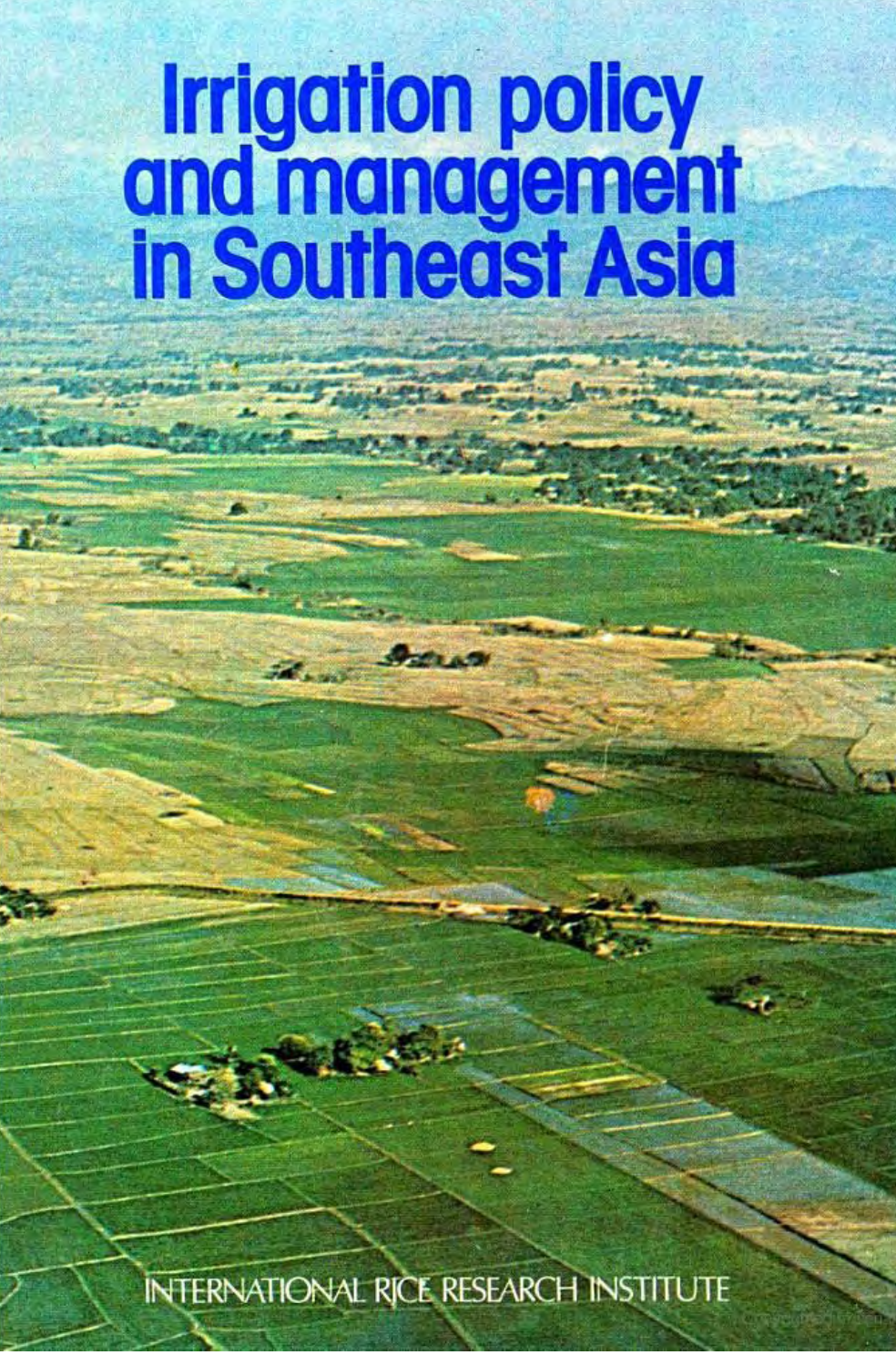
Irrigation policy and management in Southeast Asia



INTERNATIONAL RICE RESEARCH INSTITUTE

Irrigation policy and management in Southeast Asia

JOINTLY SPONSORED BY

AGRICULTURAL DEVELOPMENT COUNCIL

SOUTHEAST ASIAN
REGIONAL CENTER FOR GRADUATE STUDY
AND RESEARCH IN AGRICULTURE

AND

INTERNATIONAL RICE RESEARCH INSTITUTE

1978

INTERNATIONAL RICE RESEARCH INSTITUTE

Los Baños, Laguna, Philippines

P.O. Box 933, Manila, Philippines

Correct citation: International Rice Research Institute. 1978. Irrigation policy and management in Southeast Asia. Los Baños, Philippines.

The Agricultural Development Council (ADC), the Southeast Asian Regional Center for Graduate Study and Research in Agriculture, and the International Rice Research Institute cooperated in organizing and implementing the Seminar. Funds to cover part of the publication costs were provided to ADC by the International Development Research Centre in Canada.

The International Rice Research Institute currently receives support for its general program, as well as for this specific Seminar, from a number of donors including the Ford Foundation, the Rockefeller Foundation, the United Nations Development Programme, the United Nations Environment Programme, the Asian Development Bank, the International Development Research Centre, the World Bank, and the international aid agencies of the following governments: USA, Canada, Japan, the United Kingdom, the Netherlands, Australia, the Federal Republic of Germany, Iran, Saudi Arabia, and New Zealand.

The full responsibility for all aspects of this publication rests with the International Rice Research Institute.

Contents

Foreword v
Preface vi
Irrigation policy and management issues: an interpretive seminar summary 1
R. C. LAZARO, D. C. TAYLOR, and T. H. WICKHAM

PLANNING AND DESIGN OF IRRIGATION SYSTEMS

The importance of integrating nonengineering aspects in irrigation system design 15
S. H. THAVARAJ
Indonesia's simple *(Sederhana)* irrigation and reclamation program 25
OESMAN DJOJOADINATO
Planning and implementing land consolidation in Thailand 31
ANANDA KARUNYAKON
Fiberglass-reinforced polyester flumes as tertiary channels in Malaysian irrigation development 39
L. H. PANG

MANAGEMENT, OPERATION, AND MAINTENANCE OF IRRIGATION SYSTEMS

Water management decision-making in the Pekalen Sampean Irrigation Project, East Java, Indonesia 47
EFFENDI PASANDARAN
Practices and accountability for better water management 61
T. H. WICKHAM and A. VALERA
Effects of physical water control parameters on lowland irrigation water management 77
S. M. MIRANDA and G. LEVINE
Effects of location and water supply on water shortages in an irrigated area 93
D. F. TABBAL and T. H. WICKHAM
The water management training program of the Upper Pampanga River Project, National Irrigation Administration, Philippines 103
B. BAGADION, R. GAMBOA, L. ABESAMIS, and R. C. LAZARO

ECONOMIC ANALYSES OF IRRIGATION

Financing irrigation services in the Pekalen Sampean Irrigation Project, East Java, Indonesia 111
D. C. TAYLOR

Mobilizing local resources for irrigation development: the *subsidi desa* case of Indonesia 123
ANWAR HAFID and Y. HAYAMI

Mobilizing local resources for irrigation development: a communal system in Central Luzon, Philippines 135
G. DOZINA, JR., M. KIKUCHI, and Y. HAYAMI

The pricing of irrigation water: a case study of the Philippines' Upper Pampanga River Project 143
R. N. TAGARINO and R. D. TORRES

Preliminary analysis of selected gravity irrigation systems in the Philippines 151
R. R. HUELGAS and R. D. TORRES

Economic analysis of irrigation development in deltaic regions of Asia: the case of Central Thailand 155
NGO QUOC TRUNG

ORGANIZATION OF IRRIGATION ACTIVITIES AND BEHAVIOR OF IRRIGATORS

The organization of farm-level irrigation in Indonesia 167
R. HUTAPEA, PRAJARTA DIRJASANYATA, and N. G. S. NORDHOLT

Conflict between rice and sugarcane farmers over irrigation water: a case study in Thailand 175
KANAENGNID TANTIGATE

Local irrigators' groups: assessment of their operations and maintenance functions 185
S. DUNCAN

Stereotypes and facts in irrigation management: preliminary findings from a case study of a Philippine communal gravity system 193
R. P. DE LOS REYES

Foreword

The supply of water — more than any other single factor — controls the production of field crops in the tropics. Year-round cropping systems are generally possible in areas where water supply is dependable and controllable — a condition found only where irrigation systems are well-conceived and efficiently managed. But too often, deficiencies in the conceptualization and management of irrigation systems preclude the realization of full food-production potential within their command areas. Means to remove such deficiencies must be found and implemented so that crop production can be increased to its biological limits.

Scientists and engineers in national irrigation planning and management programs collaborate with counterparts in regional and international institutions to identify shortcomings in existing irrigation distribution systems and to devise workable schemes to improve them. Scientists in such international organizations also work with irrigation planners to incorporate efficient management methods into the operation of future irrigation systems.

The International Rice Research Institute (IRRI), the Agricultural Development Council (ADC), and the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) jointly sponsored the International Seminar on Irrigation Policy and Management in Southeast Asia. These international organizations support research and management efforts to achieve potential agricultural productivity through improved irrigation planning and implementation. This seminar highlights such efforts, which are essential to the effective utilization of biological breakthroughs. New plant varieties and better soil and crop management schemes can be fully exploited only with effective water-management practices. The seminar should help achieve such a goal.

The Institute extends appreciation to the cooperating researchers and others who participated in the seminar, and to Dr. T.H. Wickham of IRRI and Dr. D.C. Taylor of the Agricultural Development Council, Singapore, who served as joint technical editors for the published proceedings.

N. C. Brady
Director General

March 1978

Preface

A research seminar on Irrigation Systems in Southeast Asia was held 22 to 25 June 1976 at Los Baños, Laguna, Philippines. It was sponsored by the Agricultural Development Council (ADC), the International Rice Research Institute (IRRI), and the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA). Those agencies also supported the publication of this volume.

The seminar was held to

1. Provide a forum for the presentation of recent research results on irrigation policy and the management of irrigation systems;
2. Offer researchers and irrigation agency staff an opportunity to interact and exchange ideas;
3. Plan directions for future research that is relevant to the needs of professionals in the field of irrigation policy and water management; and
4. Augment the scarce literature now available to students and professionals involved in irrigation research and management in Southeast Asia.

The geographic focus of the seminar was Indonesia, Malaysia, the Philippines, and Thailand. Seminar participants included researchers (many of whom had recently completed the reported research as part of graduate study programs), senior irrigation policy makers, and irrigation system managers.

An editorial board reviewed the seminar papers and decided which to include in this volume for wider circulation. IRRI's Office of Information Services helped the board edit the papers. Some changes in format and style were made on the original manuscripts to make them more consistent for joint publication.

Part I of the volume is the interpretative summary, which identifies the main themes that emerged from the seminar and highlights the most important issues discussed.

Part II includes four papers that describe selected strategies being followed by various Southeast Asian countries in planning and designing irrigation infrastructure.

Part III deals with the management, operation, and maintenance of irrigation systems. Four of the papers report research results and one describes a training program for water management personnel.

Part IV comprises six papers that cover economic issues in irrigation. The papers include analyses of the economic performance of various types of irrigation projects and assessments of policies for securing repayment of irrigation investment.

Part V deals with irrigation organization and farmers' behavior. The content of three of the papers is primarily sociologic or anthropologic and the fourth is socioeconomic.

Most of the papers have common characteristics that make the collection a unique contribution to the literature on irrigation and water management:

1. The research papers are primarily empirical, rather than speculative or theoretical. Most are based on local research, some of which involved case studies. The authors point out the limitations of their papers and the implications of their findings for policy and

managerial decisions and for further research.

2. The nature of irrigation varies greatly from country to country, and even from region to region within individual countries. Furthermore, quite different aspects of irrigation are emphasized in different papers. The differences are highlighted in the abstracts and are elaborated in text. Readers are urged to note such differences when interpreting the findings presented.

3. Most of the research papers are authored by young professionals. Their analyses are straightforward and should interest a wide range of readers, including undergraduate and graduate students and practitioners in the field.

One of the most significant aspects of the irrigation seminar was the effective communication between irrigation field staff and policy makers, and research workers. Both groups clearly responded to the opportunity provided by the affiliation of the participants and sought out new ideas to make their work more complete.

We are grateful to the authors for their time and attention in writing the papers, to IRRI's Office of Information Services for editing them, to Ms. Cheng Bolton for painstakingly organizing them, and to Ms. Leila Hernandez for typing several drafts of each manuscript.

D.C. Taylor T.H. Wickham

December 15, 1977

Irrigation policy and management issues: an interpretive seminar summary

R.C. LAZARO, D.C TAYLOR, and T. H. WICKHAM

This interpretive summary reviews the observations and impressions of the authors from a seminar on Policy and Management Issues in Irrigation Systems in Southeast Asia.[1] The summary identifies the main themes that emerged from the presentation and discussion of the seminar papers and highlights the most important issues discussed.

The summary deals conceptually with each issue covered. The names of the authors responsible for specific ideas are shown in parentheses, but no attempt is made to document sources of ideas that emerged in the seminar discussions. The conceptual presentations are followed by summaries of relevant empirical findings and suggestions of issues deserving further study.

R.C. Lazaro, Director for Agriculture, Agriculture Department, Special Projects Office, National Irrigation Administration, Quezon City, Philippines: D.C. Taylor, Agricultural Development Council Associate and Visiting Professor of Agricultural Economics, Malaysian Agricultural University, Serdang, Malaysia: *T. H. Wickham,* Agricultural Engineer, Department of Irrigation and Water Management. The International Rice Research Institute, Los Baños, Philippines.

[1] While the authors have attempted to reflect the content and spirit of the seminar's deliberations, they accept responsibility for any omissions or errors in what is reported.

Main Themes

Three basic issues in expanding and making more equitable irrigated agricultural production in Southeast Asia were identified.

1. *Alternative strategies to develop irrigation infrastructure* were considered. They include investment strategies in constructing new projects, rehabilitating old systems, and intensifying the terminal facilities of existing systems. The seminar participants gave explicit attention to large-scale vs. small-scale irrigation infrastructure.

2. *Alternative approaches to improve the operations and maintenance (O&M) of irrigation systems* were discussed. They include the advisability of separating operational tasks from maintenance tasks, and of emphasizing the

improvement of either the main-system or terminal-system O&M, or both; the relative value of rotational vs. continuous irrigation; and means for securing greater farmer participation in terminal O&M.

3. *Specific policy options.* This third set of issues deals more directly with the social sciences. It includes the possibility of achieving income redistribution through irrigation development, the prospects for securing repayment of the costs of providing irrigation, the need for greater attention to manpower development in irrigation, the feasibility of evaluation studies that can provide insights into improved policy and management decisions, and the need for and possibility of achieving greater integration of nonengineering issues in irrigation development.

Each of the three main themes is discussed more fully below.

Alternative strategies to develop irrigation infrastructure

Constructing new irrigation projects. Irrigation projects aim to expand a country's potential for agricultural production by exploiting new sources of water. Depending on hydrologic and other technical considerations, new projects may involve pumping,[2] river diversion, or reservoir storage. Diversion projects are usually less dependable, especially during the dry season, but their financial, ecological, and social costs are usually less than those of storage projects, which involve elaborate infrastructure, the displacement of people, and the disturbance of natural habitats through reservoir flooding.

An advantage of allocating irrigation investment to new projects, rather than to rehabilitating or intensifying terminal infrastructure in old systems, is that the benefits of new projects reach out to encompass new people. If these people are relatively poor, desired redistribution effects can be realized at the same time that production potentials are raised. Indonesia's program of small-scale *sederhana* or simple irrigation development in the Outer Islands is of interest in this connection (Oesman). The projects involve up to 2,000 ha each and usually serve rather remotely located pockets of farmers with access to modest amounts of river water. The program broadens the geographic spread of government developmental efforts, since the irrigation infrastructure in the projects is technically simple to design and construct, and the gestation period between project construction and realization of irrigated production is relatively short (less than 2 years). The close link between farmers and irrigation development, which is feasible with small-scale projects, may also increase the willingness of farmers to participate in the operation of the completed systems.

Small-scale irrigation projects were the primary form of early irrigation in most countries of the region. Because of the recent renewed interest in small-scale irrigation, it would seem useful to undertake more research to document its performance. Such research could, for example, examine whether small-scale projects actually have more favorable impacts on income distribution and shorter gestation periods, and encourage greater degrees of farmer participation than large schemes. Other questions to which such research could find answers are:

1. Do the per-hectare costs of small-scale irrigation infrastructure and O&M generally differ from those of large-scale systems?
2. Which size of system is generally adapted to more intensive farming?
3. What approaches are most effective in organizing the management of widely scattered small-scale projects?

Rehabilitating existing infrastructure. Substantial investments are being made, especially in Indonesia and the Philippines, to rehabilitate irrigation facilities that have deteriorated because of inadequate maintenance. The intention is to restore the infrastructure to its original condition. Rehabilitation consists of repairing diversion dams and expanding their capacities, desilting and lining irrigation and drainage channels, repair-

[2] Pump irrigation was not a major focus of the seminar, and is not discussed in detail here.

ing and replacing water control structures, improving service roads, and providing additional training for O&M personnel.

Several papers examined the impacts of rehabilitation. Two dealt with small-scale systems: a communal system in the Philippines (Dozina et al.) and two systems in Indonesia (Hafid and Hayami). One paper involved a large-scale system, the Pekalen Sampean Irrigation' Project in East Java, Indonesia (Taylor).

The small-scale systems were rehabilitated primarily to restore their original diversion capacities. Both studies on the small-scale systems showed not only substantial production and income benefits from the rehabilitation but also high rates of mobilization of local resources, especially labor. The systems studied, however, were relatively successful and not necessarily representative of all small-scale systems in the respective countries.

The rehabilitation of the Pekalen Sampean Irrigation Project emphasized the desilting of channels and the repair of water control structures, rather than the restoration of original water-diversion capacities. The study showed that rehabilitation had no immediate observable impact on production. One explanation is that O&M was more intensive in those irrigation blocks that had deteriorated most, indicating that extra O&M was used to compensate for infrastructural deficiencies. It is also possible that the design of the original system was such that moderate deterioration did not impair minimum water deliveries to farmers' fields. If this reason is valid, the rehabilitation could have precluded possible losses in production in later years.

These findings suggest that the expected impact of rehabilitation depends on the nature of the rehabilitation activities undertaken and on their timing relative to the degree of deterioration. Studies aimed at further elaborating these aspects would provide useful guidelines for future rehabilitation decisions.

Providing more intensive terminal *facilities in existing systems.*

The intensification of on-farm facilities which began in Taiwan now receives considerable emphasis throughout Southeast Asia. It has been described as the third and most recent phase of long-term irrigation development in Thailand (Trung, Ananda) and Malaysia (Pang). Intensive on-farm terminal facilities are also being introduced in the Philippines' largest storage project, the Upper Pampanga River Project, to permit rotational irrigation among 10-ha units within 50-ha areas (Bagadion et al.).

Terminal facilities extend a system's irrigation and drainage network to provide water directly to individual fields or smaller areas. They make it possible for fields that are difficult to irrigate conventionally to receive a reliable supply of water, and for farmers who formerly depended on irrigation water that moved from plot to plot over other farmers' fields to receive water directly from the additional farm ditches installed in the system. On-farm drainage ditches also alleviate localized deep-water flooding. The development of terminal facilities usually involves the construction of farm service roads and, in some cases, such as in Thailand, land leveling and realignment of field boundaries as well (Ananda).

From a conceptual standpoint, the possibility of expanding irrigated production through more intensive terminal irrigation facilities has considerable appeal. The crucial issue is the actual impact of such facilities on irrigation performance'. In other words, to what extent does the introduction of additional terminal facilities in an irrigation system improve the adequacy of water on individual fields and the yields and production levels of the system? Are these production increases great enough to offset the additional costs of constructing, operating, and maintaining the additional facilities?

The only research presented in the seminar that dealt directly with this issue was that done in the Philippines (Wickham and Valera). The study concluded that the performance of irrigation blocks with higher ditch densities was not significantly better. But the introduction of additional ditches may be beneficial under special circumstances, such as when topography is uneven, soils are unusually

permeable, or turnouts are few and widely spaced.

Several seminar participants emphasized the undesirability of adopting uniform densities of terminal facilities in new projects. At issue at one extreme is a strategy of phased irrigation development in which terminal facilities are built over a period of years as shortcomings in existing systems are identified and local action is taken to overcome them. This strategy of gradual evolution of infrastructure is common for communal irrigation systems (de los Reyes). At the other extreme, if quick results and streamlined administrative procedures are to be achieved, standard norms and one-time terminal-improvement projects tend to be emphasized. The seminar brought out the merit of adopting a middle-of-the-road approach that would at the outset identify the problem areas within systems which are brought about by present irrigation or drainage facilities, and then provide additional infrastructure to serve those areas.

High priority research seems justified to identify inadequacies in existing irrigation performance and to determine the contributions that additional facilities could be expected to make toward overcoming such inadequacies. Research on alternative types of water distribution channels, such as fiberglass-reinforced polyester flumes vs. earth channels reported in Malaysia (Pang), would be useful. An analysis of different levels of intensity in terminal irrigation facilities and management practices is another example of research needed to guide future irrigation policies.

Alternative approaches to improve the operations and maintenance of irrigation systems

Operations deal with the allocation of water supplies and the handling of drainage runoff. Maintenance refers to the upkeep of structures and embankments and the removal of silt and vegetation from canals and channels.

Separating operations and maintenance tasks. Although a certain degree of coordination between operations and maintenance is important to the smooth functioning of each, several seminar participants stressed fundamental distinctions between the two (Duncan, Pasandaran). Operations is an everyday activity involving systems' personnel as well as farmers. Maintenance, on the other hand, takes place only periodically and may or may not directly involve farmers. The skills required to perform operations differ from those required for maintenance. It appears that the two activities are usually combined chiefly for convenience and efficiency, since both require substantial field forces.

