	0.034	0.063	0.072
1968	0.663	0.043	0.126	0.034	0.063	0.071
1969	0.660	0.044	0.126	0.034	0.064	0.072
1970	0.658	0.043	0.126	0.035	0.065	0.074
1971	0.658	0.042	0.124	0.034	0.065	0.076
1972	0.659	0.041	0.123	0.034	0.066	0.077
1973	0.656	0.041	0.123	0.034	0.066	0.080
1974	0.651	0.042	0.122	0.035	0.067	0.083
1975	0.649	0.042	0.121	0.035	0.068	0.085
1976	0.648	0.041	0.120	0.035	0.068	0.088
1977	0.644	0.040	0.125	0.035	0.068	0.089
1978	0.638	0.038	0.130	0.035	0.069	0.091
1979	0.632	0.039	0.134	0.035	0.069	0.091
1980	0.630	0.039	0.133	0.035	0.070	0.093
1981	0.627	0.043	0.131	0.035	0.070	0.093
1982	0.626	0.041	0.130	0.036	0.071	0.096
1983	0.625	0.044	0.127	0.036	0.071	0.097
1984	0.625	0.045	0.123	0.037	0.072	0.098

[a] Computed from table 1 using three-year moving averages.
[b] Other includes Oceania and the Soviet Union

Table 3. Compound Growth Rates of Net Irrigated Area - World.

Period	Rate[a] (%)	
	World	Asia
1965-84	2.0	1.6
1965-69	2.2	2.5
1970-74	2.3	2.1
1975-79	2.5	1.9
1980-84	0.9	0.7

[a] Computed from table 1 using semi-log regression techniques.

Table 4. Net Arable and Permanent Cropped Area - World ('000 Ha).

YEAR	WORLD	ASIA	AFRICA	NORTH & CENTRAL AMERICA	SOUTH AMERICA	EUROPE	OTHER[a]
1965	1,419,860	454,735	203,076	257,225	85,559	150,824	268,441
1966	1,417,273	455,666	197,031	256,185	87,820	149,536	271,035
1967	1,403,199	441,129	197,965	253,200	89,814	148,851	272,240
1968	1,365,957	437,555	157,075	258,971	91,542	147,705	273,109
1969	1,469,864	465,536	211,098	271,940	93,698	147,708	279,884
1970	1,408,362	439,834	169,110	266,881	110,996	145,248	276,293
1971	1,416,510	467,087	196,134	271,898	96,220	144,204	240,967
1972	1,438,685	447,581	203,766	267,711	98,558	143,749	277,320
1973	1,423,482	448,793	174,186	267,138	116,853	142,505	274,007
1974	1,429,591	450,741	174,346	266,838	118,619	142,520	276,527
1975	1,429,986	447,764	175,858	267,647	121,178	141,239	276,300
1976	1,439,214	452,121	179,644	267,931	121,676	141,725	276,117
1977	1,440,913	452,785	179,416	268,414	123,436	141,621	275,241
1978	1,451,666	453,896	179,642	270,665	129,628	141,821	276,014
1979	1,456,478	454,387	180,262	270,985	131,958	141,319	277,567
1980	1,459,902	452,472	181,106	273,289	134,406	140,856	277,773
1981	1,465,305	455,466	182,154	273,242	136,777	140,702	276,964
1982	1,470,560	454,274	182,503	273,894	138,752	140,697	280,440
1983	1,471,731	456,037	183,059	272,989	138,694	140,366	280,586
1984	1,476,761	456,596	184,184	274,417	139,188	140,409	281,967
1985	1,476,483	454,253	184,869	274,626	140,638	139,625	282,472

Source : FAO Production Yearbooks, 1965-1986.
[a] Other includes Oceania and the Soviet Union.

Table 5. Compound Growth Rates of Net Irrigated Area - Asia[a].

Period	Rate[b] (%)				
	South East Asia	South Asia	China	South Korea	Near East
1965-84	2.5	2.1	1.2	2.5	-0.3
1965-69	0.9	2.7	2.9	7.3	1.7
1970-74	4.0	1.9	2.9	3.1	0.4
1975-79	3.0	2.2	0.0	6.2	0.7
1980-84	2.1	1.0	0.0	0.8	-0.8

[a] Regions are as defined in the text.
[b] Computed from the Annex using semi-log regression techniques.

Table 6. Shares[a] of Net Irrigated Area - Asia.

YEAR	CHINA	SOUTH KOREA	SOUTH EAST ASIA	SOUTH ASIA 2
1965	0.424	0.008	0.095	0.472
1966	0.427	0.008	0.094	0.471
1967	0.425	0.009	0.092	0.474
1968	0.421	0.010	0.091	0.477
1969	0.420	0.010	0.091	0.479
1970	0.421	0.010	0.091	0.478
1971	0.422	0.011	0.093	0.475
1972	0.423	0.011	0.094	0.472
1973	0.422	0.010	0.095	0.472
1974	0.422	0.009	0.094	0.474
1975	0.417	0.009	0.094	0.480
1976	0.413	0.010	0.095	0.483
1977	0.405	0.010	0.097	0.488
1978	0.399	0.010	0.100	0.490
1979	0.395	0.010	0.102	0.494
1980	0.390	0.010	0.104	0.496
1981	0.387	0.010	0.105	0.497
1982	0.385	0.010	0.107	0.498
1983	0.385	0.010	0.107	0.498
1984	0.383	0.010	0.107	0.499

[a] Computed from the Annex using three-year moving averages

Table 7 -- Average annual lending and assistance for irrigation by World Bank, Asian Development Bank, U.S. Agency for International Development, and Japanese Overseas Economic Cooperation Fund, to South Asia, Southeast Asia, and Middle East/North Africa, constant 1980 prices.

Year	Lending and Assistance to Irrigation ($ million)					
	World Bank (1)	ADB (2)	OECF (3)	USAID (4)	Total of (1)+(2)+(3)	Total of (1)+(2)+(3)+(4)
1969-70	-	57	6	-	-	-
1971-73	-	69	7	-	-	-
1974-76	1,093	96	28	-	1,217	-
1977-79	1,191	219	33	-	1,443	-
1980-82	989	253	46	93	1,288	1,381
1983-85	811	162	75	83	1,048	1,131
1986-87	589	144	22	75	755	830

Sources: World Bank, ADB, OECF, USAID.

Table 8 -- Average annual lending and assistance for irrigation in South Asia by World Bank, Asian Development Bank, U.S. Agency for International Development, and Japanese Overseas Economic Cooperation Fund, constant 1980 prices.

