INCREASING FOOD PRODUCTION IN ASIA THROUGH INVESTMENTS IN IRRIGATION: POTENTIAL AND PROBLEMS

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ABSTRACT

Technological developments in rice production in Asia have greatly increased the potential returns to irrigation investments. It is likely that a substantial amount of resources will be allocated to irrigation development in the next two decades. But past experience suggests that the returns actually realized on these investments will be disappointing unless greater attention is paid to problems of effective water management, particularly in the main irrigation system. Human and institutional capabilities, and not physical or financial capital, are likely to be the most limiting factors in dealing with these problems.

RATIONALE FOR IRRIGATION INVESTMENTS

Rapid population growth in many low-income parts of the world underlies longstanding concerns about ways to increase food production. The two fundamental methods of increasing production are expansion of the cultivated area and more intensive use of existing cultivated areas. Prior to about 1960, most of the increase in production in South and Southeast Asia resulted from expansion of the area cultivated (Herdt et al.). But as the area cultivated is extended further into marginal areas, costs of bringing new land into production rise, while the value of that land in production decreases due to its lower productivity. At some point it becomes economically more attractive to increase the productivity of existing cultivated land than to bring additional land under cultivation. This intensification of existing land use can come about by increasing the number of crops grown per year, by increasing the yield per unit area per crop, or by some combination of these two. Technological developments are particularly important in this process.

During the past 15 years significant developments have occurred in the technology for the production of rice, which is the staple food crop of much of Asia. The basis for the increased productivity of this crop has been the development of varieties which, because of their morphological and physiological characteristics, have the potential to produce much higher yields per unit area per crop. Furthermore, many of these varieties are of short duration, which, in combination with their insensitivity to day length, creates the potential to increase the number of crops that are grown per year.

Realization of the yield potential of these new varieties requires large amounts of solar energy (particularly during the 45 days prior to harvest), high levels of nutrients (particularly nitrogen) and the absence of stresses associated with adverse soils, unfavorable water conditions, and insect and disease attacks. Scientists have been able to incorporate substantial amounts of resistance to insect and disease problems into the new varieties. Work on incorporating drought tolerance characteristics into these varieties has also been undertaken, but with much less success. As a result, the new rice technology is most promising in areas which are irrigated with a reliable and well-controlled source of water, and in which the farmers have access to reasonably priced nitrogen fertilizer. Within irrigated areas, utilization of the new varieties has generally been higher in the dry season, when solar radiation is considerably greater, and danger from damage from typhoons or floods is less, than in the wet season.

It is thus clear that the new technology - at least in the form in which it currently exists - has greatly enhanced the potential returns to investments in irrigation development and improvement. In fact, it has become commonplace in many circles to consider irrigation as the key - but often missing or inadequate - link in the chain of technical developments leading to increased rice production. The Director-General of the International Rice Research Institute, for example, has stated (IRRI 1980, p. v):

> "Irrigation expansion in the major rice-growing countries has been a primary component of agricultural development in the last 10 to 15 years. Rice-producing countries have recognized that good water control is a prerequisite to full utilization of high-yielding modern rice production technology to meet the growing demand for rice and other cereals."

The authors of the Second Asian Agricultural Survey of the Asian Development Bank state that "irrigation can be considered a basic prerequisite for the full exploitation of modern rice production practices" (Asian Development Bank, Vol. 1, p. 127). Research in the Philippines specifically designed to identify constraints to higher rice yields concluded that "lack of control over water is the single biggest constraint" (Herdt and Wickham, p. 22). Another study of seven Asian countries for the period from the mid-sixties to the early seventies showed irrigation to have been a major contributing force to output growth (Herdt).