Improving main system vs. terminal system O&M. The greatest potential for improved water management in irrigation systems in Southeast Asia is often said to be at the farm level. That is because irrigation infrastructure is generally more fully developed in main systems than in terminal systems, and because on-farm O&M involves many people, including farmers, most of whom have only modest or no professional training. While such views may be valid in some circumstances, the seminar papers dealing with this question provide counterevidence.

Several research projects on water management in the Philippines show that problems of water distribution are greater in lateral and sublateral canals than at the farm level (Wickham and Valera). In typical Central Luzon topography and system layout, the on-farm movement of water was found to be relatively efficient and its distribution equitable. Similar findings were reported for a Philippine communal system, where water flow in its main system was irregular and unpredictable (delos Reyes). The authors conclude that a prerequisite for further improvement in terminal-level O&M is the equitable and dependable flow of water in the main system, which requires greater O&M attention at that level.

The Pekalen Sampean Irrigation Project study in East Java (Taylor) provides indirect evidence of a similar nature. The study shows O&M expenditures in terminal systems (involving tertiary and quaternary canals and on-farm ditches) to be three to five times greater than those in main systems (irrigation headworks and primary and secondary canals).

While terminal-level O&M is possibly less efficient and therefore costs more than main-system O&M, the latter is clearly in greater need of increased support.

In view of these findings, it would seem quite important that more research be undertaken to determine exactly where within irrigation systems are problems of water distribution greatest (Tabbal and Wickham).

Adopting rotational vs. continuous irrigation. Traditional irrigation systems involve Continuous or simultaneous water flow throughout their distribution network. Forms of rotational irrigation, on the other hand, involve concentrated irrigation flows through portions of the networks at certain scheduled times. Systems of rotation vary, depending on the level within the system at which rotation takes place.

One interpretation of rotation is the prescribing of successive crops to be grown in various sections of a command area. An example is the *golongan* system in East Java, in which planting dates are staggered among irrigation blocks within an irrigation system. Each year the sequence of planting is rotated. For example, the last block planted in one year is planted first the following year. Similar forms of rotation are also reported for the Philippines (Wickham and Valera). This practice is followed to achieve equity in water distribution over time since risks of water shortage tend to be lower and yields higher on the earlier planted blocks (Pasandaran).

Another type of irrigation rotation in East Java is the *giliran* system (Pasandaran). Used during periods of unexpected water scarcity after crops are planted, it results in rotated water use among channels or parcels. The more severe the water shortage, the further down in the system (more decentralized) is the level at which rotation takes place. The rationale for the procedure is that limited water must be concentrated in a few canals for the water to flow efficiently and command the land. Other possible reasons are the farmers' feeling of social responsibility to share water with others in their communities during periods of acute shortage, and the reduced risk of on-farm water wastage with decentralized rotational irrigation.

The most common meaning of rotational irrigation in Southeast Asia is the sequential application of water to small parcels of land within larger continuously supplied blocks. This farm-level rotation may be among individual farms (Thailand), or approximately 10-ha units within 50-ha blocks (Philippines). Rotational irrigation is believed to promote savings in the amount of water required, to permit more equitable distribution during times of scarcity, and sometimes to increase yields.

Counterbalancing the possible advantages of rotational irrigation are the additional costs of the terminal infrastructure necessary to control and allocate water to separate parcels of land according to rotation schedules, and the added management, labor, and materials needed to operate and maintain the infrastructure (Miranda and Levine, Wickham and Valera). Furthermore, farmers may prefer continuous (simultaneous) irrigation flows as insurance against possible water shortages later on, and as a means of weed control.

A paper analyzing pilot rotational irrigation projects in the Angat, Peñaranda, and Santa Cruz River Irrigation Systems in the Philippines dealt with this question (Miranda and Levine). The results of the research were mixed, although there was evidence of higher rates of adoption of new technology and of higher water-use efficiency in the dry season with rotational irrigation.

Relatively large-scale field comparisons of rotational and continuous irrigation during the 1974 dry season in the Philippines Upper Pampanga Irrigation Project did not show significant differences between rotational and continuous irrigation in either yields per hectare or output per unit of water applied (Wickham and Valera). The cost of infrastructure for the rotational areas was somewhat higher, however, and that of the rotational O&M, though not empirically measured, was believed to be considerably higher than the corresponding cost for continuous irrigation.

These findings raise questions about the suitability of rotational irrigation. Many factors

can strongly influence the outcome of on-farm rotational irrigation, and further empirical studies to evaluate its suitability for specific situations are needed. In such studies, attention should be given to managerial and training requirements; the costs of O&M; levels of agricultural output and water-use efficiency; physical parameters such as soils, topography, and water source; and equity of water distribution.

Achieving greater farmer participation in O&M. There is growing interest in Southeast Asia in greater farmer participation in irrigation O&M and in an expanded role for water-user associations in irrigation development. However, attempts to achieve both have generally given only mixed results at best.

Four types of increased farmer participation were recommended during the seminar: 1) taking responsibility to pay more for irrigation, 2) assuming more responsibility to organize and perform O&M tasks, 3) giving more feedback to irrigation offices on the field performance of systems, and 4) exerting greater influence in decisions on water allocation and scheduling.

Greater farmer participation is desired to reduce the administrative and logistic burdens of irrigation, to make better day-to-day decisions on water distribution, and to provide water users with greater incentives to use water carefully. Sometimes the belief that greater farmer participation is needed is based on more philosophical grounds, namely, that the democratic approach to achieving desired discipline and control in irrigation is superior to the authoritarian alternative, and that well-organized farmers can bring modernizing pressure to bear in areas such as irrigation.

The seminar discussions led to three general conclusions on strategies to enlist greater farmer participation in irrigation:

1. *It is unrealistic to expect farmers to participate in irrigation activities, as individuals or as members of groups, unless they believe their participation will benefit them.* The two studies of small-scale rehabilitation provided illustrations of farmers who could envision the rehabilitation contributing substantially to irrigation development (Dozina et al., Hafid and Hayami). In other circumstances, farmers were reported as unwilling to participate in proposed irrigation activities because they did not believe the activities would benefit them (Duncan, de los Reyes).The studies suggest the importance of soliciting farmers' views on irrigation needs, and of bearing in mind the farm-level impact of possible changes in irrigation.

2. *The assumption that improved water management requires greater participation of farmers in irrigation needs to be double-checked.* Several authors drew attention to cases where farmers were reluctant to participate in proposed on-farm water management activities because the main irrigation systems serving them were not providing dependable water supplies (Wickham and Valera, Duncan). Under such circumstances, the government must participate more actively in O&M before farmers can be expected to do likewise. This finding suggests the importance of empirical research aimed at answering the following questions:

a. What are the current water management practices in both main and terminal systems?

b. Where are the problems in water management most severe, and what are their effects on farmers and the systems?

c. What is the most reasonable sharing of roles and functions among the government, farmers as individuals, and farmers as members of groups in solving irrigation problems?

3. *National strategies to introduce widespread, uniform water-user associations may not be advisable.* Great variation in local irrigation environments - physical, institutional, cultural, economic implies that high-priority needs may not be the same in all locations. Development-oriented leadership may be more readily available in some areas than in others, and existing organizations in

particular localities may influence the ways in which local group activities ought to be institutionalized in those areas (Hutapea et al.).

These findings suggest that a strategy of tailoring water-user associations to local needs and initiating them on a phased basis, beginning with situations in which the chances of success are greatest, may be more productive in the long run than the commonly advocated attempts in some countries for widespread and immediate introduction of associations. For either strategy, however, research can help identify the nature of local needs and determine which needs might be met most effectively through group action.

Substitutability of O&M and physical structures. The discussion thus far has treated the design and construction of irrigation infrastructure more or less independently of O&M. In reality, of course, this is an over-simplification.

The seminar brought out two ways in which infrastructure may replace O&M. First, additional investments may be made to mechanize certain parts of the infrastructure and thus reduce the need for operations. Examples are the electronic monitoring of water flows and push-button gate controls. Second, more substantial infrastructure — such as lined channels — that requires less maintenance may be constructed. Alternatively, management can be substituted for infrastructure: more and better trained O&M personnel can make a deteriorated system function more effectively.

Some of the liveliest discussions during the seminar concerned this topic. Some participants stressed the need to improve infrastructure in existing systems and minimized the possibility of improved system performance through greater management attention. Others took the opposite view, emphasizing instances in which improved management had compensated for structural inadequacies of the systems.

Although the controversy was not resolved, it seems that certain elements are critical in determining the possibilities for substituting infrastructure for O&M, and vice versa. Perhaps most important are the relative completeness and condition of existing infrastructure, the costs and relative availability of capital material items vs labor, and the attitudes and experience of managers in allocating time and effort to training and supervising field staff.

A second relationship between infrastructure and O&M concerns the possibility of deferring current maintenance expenditures and later absorbing the costs as rehabilitation investments. Almost all participants agreed that basic expenditures on maintenance should be made to enable a system to deliver minimum assured water supplies. But for levels beyond this, there was some question. Those who suggested the possibility of allowing some maintenance functions to be accumulated as rehabilitation drew attention to the fact that at present money for rehabilitation is quite readily available and on favorable terms. Under these conditions, a country may be well advised not to concentrate its scarce annual operating budget on recurring maintenance, but to take advantage of periodic cheap sources of credit for rehabilitation. This view, of course, assumes that such sources will continue to be available. Finally, the seminar brought out the importance of research studies that would examine economic and technical trade offs between rehabilitation and maintenance.

Specific policy options

A wide range of policy options extending beyond infrastructure and O&M is now covered.

Promoting more egalitarian income redistribution through irrigation development. Several participants emphasized that irrigation development usually exaggerates differences in income among different groups of people, because new projects are usually built in low-lying areas where agricultural production potentials are greatest. New irrigation development greatly enhances the value of project lands. Since large-scale systems are almost always heavily subsidized, landowners receive substantial windfall gains from the infrastructure. Such gains are often reinforced by subsidized O&M. Unless the landowners were

initially from the poorest economic strata, irrigation development aggravates existing problems of income distribution. Once investment funds are committed, they are not immediately available for projects to aid more disadvantaged people such as farmers with small rainfed holdings, and unskilled laborers.

Some evidence indicated that the rural elite use irrigation to reinforce their relative advantage by strongly influencing decisions on how scarce waters is allocated (Hutapea et al.) and how turnouts are relocated to better serve their land (de los Reyes). There are also instances of owners with large holdings exercising their economic power by buying irrigated land from farmers with smaller holdings — especially land that is favorably located relative to the water source.

No economic development program can simultaneously serve all groups of people equally well. The tendencies cited above are not, therefore, a clear indictment against irrigation. The more important issue would seem to be to search for elements in strategies for irrigation development giving explicit attention to relatively disadvantaged farmers.

The seminar participants agreed that identifying and pursuing equity as well as productivity objectives will require deliberate attention in the formulation of irrigation policies. The following approaches emerged from the discussion:

1. *Concentrating new irrigation development in areas where holdings are small and farmers poor.* An irrigation policy that gives priority to the poorest farmers would be one means of promoting income redistribution. A strategy that emphasizes small-scale irrigation development would seem to contribute toward this end. Small-scale projects are usually found in rather remote areas where economic differences among farmers tend to be small and where economic development efforts usually receive low national priority. Indonesia's program of small-scale *sederhana* irrigation is a contemporary example of such an approach (Oesman).

2. *Ensuring that the views of disadvantaged irrigators receive recognition in irrigation decision making.* Certain irrigators are inherently handicapped in gaining access to assured water supplies, because of either their remoteness from a system's source of water or their relatively low social and economic position. A precise identification of the most disadvantaged farmers, and exploring ways of guaranteeing their rights in decisions on the design of further infrastructure or allocation of scarce water would help ensure greater equity in water distribution.

3. *Analyzing the distribution of benefits from alternative irrigation strategies.* Relatively little emphasis seems to have been given to examining the effects of irrigation development on income distribution. Since these effects are of growing national concern in Southeast Asia, their empirical examination should receive high priority. Certain strategies have probably been more conducive than others to the wide diffusion of irrigation benefits.

One seminar paper that partitioned the benefits of rehabilitating a Philippine communal irrigation system showed significant absolute benefits to laborers, farm operators, and landowners, with the greatest relative benefit going to laborers (Dozina et al.). That finding, together with initial experience from the *sederhana* program in Indonesia, indicates that the equity implications of small-scale irrigation development may be more favorable than those from large-scale development. This hypothesis should be further tested, however, along with other underlying elements that may contribute to a wider diffusion of irrigation benefits.

Securing repayment for irrigation. Both national governments and international lending agencies participating in irrigation development are deeply concerned about policies for financing that development. The seminar papers dealing with irrigation repayment led to the following general conclusions:

1. *Official rates of irrigation assessments*

may not accurately reflect actual payments made for water. Discrepancies between the two may arise because indicated nominal water rates are not collected in full (Tagarino and Torres, de los Reyes), or because some payments for water are indirect or informal. Examples of indirect payments for water are a differential land tax for dry land vs. irrigated land (Taylor) and contributions by farmers of cooperative labor for canal maintenance (delos Reyes, Taylor). Examples of informal payments are gifts to ditch tenders and payments to neighboring farmers for farm-ditch rights-of-way through their fields (de los Reyes).

2. *Water rates should be considered in the context of overall financial policies for development.* This point follows from the first, since payments for water do not necessarily have to be in the form of water rates. Furthermore, charges for water cannot be considered meaningfully outside the overall perspective of a country's development goals and strategies. For example, national development strategies on the desired direction of wealth and income transfers between the agricultural and non-agricultural sectors are integrally connected with decisions on water rates, as are other issues such as efficiency of resource use and equity of income distribution.

3. *Policies for financing irrigation infrastructure and services should consider the full range of irrigation beneficiaries.* Direct beneficiaries of irrigation are landowners whose land increases in value because of its access to water, and farm operators who produce more because of more assured water supplies. Indirect beneficiaries include government and the general food-consuming public, as well as manufacturers, agricultural businessmen. retail business merchants, and laborers, The indirect benefits arise because of generally expanded economic activity induced by irrigation and the larger volume of food which sells at lower prices than it would have sold without irrigation.

The extent of benefit to each group of beneficiaries should be estimated, and the possibility considered of taxing part of the benefit to finance further irrigation development. Papers dealing systematically with this issue were not presented in the seminar; however, the study of the Pekalen Sampean Irrigation Project in East Java showed that irrigation led to a several-fold increase in production, and in requirements for hired labor (Taylor). Discussions of that study and others during the seminar suggested the following hypotheses:

a. Although the first farmers to receive irrigation usually derive income benefits, the competitive nature of agriculture makes it unlikely that they can sustain the surplus profits over time. Thus, conventional strategies for securing irrigation repayment, which focus exclusively on farm operators, should be reexamined.

b. Of the direct beneficiaries of irrigation, landowners are perhaps the most important potential source of repayment because of the several-fold increase in land values commonly associated with the introduction of irrigation. A graduated system of betterment levies implemented upon project completion is one means of extracting part of the windfall gain in land values. Implementing such a system would undoubtedly require considerable administrative discipline, but the necessary resources for enforcement could be justified if the economic case for this approach were strong.

c. It would be difficult to charge indirect beneficiaries whose volumes of business increase because of irrigation, but an increment in taxes assessed against rice millers, for example, might be feasible. Even if indirect beneficiaries could not be taxed directly for irrigation, knowing the extent of their benefits relative to that of direct beneficiaries would help clear up possible misunderstandings, such as the interpretation that farmers are being subsidized whenever they fail to pay the full costs of irrigation.

4. Higher water charges cannot be expected to provide incentive for more efficient water use unless they are assessed in

relation to the quantity of water used. It is sometimes argued that if irrigation water charges are increased, farmers will perceive water as being more precious and will therefore use it more carefully. If the charges are area-based, however, this reasoning appears to lack validity. Once an area-based water rate is paid, the charge becomes a fixed cost; even if the rate is high the farmer incurs no economic penalty from using more rather than less water. A charge on the duration or rate of flow, on the other hand, would provide economic incentive to save water because the more water the farmer uses, the more he pays.

Volumetric water pricing has not been seriously tried in Southeast Asian canal systems, mainly because of technical difficulties in measuring water deliveries to farmers. Measurement is clearly impossible where water flows from one farm to the next. Monitoring fluctuations in rates of flow night and day is difficult. Such a system would also raise difficult equity issues in that a farmer with heavy soils would pay less for water than his neighbor who might have porous soils requiring more water.

Because water generally becomes more valuable over time, ways to reflect this increase should be sought. Two compromises were briefly discussed. Water rates could be assessed on the basis of season and the crops grown, with higher rates during the dry season and for crops such as rice that use more water. An alternative would be to charge groups of farmers served by given irrigation channels, e.g., tertiaries, according to the volume of water they use, and to let each group decide how it wants to allocate its water among, and collect charges from, individual users.

An indirect way of increasing water charges with the general level of inflation is to fix the charges according to the current price of a basic product such as rice, to avoid the difficult problem of adjusting obsolete water rates to changes in price levels. The price of rice usually reflects the national cost of living reasonably well. The actual charge could be payable in kind or in cash, computed at current rice prices.

5. *Changes in financial policies for irrigation may entail additional system cost.* A decision to charge substantially higher water rates involves an implicit understanding that more assured supplies of water would be provided to farmers. If an existing irrigation system cannot provide reasonably guaranteed water deliveries, additional expenditures are probably needed for infrastructure, O&M, or both. Introducing a new form of water charge may also entail additional administrative costs for collection and enforcement which need to be evaluated in relation to the increased revenue or water-use efficiency expected from the new policies.

6. *Encouraging the international adoption of common financial policies for irrigation has serious shortcomings.* The economic-financial-institutional environment of irrigation in different countries and even among projects within some countries is too diverse to warrant broad generalizations concerning desirable financial policies. Crucial elements of this diversity are the varying emphases on different national policy goals and strategies in different countries, and marked contrasts in the amounts and types of actual payments for irrigation and efficiencies of water use in various projects of the region.

Increasing attention to manpower development in irrigation. A theme common to many papers (Bagadion et al., Duncan, Miranda and Levine, Oesman; Wickham and Valera) and much discussion during the seminar is the need for increased attention to manpower development in irrigation. As investments in irrigation infrastructure continue to mount, the organization and skills required to use the infrastructure efficiently expand even faster. Additional training, particularly for field-level personnel, becomes increasingly important for modem irrigation.

There was considerable interest in the new training program for water management technologists of the Philippines' Upper Pampanga

River Project (Bagadion et al.). The training curriculum deals with three subject areas: irrigation water management, rice production, and farmer behavior and group action. The program is divided into several phases: a 4-week orientation and field experience, a 3-week live-in seminar, two seasons of on-the-job training, 2-week evaluation and planning workshops after each season, and an evaluation of the performance of trainees during their first 2 years in the field. Several times during the training program, the reactions of the trainees and teaching staff to the program are solicited.

Training issues such as the following need attention:

1. Does the training program meet highest priority field needs?
2. What changes in subject matter emphasis or teaching-learning methods would be useful?
3. What are the most appropriate criteria for evaluating the performance of personnel in the field?
4. In what ways and to what extent does actual job performance change as a result of training?
5. What types of follow-up training would permit the continued growth of staff competency in the field?
6. What changes would field staff recommend to the higher management of systems for their more productive employment'?
7. Are the manpower policies of the parent agency consistent with the field training?
8. Are the systems physically equipped to take advantage to the skills of newly-trained staff?

Conducting and reporting applied research on irrigation. Many irrigation practitioners are interested in the results of relevant applied research. Their interest stems from their need to make decisions on certain policies of irrigation development or management in areas where the status of information or the basic Understanding of the issues are not readily available.

If research is to serve decision making, considerable effort must be devoted to developing mutual trust, understanding, and two-way communication between researchers and practitioners. The effort requires that researchers be willing to spend time in the field becoming acquainted with practical problems and getting some feeling for the constraints under which solutions must be worked out. Only under these circumstances can high-priority problems be identified for study, and can the problems be researched in meaningful contexts. In addition, the researchers will have access to more relevant data, so reports are more likely to be understandable and deal appropriately with sensitive issues. The researcher-practitioner interaction will not necessarily terminate with the publication of a formal study report. Of course, researchers should not become overwhelmed by the constraints that face irrigation managers, or become so intimately acquainted with the latter's problems that they lose objectivity in their research.

Additional Research Issues

At various points in this summary, attention has been drawn to topics for which further research would be beneficial. In this section, additional issues that could not easily be accommodated in the discussion of the main seminar findings are briefly mentioned.

1. In Indonesia and the Philippines, large-scale studies to monitor irrigation benefits are being launched. In a proposed study for Indonesia, attention will be given to monitoring for 5 years the irrigation performance of five recently rehabilitated large-scale projects, as well as the nature, extent, and distribution of the benefits from the projects.

2. Many economists are attracted by the possibility of undertaking benefit-cost evaluation studies of irrigation. The discussion of the post-evaluation studies reported for the Philippines (Huelgas and Torres) brought out the importance of analyzing both physical and monetary differences between projected and actual project performance. There was no clear agreement on how many years projects must

be in operation before meaningful post evaluations can be made, however, or over how long a period the evaluation should extend for satisfactory accounting for year-to-year variations.

3. One paper (Pasandaran) examined interrelationships between irrigation and agricultural performance. The research involved a comparative study of tertiary blocks that exhibited different patterns of water availability. The impact of water availability on crop yields, on the nature of cropping patterns, and on cropping intensities was investigated.