Year	Lending and Assistance to Irrigation ($ million)					
	World Bank (1)	ADB (2)	OECF (3)	USAID (4)	Total of (1)+(2)+(3)	Total of (1)+(2)+(3)+(4)
1969-70	-	18	0	-	-	-
1971-73	-	8	0	-	-	-
1974-76	349	32	0	-	381	-
1977-79	514	85	4	-	603	-
1980-82	651	100	15	54	766	820
1983-85	533	74	10	68	617	685
1986-87	317	48	3	29	368	397

Sources: World Bank, ADB, OECF, USAID.

Table 9 -- Average annual lending and assistance for irrigation in Southeast Asia by World Bank, Asian Development Bank, U.S. Agency for International Development, and Japanese Overseas Economic Cooperation Fund, constant 1980 prices.

Year	Lending and Assistance to Irrigation ($ million)					
	World Bank (1)	ADB (2)	OECF (3)	USAID (4)	Total of (1)+(2)+(3)	Total of (1)+(2)+(3)+(4)
1969-70	-	35	6	-	-	-
1971-73	-	61	7	-	-	-
1974-76	319	52	16	-	387	-
1977-79	467	134	29	-	630	-
1980-82	237	153	31	17	411	438
1983-85	147	87	59	5	293	298
1986-87	88	96	18	9	202	211

Sources: World Bank, ADB, OECF, USAID.

Table 10 -- Average annual lending and assistance to irrigation in Middle East/North Africa by World Bank, Asian Development Bank, U.S. Agency for International Development, and Japanese Overseas Economic Cooperation Fund, constant 1980 prices.

Year	Lending and Assistance to Irrigation ($ million)					
	World Bank (1)	ADB (2)	OECF (3)	USAID (4)	Total of (1)+(2)+(3)	Total of (1)+(2)+(3)+(4)
1969-70	-	5	0	-	-	-
1971-73	-	0	0	-	-	-
1974-76	425	20	18	-	463	-
1977-79	210	0	0	-	210	-
1980-82	103	0	0	22	103	125
1983-85	130	0	9	9	139	148
1986-87	184	0	0	37	184	221

Sources: World Bank, ADB, OECF, USAID.

Table 11 -- World Bank average annual total lending, agricultural lending, and lending to irrigation, total for South Asia, Southeast Asia, and Middle East/North Africa, 1974-87, constant 1980 prices.

Year	Total Lending	Agricul-tural Lending	Irriga-tion Lending	Agric. as % of Total	Irrig. as % of Total	Irrig. as % of Agric.
	------	$ million	-------	---------	%	-----------
1974-76	6,208	1,592	1,093	25.6	17.6	68.7
1977-79	6,297	2,127	1,191	33.8	18.9	56.0
1980-82	5,589	1,629	989	29.2	17.7	60.7
1983-85	4,788	1,313	811	27.4	16.9	61.8
1986-87	4,299	920	589	21.4	13.7	64.0

Source: World Bank.

Table 12 -- World Bank average annual total lending, agricultural lending, and lending to irrigation in South Asia, 1974-87, constant 1980 prices.

Year	Total Lending	Agricultural Lending	Irrigation Lending	Agric. as % of Total	Irrig. as % of Total	Irrig. as % of Agric.
	--------	$ million	--------	----------	%	----------
1974-76	1,607	441	349	27.4	21.7	79.1
1977-79	2,024	795	514	39.3	25.4	64.7
1980-82	2,421	862	651	35.6	26.9	75.5
1983-85	2,388	703	533	29.4	22.2	75.8
1986-87	2,248	523	317	23.3	14.1	60.6

Source: World Bank.

Table 13 -- World Bank average annual total lending, agricultural lending, and lending to irrigation in Southeast Asia, 1974-87, constant 1980 prices.

Year	Total Lending	Agricultural Lending	Irrigation Lending	Agric. as % of Total	Irrig. as % of Total	Irrig. as % of Agric.
	--------	$ million	--------	----------	%	------------
1974-76	1,727	488	319	28.3	18.5	65.4
1977-79	2,091	833	467	39.8	22.3	56.1
1980-82	1,754	568	237	32.3	13.5	41.7
1983-85	1,277	366	147	28.7	11.5	40.2
1986-87	1,219	214	88	17.6	7.2	41.1

Source: World Bank.

Table 14 -- World Bank average annual total lending, agricultural lending, and lending to irrigation in Middle East/North Africa, 1974-87, constant 1980 prices.

Year	Total Lending	Agricultural Lending	Irrigation Lending	Agric. as % of Total	Irrig. as % of Total	Irrig. as % of Agric.
	--------	$ million	---------	-----------	%	-----------
1974-76	2,875	663	425	23.1	14.8	64.1
1977-79	2,183	499	210	22.9	9.6	42.1
1980-82	1,413	198	103	14.0	7.3	52.0
1983-85	1,123	244	130	21.7	11.6	53.3
1986-87	832	184	184	22.1	22.1	100.0

Source: World Bank.

Table 15 -- Asian Development Bank, average annual total lending, agricultural lending, and lending to irrigation, total for South Asia, Southeast Asia, and Middle East/North Africa, 1969-87, constant 1980 prices.

Year	Total Lending	Agricultural Lending	Irrigation Lending	Agric. as % of Total	Irrig. as % of Total	Irrig. as % of Agric.
	-------- $ million		-------	---------- %		----------
1969-70	386	163	57	42.2	14.8	35.0
1971-73	912	168	69	18.4	7.6	41.1
1974-76	868	338	96	38.9	11.1	28.4
1977-79	1,316	437	219	33.2	16.6	50.1
1980-82	1,225	480	253	39.2	20.7	52.7
1983-85	1,353	470	162	34.7	12.0	34.5
1986-87	1,316	444	144	33.7	10.9	32.4

Source: Asian Development Bank.

Table 16 - U.S. Agency for International Development, average annual lending and assistance for agriculture and irrigation, total for South Asia, Southeast Asia, and Middle East/North Africa, 1979-89, constant 1980 prices.

Fiscal Year	Development Assistance			Economic Support Fund			Total		
	Agric.	Irr.	Irr.as % of Agric.	Agric.	Irr.	Irr.as % of Agric.	Agric.	Irr.	Irr.as % of Agric.
	$ million								
1980-82	267	44	16.5	188	49	26.1	455	93	20.4
1983-85	196	53	27.0	206	30	14.6	402	83	20.7
1986-87	124	24	19.4	172	51	29.7	295	75	25.3
1988-89[a]	74	9	12.2	135	53	39.4	209	62	29.7

[a]Programmed funds.

Source: USAID.

Annex. Net Irrigated Area by Country - Asia
('000 Ha.)