It is therefore not surprising that several studies examining the future requirements for increasing food production in Asia have placed considerable emphasis on the importance of additional investments in irrigation. At least five such

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New Jersey Agricultural Experiment Station Publication No. D-02002-2-82, supported by State funds and by U.S. Agency for International Development funds.

studies have been undertaken. A task-force report to the Trilateral Commission projected a need for $52.6 billion (in 1975 dollars) in irrigation investment in South and Southeast Asia over the 15 years ending in 1993 to meet production targets established by estimates of the growth in demand for rice. It was envisioned that this investment would involve the conversion of approximately 30 million hectares of rainfed land to irrigated land, and the improvement of irrigation on an additional 17.5 million hectares (Colombo et al.). The International Food Policy Research Institute published a study in 1979 giving projections for investment requirements for the period 1976-1990 to increase food production in thirty-six low-income nations. For the eight Asian nations included, the study projected the need to expand irrigation facilities into rainfed areas on about 22 million hectares (which would raise the percentage of arable area irrigated from about 24 to about 34 percent), and to improve existing irrigation facilities on an additional 27 million hectares. The projected cost of these investments, in 1975 prices, was approximately $46 billion (Oram et al.).

The authors of the Second Asian Agricultural Survey concluded that a total investment of $42 billion (again in 1975 prices) would be needed in sixteen Asian countries over the same 15-year period to increase production enough to keep pace with the projected increases in demand (Asian Development Bank). A study conducted by the Food and Agriculture Organization of the United Nations also concluded that irrigation would be "the single most important factor for increasing rice productivity" (p. 15). In this study it was estimated that for fifteen Asian countries, the "fully irrigated area" would need to expand by 24 million hectares between 1980 and 1990, and by another 21 million hectares in the following decade, at an estimated total cost of $44 billion over the 20-year period (pp. 18, 44).

Herdt et al. used a modelling approach to estimate the investment requirements for both fertilizer and irrigation under several alternative scenarios regarding rates of growth in input use between 1974 and 1985. Their results emphasized both the importance of investments in irrigation at rates substantially greater than have existed in the past, and the need for further developments in technology. Based on the projections of their model, they concluded that "it will be impossible for production to grow fast enough to match population growth even with a level of annual investment (in fertilizer and irrigation) twice as high as that of the past decade" (p. 201).

It is thus clear that the increased potential returns to irrigation resulting from the new rice technology has created a strong impetus for governments to make very substantial new investments in irrigation. But caution needs to be expressed on two points. First, the returns to irrigation might be substantially reduced if some technological break-throughs were to occur for rainfed wetland rice production. Although there has been only rather limited work on the development of this type of technology, it has been suggested that the potential return to such efforts might be quite high (Barker and Herdt). Such technological development could be a very attractive alternative to irrigation investments, especially in areas where the provision of irrigation will be very costly.

The second point of caution regarding the potential returns to new investments in irrigation comes from the fact that past experience with such investments in low-income areas of Asia has frequently been disappointing. Numerous problems have been encountered, lowering returns considerably below original expectations. These problems were summarized in the Second Asian Agricultural Survey as follows (Asian Development Bank, Vol. 1, p. 136):

> "It is clear, however, that important questions of inefficiency, underutilization and low levels of productivity have remained unresolved for many (irrigation) systems in all countries in the region... Performance studies of completed systems have invariably shown higher costs and lower yield benefits than even the more pessimistic estimates at the feasibility stage. It would thus appear that irrigation has contributed to agricultural production largely through the increased number of hectares brought under the command of water, and not through high levels of performance in converting the water into output."

As concerns such as these have developed, attention in irrigation has shifted somewhat away from the problems of construction of the main irrigation facilities (headworks, canals and the associated control structures) to problems of operation and management of the irrigation systems, and to the types of investments needed to improve their management so as to enhance the productivity of the irrigation investment. Some of these problems are explored in the next section of the paper.