4. The importance of learning how decisions on water allocations are actually made in the field was stressed in several papers (de los Reyes, Pasandaran). Water-users, local irrigation officials, and, sometimes, other local government officials probably play a role in the decisions, but how they interact and the concepts used in allocating scarce water may vary considerably from one area to another. From such studies, much that is broadly relevant to improved water management may be learned. An example is the *pasten* concept in East Java (Pasandaran). The concept, which involves a formula relating water availability to water requirements, is used to plan cropping patterns and adjust water allocations during unexpected scarcities.

5. Discussions drew attention to a frequently observed inverse relationship between levels of water-use efficiency and yields. These observations referred to farms irrigated from the downstream or tail ends of canals that receive less water than upstream farms. The downstream farms have higher water-use efficiencies but lower yields than upstream farms (Wickham and Valera). This outcome seems to reflect a diminishing marginal return to the use of water, and raises a basic question on an optimal strategy for designing and operating systems. What are the trade offs in total production and equity of distribution between a given water supply to serve a large command area with frequent periods of water scarcity, vs. its use in serving a smaller command area in which water is more assured? What analogous implications are there for designing and operating systems to serve upland crops that require less water than rice?

Achieving Greater Integration in Irrigation Development

The need for and possibility of achieving greater integration in irrigation development emerged several times during the seminar. Several dimensions of integration were suggested.

Attention was called to the need for integrating the perspectives of engineering, agriculture, economics, sociology, and ecology in designing suitable irrigation systems. This integration was approached in redesigning and operating Malaysia's Muda River Irrigation Scheme (Thavaraj).

The need for an integrated approach in Thailand was cited (Ananda). In this case, integration pertains to intrafarm and interfarm development, with attention to land leveling, field boundary realignment, and the location of irrigation and drainage ditches and service roads.

Finally, the seminar highlighted the importance of integration between research and practice. It provided researchers and practitioners the opportunity to interact. Relations among the participants were cordial and informal, but reactions were candid. There is basis for the belief that the seminar achieved significant progress in developing constructive relationships between the community of irrigation practitioners in Southeast Asia and those interested in research on irrigation.

PLANNING AND DESIGN OF IRRIGATION SYSTEMS

The importance of integrating nonengineering aspects in irrigation system design

S. H. THAVARAJ

ATTENTION TO A WIDE RANGE of factors in the design of irrigation infrastructure can help ensure that the completed systems will function satisfactorily. The factors include data on rainfall patterns, soil permeability and topography, crops' water requirements and their response to water stress, costs of alternative construction materials, availability and costs of labor and machines, legal and environmental factors, and social factors such as local leadership, cultural patterns, values, and institutions. The paper describes the application of many of these factors in Malaysia's Muda Irrigation Scheme.

The growing demand for food increases the importance of irrigation and drainage in the humid tropics. Improved water control is important to the achievement of the full yield potential of modern rice varieties and is a most promising means of increasing food production (Homing, 1970).

Many irrigation projects have fallen short of expectations, however, partly because they have been designed and managed almost exclusively from an engineering point of view. Because irrigation projects are becoming increasingly expensive, it is especially important to distill from past experience insights that can be used for future irrigation planning and design.

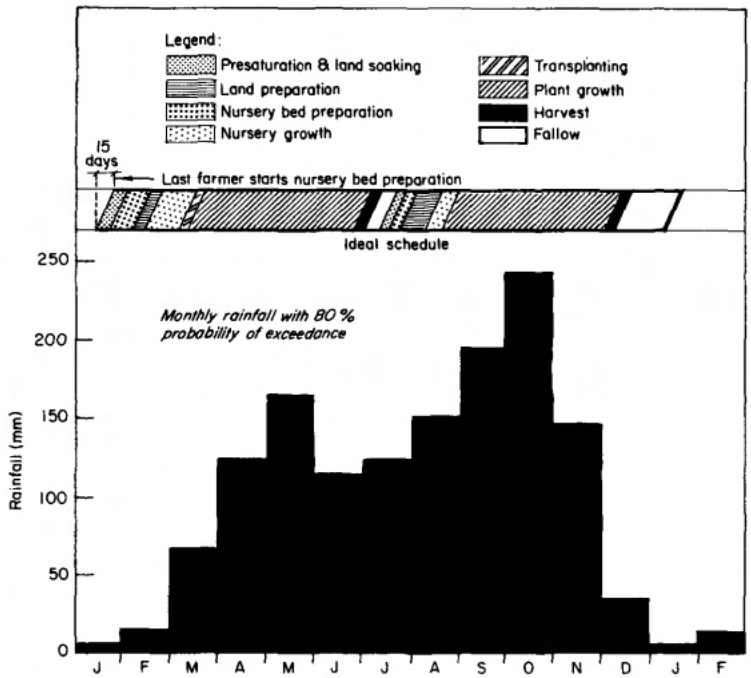
In this paper, the importance of nonengineering aspects in the design of the Muda Irrigation Scheme in Malaysia is emphasized, and the need for an integrated approach in the design process is highlighted. The need for further research and technological forecasting as new projects are conceived, designed, and constructed is also discussed.

The design of irrigation systems for long-term stability must include not only engineering considerations of water storage, conveyance, and delivery, but also agricultural, economic, social, political, legal, and environmental considerations. Engineers clearly cannot carry out the complex task of irrigation design alone. A multidisciplinary approach, in which each specialist understands the interaction between his discipline and that of his coworkers, is required to integrate these various factors into a final design. Specialists from various disciplines must collaborate from the outset in the design process of problem identification, data collection, field investigation, design analysis, pilot testing, selection of final design, and project implementation.

Agricultural Factors

Three examples of complex agricultural factors that are important in designing irriga-

S.H. Thavaraj, Deputy Director-General, Drainage and Irrigation Department, Ministry of Agriculture and Rural Development, Government of Malaysia, Kuala Lumpur, Malaysia.



1. Calendar of proposed cropping schedule. Muda Irrigation Scheme, Malaysia.

tion for lowland flooded rice are 1) cropping schedules, 2) the availability of labor and machines, and 3) plant-water relationships critical to achieving high yields.

Cropping schedules

Cropping schedules are generally controlled by soils, rainfall distribution, and the availability of irrigation water. Once determined, the cropping schedules and climatic factors are used to plan the timing and quantity of irrigation application.

Figure 1 shows the amount of available water, based on 80% probability of rainfall exceedance, superimposed on a proposed double-cropping schedule in the Muda Irrigation area. The rainfall distribution is bimodal, so the wettest months of May, September, and October should coincide with periods of crop growth. The wettest months should also occur late enough during crop growth so that the increased water depth in the field does not cause inundation damage — but not so late that it interferes with the harvest. Timing is also important to optimally utilize available water for soaking during land preparation. If double or more intensive cropping is practiced in new irrigation schemes, from 2 to 4 weeks of soaking is desirable during land preparation to soften the hard soil and to leach toxic degradation products. An ideal cropping schedule also allows the harvest of the first crop in June or July, and the second crop in December, both relatively dry periods. For economical use of irrigation, plantings should be scheduled so that most vegetative growth occurs during wet months, and harvests during dry months.

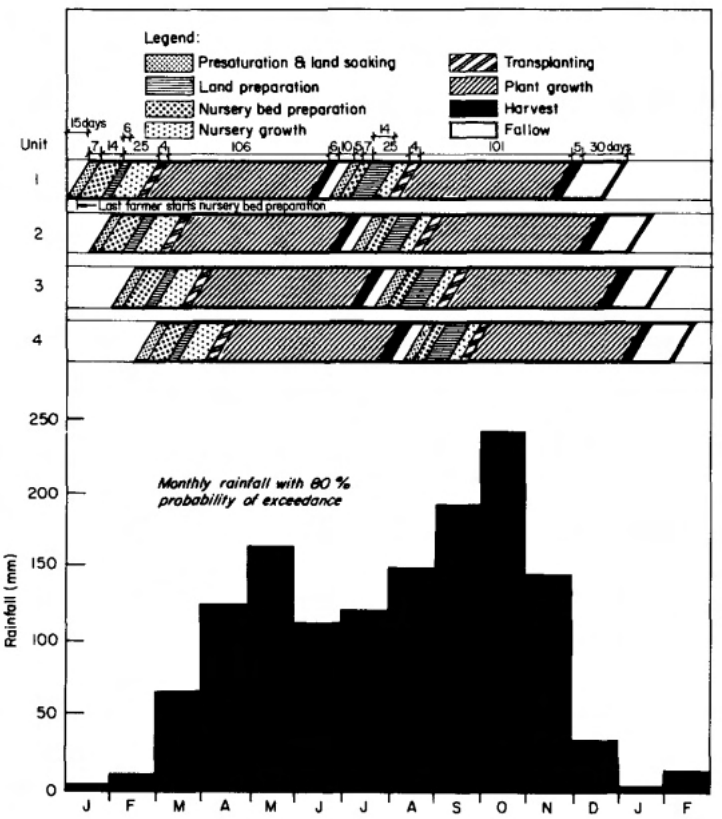
Availability of labor and machines

The availability of labor and machines during peak land preparation and transplanting periods may be insufficient for timely planting

Table 1. Labor use for rice production in the Muda Irrigation Scheme, Malaysia, 1973 wet season.

Tasks	Labor use (working hours/ha)		
	Family	Hired	Total
Nursery preparation	25	3	28
Plowing[a]	1	5	6
Leveling and raking	9	18	27
Cleaning ditches	32	0	32
Transplanting	36	88	124
Weeding and cleaning ditches	61	8	69
Fertilizer. and insecticide application	20	0	20
Harvesting	30	111	141
Threshing	20	45	65
In-field transport	18	26	44
Winnowing and drying	86	0	86
Total	338	304	642

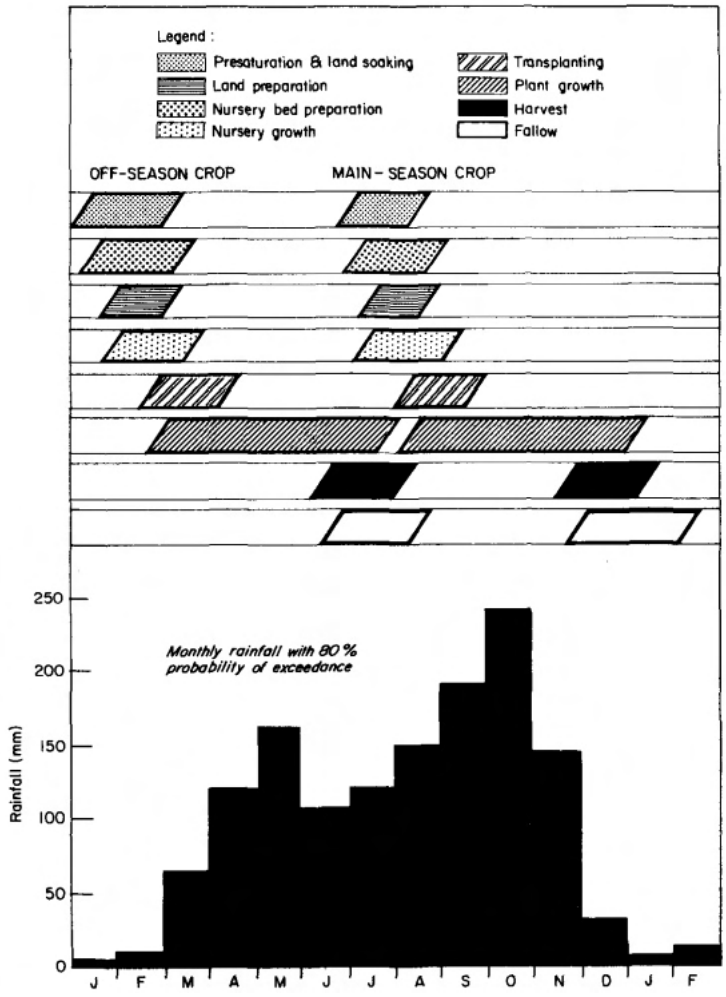
[a] Based on the use of a four-wheel tractor.



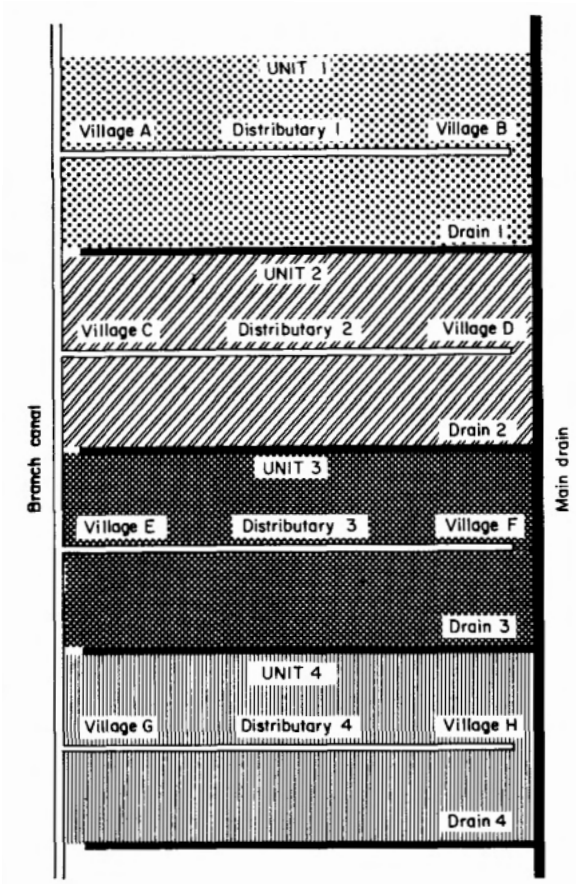
2. Calendar of proposed cropping schedules for four units. Muda Irrigation Scheme, Malaysia.

in either season. In the Muda Irrigation Scheme, about 34% of the total labor required is for nursery preparation through transplanting, and 52% for harvesting through drying (Table 1). More than half of the labor used in both phases is locally hired. Labor requirements can be more evenly distributed across the entire system, and peak water requirements for land preparation can be reduced by incorporating any or all of the following factors into the design:

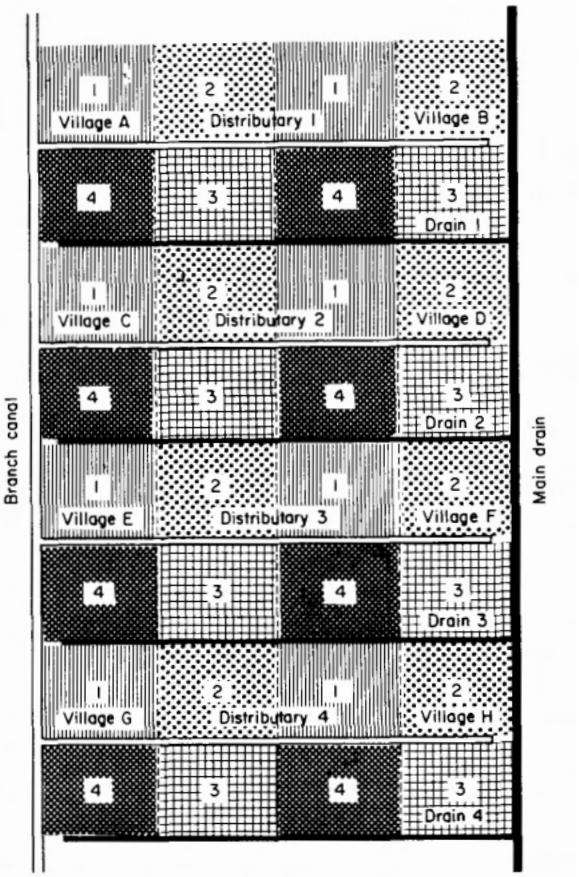
Staggered activities. If labor is mobile, it can be utilized more efficiently by properly sequencing activities. A typical schedule of four staggered units for the 80% exceedance rainfall pattern taxes the limit of labor availability (Fig. 2). Harvesting and transplanting should not coincide with the wettest months because of the adverse effects of submergence; hence, the fourth unit calls for completion of harvest and transplanting during August and



3. Condensed calendar of farm activities for four units. Muda Irrigation Scheme, Malaysia.



4. Diagram showing schedule for four units.



5. Diagram showing schedule by small units.

September, respectively. Similarly, the harvest of the second crop for unit 1 is in late November, when the probability of heavy rainfall is less. A calendar of farm activities can be condensed from the schedules of these four units (Fig. 3). It shows staggered presaturation water requirements and permits the design of smaller and less costly canals.

Irrigation schedules may be organized and combined to maximize labor and machine output from each village and concurrently to reduce canal capacities, as shown by simplified schematic diagrams (Fig, 4, 5). The schedules assume no sequencing within any of the villages but, instead, sequencing among the four large village units. The schedule assumes that machinery is insufficient and labor is immobile in the villages. While land in villages A and B is being prepared, farmers in villages C through H (on distributaries 2 through 4) are idle, waiting for irrigation water.

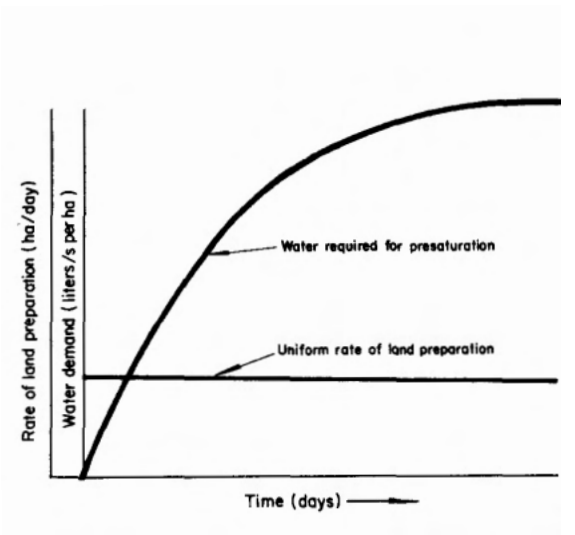
Alternatively, if intravillage sequencing is practical, irrigation can be introduced simultaneously in the first portion of each of the villages (Fig. 5). With this schedule, labor and machines in each village are engaged over a longer period, and less village labor availability or mobility is required. Similarly, with only one fourth of the land in each village requiring presaturation water at any one time, smaller and less costly water delivery channels can be designed.

Introduction of early-maturing varieties.

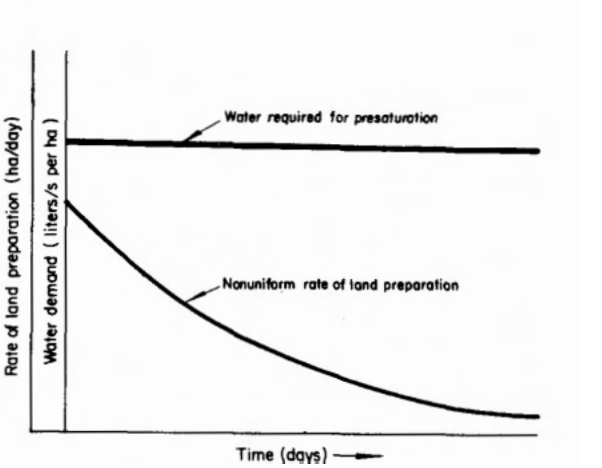
Use of early-maturing rice varieties increases flexibility in staggering production within climatic constraints (Fig. 2). Use of varieties of significantly shorter growth duration can also save water and give flexibility to farmers who fall behind the cropping schedule.

Introduction of communal or commercial nurseries. The continuous-flow or paddy-to-paddy method of farm irrigation prevalent throughout Southeast Asia involves a particular sequence of activities. A block of fields is flooded, then nurseries are prepared and sown. Because the fields remain flooded for 25 days (until the seedlings are ready for transplanting), considerable water is lost to evaporation, runoff, seepage, and percolation. The introduction of communal or commercial nurseries would save time and water, and would also influence the cropping schedule because groups of farmers would tend to transplant at the same time.

Introduction of mechanization. Mechanization sometimes helps achieve timely transplanting if the labor supply is inadequate in a project area. But it may not reduce the total labor requirement because it may intensify other cultivation activities such as weeding. Mechanization affects many irrigation design parameters, such as optimum field size, density of access roads and bridges, land leveling, land consolidation, and dimensions and sizes of tertiary units.



6. Water required for presaturation with uniform rate of land preparation.



7. Water required for presaturation with nonuniform rate of land preparation.

Machine availability has a strong impact on the rate of land preparation, which in turn greatly influences the rate of water supply needed for presaturation. A formula for computing presaturation requirements (MADA, 1975) shows that the design discharge should increase gradually to a peak if the rate of land preparation is kept at a constant value (Fig. 6). But if machines are available, the rate of land preparation can be adjusted to match machinery capacity, so that the discharge requirement is constant at a moderate level (Fig. 7). An optimum trade-off between mechanization and discharge capacity can be determined by considering the costs of alternative canal capacities and the opportunity costs of extended time duration in land preparation.

Plant-water relationships

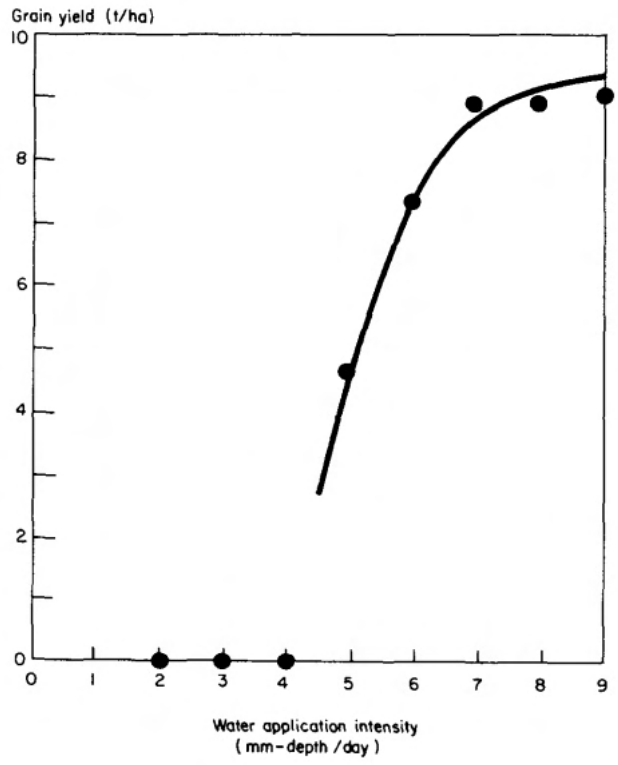
Modern rice varieties are less tolerant of' deep flooding or moisture stress than are tradi-

tional varieties. Basic agronomic data are required for the design of systems for optimum management. Applied agricultural research is needed to provide those who design and operate irrigation systems with information such as the following:

Basic water requirements of rice. Water requirements for lowland rice are based on rates of evapotranspiration, seepage, and percolation. In sizing the distribution system and reservoir capacity, such rates must be adjusted upward to compensate for losses at each level in the system back to the! reservoir.