YEAR	CHINA[a]	SOUTH KOREA	INDONESIA	MALAYSIA	PHILS[b]	VIETNAM	KAMPUCHEA	LAOS	THAILAND	SOUTH EAST ASIA	BURMA	BANGLADESH	INDIA[c]	NEPAL	PAKISTAN	SRI LANKA	SOUTH ASIA
1965	34,700	702	4,150	245	958	980	89	15	1,768	8,205	753	572	26,299	86	12,043	341	40,094
1966	37,300	731	4,175	247	960	980	89	15	1,768	8,234	773	620	26,771	105	12,200	398	40,867
1967	38,000	753	4,200	254	1,000	980	89	15	1,791	8,329	781	686	27,312	150	12,300	398	41,627
1968	38,700	759	4,230	226	1,050	980	89	17	1,795	8,387	816	946	28,262	181	12,400	413	43,018
1969	39,400	993	4,253	240	1,100	980	89	17	1,830	8,509	818	1,058	29,700	181	12,549	403	44,709
1970	40,300	1,000	4,280	265	1,150	980	89	17	1,960	8,741	839	1,058	30,902	181	12,958	465	46,403
1971	41,500	1,030	4,300	270	1,200	980	89	19	2,106	8,964	890	1,047	31,647	181	13,000	439	47,204
1972	42,500	1,060	4,325	278	1,271	980	89	11	2,197	9,151	890	1,212	31,920	185	13,043	430	47,680
1973	44,000	1,100	4,350	281	1,311	980	89	11	3,018	10,040	971	1,212	32,275	185	14,043	427	49,113
1974	45,300	1,130	4,380	284	1,351	980	89	11	3,018	10,113	987	1,212	33,165	185	14,100	430	50,079
1975	45,450	915	4,380	300	1,391	980	89	11	3,149	10,300	976	1,500	34,162	180	14,300	440	51,558
1976	45,600	936	4,840	310	1,430	980	89	11	2,448	10,108	984	1,420	34,871	190	13,600	530	51,595
1977	44,540	1,082	4,900	335	1,113	980	89	11	2,576	10,004	1,000	1,300	35,850	200	13,800	540	52,690
1978	45,465	1,122	5,304	340	1,113	1,450	89	78	2,600	10,974	981	1,450	37,306	210	14,000	536	54,483
1979	45,503	1,140	5,360	360	1,269	1,684	89	78	2,630	11,470	1,044	1,520	38,269	220	14,450	550	56,053
1980	45,388	1,170	5,418	370	1,300	1,542	89	115	3,015	11,849	999	1,639	38,642	230	14,680	525	56,715
1981	45,074	1,160	5,430	380	1,340	1,650	89	116	2,660	11,665	1,056	1,680	39,365	230	14,320	525	57,176
1982	44,770	1,170	5,450	390	1,370	1,700	89	118	3,340	12,457	1,044	1,800	39,947	230	14,700	519	58,240
1983	45,144	1,190	5,418	334	1,400	1,730	89	118	3,472	12,561	1,011	1,848	39,500	230	14,720	538	57,847
1984	45,420	1,200	5,420	336	1,430	1,750	89	118	3,550	12,693	1,064	1,920	39,700	640	15,320	550	59,194

Source : FAO Production Yearbooks, 1965-86.

[a] Data from 1965-1974 was taken from "Food Production in the People's Republic of China", by A.M. Tank and B.Stone, IFPRI Research Report 15,1980.

[b] Changed basis for reporting area in 1977.

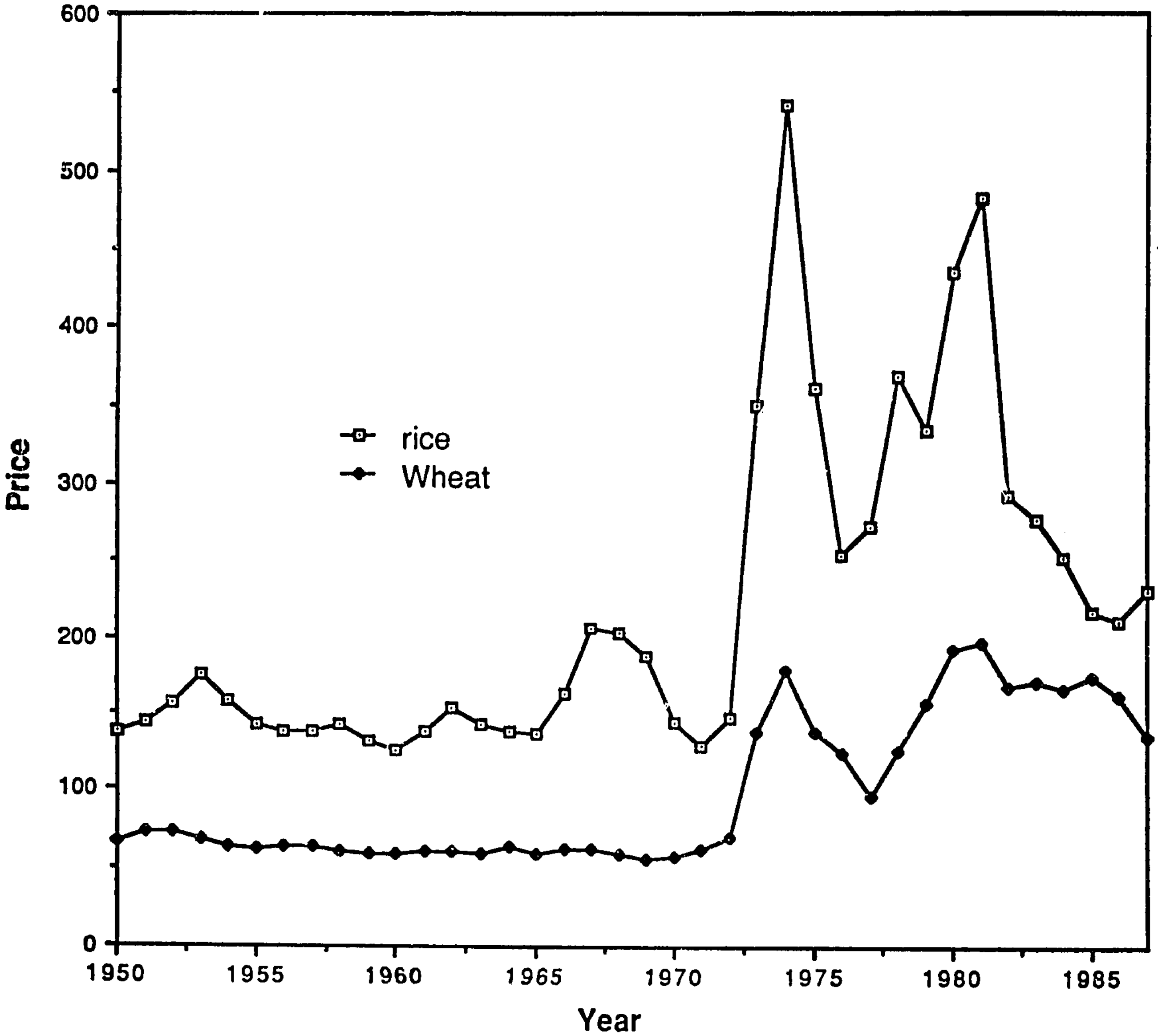
[c] Data from 1965-82 was taken from GOI statistics books.