IMPROVING WATER MANAGEMENT: MAINS SYSTEM vs. TERTIARY SYSTEM

An initial reaction to evidence of the need to improve water management within irrigation systems was to focus on the lack of control structures at the tertiary or "on-farm" level (below the point at which water is turned out from a lateral canal maintained and operated by the irrigation agency). It is at this level that evidence of the effects of poor water management (over-irrigation and runoff) are most readily observed. Proposed remedies frequently involve the improvement of these tertiary facilities through such activities as installation of more control structures (such as gated turnouts), construction of more field channels, etc., coupled with efforts to organize farmers into irrigation associations which would be responsible for maintaining these structures. Many irrigation development programs (e.g., land consolidation in Thai irrigation systems; rehabilitation of systems in the Philippines) appear to have taken this approach. And yet some of these programs have encountered considerable farmer resistance. It is not at all uncommon for field channels built in Philippine irrigation systems as part of rehabilitation efforts to be quickly "erased" by the farmers. Similar problems were encountered under the Ditches and Dike program in Central Thailand (Small 1973). These reactions suggest a need to reexamine the assumption that the major problems in water management lie at the tertiary level.

Some researchers have suggested the possible existence of more fundamental management problems at the level of the main irrigation system. Although research in this area has been limited, there is now a body of empirical findings which suggest that in many situations the major management problems may not be at the tertiary level, but rather at the level of the management of the main irrigation system. Most of this work has been conducted in South Asia and in the Philippines (Chambers). As Wickham and Valera note, in summarizing the research findings from the Philippines (p. 74):

> "Although the effects of poor water management are observed on the farmer's field in the form of over-irrigation and drainage, it does not mean that the farmer is at fault. Frequently the flow and elevation of water in the canal - a responsibility of the system- are such that excessive irrigation cannot easily be avoided in traditional systems."

Another way of stating this point would be to say that under the existing level of management of the main irrigation system, individual farmers would have to incur substantial costs (effort) to prevent over-irrigation, with no corresponding benefit.

As evidence of the notion that the most severe and limiting management problems occur in the management of the main system, Wickham and Valera note the finding that location on the main supply canal was a much more important factor in determining yield than was the distance of the farm field from the point at which the water was turned out from the main supply canal (lateral) into the tertiary unit. On the other hand, the various studies they reviewed did not show ditch density at the tertiary level to have much if any relationship to yields, nor did these studies show water rotation among farms within the tertiary unit to have any significant effect, other than increasing the costs of water distribution. They concluded that a number of actions could be taken by the operating personnel of the irrigation system to enhance the distribution of water and improve yields, even with deteriorated physical structures (ungated turnouts, silted and scoured canals, etc.). Some improvement in the physical structures would further enhance this effort.

Some additional recent work tends to reinforce the conclusion that problems in main system management may be the major constraint to improved irrigation performance in many cases. Bottrall in three case studies of irrigation projects in Pakistan, India and Indonesia found serious deficiencies in the management of the main systems. He notes that these findings suggest that "many of the water management 'problems' below the tertiary outlet, attributed by official agencies solely to deficiencies in farmers' organization,... have their origins higher up in the system" (Bottrall, p. 5). In a detailed empirical study of farmers in a section of a large government irrigation system in the Central Luzon region of the Philippines, Svendsen found that the main water management activity which farmers undertook as a group involved efforts (frequently in the form of nighttime "raids" to the upstream areas of the lateral canal serving them) to obtain a supply of water to their turnout in the lateral canal. In other words, their efforts were not directed to concerns about the distribution of water among themselves at the tertiary level, but rather were directed to getting water provided in the main system to their common turnout. This again suggests that the major management problems lie at the level of distribution of water within the main system. Another study was conducted in a 2,500 hectare area served by a government-operated irrigation system in Central Luzon in the Philippines (Early). The study, which was a joint venture between the National Irrigation Administration of the Philippines and the International Rice Research Institute involved an attempt to improve the distribution of water within the main irrigation system. The approach used was to calculate estimated crop demands for water for each tertiary unit within the irrigation system, and then to match deliveries to these targets. It appears that even this seemingly simple management effort was not easily accomplished.