Crop response to rate of water supply. Yield response differs with variety, climatic condition, and other site-specific parameters. An example is the yield response of the variety IR8 to a range of water application rates in the 1969 dry season (IRRI, 1970; Fig. 8). Data on factors that affect yield response are essential in planning optimum water delivery schedules.

Crop response to water depth. Constant and shallow water depths of less than 5 cm have generally been assumed to produce the most favorable rice yields, but fields must be level and weeded regularly for optimum results with shallow water depths. Both leveling and weeding have costs that must be balanced against the increased yields. Recent research in the Philippines indicates that water depths up to 15 cm do not significantly affect yields (IRRI, 1970). The potential weed-control benefits of fluctuations in water depth over the



8. Yield response of IR8 to treatments of varied water application intensity. IRRI, 1969 dry season.

Table 2. Estimated submergence damage to rice by growth stages in Japan.[a]

Growth stage	Yield reduction[b] (%) at days of Submergence							
	Clear water				Muddywater			
	1-2	3-4	5-7	7+	1-2	3-4	5-7	7+
20 days after transplanting	10	20	30	35	*d*	*d*	*d*	*d*
Young panicle formation, partly inundated[c]	10	30	65	90-100	20	50	85	90-100
Young panicle formation, completely inundated	25	45	80	80-100	70	80	85	90-100
Heading stage	15	25	30	70	30	80	90	90-100
Ripening stage	0	15	20	20	5	20	30	30

[a] Source: Fukuda and Tsutsui (1968). [b]Damage figures are reduced by 50% for half-day submergence. [c] "Partly" means leaves (9 to 15 cm long) remain above water surface. [d]Data not available.

full growth period should, therefore, be evaluated.

Effects of water stress at different growth stages. Two aspects of water application — quantity and timing — affect the level of plant stress at various growth stages. The distance of a field from its irrigation source also affects its water regime and incidence of stress. The distribution system must be so designed and operated as to minimize moisture stress during critical growth stages. During periods of water shortage, an entire system may irrigate, on a high priority basis, only those areas with crops in critical growth stages.

Submergence damage to rice in relation to growth stage: The design of drainage systems requires an estimation of flood risks. Data on the extent of yield reduction due to depth and duration of flooding will be useful in designing and sizing the drainage system (Table 2). The cost of added units of drainage protection can also be balanced against the cost of anticipated flood damage to the crop (Cheong, 1971).

Crop tolerance for saline water. If the water supply of an irrigation scheme is influenced by tidal conditions, the system design should take into account the salinity tolerance of potential crops. The effect on rice yields of alternating saline and nonsaline water also needs to be specified.

Economic and Production Factors

Production incentives for farmers are important to the success of an irrigation scheme. One important incentive is the provision of on-farm roads and facilities for applying and removing irrigation water. Because roads and similar facilities are very costly, their requirements should be carefully scaled to present and future expected traffic patterns, with attention to likely sizes of vehicles. The opportunity costs of scarce capital must also be balanced against the economic returns expected from such investments.

High density of field channels is often associated with improved control and management of water. Better irrigation and drainage facilities generally save water. Rapid removal of excess water can lead to earlier harvests. Integrating access roads with the irrigation layout can result in a better managed and less expensive system. Improved access allows products to be rapidly transported to and from

markets, thus reducing losses. Individual farmer control of water also allows management of fertilizer with minimum losses. All these attributes must be economically evaluated and incorporated into the on-farm system design. Additional economic analysis is needed to define the breakeven points between the cost of an added investment and the benefit attributable to that investment.

Social and Political Factors

The success of an irrigation project depends ultimately on its social acceptability and farmer involvement. Detailed knowledge of social structure, cultural attributes, values, and leadership patterns is essential to appropriate planning and design. Changing attitudes toward manual labor may require an early introduction of mechanization and a system layout readily adaptable to such technology.

The optimum size of the tertiary irrigation unit depends not only on physical criteria but also on the size of farmer groups that can effectively manage the water, and on the leadership required for efficient collective activity. Highly individualistic farmers may require more facilities or smaller tertiary units (Coward, 1972). Channel layout at the tertiary leve1 must often compromise hydraulic efficiency for social acceptability — for example, field channels are made to follow property boundaries to avoid fragmenting farm holdings.

Farmer participation in constructing and maintaining on-farm facilities is generally considered desirable. Many small, successful irrigation schemes in Southeast Asia are constructed and are equitably operated solely by farmers. But irrigation development will require sustained support from government agencies because increasingly large-scale development and investment are required.

Design and layout must conform to attainable levels of farmers' management, as well as to the operating agency's capabilities. Sociologists can help determine farmers' abilities to cope with rigid schedules of water management. Farmers' responses and their inputs in planning the cropping schedules are critical prerequisites to the acceptance and implementation of the schedules.

The political environment influences design decisions. Examples include the police action used to ensure farmer cooperation in water distribution during the Japanese occupation of Taiwan. Likewise, when rotational irrigation was implemented in Taiwan years later, the physical infrastructure was supplemented by strong political support. These are extreme examples; more common political involvement in Southeast Asia occurs in decisions on the intensity of infrastructure, setting of irrigation fees, and commitment to their collection.

Legal and Environment Factors

The management and operation of irrigation systems often have legal ramifications. Laws that constrain development may require modification. The involvement of lawmakers and sociologists may ensure more effective and fair rules and regulations. Land consolidation as a part of irrigation schemes is often without precedent and requires new legislation and extensive trials in pilot areas. Experience thus gained can make an important input to the legislative process.

The implementation of irrigation projects often significantly affects the environment. For example, in an area with a long dry season, the effect of a reservoir and a large sheet of water over the landscape would probably cause local microclimatic changes. If a river is diverted to another basin for irrigation, the river regime may change significantly. Increased flow may cause seasonal flooding and erosion of banks with resulting loss of land and siltation damage. Reduced flow may result in serious saline water intrusion. Pumping sometimes increases the depth of the water table to the point that domestic water supply is threatened. Irrigation system layout often interferes with village sanitary systems and causes waterlogging that increases water-borne disease incidence. These hazards require that health authorities be involved in the design of a system and in its operation.

Research and Technological Forecasting

An important prerequisite for design, as elaborated earlier, is information on the farm-level agricultural and social requirements of irrigation development. This information comes from applied research and testing under field conditions and is not generally available unless the design requirements are known well in advance of construction. Specific adaptation of the research to a designed project is necessary for direct incorporation of the results.

Because the design of system-level and on-farm facilities involves many constraints, variables, and unknowns, optimum design decisions cannot be made until the project has been partially implemented. Pilot projects allow field-testing and evaluation of alternative solutions. A successful pilot project can serve as a demonstration or as a nucleus for further development, provided it is recognized that problems from small areas have an aggregating effect when applied to larger areas. The lessons learned can thus be applied to the design of the main system.

Technological forecasting — predicting likely scientific and technological development in the future — may have frequent application in irrigation design. For instance, an acute land shortage and an increasing population may make land consolidation and intensification of agricultural production attractive. Demand for increased irrigation with limited water resources may create the need for water-saving techniques such as rotational irrigation. With improved standards of living and changing social values, women may not continue to be available for transplanting rice. The gradual urbanization of rural areas may provide better employment opportunities, resulting in a drift of labor out of agriculture. These and many other factors should be examined carefully and the probable course of agricultural development projected in a flexible master plan as an integral part of the system design process. In this approach the design serves as a framework for future project development.

Conclusion

The design of irrigation projects must consider the entire production process. Agricultural, economic, social, political, legal, and environmental factors should be considered in addition to the usual engineering aspects. Timely research applicable to the design process is required, as is pilot-testing of alternatives before their full implementation. Lessons from pilot projects are especially important regarding questions of farmer acceptance of integrated development. Technological forecasting should lead to a master plan that avoids early obsolescence of the system.

Irrigation design thus involves people from many disciplines. The creation of engineering hardware is not an end in itself but a means to provide an environment favorable to crop production and increased farm income.

References Cited

Cheong, C.L. 1971. Integrated farm water management. Irrigation and Drainage Paper No. 10, F.A.O. Rome. 29 p.

Coward, E.W., Jr. 1972. Institution and social organization factors affecting irrigation: their application to a specific case. International Institute of Rural Reconstruction. Paper presented at Water Management Workshop, Dec. 1972, UPCA and IRRI, Los Baños. Philippines.

Fukuda, H., and H. Tsutsui. 1968. Rice irrigation in Japan. F.A.O. Rome. 60 p.

Homing, H.M. 1970. The role of water management in the field. Paper presented at Seminar on Farm Water Management held in Manila, October 1970.

International Rice Research Institute (IRRI). 1970. Annual report 1969. Los Baños, Philippines. 266 p.

Muda Agricultural Development Authority (MADA). 1975. Proposals for on-farm improvement in the Muda Scheme — The Tanah Merah Project, Alor Setar: Muda Agricultural Development Authority, December, 1975.

Indonesia's simple (Sederhana) irrigation and reclamation program

OESMAN DJOJOADINATO

INDONESIA'S STRATEGY FOR IRRIGATION DEVELOPMENT includes the construction of new irrigation and reclamation projects, and the rehabilitation of existing systems. This paper focuses on the program to develop small-scale *sederhana* projects of 2,000 ha or less. More than 85% of the projects are in the Outer Islands. Their infrastructure is relatively simple to design and construct, thereby hastening their completion and intensifying the use of local labor. Implementation of the *sederhana* projects is the joint responsibility of provincial departments of public works and agriculture, and of local government.

Indonesia is a large archipelago located between the continents of Asia and Australia. It stretches about 5,470 km from 95° to 141° E longitude, and 1,770 km from about 6° N to 11° S latitude. The country consists of more than 3,000 major islands organized under 26 provinces and covers an estimated land area of 1.90 million sq km (see figure).

Indonesia's population was estimated to be 125 million in 1975 and increasing at 2.5%/year. About 70% of the people live in Java and Madura, which together make up only 7% of the country's land area. The population density in some parts of Java is as high as 772 people/sq km.

Rice is the staple food in Indonesia, where the annual per capita consumption is about 100 kg. From 1969 to 1974, Indonesia's rice production increased by 26% from 12.25 to 15.45 million tons (Table 1). About 18% of the increased production was due to expansion in area; the remainder was due to increases in yield.

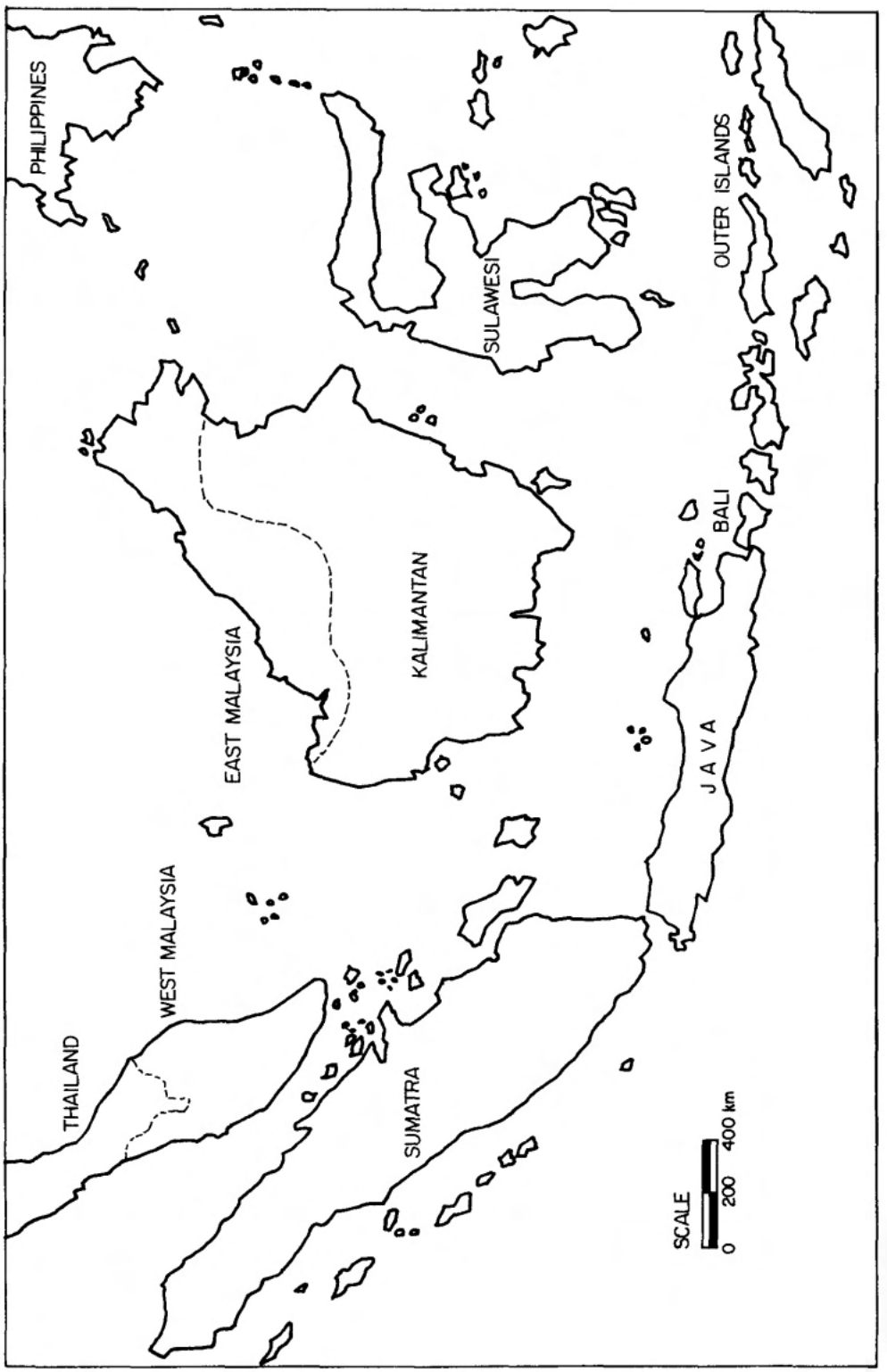
The plains area of Indonesia, defined to have a slope of less than 8%, comprises about 79 million ha (Table 2). However, only the alluvial portions are well-suited to irrigation. About 4.1 million ha or about 25% of the alluvial land and 5% of the total plains area are now irrigated. Much less land is available in Java for further extension of irrigation than in the Outer Islands, especially in Sumatra and Kalimantan.

Java, which accounts for more than 65% of the country's irrigated area, has a long experi-

Table 1. Rice productton and cropped area by years. Indonesia, 1969-74.

Year	Rice productton (million tons)	Cropped area (million ha)
1969	12.25	8.01
1970	13.14	8.14
1971	13.72	8.32
1972	13.29	7.90
1973	14.70	8.40
1974	15.45	8.54

Oesman Djojoadinato, Director of Irrigation, Directorate General of Water Resources Development, Ministry of Public Works and Electric Power, Jakarta, Republic of Indonesia.



1. Major islands of Indonesia.

Table 2. Total plains, alluvial plains, and irrigated areas by region, Indonesia. 1975

Island	Area (thousand ha)		
	Total plains	Alluvial plains	Irrigated
Java [a]	3,039	2,039	2,699
Sumatra	27,648	2,442	659
Kalimantan	24,544	4,276	149
Sulawesi	3,157	761	342
Nusa Tenggara [a]	653	243	252
Maluku	1,226	313	1
West Irian	18,718	6,758	0
Total	78,985	16,832	4,102

[a] A small portion of the nonalluvial land is Included in the irrigated area

ence in rice cultivation. It is so densely populated that individual holdings are exceedingly small, the vast majority being less than 0.75 ha. Policies for increasing rice production emphasize intensive land use and improved farm-level water management and agricultural practices.

In Sumatra, Kalimantan, Sulawesi, and the other Outer Islands, however, the population density is low and local farmers have little experience in rice cultivation. The policies for increasing rice production involve extending irrigation into new areas, where transmigrants from Java and Bali sometimes settle.

The Sederhana Program

Past experience in Indonesia shows that increasing rice production through new, large-scale irrigation projects requires considerable capital and time. That has helped prompt the government to introduce a program of small-scale, simple *(sederhana)* irrigation and reclamation projects. lrrigation for about 550,000 ha is planned for the *Sederhana* Program during Indonesia's Second Five-Year Development Plan, *Repelita* II, covering 1974-75 to 1978-79 (Table 3).[1] Of the systems built during the first 3 years of the plan, those in

[1] A US$20-million loan from the United States Agency for International Development (USAID) is being used to finance part of the *Sederhana* Program.

Table 3. Planned project area for the *Sederhana* Program, Indonesia. Fiscal years 1974-75 to 1978-79.

Fiscal year (Apr. 1 — Mar. 31)	Planned area (ha)
1974-75	40,000
1975-76	60,000
1976-77	100,000
1977-78	150,000
1978-79	200,000
Total	550,000

Sumatra received the most emphasis, followed by those in Sulawesi (Table4). Greater emphasis was given to intensifying production in previously rainfed rice areas than to extending production into new areas, but in 1976-77 this relationship was reversed. New areas in the *Sederhana* Program are relatively most important in Kalimantan and least important in Java and Bali.

The *Sederhana* Program is designed to bring new infrastructure and modern irrigated-rice technology, sometimes involving double-cropping, to relatively remote areas. Each of the *Sederhana* systems covers an area of less than 2,000 ha and involves technically simple irrigation structures that may be constructed within 1 or 2 years through rather labor-intensive methods.

The typical system includes a simple diversion weir with control head gates, an unlined main canal, a few secondary and tertiary conveyance ditches, some small diversion and turnout structures, and simple drainage works. The diversion weir is generally constructed of gabions or river-stone masonry. Such low-cost structures are relatively short-lived (up to 10 years). The plan is to make them permanent after the irrigation areas are further developed and farmers' skills in rice production are improved. However, permanent diversion structures may be built from the outset if they cost only slightly more than gabion weirs and show prospects for higher rates of return on investment.

It should be noted that the *Sederhana* Program is only one component of Indonesia's overall imgation development strategy. The other components are the rehabilitation of exist-

Table 4. Projects undertaken in the *Sederhana* Program, Indonesia. Fiscal years 1974-75 through 1976-77.

Region	1974-75				1975-76				1976-77[a]				Total			
	Projects (no.)	Area (ha)			Projects (no.)	Area (ha)			Projects (no.)	Area (ha)			Projects (no.)	Area (ha)		
		Rainfed	New	Total		Rainfed	New	Total		Rainfed	New	Total		Rainfed	New	Total
Java and Bali	62	10,543	371	10,914	29	6,391	219	6,610	37	6,025	2,176	8,201	128	22,959	2,766	25,725
Kalimantan	7	540	817	1,357	9	80	2,592	2,672	30	4,962	4,755	9,717	46	5,582	8,164	13,746
Sulawesi	21	3,779	5,169	8,948	43	11,551	6,610	18,161	36	11,157	10,884	22,041	100	26,487	22,663	49,150
Sumatra	76	13,835	3,968	17,803	98	17,912	10,099	28,011	120	13,810	23,276	37,086	294	45,557	37,343	82,900
Others	0	0	0	0	9	1,930	400	2,330	18	1,475	5,335	6,810	27	3,405	5,735	9,140
Total	166	28,697	10,325	39,022	188	37,864	19,920	57,784	241	37,429	46,426	83,855	595	103,990	76,671	180,661

[a]Subject to revision.

ing irrigation infrastructure — primarily in Java — and the construction of new medium- and large-scale irrigation projects throughout the country.

Benefit-Cost Evaluation

As mentioned earlier, the target area of the *Sederhana* Program during the Second Five-Year Development Plan is 550,000 ha. About 330,000 ha of this land had been previously planted to rainfed rice; the remaining 220,000 ha is newly farmed land.

In previously rainfed areas, the *Sederhana* Program is intended to improve water control and, hence, reduce crop losses due to drought, as well as to increase the possibilities for off-season crops. The average cropping intensity is expected to increase from 1.2 to 1.4 crops/year, and rice yields are expected to increase from about 1.6 to 1.8 t/ha. The estimated annual yield on the previously rainfed areas before the project was 1.9 t/ha (1.6 t/ha at 1.2 crops/year). After the project, the expected annual production is 2.5 t/ha (1.8 t/ha at 1.6 crops/year), representing an average annual increase of about 0.6 t/ha.

In the newly irrigated areas, cropping intensity is expected to increase from 0 to 1.4 crops/year. Yield may increase from 0 to 1.8 t/ha, giving an annual production of 2.5 t/ha. These estimates assume no fertilizer usage and no BIMAS program.[2]

Assuming these expected yield increases for previously rainfed and for newly irrigated areas, we computed an estimated aggregate increase in annual production of 752,400 t.[3] For rice valued at US$193/t, the value of the annual production increase becomes $145,000,000.[4]

The estimated costs of the *Sederhana* Program are as follows:

Main system construction $ 132,000,000

[2] BIMAS is a credit package program provided by the government to farmers to increase yield.