Annex (cont.). Net Irrigated Area by Country - Near East
('000 Ha.)

YEAR	MOROCCO	TUNISIA	EGYPT	JORDAN	NORTH YEMEN	NEAR EAST
1965	660	80	2,672	60	90	3,562
1966	690	80	2,780	60	90	3,700
1967	710	80	2,801	60	90	3,741
1968	740	80	2,801	60	90	3,771
1969	770	85	2,835	60	90	3,840
1970	800	85	2,843	60	100	3,888
1971	830	85	2,852	60	100	3,927
1972	850	90	2,855	60	100	3,955
1973	850	90	2,855	60	100	3,955
1974	850	90	2,855	60	100	3,955
1975	440	125	2,855	60	230	3,710
1976	470	130	2,826	60	230	3,716
1977	470	130	2,831	60	230	3,721
1978	475	140	2,838	85	230	3,768
1979	500	140	2,850	85	243	3,818
1980	510	156	2,447	87	245	3,445
1981	520	163	2,860	85	245	3,873
1982	530	178	2,470	38	245	3,461
1983	520	201	2,471	38	245	3,475
1984	520	210	2,474	38	245	3,487

Source: FAO Production Yearbooks, 1965-86.

FIGURE 1. EXPORT PRICES (US$/t FOB) OF RICE AND WHEAT, 1950-87



[a] fob = free on board

[b] 5% brokens, milled, fob Bangkok

[c] Canadian No. 1 Western Red Spring 13.5%, in store Thunder Bay, domestic, from 1985 St. Lawrence export

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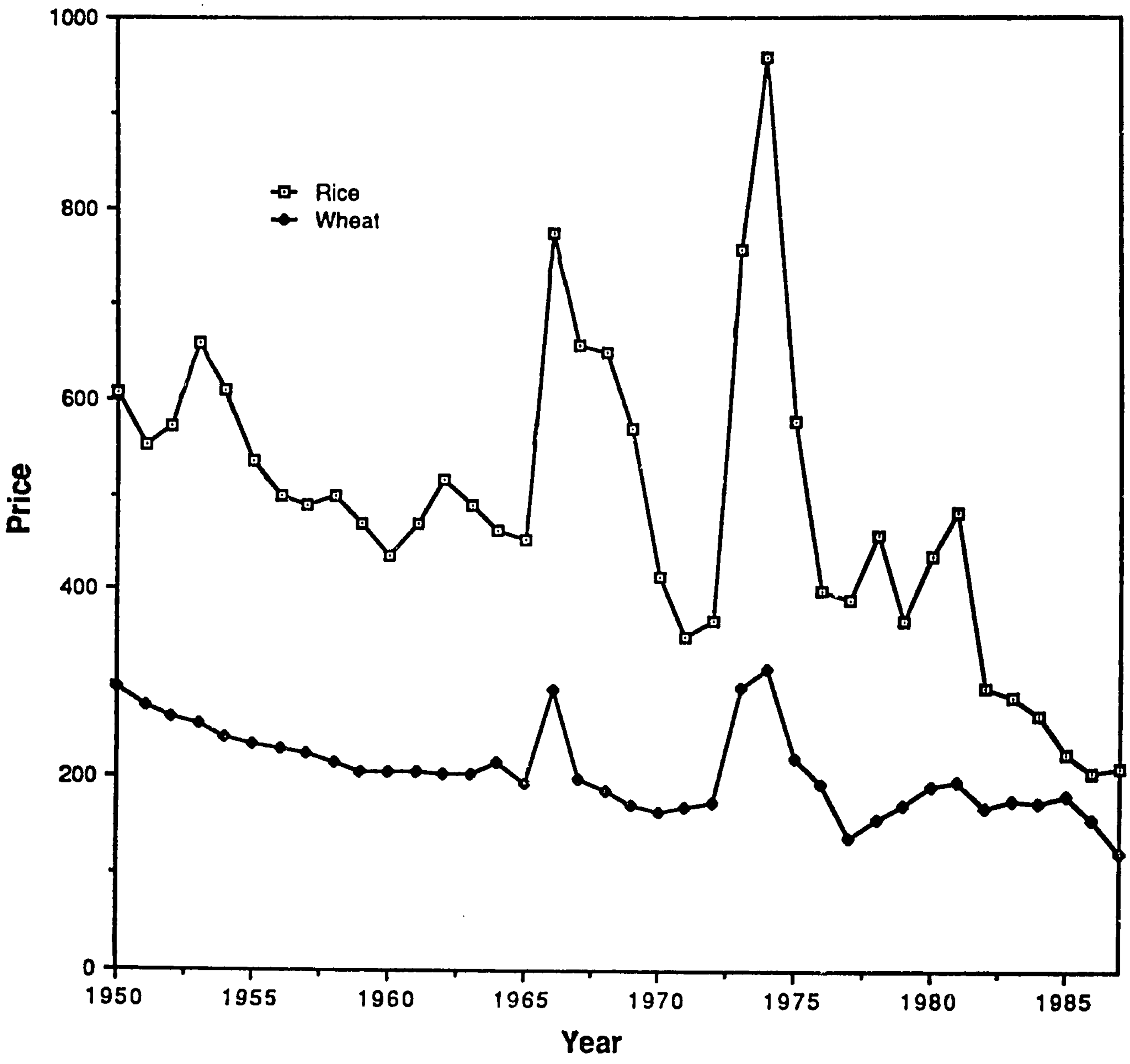
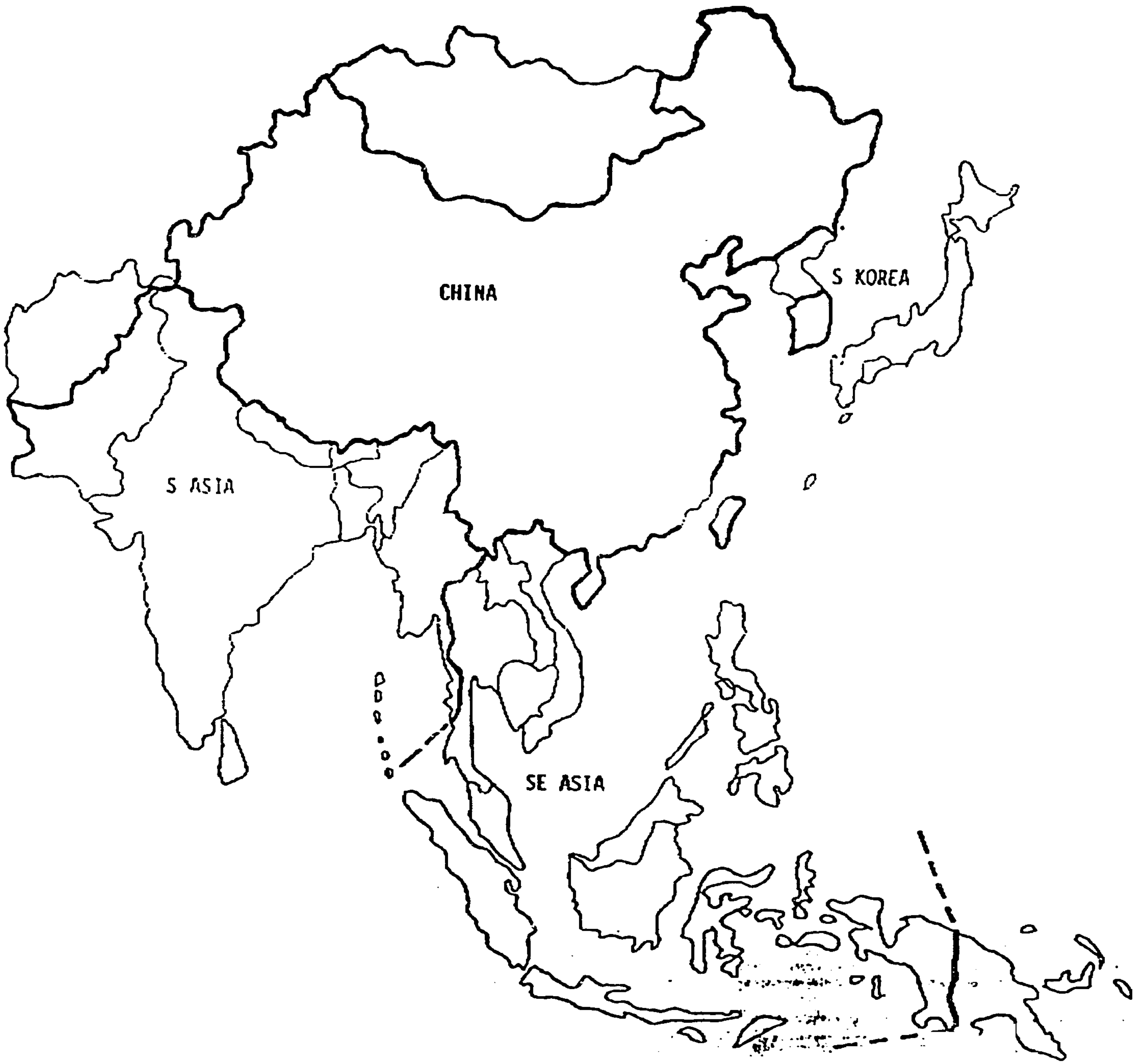
FIGURE 2. CONSTANT 1980 PRICES (US$/t FOB) OF RICE AND WHEAT, 1950-87