The evidence that severe problems in water management may exist in the main system of many irrigation projects does not mean that problems of water management at the tertiary level can be ignored. But it does suggest that investments to improve management at the tertiary level may not be highly productive if the main system management is inadequate to provide the needed deliveries to the tertiary level. On the other hand, it appears that main system improvements can be productive even prior to any improvements in the tertiary systems. Thus, a strategy of investment in improved water management should involve a careful assessment of the extent and nature of the problems at both the main system and tertiary levels, and a recognition that increased management capacity at the tertiary level cannot be translated into economic returns if the main system is unable to operate effectively in delivering water to the tertiary units. Unfortunately, as pointed out by Bottrall and by Wade and Chambers, both governments and development agencies tend to be blind to the problems of main system management. Although there is thus a tendency to prefer to concentrate on water management problems at the tertiary level, concern over the economic returns to irrigation investments should lead these agencies to place more emphasis on main system management, and the associated problems of how the irrigation bureaucracy actually functions.

It is important to note that much of the investment required to improve the management of main systems involves human and institutional development (sometimes called "software"). Although some improvements in the physical infrastructure may be desirable, the increase in the management performance of the main system requires changes in the method of operation of the personnel of the irrigation agency. Thus, the roles of training, supervision and incentives become critical. Relatively little work has been done in these areas. It seems that there is even now only the beginning of an awareness that irrigation systems are essentially behavioral in nature (Levine). Recognition of this fairly obvious fact leads to the conclusion that the role of incentives faced by many groups of people involved in irrigation systems is of critical importance to irrigation performance. And yet frequently we have very little knowledge or understanding of the nature of the incentives that many of the actors within the system face.

Part of the "software" which is needed for improved main system management are some new management tools which can be used in planning for and evaluating the distribution of water. One such tool has been suggested by the study in the Philippines reported by Early. The critical management tool used in that experimental case study was the concept of weekly target deliveries to each tertiary unit, which could be aggregated to establish targets for the various laterals in the system. The utilization of this tool requires information on the cropping status within each of the tertiary units, and the ability to measure water flows at various points in the system (particularly at the heads of the laterals). Another management tool which has been suggested is that of a water shortage index to evaluate water adequacy at various points throughout the irrigation system (Small, 1981). In the absence of the ability to measure discharges at each of the turnouts from the canals of the irrigation system, a field measure of the adequacy of water which is based on daily observations of selected sample paddies provide a basis for evaluating the adequacy of the various sections of an irrigation system. Although crop yield is sometimes used to evaluate the overall performance of the system, the water shortage index may be more useful as a management tool because it is more directly related to the factors that are under the control of the people who manage the irrigation system. Yields are influenced by many extraneous factors (pest and typhoon damage, for example) which are essentially unrelated to the performance of the irrigation agency personnel. Another advantage of the water shortage index as a management tool is that it requires field personnel to get into the field on a daily basis to observe actual water conditions. It seems likely that this increased knowledge on the part of the field personnel of actual field conditions may lead to actions to improve water distribution.

In many situations, it can be anticipated that very favorable economic returns could be earned from investments to improve the management of the main irrigation system. Total costs - especially where the amount of physical infrastructure upgrading is not great - are likely to be relatively low. In the case of the 2,500 hectare project in the Philippines discussed above, the total annualized cost for the improved management was estimated to be only about US $2.20 per hectare (Small et al. 1980). Although it is possible that the entire cost of the outside intervention was not fully accounted for, the potential for very high returns on the necessary investment seems clear.

CONCLUSION

A major issue of concern with the increased emphasis on additional irrigation investments is the productivity of these investments. Past experience suggests that major problems are likely to be encountered unless substantial and concerted efforts are put into improving the management and operation of the main irrigation system so that it more adequately provides water to the farmers. The major constraint in doing this is not likely to be physical or financial capital, but rather the willingness, ability and knowledge required to develop the human and institutional capital needed to make such a system work. There is a danger that the irrigation investments will focus too narrowly on the design and construction phases, where large sums of money are quickly commited and spent. This may fit well within the operating procedures of international aid and lending institutions and of national irrigation agencies but may be very inappropriate from the viewpoint of the societies in which these projects are built. The potential for obtaining and using funds for construction of irrigation projects is likely to exceed greatly the absorptive capacity of many countries in the sense that constraints on the development of effective management of the resulting projects are likely to exist. This suggests that a shift in emphasis toward investments and activities designed to promote effective water management within the main irrigation systems would be highly desirable.

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