[3] 330,000 ha at 0.60 t/ha (previously rainfed) plus 220,000 ha at 2.52 t/ha (new areas).

[4] All cost and price data in this paper have been converted to US dollars at Rp 415 = US$1.

Consulting services and equipment	4,700,000
On-farm construction	5,300,000
Total	$ 142,000,000

The projects are assumed to last for 10 years, with the full project area irrigated by the sixth year. The interest rate for use in discounting is 15%. The assumptions imply an annual capital cost of $85,400,000 for the program. Annual operation and maintenance (O&M) costs are projected at about $3.85/ha, or $2,100,000 for the 550,000 ha. The total annual cost thus becomes $87,500,000 and the value of the benefit-cost ratio is 1.66,[5] suggesting that the *Sederhana* Program is economically viable.

Project Selection

Individual systems are selected for the *Sederhana* Irrigation and Reclamation Program on the basis of the following criteria:

1. The proposed land has been cultivated satisfactorily as rainfed rice or is believed suitable for rice cultivation.
2. Sufficient water of suitable quality is available for irrigation.
3. The land is not subject to flooding that would be difficult or costly to control.
4. There are no land status problems that would delay implementation.
5. An adequate number of local farmers are available, or can be made available through an organized transmigration program.
6. The communications and transportation infrastructure in the area is at least partly developed.
7. Adequate markets are available.
8. Other aspects of the general agroservices environment are favorable.

In addition, attention is being given to developing an environmental impact criterion.

The Directorate General of Water Resources Development (DGWRD) in the Ministry of Public Works and Electric Power has responsibility for the *Sederhana* Program. It initiates the selection procedure by circulating a questionnaire to the provincial governments, requesting proposals for projects that might qualify for the program. The proposed projects are evaluated and ranked by means of the above criteria as well as by benefit-cost analysis.

Organization

While the DGWRD has overall responsibility for planning and supervising the *Sederhana* Program, the provincial public works offices have primary responsibility for constructing the systems. They survey, map, plan, and design the main-system infrastructure for each project, and then either carry out construction work directly or contract it through competitive bidding. The public works offices also design the tertiary systems and operate and maintain the irrigation systems down to the first 50 m of tertiary canals. Funding main-system O&M expenses is a provincial responsibility. IPEDA, a local land development tax, is the principal source of revenue.

The farmers have primary responsibility for tertiary or on-farm development. The local government district chief, *bupati*, coordinates construction in conjunction with provincial agricultural officers. If farmers encounter difficulties, the provincial public works offices may assist them in constructing canal structures and may provide equipment, materials, and guidance in the technical aspects of construction. Furthermore, credit to finance the leveling and shaping of the rice fields is available to farmers through the Indonesia People's Bank. O&M at the terminal level is the farmers' responsibility, and is carried out under the direction of village ditch tenders, *ulu-ulu desa.*

The provincial agriculture offices are responsible for organizing water-user associations, giving extension training for on-farm water management and providing general guidance in modern rice cultivation.

The *Sederhana* Program is expected to give fast results because its individual systems are small and involve technically simple irrigation structures. However, problems of management

[5] $145,000,000/$87,500,000. The calculations do not apply to the first 5 years of the system. A more complete analysis would involve determining the present value of each of the benefit and cost flows over the 10-year period and computing the ratio of the respective sums.

and coordination exist because the systems are scattered over the 24 provinces of Indonesia.

Beginning with the fiscal year 1976-77, consultant teams with members from Indonesia and overseas will assist the DGWRD and the Ministry of Agriculture (MOA) in the training for implementation of the overall *Sederhana* Program. One team will be located in each of the four regional branch offices: Jakarta, West Java; Medan, North Sumatra; Palembang, South Sumatra; and Ujung Pandang, South Sulawesi.

The central consultant team will be in Jakarta. It will consist of a design engineer as team leader, an irrigation design engineer, and a farm irrigation specialist. Each regional branch team will include a design engineer and an irrigation or drainage construction engineer, one of whom will have special qualifications in O&M. A third member will be a farm irrigation specialist. The central consultant team leader and the four farm irrigation specialists will be hired for at least 33 months, and the others for at least 24 months.

The team leader will work directly with the project management. He will be responsible to the DGWRD and MOA for the overall coordination and supervision of the activities of the central and regional branch consultant teams. The other members of the central team will be assigned counterparts in the Directorate of Irrigation in the DGWRD. The engineers of the regional branch consulting teams will work with their respective provincial public works officials and the farm irrigation specialists with the provincial agricultural inspectors.

Training And Evaluation

The *Sederhana* Program has a substantial training component for upgrading the skills of technical and management staff and for training water users. Although employees may have thorough initial education and some on-the-job training, continuous training is necessary for them to perform well.

The program provides overseas training for senior management and technical officers of the Directorate General of Food Crops (DGFC) and the Agency for Agricultural Education, Training, and Extension (AAETE), and for some technical officers from each province. The DGWRD will provide graduate engineers with in-country training on project planning and design, project management, construction, supervision, monitoring, and O&M. Other staff will take technical high school courses in construction, inspection, surveying, mapping, and O&M.

The AAETE and DGFC will train graduate agriculturists in on-farm irrigation and drainage construction, principles and practices of irrigation, and on-farm O&M. They will also train provincial and district *kabupaten* officers in irrigation water management; field extension workers in water-user associations and water management; and association leaders in leadership. The courses will include environmental aspects of irrigation development.

The various in-country training courses will require from 1 to 13 months. In general, adequate facilities for the courses are available. They include training and information centers used by several ministries. The proposed locations for in-country training are: Medan for North Sumatra; Bandung for South Sumatra and West Java; Yogyakarta for Central Java and Kalimantan; Surabaya for East Java, Bali, and Nusa Tenggara; and Ujung Pandang for Sulawesi and the Maluku Islands.

Finally, preliminary evaluation of the systems completed by the third year of the program is being planned. It will examine the extent to which the *Sederhana* Program has achieved its objectives to increase rice production and improve the welfare of poor farmers in remote locations.

Planning and implementing land consolidation in Thailand

ANANDA KARUNYAKON

PROCEDURES AND GUIDELINES for planning and implementing land consolidation in Thailand are outlined. The land consolidation activities include the leveling of land, the construction of irrigation and drainage channels and farm roads, and the realignment of parcel boundaries. In 1976 the cost of land consolidation in pilot areas of the Central Plain was US$578/ha.

Land consolidation in Thailand is a package of technical improvements at the farm level to remove obstacles to increased agricultural output. It includes an integrated program of land development that requires the planning and construction of minor irrigation and drainage works, farm roads, and land leveling.

Combined with those activities is the adjustment of land ownership by the reallocation of plots into regular, compact holdings that improve conditions for agricultural production.

Three interdependent categories of technical activities are required in irrigated agriculture:

1. Headworks and main irrigation system components, such as dams, main canals, and drains;
2. On-farm development works, including land leveling, irrigation and drainage ditches, and farm roads; and
3. Institutional services, such as organization for water use and agricultural extension.

Some of the salient features in planning on-farm development for land consolidation are discussed in this paper.

Ananda Karunyakon, Chief of Dikes, Ditches and Land Consolidation Branch, Royal Irrigation Department, Thailand.

Outline of Planning Procedures

Planning for on-farm development involves two major phases: preparation of basic data, and planning and design of technical features.

Preparation of basic data

Aerial photography. Aerial photographs are used as a base for cadastral, topographic, and soil classification surveys, and for planning purposes. The photographs are made with an 80% end overlap and a 43% side overlap at a scale of 1:15,000. A terrestrial survey of check points can be used to rectify the original aerial photographs. The negative film serves as the basis for the required positive enlargements to scales of 1:10,000, 1:4,000, and 1:2,000.

Cadastral survey. Cadastral surveyors show the rectified photomaps to land owners and users. After consultation, property boundaries are indicated on the photomaps, referenced by their immediate surroundings rather than by some remote points. All boundaries or other features that are required on the cadastral map are measured in the field through a number of cross-reference points or lines established for this purpose.

A list of owners is then drawn up, and the plot boundaries and sizes are carefully checked against the rectified photomaps by planimetry. Land balances are also prepared for the areas under consideration and all information is placed on the photomap. Finally, contour lines with intervals of 0.25 m are added to the cadastral information.

Topographical survey. The spot heights, which are marked on the rectified photomap during the field survey, are transferred onto a contact positive photomap at a scale of 1:4,000. The 0.25-m contour lines are drawn onto a diazo copy and then transferred to another contact positive photomap that already shows the actual cadastral situation.

Soil classification survey. The soil classification survey is completed using a 1:10,000 photomap. It can then be composed on transparent paper using the photomap as an underlay.

Planning of technical features

General planning. Photomaps at a scale of 1:10,000 are used to select areas for tentative survey and to locate check points for the terrestrial survey required for rectification.

Layout. From the maps showing contour lines and cadastral information, one map is produced at a scale of 1:4,000 for the layout. In preparing such a map, the spot-height map and copies of the rectified photomaps on the same scale are consulted.

Reallocation planning. A basic map is traced onto a transparent overlay on the rectified 1:4,000 aerial photograph. The overlay will show block boundaries, existing buildings, and rights-of-way of the main irrigation, drainage, and road systems. The actual reallocation of fields is drawn on the basic map, using as underlays rectified aerial photographs or prints of the actual cadastral maps, or both.

Final plans. Rectified aerial photographs of the same scale are used as underlays in the preparation of the final construction plan showing the new layout of fields, roads, and water courses (1:2,000 scale). Also traced on the underlays are block boundaries, existing boundaries, unchanged properties, and existing rights-of-way of the main irrigation, drainage, and road systems. These final plans are used to stake out center lines and to identify new property boundaries. The center lines are also indicated on the 1:2,000 rectified photographs to facilitate location in the fields.

Design of technical features

The technical features of an irrigation system should be designed for optimum water control at all levels, and farmers should be able to irrigate or drain every farm plot at any time. Therefore, each farm plot must be directly connected to the irrigation and drainage system.

Water control structures. In a minor irrigation system, ditches and structures should have sufficient capacity, and the level of water supply should be high and almost constant to provide dependable irrigation. The distribution system should encourage economical water use and allow efficient management.

The rate of irrigation supply to a ditch is determined by the average intensity of cultivation in its command area. The command area served by one ditch in the dry season is assumed to be as much as 90% of its total area.

Maximum irrigation is required in April when evaporation is highest. Presupposing an average crop water use of 4.0 mm/day, with 20% ditch and on-farm losses, the irrigation requirement Q at the ditch inlet would be:

$$Q = (90\%) \times \frac{4.0}{80\%} = 4.5 \text{ mm/day, or } 0.52 \text{ liter/s per ha.}$$ [1]

Assuming rotation on the lateral with a time factor of 0.5, the ditch should be designed for twice this capacity, or 1.06 liters/s per ha. This capacity would be sufficient for both wet and dry seasons.

[1] 1 liter/s per ha = 8.65 mm/day.

Ditch dimensions can be calculated by the use of Manning's formula.[2] Since vegetation and other obstructions hinder flow considerably in these canals, a high roughness *n* is used (*n* is the coefficient of roughness in Manning's formula). The minimum width of the canal bed should be 0.4 m.

Water-control features of land consolidation in Thailand were designed by the Royal Irrigation Department engineers, as follows:

1. The selection of alignments and the slopes of water courses are based on detailed topographic information, so that supply levels are always sufficient for gravity command. A grid survey with approximately 400 points/km^2 is required.

2. To ensure a constant supply to the fields, water levels in the canals should vary as little as possible, especially for furrow irrigation in the dry season. However, checks[3] are introduced to compensate for uncertain supply because supply levels vary with the discharge rate, and because design dimensions and slopes cannot be met precisely during construction, nor can they be retained thereafter.

3. In some places permanent weirs are provided at carefully established sill levels to prevent siltation that could interfere with the operations of the system and cause rapid deterioration.

Many types of gates and measuring devices are used for control. The most common type of gate in water distribution systems is the vertical lift with hand wheel and spindle. It may be square, rectangular, or round; the size is determined by the amount of water required and the available head. For larger gates, ball bearings are used in the hoist.

Many types of measuring devices, most of which are standard, are used. For land consolidation in Thailand, constant head orifices are preferred because they combine water measurement and regulation.

To install such devices on each farm would be too expensive and would require too much attention from the common irrigators responsible for operation. Therefore, simple pipe outlets that allow dependable water delivery under proper management are used. If water levels in the ditches are controlled, the only additional factor needed to determine the discharge is the water level at the downstream end of the pipe. Such discharge may be controlled by an overflow device. But such a device requires strict accuracy in construction because it tends to deteriorate over time. In estimating costs, it was assumed that all farms were to be provided with this device.

Gates to close the pipes were not provided because they are usually fragile and likely to be stolen. Farmers may close their pipes with earth or homemade plugs.

A flow of about 0.03 m^3/s through pipes 0.20 m in diameter at a head of 0.09 m is planned for each farm. The supply through the ditch inlet is a multiple of this amount. The total supply to each farm is regulated on a time-rotation basis. The ditches will have a capacity of between 0.06 and 0.12 m^3/s, allowing from 2 to 4 farmers to irrigate at the same time. Downstream water levels will probably not vary much even if there are no control structures at the farm outlets, so distribution may be expected to be relatively accurate.

The common irrigator is expected to exercise sufficient supervision over water distribution and canal maintenance. He should prepare rotation schedules that ensure that each farmer gets the same share of irrigation water at night. The irrigator should also be informed of supply periods and delivery through ditch inlets and, in turn, should inform the farmers. However, he is not obliged to always be present during irrigation. The farmers are expected to open and close pipes and culverts at the times indicated on the rotation schedule. The common irrigator should mediate in disagreements.

Drainage system. Drainage requirements depend on many considerations such as rainfall pattern and intensity, irrigation method and efficiency, salt consideration, crop tolerance for submergence, and farming schedules. Systems may be designed for surface or internal drainage,

---

[2] Manning's formula is: $V = \frac{1.49}{n} R^{2/3} S^{1/2}$; where V = velocity, R = hydraulic radius, S = slope, and n = Manning's roughness coefficient.

[3] Check gates in the canals obstruct the flow of water and rhus increase its head upstream of the check.

or both. Internal damage, the removal of water below the ground level through deep open ditches or tile drains, is not generally necessary unless a salinity problem exists or the water table rises above a certain level. At present there seems to be no serious salinity problem in the project area,[4] but from 5 to 10% of the area may need internal drainage for other reasons.

For proper water control, a minor drainage system must be constructed to collect excess surface water from the field. Each plot should be connected to a drain designed to handle maximum expected drainage flow. In areas of a few square kilometers, the maximum drainage runoff is determined from rainfall. For newly planted rice, water depths that exceed 50 mm are injurious, so farmers should be able to drain off excess water within 3 days. This rather stringent requirement would demand expensive design. Therefore, it is proposed that the drains be built to serve areas that do not exceed 5 km^2, with a surface runoff of 6.25 liters/s per ha. This runoff rate corresponds to a discharge of approximately 54 mm/day, a rate expected to occur only once in 10 years in the project area. Discharges of 44 and 62 mm/day correspond to recurrence intervals of 5 and 20 years, respectively.

As rain does not fall simultaneously across a given area, the maximum runoff decreases as area increases. Little is known, however, about drainage runoff from large areas. If the fields in the project area drain within 2 months from the end of the growing period, and if the water depth in the fields averages 0.15 m, the discharge rate should be 2.5 mm/day . Because additional rain is expected during this period, the drainage discharge will probably be higher, ranging from 5 to 6 mm/day . Assuming a maximum discharge of 5.4 mm/day, the discharge rate Q is 0.63 liter/s per ha.

Since the drains will generally serve surface drainage only, full supply levels should be designed at ground level. Side slopes may be taken at 1:1. The minimum cross section will have a bed width and water depth of 0.50 m. The maximum cross section will be 1.00 m, both for bed width and water depth. The design dimensions were calculated according to Manning's formula, assuming $n = 0.025$.

As the areas under consideration for internal drainage are situated on high levees with surface slopes of 1.5 to 5 m/km, there will generally be sufficient head for an internal drainage system to discharge into the minor drains.

Land leveling. Land leveling is a prerequisite to efficient irrigation and farm management, Grading eliminates local variations of water depth on rice fields. Currently, higher parts of the field become dry and crops are damaged when water stagnates. Field irrigation of dry-season crops in a large area requires well-graded land for uniform water distribution, resulting in savings of water and higher crop yields. With leveling, plots can be made larger and more regular in shape. Leveling requires that farms be divided, but it is important for efficient farming, especially if the latter is mechanized. Tentative criteria have been set for the moving of earth to strike a balance of expenditure and benefit. Irrigation plots with a minimum length of 110 m, a minimum width of 40 m, and an elevation difference of no more than 0.10 m within a field seem to satisfy the criteria.

Farm roads. A good system of roads to improve access to individual farms will increase farm income through reduced transport costs. Farm roads could be constructed along irrigation ditches or minor drains to make all plots accessible throughout the year. Roads along ditches have distinct advantages over those that follow field drains, by permitting farm turnouts to be reached by bicycle. Since rotational irrigation will be applied in both the wet and dry seasons, turnouts will have to be tended regularly.

The following criteria should be used for road planning in the land consolidation area:

1. The farmers on plots that are not directly connected to a farm road should have right-of-way across adjoining properties along ditches or drains.

2. If right-of-way is planned along field drains, it should have a maximum length of 300 m to the farm road, crossing fewer than 4 plots.

3. Because drainage is poor in the vicinity of

[4] The Pilot Land Consolidation Project in Channasut, in the central Plain of Thailand. Data for this paper came largely from that project.

ditches, right-of-way along ditches should be 100 m.

Earthen roads should be provided with 0.50-m shoulders, 1:l side slopes, and top widths of 2.50 m so that vehicles coming from opposite directions can pass through. Therefore, no passing strips will be needed. The top of the road should be about 0.60 m above ground level to avoid softening by capillary movement if water levels are high in adjacent fields, and to provide sufficient soil cover to avoid damage of farm turnout pipes.

Farm roads and ditches should be constructed simultaneously. First, a dike is built and compacted, then the ditch is excavated in the dike and the soil worked over the remaining dike area and compacted again. Thus, a well-compacted earthen road, passable throughout the year, may be built.

Reparceling. Land should be reparceled for efficient farming with machinery and for row cropping. Reparceling will counterbalance the fragmentation caused by the construction of the terminal system of irrigation ditches, field drains, and farm roads, and will thus straighten property boundaries. Reparceling will also remodel elongated properties for efficient farming, and combine fragmented properties somewhat.

Either maximum or block reparceling may be used. With maximum reparceling all fields are rearranged — without regard for present property boundaries — along straight lines parallel to ditches, fields drains, and farm roads. With block reparceling, boundaries, ditches, drains, and roads are planned along present property boundaries, if possible. A limited number of parcels in one block are then rearranged. Land is reparceled only if considered necessary to meet the earlier criteria.

Preparation of Plans

Tentative plans should be prepared for blocks of 800 to 1,600 ha at a time. They should show ditches, minor drains, farm mads, and provisional relocation of plots. Next, interested parties are consulted and a common irrigator is elected. Definite plans can then be prepared showing layouts of irrigation ditches and structures, minor drains, farm roads, and final allocation of plots. Next, designs and details for execution of the works can be made and cost estimates prepared.

When the definite plan is completed, the project goes into implementation. This stage includes signing the agreement with the parties involved; staking out boundaries of new plots,

Table 1. Estimates of quantities of earthwork required and rate of progress for specified field work activities of land consolidation based on 1,600-ha unit areas. Land Consolidation Project, Thailand, 1976.

Activity	Total quantity required	Av unit earth-work	Total earthwork required (m^3)	Rate of progress (ha/day)
Land clearing	1,600 ha	–	–	8[a]
Construction of road and ditch embankments	45,000 m	6 m^3/m	270,000	3.6 to 4.5[b]
Excavation of canals and ditches	45,000 m	1.3 m^3/m	58,500	11[c]
Excavation of drains	45,000 m	1.3 m^3/m	58,500	
Land leveling	1,440 ha	31 2 m^3/ha	449,280	

[a] Based on one track-type bulldozer for two-thirds of the work, and one wheel-type bulldozer for one-third of the work. [b] Based on 4 scrapers of 6.9 m^3 (9 cubic yards) capacity each, or 3 of 8.41 m^3 (11 cubic yards) each. [c] Using three backhoes simultaneously.

Table 2. Estimated costs [a] for land leveling performed by different types of equipment. Land Consolidation Project, Thailand, 1976.

Type of equipment	cost (US$/ha)
Track-type bulldozer, 140 hp	157
Rubber-wheel bulldozer, 170 hp, in combination with an offset disc harrow (for loose earth)	167
Self-loading motor scraper, 162 hp (dist. 150 m) 6.8 m^3 bucket	122
Self-loading motor scraper, 146 hp 8 m^3 bucket	110
Self-loading motor scraper, 146 hp, 8 m^3 bucket, laser plane-controlled	120
Farm tractor, 65 to 80 hp, with blade and disc harrow	119

[a] Includes all costs except salary of engineer in charge.

ditches, drains, and roads; establishing boundary posts; constructing ditches, drains, roads, and structures; leveling land and reconstructing fields; preparing revised cadastral maps on the basis of execution data; issuing new title deeds to the farmers; and teaching the farmers to work with the new system.[5]

To finalize a definite plan, different kinds of work based on a unit area should be estimated. The estimates relate the construction of farm ditches, drains, roads, control and measuring structures, land leveling, equipment needs, and other factors (Table 1).

About 1,120 hours of work are estimated for the field work associated with land consolidation for the 1,600-ha unit area. These estimates are based on 23 working days/month during the 5-month period from 15 January to 15 June, when rainfall is low. The estimates are broken down into categories of land clearing, road and ditch embankment construction, canal and ditch excavation, land leveling, and construction of structures. The rate of progress for these operations is estimated in Table 1.