a fob = free on board. Prices deflated by Manufacturing index

b 5% brokens, milled, fob Bangkok

c Canadian No. 1 Western Red Spring 13.5%, in store Thunder Bay, domestic, from 1985 St. Lawrence export


CHINA
S KOREA
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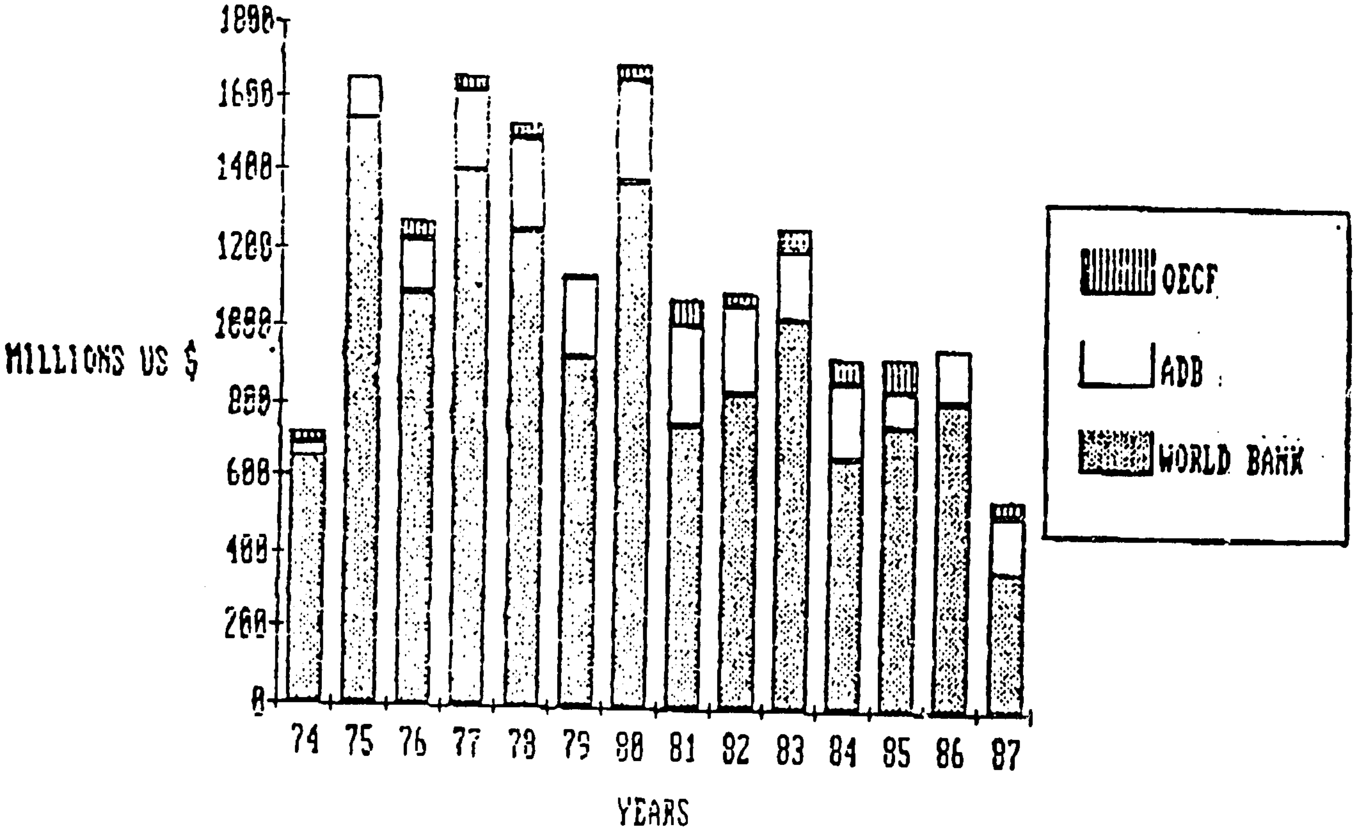

Fig. 24 World Bank, ADB, and OECF irrigation loans M. East, South and Southeast Asia, (1980 prices).