Land leveling is one of the more expensive factors of land consolidation. Its cost estimate is based on several alternative equipment combinations (Table 2). The use of farm tractors should be encouraged in areas where little earth is to be moved, and bulldozers used only for relatively short distances of earth movement, preferably less than 60 m. Motor scrapers may be advisable where moving distances are long.

Summarized cost estimates for the various activities of land consolidation are listed based on those unit costs (Table 3).

Table 3. Estimated costs[a] of different activities comprising land consolidation in Thailand, 1976

Activity	Cost (US$/ha)	
Surveys		
Aerial survey	1.55	
Topographical survey	5.27	
Cadastral survey	4.65	
Land suitability survey	4.03	
Rehabilitation survey	3.10	
Subtotal		18.60
Design and preparation		
Land consolidation	12.40	
Rehabilitation	4.65	
Subtotal		17.05
Implementation		
Staking out and surveying	21 70	
Clearing	21.70	
Road construction and fill	90.00	
Irrigation ditches and drains	52.70	
Land leveling	192.20	
Structures	46.50	
Rehabilitation	77.50	
Subtotal		502.30
Administration, supervision, and service		31.00
Issuing of title deeds		9.30
Total		578 25

[a] Excluding annual costs of operations and maintenance (estimated at US$12.40/ha per year), interest on borrowed capital, and costs of consultants. All estimates are based on work undertaken by the Royal Irrigation Department, the cost of which is lower than corresponding costs for private contractors. Data based on Pilot Land Consolidation Project, Channasut, Chamat, Thailand.

[5] Unexpected circumstances sometimes necessitate deviation from the plan, so that the plan and final cadastral layout do not always tally.

Conclusions

In this discussion, the various considerations given to the planning and implementation of the Land Consolidation Project in Thailand were detailed. The following general observations can be made about the project:

1. Land consolidation is no longer considered an isolated or independent enterprise. It is to be keyed into or associated with other development and should be considered as one link of the entire development plan.

2. The cost of land consolidation in Thailand is estimated to be US$578/ha. But the decision whether to consolidate land is not merely a matter of spending or saving $578/ha. If properly carried out, land consolidation will provide for factors essential to agricultural development such as the increasing need for ditches, minor drains, farm roads, and land leveling.

3. An integrated approach to the development of minor irrigation and drainage networks, farm roads, land leveling and relocation of holdings is required to realize the full potential of land consolidation in Thailand.

References Cited

Blom, G.A. 1970. Notes on investment for land consolidation. Netherlands Development Company (NEDECO).

Chow, Lee. 1966. Lecture notes on irrigation engineering.Ilaco, 1976. Chao Phya irrigated agriculture development project.

Netherlands Development Company (NEDECO). 1966. Report on the feasibility of land consolidation. Phase I.

Van Dia, M.M. U. 1970. NEDECO Technical Officer. Land Consolidation.

Fiberglass-reinforced polyester flumes as tertiary channels in Malaysian irrigation development

L. H. PANG

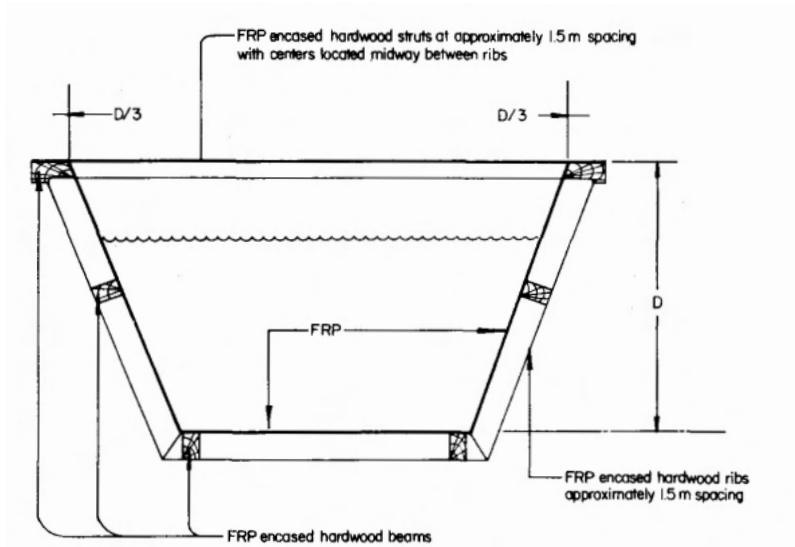
FIBERGLASS-REINFORCED POLYESTER (FRP) flumes to carry water above ground have recently been developed in Malaysia and are being introduced in some irrigation projects. FRP can be installed more quickly than conventional earth channels, thus precluding the loss of a crop season. They require less right-of-way acquisition, less maintenance, and save irrigation water. The agricultural and engineering benefits associated with FRP flumes more than compensate for their high capital construction costs.

Malaysia has a long history of rice production. Before 1900, the country had more than 240,000 ha under rainfed cultivation in the wet season. The country's first phase of irrigation development, which lasted until about 1960, involved the provision of irrigation facilities to supplement wet-season rainfall and thereby ensure a single crop of rice each year. Additional facilities, including reservoirs with large storage capacity and large pumping stations, were provided in the second phase to allow double-cropping. Of Malaysia's 432,000 ha of lowland rice in 1975-76, about 320,000 ha were irrigated; of that, about 240,000 ha were double-cropped.

The main rice policy objectives of Malaysia's Third Plan (1976-80) are to increase production enough to maintain and perhaps expand the country's 85-90% level of rice self-sufficiency and to improve the producers standards of living. But because the nation's major irrigation sources have already been tapped, and because the short-duration, high yielding rice varieties require a more exacting water environment. Malaysia's irrigation strategy has moved into a third phase that emphasizes intensified terminal irrigation and drainage facilities. In this phase, added attention is given to tertiary and quaternary infrastructure and on-farm water management. The presupposition is that more decentralized and improved water control will permit higher cropping intensities and larger and more assured harvests.

Malaysia's Drainage and Irrigation Department (DID) has considered two types of terminal conveyance channels: 1) structural channels such as fiberglass-reinforced polyester (FRP) flumes and concrete, steel, or plastic pipes, and 2) excavated channels of earth, some of which are lined with concrete. Of the structural alternatives, the FRP flumes were

L.H. Pang, Director-General, Drainage and Irrigation Department, Ministry of Agriculture and Rural Development, Government of Malaysia, Kuala Lumpur, Malaysia.



1. Cross-section of an irrigation conveyance channel made of fiberglass-reinforced polyester (FRP).

found to be least costly; of course, earth channels are less expensive than concrete-lined channels, although their maintenance is more expensive.

In this paper, FRP flumes are compared with earth channels. The paper is based largely on experimental data and a pilot project in the Tanjung Karang Irrigation Project, Malaysia, but its specific application is a feasibility study in the Lemal Irrigation Project in North Kelantan. Because the FRP flumes were only recently developed, some background on their physical characteristics is given first.

Fiberglass-Reinforced Polyester Flumes

The DID, which conceived the idea of FRP flumes, has developed a commercially feasible production process for manufacturing them. The standard flumes are about 6.1 m long. They vary from about 30 to 90 cm in width, 25 to 70 cm in depth, and 2 to 3 mm in thickness depending on their design discharge (Fig. 1). They are trapezoidal in cross-section, and are supported above ground by hardwood piles, generally at a height at which the water level in the flumes[1] is about 30 cm above the ground surface. Water is siphoned from them to the rice fields. The flumes are usually spaced at least 0.8 to 1.0 km apart to minimize the need for equipment and farm animals to cross them.

The main components of the flumes are locally available FRP and hardwood. FRP is a composite of a resilient durable resin reinforced with fiberglass. It provides watertightness as well as durability and high tensile strength. But by itself, FRP would be too expensive and insufficiently strong to serve as a conveyance channel. Adding wood to the FRP gives compression strength, stiffness, lateral support, and added tensile strength. The wood in a flume is completely encased by the FRP, which protects it from water and other elements (Fig. 1). The resin is pigmented with carbon black to resist weathering due to sunlight.

The fiberglass used in the flumes is woven into mats of varying weights. By selecting mats of appropriate weight and combining

[1] The design water level in the flumes is about 60% of the total flume depth.

them in varying numbers of layers, channels of different sizes and strengths can be made.[2]

The fiberglass mats are laid out in a waxed and gel-coated steel mold, after which resin is applied and the mats are rolled. Because a polyester resin is used, the molding takes place without heat or pressure. Wood and plastic are laminated into the ribs stage by stage until the desired design is finished.

The manufacturing process is simple, small scale, and labor intensive. No sophisticated skills are required, so FRP manufacture might be excellent for absorbing rural labor.

Earth vs. Fiberglass-Reinforced Polyester Flumes as Tertiary Channels

Without question, the initial construction cost of earth channels is less than that of FRP flumes. The advantages of FRP flumes must be weighed against that factor.

Advantages of FRP flumes

Reduced land acquisition. Because FRP flumes are placed above ground, they take up only 20% of the land required for earth channels. That reduces both the time and costs of acquiring channel right-of-way — factors that are of considerable economic, social, and legal importance in Malaysia where average rice holdings are only 1.0 to 1.5 ha each.

Easier and speedier construction. FRP flumes can be manufactured away from an irrigation project site and easily carried to it. The time required for driving piles and anchoring flumes is less than that for excavating earth channels. During construction these factors imply 1) less relocating and compacting of soil, with fewer adverse short-term effects on crop yields, and 2) less disturbance of crop schedules, which is particularly important in areas that are already double-cropped.

Crop-drainage. FRP flumes do not interfere with cross-drainage channels, as earth-excavated irrigation channels often do.

Reduced seepage. With FRP flumes, seepage is almost totally eliminated. That saves scarce irrigation water for use elsewhere and reduces per hectare pumping costs in Kelantan where water is pumped up into the canal system from the Kemubu River. Reduced seepage can also make upland crops feasible in areas that are otherwise too waterlogged for efficient production.

Reduced maintenance. Vegetative growth in FRP flumes is almost nil, thereby reducing an important operations and maintenance (O&M) task in earth channels. Damaged FRP flumes can also be repaired or replaced more easily than damaged earth channels.

Economic analysis of FRP flumes

An economic analysis was undertaken to ascertain the feasibility of using FRP flumes vs. earth channels as tertiary canals in the Lemal Irrigation Component of the North Kelantan Agricultural Development Project. A summary of the findings, with the 12,000-ha project as the unit of analysis, follows.

Three cost components of irrigation were examined (Table 1). The capital construction costs[3] for the FRP flume system were projected to be US$4.2 million ($356/ha served), or slightly more than 2.5 times as much as for the earth channel system. The period of construction was assumed to be 4 years rather than 6 for earth channels. The estimated total savings in land acquisition costs and O&M for FRP flumes during the first 10 years were substantially less than their added capital construction cost relative to earth channels.

The wet-season area under both tertiary irrigation systems was projected to increase modestly from 10,800 to 11,760 ha by the 7th year (Table 2). But shorter delays in right-of-way acquisition and speedier construction for FRP flumes were projected to result in attaining the full target dry-season area 2 years before it would be attained with earth channels. The cropping intensity was projected to

[2]For example, a channel 25 cm deep and 30 cm wide could handle a flow of about 20 liters, whereas a channel 80 cm deep and 90 cm wide could handle a flow of about 400 liters/s.

[3]All cost and price data in this paper have been convened to US dollars at M$2.46 = US$1.

Table 1. Costs of fiberglass-reinforced polyester (FRP) flumes and earth channels as tertiary canals. North Kelantan Rural Development Project, Lemal Irrigation Component, Malaysia. 1975

Year	Total area (ha)		Capital construction cost (million US$)			Land acquisition cost[a] (million US$)			Operations and maintenance cost[b] (million US$)		
	FRP	Earth	FRP	Earth	Difference due to FRP	FRP	Earth	Difference due to FRP	FRP	Earth	Difference due to FRP
1	3,420	1,620	1.20	0.23	- 0.97	0.0[c]	0.01	0.01	0.01	0.01	0.00
2	6,840	3,900	1.20	0.30	- 0.90	0.01	0.02	0.01	0.01	0.01	0.00
3	10,260	5,980	1.20	0.30	- 0.90	0.01	0.03	0.02	0.01	0.03	0.02
4	11,970	8,170	0.60	0.30	- 0.30	0.01	0.04	0.03	0.02	0.04	0.02
5	11,970	10,350	0.00	0.30	0.30	0.01	0.05	0.04	0.02	0.05	0.03
6	11,970	11,970	0.00	0.22	0.22	0.01	0.06	0.05	0.02	0.06	0.04
7	11,970	11,970	0.00	0.00	0.00	0.02	0.06	0.04	0.02	0.06	0.04
8	11,970	11,970	0.00	0.00	0.00	0.02	0.07	0.05	0.02	0.06	0.04
9	11,970	11,970	0.00	0.00	0.00	0.02	0.08	0.06	0.02	0.06	0.04
10[d]	11,970	11,970	0.00	0.00	0.00	0.02	0.08	0.06	0.02	0.06	0.04
First 10-year total			4.20	1.65	-2.55	0.13	0.50	0.37	0.17	0.44	0.27

[a]Assuming that the remainder of the project, including flood control works and drainage, is implemented. Land values are based on projected yields, cropping intensities, input usage, and prices. [b]The annual O&M costs for FRP flumes are assumed to be $1.70/ha; for earth channels, $4.69/ha. [c]The figure is positive but less than 0.005, [d]The cost projected for the 10th year would continue at the same rate in the 11th to 20th years of the project.

Table 2. Area and yield assumptions for fiberglass-reinforced polyester (FRP) flumes and earth channels as tertiary canals. North Kelantan Rural Development Project, Lemal Irrigation Component, Malaysia, 1975.

Year	Wet season[a] (ha)	Area					Yield					
		Dry season (ha)		Cropping intensity (%)[b]			Wet season			Dry season		
		FRP	Earth	FRP	Earth	Difference	FRP (t/ha)	Earth (t/ha)	Ratio[c]	FRP (t/ha)	Earth (t/ha)	Ratio[c]
0	10,800	5,800	5,800	154	154	0	1.75	1.75	1.00	2.60	2.60	1.00
1	10,800	6,300	6,300	158	158	0	1.75	1.75	1.00	2.60	2.60	1.00
2	10,900	7,600	7,000	170	164	6	1.85	1.81	1.02	2.70	2.66	1.02
3	11,000	8,400	7,700	176	170	6	1.95	1.86	1.05	2.85	2.75	1.04
4	11,200	10,200	8,700	191	178	13	2.15	1.95	1.10	3.05	2.85	1.07
5	11,400	11,000	9,500	196	183	13	2.40	2.15	1.12	3.30	3.05	1.08
6	11,600	11,160	10,100	196	187	9	2.65	2.40	1.10	3.50	3.30	1.06
7	11,760	11,160	10,600	195	190	5	2.90	2.60	1.12	3.55	3.55	1.00
8	11,760	11,160	11,160	195	195	0	2.95	2.95	1.00	3.60	3.60	1.00
9	11,760	11,160	11,160	195	195	0	3.00	3.00	1.00	3.65	3.65	1.00
10	11,760	11,160	11,160	195	195	0	3.05	3.05	1.00	3.70	3.70	1.00

[a] The same areas are irrigated under both systems during the wet season. [b] Cropping intensity is the sum of wet and dry season areas divided by the wet season area and multiplied by 100. [c] Ratio of FRP to earth systems.

Table 3. Agricultural production costs of fiberglass-reinforced polyester (FRP) flumes vs. earth channels as tertiary canals, and net benefits from FRP flumes. North Kelantan Rural Development Project, Lemal Irrigation Component, Malaysia, 1975.

Year	Production costs						Net benefit of FRP (million US$)		
	Wet season			Dry season					
	FRP (million US$)	Earth (million US$)	Ratio[a]	FRP (million US$)	Earth (million US$)	Ratio[a]	Wet season	Dry season	Total
0	1.20	1.20	1.00	0.73	0.73	1.00	0.00	0.00	0.00
1	1.22	1.22	1.00	0.80	0.80	1.00	0.00	0.00	0.00
2	1.28	1.27	1.01	1.02	0.93	1.10	0.09	0.37	0.46
3	1.38	1.34	1.03	1.19	1.06	1.12	0.20	0.52	0.72
4	1.49	1.42	1.05	1.55	1.26	1.23	0.41	1.07	1.48
5	1.62	1.53	1.06	1.79	1.44	1.24	0.52	1.23	1.75
6	1.75	1.65	1.06	1.92	1.68	1.14	0.53	0.99	1.52
7	1.86	1.86	1.00	2.04	1.94	1.05	0.76	0.33	1.09
8	2.00	2.00	1.00	2.15	2.15	1.00	0.00	0.00	0.00
9	2.13	2.13	1.00	2.24	2.24	1.00	0.00	0.00	0.00
10	2.22	2.22	1.00	2.33	2.33	1.00	0.00	0.00	0.00

[a] Ratio of FRP to earth systems.

Table 4. Net project benefits from fiberglass-reinforced polyester (FRP) flumes relative to earth channels as tertiary canals. North Kelantan Rural Development Project, Lemal Irrigation Component, Malaysia, 1975.

Year	Irrigation costs (million US$)				Agricultural benefits (million US$)	Total net project benefits (million US$)
	Capital construction	Land acquisition	Operations & maintenance	Total costs		
1	–0.97	0.01	0.00	–0.96	0.00	–0.96
2	–0.90	0.01	0.00	–0.89	0.46	–0.43
3	–0.90	0.02	0.02	–0.86	0.72	–0.14
4	–0.30	0.03	0.02	–0.25	1.48	1.23
5	0.30	0.04	0.03	0.37	1.75	2.12
6	0.22	0.05	0.04	0.31	1.52	1.83
7	0.00	0.04	0.04	0.08	1.09	1.17
8	0.00	0.05	0.04	0.09	0.00	0.09
9	0.00	0.06	0.04	0.10	0.00	0.10
10	0.00	0.06	0.04	0.10	0.00	0.10
11-20	0.00	0.06	0.04	0.10	0.00	0.10

increase from 154 to 195%, with 5 to 13 more percentage points for the FRP cropping intensity from the 2nd to the 7th years than for the earth-channel case.

Over the duration of the project, yields were projected to increase from 1.7 to 3.0 t/ha in the wet season, and from 2.6 to 3.7 t/ha in the dry season. Wet-season yields wouid increase from 2 to 12% faster for the FRP flumes than for earth channels from the 2nd to 7th years; dry-season yield increments would be nearly equal between the two systems (Table 2).

The higher cropping intensities and higher yields for the FRP flume systems imply annual increases in costs of rice production of up to 24% during the 2nd to 7th years of the project (Table 3). The combined effect of higher cropping intensities, higher yields, and higher production costs would lead to annual net benefits of agricultural production ranging from $460,000 to $1,750,000 for the entire area, with benefits during the dry season roughly twice those during the wet season.

These agricultural benefits were compared with the added costs of FRP flume irrigation reported in Table 1. The net project benefits from FRP flume irrigation are negative during the first 3 years, but they become strongly positive during the next 4 years and continue positive thereafter (Table 4). The internal rate of return during the project's life shows a 45% increase over the added investment required for the FRP flume construction.

This analysis does not take into account the benefits of reduced seepage with the FRP flume channels, and neither does it consider the possible disadvantages of FRP flumes other than their higher initial cost. It will be important to learn more, for example, about the long-term physical durability of FRP flumes under field conditions; their effects on water use and water conflict (because they give water-users ready access to water supplies via easily movable siphons); and inconveniences that they may cause to overland movement of equipment, animals, and people. On the basis of what is now known, however, FRP flumes appear to be a very attractive alternative for use in the further development of Malaysia's terminal irrigation infrastructure.

MANAGEMENT, OPERATION, AND MAINTENANCE OF IRRIGATION SYSTEMS

Water management decision-making in the Pekalen Sampean Irrigation Project, East Java, Indonesia

EFFENDI PASANDARAN

THE TOOLS AND CONCEPTS used in making decisions on water allocation in Indonesia's 274,000-ha river-diversion Pekalen Sampean Irrigation Project in East Java are described. Remarkably sophisticated procedures are used to plan cropping systems in relation to expected water supplies, and to adjust water allocations when water shortages arise. Cropping intensities in the study area are commonly 2.5 to 3.0 crops/year. The relationship between water availability and crop performance is explored. Evidence suggests that irrigation blocks with the shortest span of planting dates have the highest yields.

This paper describes certain systems of irrigation management in the Pekalen Sampean Irrigation Project (PSIP), East Java, Indonesia, and analyzes the effects of water availability and water management decisions on cropping systems, intensities, and yields.

Special attention is focused on the concepts and procedures used in allocating and distributing water within irrigation systems. Many of these practices have been developed from past experience and take into consideration the water requirements at various stages of crop growth as well as the principles and criteria used in planning cropping systems. Also described are the effects on crop yields of different patterns of irrigation flow, of different planting durations, and of staggered planting dates within tertiaries.

The research reported was part of a larger 1973-74 study[1] to determine a level of water charge in the PSIP that would be high enough to offset operations and maintenance (O&M) costs, but fair to farmers. Because of limited resources only one of the three PSIP irrigation divisions, Bondowoso, was studied. Two districts in Bondowoso — Rawatamtu and Jember in the south-central project area — were represented by 12 tertiary blocks from 6 irrigation systems. In each tertiary block, 15 farmers were interviewed concerning O&M. All 16 *ulu-ulu desa*[2]

Effendi Pasandaran, Land and Water Management Section, Directorate of Food Crop Protection, Directorate General of Agriculture, Ministry of Agriculture, Pasarminggu, Jakarta, Indonesia.

[1] The complete results are reported in Agro-Economic Survey (AES, 1975). Earlier findings have been reported by Pasandaran and Taylor (1976).

[2] *Ulu-ulu desa* are local village ditch tenders. Although not part of the Government Irrigation Service, they represent the irrigation needs of local communities and are responsible for water management at the tertiary and farm levels.

and 9 *juru pengairan*[3] assigned to the study areas were also interviewed.

Concepts in Water Management

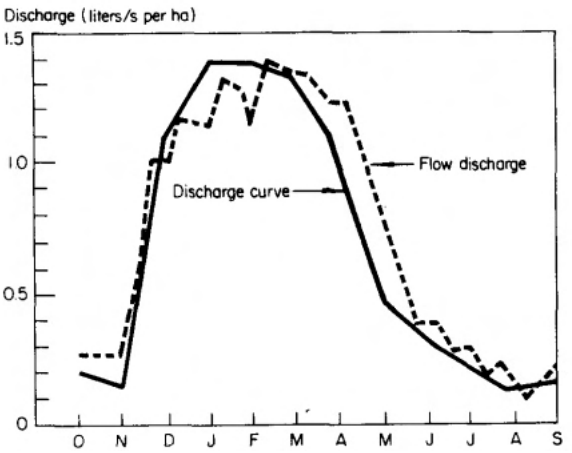
Two types of decisions — on planning and on operations — are made in managing irrigation water. In decisions on planning, the potential availability of water is estimated and appropriate cropping systems are then determined to optimize use of the anticipated water. Operational decisions refer to the allocation and distribution of water to planted areas; these decisions are especially critical when water supplies are low.

Planning and operational decisions revolve around the basic concept of *pasten.*[4] During periods of critical water shortage, measures supportive of this concept such as *suppletion* (water reallocation) and *giliran* (field rotation) are also used. Although these terms are not precisely defined, the following descriptions explain their use in PSIP.

The *pasten* concept

The *pasten* concept describes a relationship between the water supply that is available at the intake gate and turnouts, and the water needed by crops at different growth stages. For planning purposes, potential water availability is estimated by studying historical records of the discharge curve for the water entering the system. Operational decisions are based on day-to-day records of flow discharge. The demand for water is estimated by using indexes of relative irrigation requirements (RIR) for various crops at different growth stages.

Discharge curve. The discharge curve, expressed in liters per second, shows the average rate at which water is discharged through the intake gate of an irrigation system throughout the previous 10 years. It is used to determine how much water is expected to be available to the system during an operational year. The data are important in planning the allocation and distribution of irrigation water to various tertiaries, particularly with respect to alternative cropping patterns.



1. Average discharge curve over 10 years and flow discharge curve for 1973–74, Bangsalsari System. Pekalen Sampean Irrigation Project, Indonesia, 1973–74.

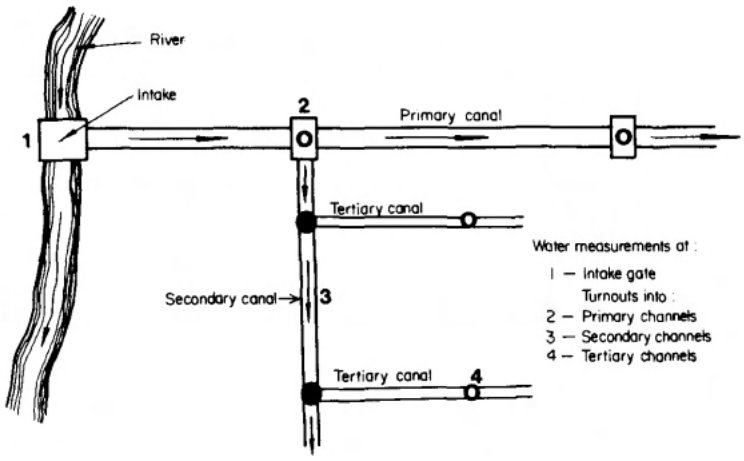
Flow discharge. The rate of flow at a particular time and location in an irrigation system is the flow discharge. Differences between the 1973-74 flow discharge and the average discharge curve over 10 years for the same intake are expected (Fig. 1). The various locations at which flow discharges may be measured are shown in a schematic layout of an irrigation system (Fig. 2). Romain measuring devices are commonly used in primary and secondary canals, and Cipoletti weirs at the tertiary level. Flow discharge is measured once or twice daily (depending on hourly fluctuations in flow), averaged, and recorded at 10-day intervals. If reliable measuring devices are available, measurements are made at the intake gates and at successive levels in the system down to the heads of the tertiaries.[5] The three types of flow discharge curves representing three tertiaries are shown in Figure 3.

Relative irrigation requirement. The de-

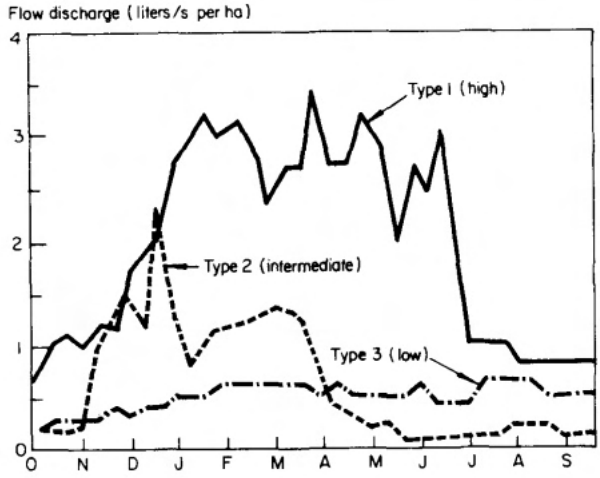
[3] *Juru pengairan* are heads of irrigation sub-subsections *kemantren;* in the Irrigation Service they are the lowest ranking staff who have decision-making responsibility.

[4] Probably derived from the Javanese word meaning a fixed share of water flowing in a channel.

[5] In Indonesia, an irrigation system with a measuring device only at its intake gate is called a semitechnical system; one with measuring devices down to the tertiary level is called a technical system.



2. Schematic layout of irrigation channels and potential locations for water measurement in an irrigation system.



3. Flow discharge curves for Type 1 flow in BW4 tertiary, Mayang Irrigation System; Type 2 flow in Kijingan Kanan tertiary, Bangsalsari Irrigation System; and Type 3 flow in KS_{IV} tertiary, Sumber Pakem Irrigation System. Pekalen Sampean Irrigation Project, Indonesia, 1973–74.

mand for irrigation water depends on the crop to be irrigated and its stage of growth. The RIR is the estimated water requirement, in liters per second per hectare, based on an index value of 1, which is the requirement for secondary crops.[6] The RIR formula assumes that fields are provided with their full water needs, which in rice means that they are flooded throughout crop growth. RIR values have been developed from past experience for different stages of rice production and for sugarcane, relative to values for secondary crops (Table 1). Rice seedbeds that are small and scattered have an RIR of 20 because seepage and percolation losses are high. Fields of rice require about four times as much

[6] Secondary crops that are most commonly irrigated in the study area are maize, soybean, and tobacco.

water as those of secondary crops.

The simplest expression of the pasten concept is shown in the following equation, which relates the quantity of available water to the irrigated area:

$$P = \frac{Q}{A}, \text{where}$$

P = *pasten* index,

Q = rate of water flow, in liters per second, taken from a discharge curve or from flow discharge data, and

A = irrigated area in hectares, assuming that only secondary crops are grown.

Applying the RIR concept to this equation. we can specify the *pasten* formula in greater detail as follows:

$$P = \frac{Q}{RIR \quad (A)} = \frac{Q}{(RIR_i A_i)}$$

where i refers to different crops. Thus, using RIR values from Table 1,

$$P = \frac{Q}{1A_{pl} + 1.5A_{sc} + 20A_{rsb} + 6A_{rlp} + 4A_{rtr} + 1A_{run}}$$

where

A_{pl} = area of secondary crops,

A_{sc} = area of sugarcane,

A_{rsb} = area of rice seedbed,

A_{rlp} = area under rice land preparation,

A_{rtr} = area of rice after transplanting, and

A_{run} = area of unauthorized rice.

Care is taken in planning and operation to ensure that the value of *pasten* at the intake gates does not fall below 0.20 on heavy soils or 0.25 on light soils. Thus, enough water, in liters per second, should always be available to exceed by four or five times the sum of the areas in each crop (in hectares) multiplied by their RIR.

Supporting measures

The following concepts of water management are used during periods of unusual water shortage.

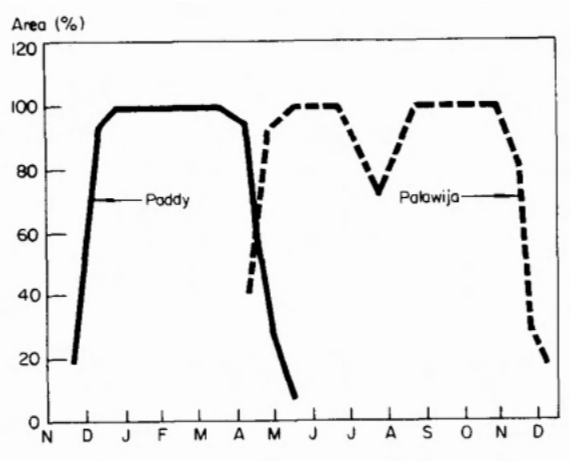
Table 1. The relative irrigation requirements (RIR) for various crops and stages of production. Pekalen Sampean Irrigation Project, Indonesia, 1973-74.

Crop production stage	RIR index[a]
Paddy rice	
Seedbed	20
Land preparation	6
Growth	4
Sugarcane	1.5
Secondary crops	1
Unauthorized rice[b]	1

[a] Water requirements in liters per second per hectare relative to an index value of 1, the requirement for secondary crops such as maize, soybeans, and tobacco.
[b] Rice that was not included in the cropping system plan.

Suppletion is implemented by members of the Provincial Irrigation Service or by the various villages, depending on the level of irrigation administration at which the operation is undertaken. In *suppletion,* the drainage runoff from one irrigation system is recycled as an additional source to another, or surplus water is transferred from one area to another within an irrigation system. Water reallocation within an irrigation system requires only routine operations, unless a *suppletion* channel connects a surplus area to an irrigation channel in a deficit area.

Rotational irrigation, *giliran,* is another supporting measure used if the pasten ratio falls below the minimal values of 0.20 or 0.25 and when *suppletion* is not possible or is inadequate. The most common forms of rotational irrigation are 1) rotation among secondary canals served by a primary; 2) rotation among tertiary channels served by a secondary; 3) rotation among areas within a tertiary; and 4) rotation among farm parcels. Each succeeding form of rotation serves successively smaller blocks of land. There is a corresponding shift in responsibility for implementing the practice with *juru pengairan* or, in some cases, heads of irrigation sub-sub-sections responsible for rotation among secondaries and tertiaries; *ulu-ulu desa,* for rotation within a tertiary; and farmers, for rotation among farms. In all cases, the level to practice *giliran* is decided by the Irrigation Service, whose usual



4. Percentages of rice area planted to rice and to secondary crops in the wet season, Kajingan Kanan tertiary, Bangsalsari lrrigation System. Pekalen Sampean Irrigation Project, Indonesia, 1973–74.

guidelines are for more decentralized rotation (i.e., rotation among smaller blocks) when water scarcity is greater.

Application of the Water Management Concepts

Planning cropping systems, including the staggering of planting dates

A cropping system is the sequence of crops grown on a particular block of land over a 12-month period. It reflects the crops planted, times of planting and harvesting, and area under each crop (Fig. 4). Values of less than 100% reflect periods when the land is without crops (after one crop is harvested and before the next is planted). An important operational rule in planning the cropping system is that the whole area should be cropped, if possible, all the year round.

Wet season. In setting up a cropping system, the wet season, which is concerned only with rice, is first considered. Water management issues in the wet season, therefore, concern the time when various blocks should be planted, not the crops to be grown.

The staggering of planting dates refers to the Indonesian *golongan* system of successively allocating irrigation water among sections within an irrigation block early in the planting season.

The speed and progress of rice planting depends largely on water availability in the area being prepared.[7] If water is sufficient, an entire block may be planted simultaneously and the planting period will correspond to the time required for complete saturation and planting of all parcels within the block. That time was roughly 30 days in the study area. But if water is limited, p1anting will be allocated by turns to two or three sections within the block. This means that successive sections will have to wait an additional 2 to 3 weeks, with the result that the planting dates in a 3-section block will usually extend to 70 or 80 days.

The discharge curves for run-of-the-river diversion systems, such as the PSIP, obviously correspond closely to the pattern of seasonal rainfall; discharge increases rapidly at the beginning of the wet season, then declines. A major challenge is determining when to rapidly plant rice during the wet season so that periods of peak water requirements (for land saturation and planting) match periods of peak flow. The *pasten* formula is used to evaluate the level of the discharge curve and its rate of change, particularly early in the wet season. The need to stagger planting dates generally corresponds to the slope of the discharge curve at the beginning of the wet season. If the expected discharge curve increases rapidly, there is less need to stagger planting dates. However, estimates of water availability are also needed for later stages in the crop season as well. Thus, if currently available water would permit the planting of larger areas than could be irrigated later in the season, a reduction in the planted area would be required.

Dry season. In the dry season, rice and secondary crops such as maize, soybeans, and tobacco may be grown. Of these crops, rice has the longest growth duration and requires the most water. Thus, a key problem in planning cropping patterns for the dry season is deciding

[7] Among other factors influencing the rate at which rice can be planted are the availability of labor and power for land preparation.

the area of rice relative to that of secondary crops.[8]

To illustrate the development of a dry-season cropping system, we assume that a tertiary block has heavy soil, for which the minimum *pasten* value is 0.20; that 5 ha of rice seedbeds has been established; and that 50 ha of land is being prepared. If the discharge curve for the period indicates that 100 liters of water/s is available to the tertiary, the area that could be planned for secondary crops may be computed by solving for A_{pl} in the following formula:

$$P = \frac{100}{1\ A_{pl} + 20(5) + 6(50)} = \frac{100}{A_{pl} + 400}$$

and $A_{pl} = 100$ ha.

Thus, the anticipated water supply is sufficient to plant 100 ha of secondary crops as well as the 50 ha of rice already being planned.

Information on how these procedures are actually applied is limited. The decision-making process appears to begin with the suggestion that a certain area of rice or secondary crops be planted in a block. Using the discharge curve, the suggested areas of selected crops, and the *pasten* formula, the *juru yengairan* determines whether or not water would be sufficient to plant the entire block. If the computed values of A_{pl} for the area originally suggested for secondary crops, added to that for rice A_{rtr}, were less than the total area of the block, then the area planned for rice would have to be reduced to preclude some land from lying fallow during the dry season. Alternatively, if the computed sum of A_{pl} and A_{rtr} were greater than the total block area, the *ulu-ulu desa* could inform the farmers that it would be feasible to grow more rice than originally suggested. Final plans for a feasible cropping system could eventually be formulated through an iterative process such as this between the *ulu-ulu* desa representing the farmers and *juru pengairan* representing the irrigation service.

Deciding how water should be allocated after planting

If actual water flows measured by the Irrigation Service correspond to or exceed the values of the discharge curve, no special water allocation is required. But if actual flows fall below expected values during periods of water shortage, *suppletion* may be used (provided channels link a deficit irrigation system with a water-surplus area). Rotational irrigation *(giliran)* may also be used.

The form of rotation depends on the severity of water shortages, as reflected by the *pasten* ratio. This ratio is computed on the basis of actual flow at the intake gate of the turnouts and the area of crops already planted in the corresponding blocks. The more severe the water shortage, the more localized the form of rotation. For example, in a mild water shortage, secondary rotation might be adopted, but in severe shortage, rotation might be practiced at the farm-parcel level.

The rationale for adopting a given form of rotation was not investigated in this study, but an explanation, similar to that of "critical mass," is that scarce water needs to be concentrated to a point where it can flow efficiently along irrigation channels. Other possible explanations are responsibility or social pressures to share water during acute shortages and the fact that with more localized rotation, surplus water is less likely to build up on farmers' fields because it can be diverted among sections with greater control and precision.

The use of rotational practices clearly depends on the facilities for measuring and controlling water flows, plus the skill of the Irrigation Service personnel and the farmers.

Data on actual *pasten* values collected in this study are somewhat rough, but they reflect values ranging from 0.20 to 0.25 for rotation at the secondary level, to as low as 0.05 to 0.10 along tertiary canals. Such small values could have been caused by a combination of normal

[8] Some sugarcane is also grown in the area, but it requires a 16-month production period. Once planted, a sugarcane crop becomes a somewhat fixed element in a cropping system, so its water requirement must be subtracted from the total available water; the remaining amount can be used for paddy or secondary crops, or both. To simplify this discussion, we have omitted consideration of sugarcane planting.

conveyance losses[9] and unusual water shortages in the tertiary blocks. Neither the degree nor the effects of moisture stress on crop growth are known.

Effects of Water Availability and Management Decisions on Crop Performance

Patterns of water availability differ markedly because of variations in flow from a river and decisions on the allocation of the water among the tertiaries within irrigation systems. Three flow patterns were encountered in this study[10] (Fig. 3):

Type 1 — relatively high discharge in both the wet and dry season;

Type 2 — relatively high discharge only in the wet season; and

Type 3 — relatively low discharge throughout the year.

The relationship of flow discharge to cropping systems and cropping intensities

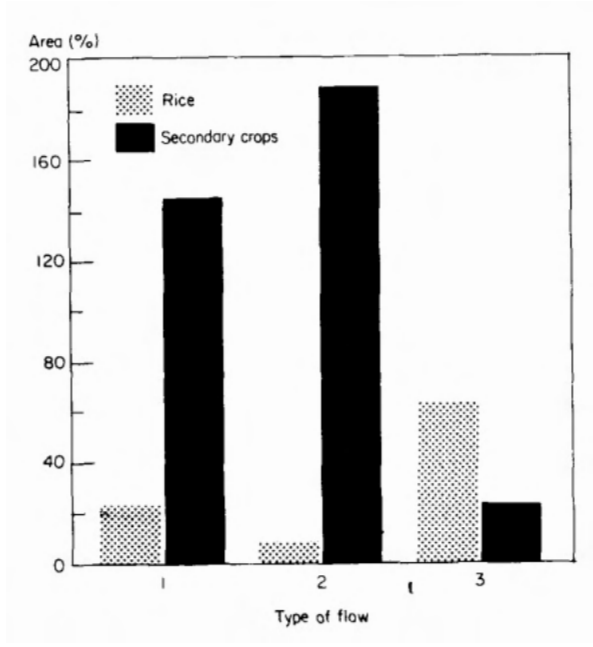
This analysis explores the relationship between flow discharges and cropping systems as well as cropping intensities (defined as the ratio of the total cropped area in an irrigation block during a year to the cropped area in the wet season only).

It was hypothesized that the Type 1 tertiary blocks with abundant water would have the highest cropping intensities and the largest proportions of rice, while the Type 3 blocks, which are short of water would have the lowest intensities and smallest proportions of rice.

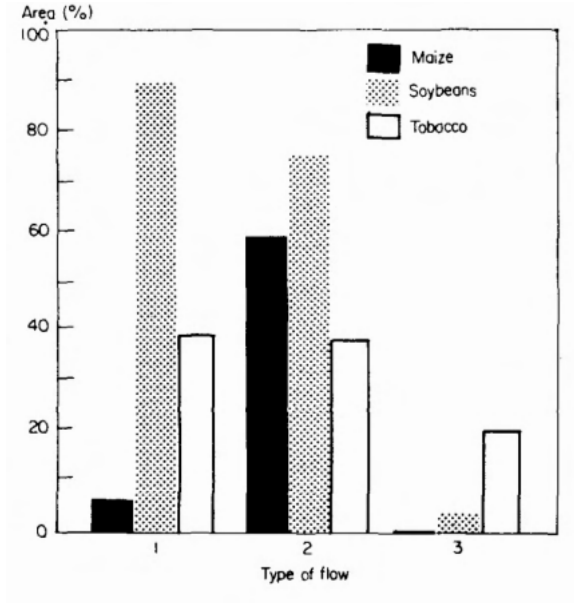
An analysis of the 1973-74 cropping data from the study areas showed intensities of 2.69 for Type 1, 2.93 for 2, and 1.81 for 3, reflecting remarkably intensive land use for all three flow types. But the data are not consistent with the

[9] The *pasten* value for successive turnouts is usually found to be progressively smaller, reflecting the cumulative effect of conveyance losses and reduced supply further along a canal.

[10] seven tertiaries were of Type 2, three were of Type 1, and two of Type 3. The limited sample size should be considered when interpreting these findings.



5. Dry-season areas of rice and secondary crops expressed as percentages of wet-season rice areas by type of discharge flow. Pekalen Sampean Irrigation Project, Indonesia, 1973–74.



6. Dry-season areas of maize, soybeans, and tobacco expressed as percentages of wet-season rice areas by type of discharge flow. Pekalen Sampean Irrigation Project, Indonesia, 1973–74.

hypothesis for the Type 1 vs Type 2 areas.

Since all tertiary blocks were planted completely to rice during the wet season, detailed attention was given only to dry-season cropping patterns. The areas of dry-season crops were expressed as percentages of the wet-season rice areas for each of the three types of tertiary flow (Fig. 5, 6).

Although cropping intensities and cropping systems generally conform to the hypothesized relationships, in certain respects they do not. Examples of conformity include the findings that rice was planted more widely in tertiaries with Type 1 flow than in those with Type 2, and that areas with both types of flow had substantially higher cropping intensities than Type 3 areas. Moreover, tobacco and soybeans, the crops that require the least irrigation, were widely planted in Type 2 and 3 areas.