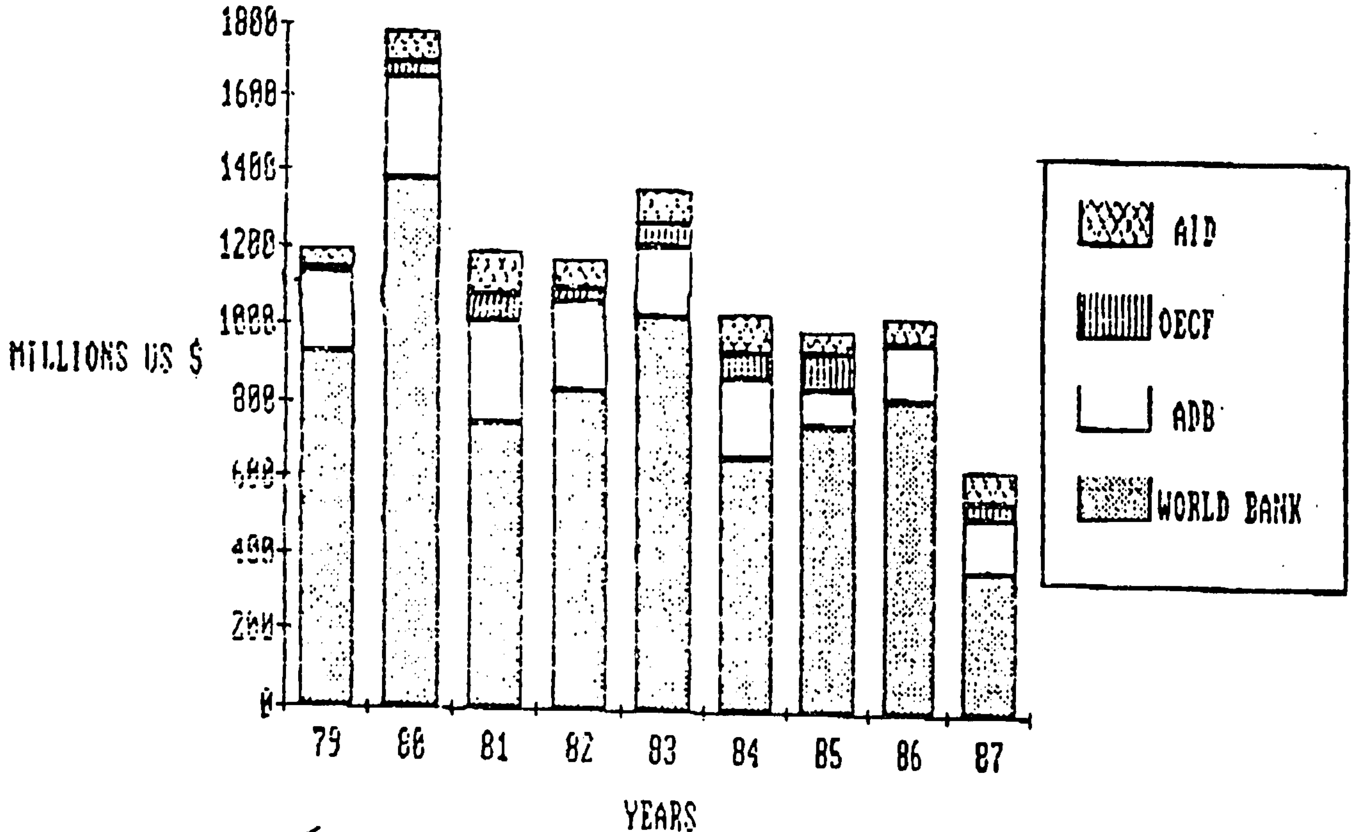

Fig. 5 World Bank, ADB, OECF, and AID irrigation loans to Middle East/North Africa, South and Southeast Asia (1980 prices).

The problem of deterioration has a number of ambiguities. In certain situations, such as a the highly erosive environments of the middle hills of Nepal, any substantial inadequacy in system maintenance results in rapid failure of the system. The need for adequate maintenance resources obviously is critical. In many, and probably most other systems in the region, however, deterioration to the point of necessary rehabilitation occurs over an extended period -- 20 to 30 years -- and it is not obvious that this deterioration period can, or should be reduced significantly. The nature and pace of the deterioration, the impact on performance of that deterioration and the influence of relatively high discount rates in developing countries combine to suggest that 'deferred maintenance' and periodic 'rehabilitation' may be reasonably efficient, economically, though not without problems of maintaining equity[11].

The argument of lack of responsiveness of systems also has difficulties. The evidence to suggest that the systems are inadequately responsive to the needs of the farmers and that this lack of responsiveness is significantly related to the lack of financial resources for the irrigation system is not strong. Systems, such as the Warabandi[12] in the Punjab of India and Pakistan, are designed to be non-responsive, but the evidence is that the farmers are able to introduce significant variation in their cropping and agricultural practice, at least in part because the systems are predictable. In a very different context

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and design approach, the National Irrigation Administration in the Philippines had, in its Upper Pampanga River Irrigation System, the entire physical and organizational infrastructure necessary for a very responsive operation, responsive at the group level if not to individuals. An elaborate system of field data collection and transmission existed, and physical control structures were in place from the reservoir to the 50 hectare distribution level. Yet, after a relatively short period of experience, the data collection was curtailed, and operation organized by relatively simple and rigid procedures. Nevertheless, substantial variation in agricultural practice exists in the command area, though by far the greater proportion remains in rice. The appropriate degree of 'responsiveness' is not easily defined and the causes of a lack of responsiveness are not adequately understood.

Notwithstanding these ambiguities, there is a need for money to operate and maintain irrigation systems, even at existing levels, and, as suggested earlier, there is strong pressure from international lenders that the water users should provide these funds.

Primarily from a pragmatic perspective, rather than efficiency or beneficiary rationales, the only source of additional resources for operation and maintenance is the water user, and there is major interest in devising ways to obtain those resources from the farmers. It should be recognized, however, that farmers in most developing countries are likely to consider water fees a tax and not a fee for service, and that this point of view has validity. Three basic approaches, sometimes in combination, are being used to obtain more O&M resources from the water users: 1) coercion; 2) development of a service orientation; 3) transfer of responsibility.

1) coercion: imposition of water fees, as with any tax, requires a collection system to be effective. The single factor most closely correlated with percent of fees collected in the Philippines is the number of staff involved in the collection process[13]. Addition of the fee to the regular land tax, for collection by the Revenue Department utilizes the normal coercion mechanisms of the government. The extent of water fee evasion can be assumed to be similar to that for normal tax evasion, though in the case of irrigation fees related to crop area reporting, there is incentive to under-report irrigated cropping.

2) service orientation: there is evidence that farmers are willing to pay a water fee if it is clear that the additional payment will, in fact, be used for operation and/or maintenance in their system. This has been the basis for significant levels of fee collection in the Taiwan irrigation associations, and has been indicated as a basis for payment by water users in Sri Lanka. It is the demonstrated basis for operation and maintenance of most communal irrigation systems, and most non-

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governmental systems that rely on groundwater pumping. In this situation, the fee <u>is</u> considered a charge for service, rather than a general tax. In addition, the focus on the local system permits the substitution of 'in-kind' contributions, particularly labor, which can represent a substantial proportion of the O&M needs.

3) transfer: the alternative to collecting money from the water users to operate and maintain the system, is to turn over responsibility for all or part of the system directly to the users, thus easing the burden on the government. This approach to dealing with the O&M problem is gaining favor among both the lenders and governments for reasons beyond the direct financial benefits. The mechanisms for effecting this transfer are varied, ranging from devolution of responsibility for specific portions of the systems, as in India, where the Government of India is recommending transfer of systems below the Minors to water user groups, to encouragement of private substitutes for government systems, as in the case of the closure of government tubewells in Pakistan[14].

The transfer of operation and maintenance responsibilities to water user groups has gained popularity for two reasons. There is a feeling, partially supported by research, that water user group operation of portions of systems is more efficient and effective than government operation, and relatively successful techniques for assisting farmers in organizing water user groups have been developed and tested in the Philippines, Sri Lanka and Nepal[15].

Inefficiency in Use of Water and Irrigation Infrastructure

The uncertainties associated with our understanding of the extent of resource and infrastructure inefficiency have been expressed in Chapter III, but the conclusion offered is that most government systems probably are not as inefficient as they appear from superficial examination. Nevertheless, there generally is substantial opportunity for improvement.

Programs to obtain this improvement typically have focused on improvement of system physical infrastructure, including the extension of that infrastructure closer to individual farms, addition of more control structures such as measuring structures and adjustable gates and on-farm land improvements, such as leveling. To illustrate, much of the effort of the Command Area Development Authorities, in India, has been in the area of physical improvement below the canal outlet, even though their major purpose, initially, was to improve the coordination among the various agencies involved in the irrigation sector. Similar physical improvements characterize projects in Indonesia, Pakistan and Egypt.

There has been intellectual recognition of the need to have corresponding institutional changes, in terms of organiza-

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tional changes in the government irrigation departments, changes in the rules for allocation water and in the roles and responsibilities of the water users, and many rehabilitation and improvement projects have included elements for these purposes. However, as evidenced by the CADA program in India, it has been difficult to implement and maintain these parts of the program and there are only a few examples of significant changes. Two examples illustrate apparently more successful approaches.

In Sri Lanka, recent experience of the Minipe and Gal Oya projects has shown that systematic involvement of the water users in decisions at a range of levels in the systems results in improved water use and higher levels of cropping intensities, as well as improved relations between the irrigation department staff and the farmers, On the basis of this experience, the decision was made to radically change the structure of irrigation system governance from a typical government hierarchical technical organization to a project-based structure, with a Project Manager and operating committees that include farmer representatives, as well as representatives of other agricultural ministries. Decisions about system water allocation and system operation are made with input from committees at different levels in the system, by contrast to the previous procedures where decisions were made by technical rules (frequently modified by political influence). The larger scale results of this major change in approach have not been evaluated, as yet, but there is considerable optimism about the changes.

In India, a less radical approach is being taken under the World Bank supported National Water Management Project (NWMP). In this project, the emphasis is on providing "a more reliable, predictable and equitable irrigation service". Its essential feature is the preparation of an Operational Plan for each scheme to define the principles of water distribution and to allocate responsibilities for implementation.[16] Limited funds are provided to facilitate application of the plan, and provision is made to improve coordination with other irrigation-related programs, such as that of Command Area Development. The NWMP anticipates evolutionary changes in system operation and organization, with the impetus coming from requirements for implementation of the new operational plan. Initial results are encouraging, with modest increases in area served and cropping intensity. Some of these increases have occurred without any changes in physical infrastructure.

In both the Sri Lanka and India examples, there is a movement away from the traditional view of irrigation systems as government enterprises in which the farmers are necessary (if not always desirable) participants toward a view that the systems are intended to serve the farmers, and that the government bureaucracy is a service organization. How deep (and how high) this change in perspective will penetrate, and how persistent it will be are not clear at this time.

Flexibility and Diversification

The relatively low prices for rice and wheat, mainstays of irrigated cropping in many systems in the developing countries, and the increasing costs for new irrigated land have resulted in increased interest in production of other crops. The assumption then follows that irrigation systems must be operated in a more <u>flexible</u> manner to permit this to occur. There is no generally accepted definition of "flexibility", in the irrigation context, but presumably it means the ability to respond to spatial and temporal variations in water need associated with diversified cropping patterns. The parts of the definition that are very ambiguous are the "level" in the system at which flexibility is necessary, and the "degree" of flexibility that would be necessary and/or appropriate. To the extent that flexibility implies greater "management" of the system, by contrast to "administration" there is an implication of greater cost.

There is little objective guidance on what constitutes an appropriate level and type of flexibility. At one extreme is the Warabandi, with (nominally) complete rigidity <u>to</u> the farm level, but complete flexibility <u>on-farm</u>, to the individual farmer demand model of complete flexibility that characterizes some smaller pump irrigation systems. Among larger systems, flexibility can be incorporated in the operations at the field channel level (usually in conjunction with some form of water user organization), at the minor level, or successively up the system to the water source. This increasing flexibility, or management, can be regularly in-place, as was anticipated in the Upper Pampanga River Irrigation System (UPRIS) design, or occur in a "default-upward" mode that characterizes some of the Taiwan systems[17]. The fact that farmers in rigid systems are able to make adjustments in cropping practice, that systems such as the UPRIS have made revisions in the operational procedures that reduce the flexibility intended in the original design, and the elimination of physical control structures in other systems where increased management capability was tried, suggest that there is a need for improved understanding of requirements for flexibility and of procedures for obtaining it.

Chapter V IMPLICATIONS FOR USAID POLICY AND PROGRAMS

The uncertainties in predicting the future of an important complex sector that has demonstrated substantial volatility makes the identification of appropriate directions difficult. Nevertheless, there are indications in past trends and in our more recent experience that have implications for USAID's irrigation portfolio.

-- There are sufficient differences among the countries of the region in terms of both irrigation potential and the stage of irrigation development that a single pattern to the development of irrigation activity is unlikely to be appropriate.

-- It is clear that, notwithstanding significant development of understanding of the irrigation sector and irrigation organizations during the past 15 years, there still is much that is not adequately known. This is well-illustrated by the differences of opinion illustrated by the three scenarios cited in Chapter I. The fact that there is this wide a range of perception of the irrigation sector strongly suggests that increased study would be not only appropriate, but urgent.

-- The evidence suggests that adequate data collection and problem analysis do not precede significant policy and design decisions. USAID should consider the fostering of increased capability in this area, not only through programs of staff training, but through structural organizational changes that would institutionalize the process.

-- There is need to examine more carefully shifts in investment priorities which have occurred recently within the irrigation sector and the potential impacts of the downward trends in investments and new area irrigated documented in this paper.

-- One specific component of the sector where there is an obvious need for better understanding is the role of private sector irrigation, as an independent activity and in conjunction with public systems. This latter frequently occurs in the context of groundwater utilization, resulting in unplanned, unregulated and, often, unknown conjunctive use.

-- In most of the countries, increased emphasis on effective farmer participation in the irrigation sector probably would be valuable. In some countries, this emphasis might appropriately be to increase knowledge of the local situation, in others where current understanding is greater, it might take the form of pilot implementation. In a few, emphasis might be on institutionalization of proven routes and procedures through fostering of organizational change, including necessary modifications in legal rules.

-- In most countries, increased attention to the structure and operation of irrigation organizations -- governmental and non-governmental -- should be beneficial. In some countries this attention might be limited to research, to better understand the functioning of the organizations. In other countries, it might be to support modification of functioning, as the NWMP attempts to do in India. In others, support for substantial changes would be appropriate, as has occurred in Sri Lanka and is currently occurring in Nepal. In some countries, there will be an environment to encourage relatively total organizational restructuring, e.g. the conversion of the government irrigation department into a public utility. USAID is in a relatively strong position to identify these different opportunities, and to design programs of support.

-- Experience suggests that there will be an ongoing need for system rehabilitation. For this investment to be most valuable, it must be initiated before the adverse effects of deterioration have proceeded too far and it must foster adaptation of the new system to current and anticipated environments. This implies more effective monitoring of system performance and greater attention to the design of the rehabilitation, including not only physical and organizational infrastructure needs, but also the rehabilitation process, itself.

-- In addition to research at the sector level, there is a major need for additional understanding of the maintenance/-rehabilitation tradeoff, as well as for better understanding of the appropriate roles of water user organizations under a variety of irrigation situations.

-- As a consequence of the decline in world grain prices and surplus of stocks (prior to this year) there has been a growing interest in the diversification of crop production in irrigated areas. We need to understand how systems can be designed and managed more flexibly to enhance the potentials for crop diversification.

-- While it can be anticipated that much of USAID's programs will emphasize the "software" aspects of the irrigation sector, in countries with significant undeveloped potential for expansion of irrigated area, support for development of physical infrastructure would be appropriate. Where this is the case, the lessons of past experience and of understanding based upon research should be evaluated carefully for application in the new systems.

-- The foregoing suggests that USAID has significant opportunities for major contributions to irrigation development in the region, but that appropriate country irrigation portfolios are likely to be relatively complex mixes of activities --

physical infrastructure development, organization and institutional change support, and sponsorship of field studies and research and training. This represents a major challenge for USAID.

1. See, for example, Barker,R. and Herdt,R. 1985 (insert full citation) pp 46 to 53.

2. Op cit p. 98

3. For example, the World Bank recently advised the Philippine Government to reduce its irrigation investments for a period of 10 years.

4. Defined by the FAO as areas purposely provided with water, including land flooded by riverwater for crop production or pasture improvement, whether this land is irrigated several times or only once during the year stated.

5. Share percentages are based on 3-year moving averages centered on the middle year and may not agree exactly with single year figures.

6. Asia is defined here as extending from Pakistan in the West to Korea in the East but excluding Soviet Asia and Japan. Taiwan is included in the figures for China.

7. These were chosen to include the North African and West African countries covered by USAID's Asia/Neareast Bureau. They are Morocco, Tunisia, Egypt, Jordon and North Yemen.

8. Olivares,J. 1987. Options and Investment Priorities in Irrigation Development. The World Bank/UNDP Inter-regional Report INT/82/001. Agriculture and Rural Development Department.

9. For example, an area growing sugar cane growing during the full year would be characterized with a cropping index of 1.; an area with three, 120 day rice crops (including land preparation) would have essentially the same index. An area with two, 120 day crops would have an index of 0.66. If this latter area had sufficient water for 300 days of crop growth, its cropping index efficiency would be 80 percent. As a first approximation, 'sufficient water' could be equated with a water supply (rainfall and irrigation) equal to 'potential evapo-transpiration'; reasonable estimates of potential evapo-transpiration can be made using standard meteorological data.

10. Data from IRRI indicate yields of * T. are available for a number of new varieties, and data from CIMMYT suggest that yields of ** T. are available for adapted wheat varieties.

11. For a more complete elaboration of this argument, see Levine. G. 1987

12. These systems are designed to operate in a relatively rigid fashion, with a fixed time schedule for each water user and with actual water deliveries dependent upon supply conditions. In principle, and in design, there is little opportunity for adjustment of either time or amount; in practice, the farmers can make modest adjustments through informal trading of time and through unauthorized control of structures. For a more complete description of the 'ideal' Warabandi system, see, Malhotra

13. See Ongkingco, P. (Univ. of Arizona thesis)

14. The SCARP (Salinity Control and Reclamation Program) Transition Program, in Pakistan, is designed to remove government from operation of wells in the fresh groundwater areas of Pakistan, and provides inducements for the users to either take over the operation and maintenance of these wells or to develop their own. It is anticipated that both the drainage and water supply augmentation benefits associated with the SCARP wells will be maintained through this private sector approach.

15. See Korten,F. and Bagadion,B. (* specific citation) and Uphoff, et al (* specific citation) for descriptions of this experience.

16. World Bank, New Delhi Office and Asia Technical Department, 1988. India National Water Management Project: Guidelines for Preparing a Scheme Proposal. The World Bank, March 1988.

17. See Levine,G. (complete citation) for a description of this mode of operation.