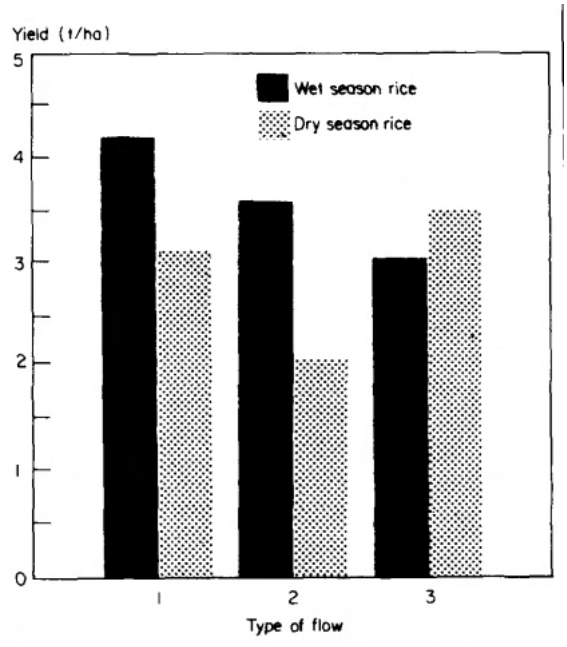
Inconsistent with the hypothesis is the finding that 60% of the Type 3 areas were planted to rice, only 20% to tobacco, and 2% to maize and soybeans. Maize was substantially planted in Type 2 areas, while soybeans were important in Type 1 and 2 areas.

So much contradictory evidence suggests that the hypothesis that cropping intensity and rice areas decrease as availability of water decreases is wrong or that other conditions in the comparisons are not equal. Resolving the issue conclusively was not possible because a limited number of tertiaries were studied and data were collected and analyzed for relatively few variables. But the following analyses provide additional insights.

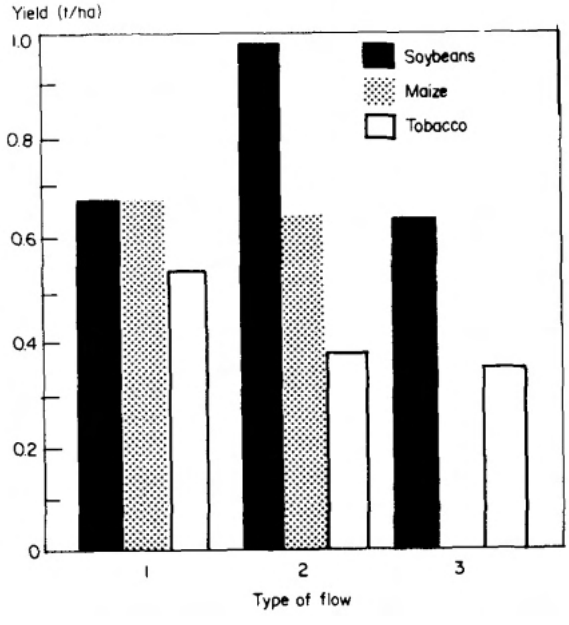
Relationship of flow discharge to crop yields

Tertiary blocks that were abundant in water were hypothesized to have high yields. Yield data classified by type of flow, season, and crops generally support this hypothesis (Fig. 7, 8). Wet-season rice yields were highest with Type 1 and lowest with Type 3 flows. Dry-season yields of maize and tobacco were also highest with Type 1 flow.

However, rice yields in the dry season were not consistent with this trend, since yields from Type 3 tertiaries were slightly higher than those with other flow types. Water availability was



7. Yield of wet- and dry-season rice classified by type of irrigation. Pekalen Sampean Irrigation project, Indonesia, 1973–74.



8. Yield of dry-season secondary crops classified by type of irrigation. Pekalen Sampean Irrigation Project, Indonesia, 1973–74.

also not associated with higher soybean yields, but this is not surprising since soybeans require less water than the other dry-season crops, and in fact are highly sensitive to excess water sometimes supplied by Type 1 flow (Fig. 3).

Type 3 tertiaries, which have the least water supply, had a greater percentage of rice during the dry season than the more water-abundant Type 1 and Type 2 tertiaries. This observation may be related to the dry-season rice yields also being highest in Type 3 tertiaries. Similarly, those tertiaries producing the highest dry-season yields of each of the secondary crops also had the largest area planted to those crops (Fig. 6, 8).

These findings suggest that factors in addition to water availability influence the cropping systems, the planting intensity of certain crops, and crop yields. This study touches on some of those other factors, but considerable research remains to be done on such issues as the relative profitability of different crops and their accessibility to markets; differences in capital and labor requirements for different crops; differences in the ability of local irrigation personnel to carry out refined procedures of water management; differences in water seepage and percolation and, as a result, in drainage conditions; and the influence of local officials' moral persuasion on cropping systems.

Relationship of span of planting time to rice yield

The effect of planting duration on rice yields within individual tertiaries during the wet season is examined in this section. We attempted to determine if water tends to be short near the end of the season before crops that were planted late can fully mature and, if it does, whether yields would be lower in tertiary blocks with extended planting periods.

The span of planting dates in the tertiary blocks varied from 30 to more than 60 days. For this analysis, the tertiaries were classified into three groups: Group A, with a span of from 30 to 39 days; Group B, 40 to 49 days; and Group C, 50 or more days.[11] The average yields from Groups A, B, and C — 4.4, 3.7, and 2.6 t/ha, respectively — strongly support the value of shortened periods of presaturation and land preparation. The extent to which land preparation can be shortened depends largely on water availability and management, especially early in the wet season.

An important characteristic of the three types of irrigation flow, discussed earlier in the paper, is the rate at which water becomes more plentiful in the wet season. That rate is greatest for Type 1 areas and least for Type 3. To make a preliminary assessment of the interaction of initial water availability and planting spans, we reclassified the tertiaries according to both their flow type and spans of planting times (Groups A, B, and C). Two of the three Type 1 (water abundant) tertiaries are in Group A (short span), four of the seven Type 2 tertiaries are in Group B (medium span), and one of the two Type 3 tertiaries is in Group C (long span). This suggests that early water availability permits shortened planting periods, and that careful management of available water may also speed up the saturation, land preparation, and transplanting of wet-season rice.

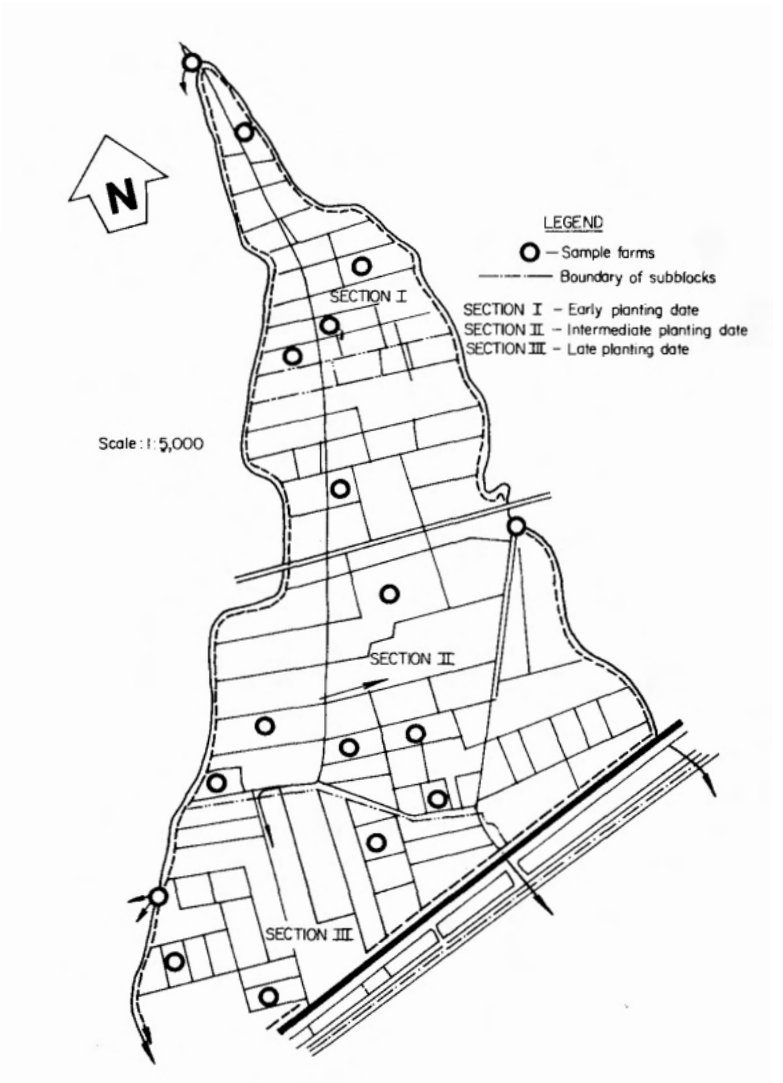
Relationship of staggered planting dates to rice yields

This analysis of the yield performance of rice in early vs. late-planted sections within tertiary blocks is based on data from the Karisan Tengah and Plendo tertiaries in the Denoyo Irrigation System. Planting dates of sections within each tertiary were identified and classified as early, intermediate, or late.

Karisan Tengah tertiary. Plantings of sections in the Karisan Tengah tertiary are distributed successively from head to tail as early, intermediate, and late (Fig. 9). The flow discharge into the tertiary is Type 1 with ample water supplies throughout the year (Fig. 10). The tertiary channel has two division boxes, one serving the intermediate section and the other the late section. The entire tertiary is served by quaternary channels to give all farmers equal access to water once it reaches their sections.

Plendo tertiary. The areas planted early or late in the Plendo tertiary are rather dispersed

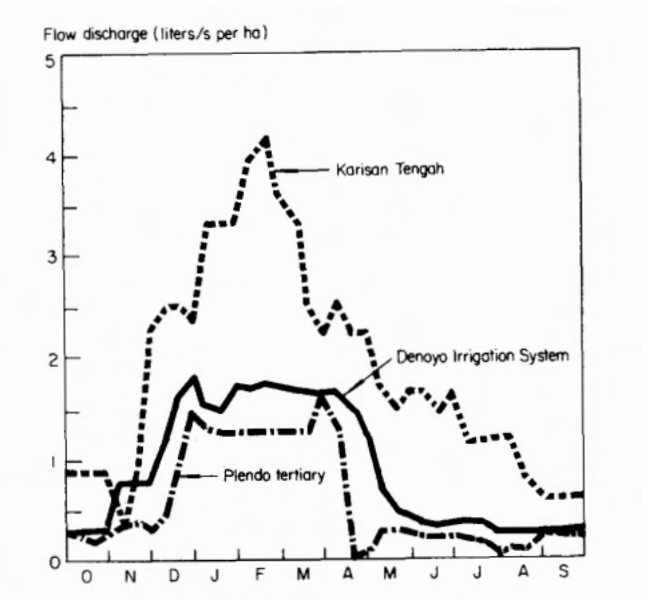
[11] There were 3 Type A tertiaries, 6 Type B, and 3 Type C.



9. The staggering of planting dates among subblocks of the Karisan Tengah tertiary, Denoyo Irrigation System. Pekalen Sampean Irrigation Project, Indonesia, 1973–74.

(Fig. 11). The flow discharge is Type 3 with relatively modest rates of flow throughout the year (Fig. 10). Each section of the tertiary is equipped with a turnout and measuring device.

For both the Plendo and Karisan Tengah tertiaries, yields were lowest in the sections with late planting dates, especially for the dry-season crop (Table 2). The yields of the early-planted section were either comparable to or substantially lower than those of the intermediate-planted section. Except for high yields from some rice planted at intermediate dates, these findings reinforce the previous evidence that yield is positively related to planting date, and may explain why farmers in the study area change the sequence of sections in the *golongan* rotation each year (the last block planted one year is the first to be planted the following year). The



10. Flow discharge curves for the Karisan Tengah and Plendo tertiaries and their parent Denoyo Irrigation System. Pekalen Sampean Irrigation Project, Indonesia, 1973–74.

practice may ensure equal yield benefits over time among farmers in different sections of each *golongan* block.

Summary and Conclusions

The most important concept underlying decisions in the allocation and distribution of water in the Pekalen Sampean Irrigation Project is the *pasten* ratio. which relates the availability of irrigation water to the demand of various crops at different growth stages.

The *pasten* concept requires data on three water-management variables. Two are measures of water availability: the flow discharge, or the measured rate of irrigation flow during a particular period; and the discharge curve, or the average rate of irrigation flow for the same

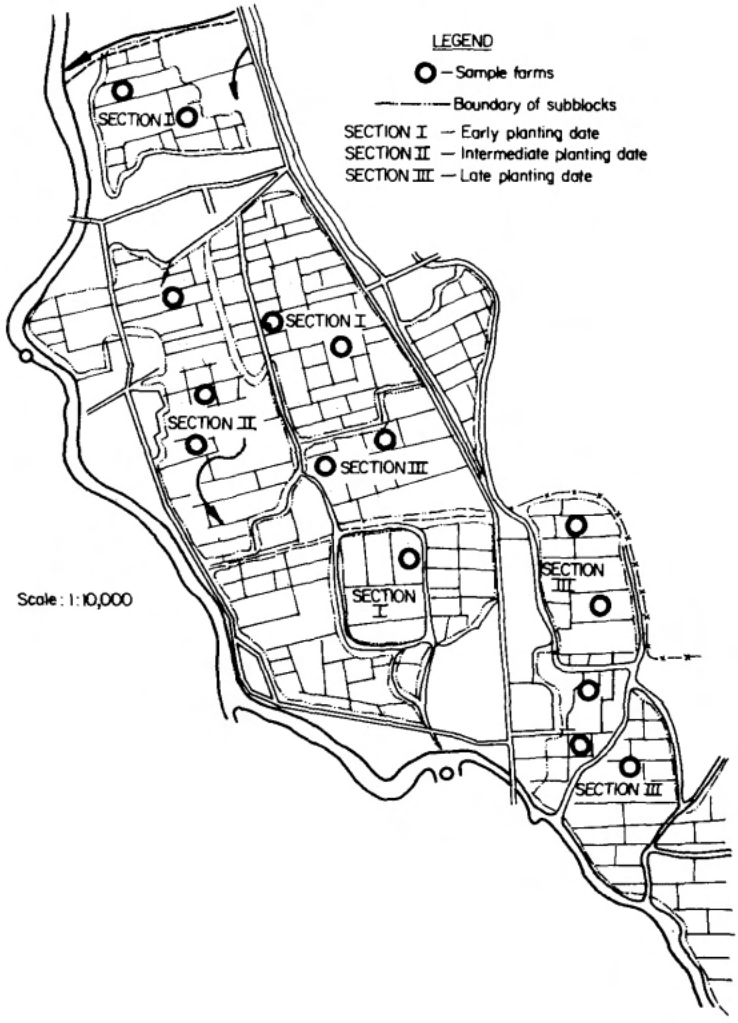
Table 2. Mean yields of rice in sections planted successively later in two tertiaries of the Denoyo Irrigation System Pekalen Sampean Irrigation Project, Indonesia, 1973-74.

Planting date	Yield (t/ha)			
	Karisan Tengah tertiary		Plendo tertiary	
	Wet season	Dry season	Wet season	Dry season
Early	3.4	3.2	2.8	3.0
Intermediate	4.3	3.3	2.8	4.4
Late	3.2	1.8	2.3	1.2

period during the previous 10 years. The third variable, relative irrigation requirement, is an index of crop water requirements based on historical experience.

In planning cropping systems for the wet season, the principal issue is whether the expected water will be sufficient for crops to be simultaneously planted in all sections of a tertiary (or in all tertiaries under a secondary). To make this decision, data on discharge curve and irrigation requirements for possible crops are required. The relationships among these data are then evaluated by the *pasten* formula.

In the dry season, the principal issue is determining the relative areas to be planted to rice and to secondary crops. The water demands of various crop combinations are determined with data on the relative irrigation requirements



11. The staggering of planting dates among sections of the Plendo tertiary, Denoyo Irrigation System. Pekalen Sampean Irrigation Project, Indonesia, 1973–74.

and the discharge curve, in conjunction with the *pasten* formula.

During periods of unusual water shortage, one or two courses of action may be taken. If a channel links an area with surplus water to another with water deficit, *suppletion* which involves the recycling of drainage runoff from one irrigation system into another; or from one location to another within the same system, may be used. Rotational irrigation (*giliran*) may also be used. The more limited the water, the more intensive or localized the system of rotation. The *pasten* formula provides the analytical framework for assessing the degree of water shortage. Empirical findings on the effect of water availability and management decisions on crop performance are

1. Cropping intensities in the study area were remarkably high, averaging 2.5 to 3.0 crops/year in 9 of the 12 tertiary blocks studied. The blocks with lowest cropping intensities had the lowest water supplies throughout the year.

2. Where water was plentiful, larger areas were generally planted to rice and yields were higher. However, there were exceptions to this. For example, the tertiary blocks with the lowest water supplies had the largest area planted to rice in the dry season and had higher yields than tertiaries with greater water supply.

The findings illustrate the need for further research to investigate other factors that influence decisions on cropping systems and the performance of irrigated crops. Integration of irrigation and agricultural perspectives would be especially useful in such research.

3. Longer periods of presaturation and land preparation before transplanting are associated with lower crop yields. Tertiary blocks in which land preparation and planting were completed from 30 to 39 days had average yields of 4.4 t/ha, but those in which such activities lasted more than 50 days had yields of only 2.6 t/ha. The differences could be due to water shortages late in the crop seasons. The finding provides a rationale for the traditional practice of year-to-year rotation of the sequence in which various sections are planted. It also highlights the importance to farmers of further improvements in water management that would reduce the presaturation, land preparation, and transplanting period for rice.

References Cited

Agro-Economic Survey (AES). 1975. Research on irrigation water rates in Pekalen Sampean, East Java (Peneletian Iuran Air Irigasi di Pekalen Sampean, Java Tumur). Report No. 07/75/L. Agro–Economic Survey, 13 May 1975, Jakarta.

Pasandaran, Effendi, and D.C. Taylor. 1976. The management of irrigation system in the Pekalen Sampean Irrigation Project, East Java, Indonesia. Research Note No. 10/76/RN, Agro-Economic Survey, 22 March 1976, Jakarta.

Practices and accountability for better water management

T. H. WICKHAM and A. VALERA

AN OVERVIEW OF THE RESULTS of several recent field studies on water management and distribution in the Philippine provinces of Laguna, Bulacan, and Nueva Ecija is presented. The diversion irrigation systems studied ranged from 3,600 to 75,000 ha in size. Factors found to have insignificant influence on the performance of the systems are farm-ditch density, the distances of farms from turnouts, and the rotation of water supplies at the farm level. But the location of farmers' fields along distribution canals and the rotation of water supplies among laterals or sublaterals markedly influenced the performance of the systems.

The importance of good water management has become widely accepted among those concerned with irrigation in Southeast Asia. To the farmer, good water management enables him to grow rice with full water adequacy from seedling to harvest, and offers the possibility of planting a second crop. To the operators of irrigation systems, however, good water management usually means the careful application of water to the field to reduce overirrigation and consequent drainage losses. Reduced use of water on currently irrigated land saves water that can be used to irrigate a larger area. Both these aspects of good water management are important in increasing agricultural output through either higher yields or larger irrigated areas.

While it is generally agreed that better water management is needed, it is not clear what is required to achieve it. What do we really mean by improved water management, and how can it be attained? This paper explores research that has been undertaken in the Philippines, seeking clues to how well certain practices work in improving water management under field conditions.

The research projects studied were all joint undertakings during the last 6 years between the National Irrigation Administration (NIA) and the University of the Philippines at Los Baños (UPLB), or the International Rice Research Institute (IRRI). The irrigation systems selected for study were relatively large ones (3,600 to 75,000 ha) in the provinces of Laguna, Bulacan, and Nueva Ecija. Although drawn from Philippine studies, the results should apply to varying degrees in other countries of the region, depending on the extent to which the underlying conditions are similar.

The paper discusses those practices that have and have not resulted in major improvements in

T. Wickham, Agricultural Engineer; and *A. Valera,* Research Assistant, International Rice Research Institute, Los Baños, Philippines.

water management. A concluding section attempts to generalize these findings and recommends logical responsibilities for farmers and systems personnel in the management of systems.

Factors Not Associated with Better Water Management

Density of farm ditches

In studies of existing systems, Kampen (1970), Miranda (1975), and Tabbal (1975) estimated the extent of farm ditches and found that lengths between 10 and 100 m/ha served different areas. However, only Tabbal (1975), who studied Lateral C of the Peñaranda River Irrigation System (PRIS), made systematic analyses relating farm ditch density to system performance. He related the number of stress days — or days that sample paddies were drained of surface water — to a number of physical factors, including farm ditch density. On the average, the area had less than 12 m of ditches/ha. In a multiple regression model relating six physical variables to stress days, increasing farm ditch density was found to be associated with slightly greater stress rather than with less stress. The effect, however, was not significant.

Evidently other factors interact with farm ditch density. The data from Lateral C were therefore further analyzed according to overland distance of the sample paddies from their water sources. Classifying the paddies into three (high, medium, and low) farm ditch density groups revealed that stress days were significantly fewer where: farm ditch density was highest, provided the paddies were located far from their water sources (Table 1). But for paddies located near their sources, stress days were not related to farm ditch density; they even increased significantly with greater density for paddies at intermediate distances from the water source. Interactions between farm ditch density and several other physical parameters were not significant, indicating that only those farms located far (greater than 300 m) from their water sources benefited from more farm ditches.

These findings should not be interpreted to mean that farm ditches are not important to good water management. In many cases the ditches are critical means of delivering water to inaccessible places. Perhaps their use is most important in areas separated from their water sources by depressions. Farm ditches can usually be found supplying these areas from points farther upstream (Fig. 1).

Table 1. Mean number of stress days as affected by farm ditch density for different overland distances (near, intermediate. and far).[a] Lateral C, Peñaranda River Irrigation System, Philippines, 1974 dry season.

Farm ditch density[b]	Stress days (no.)[c]		
	Near	Intermediate	Far
Low	23.7 a	21.7 a	38.2 a
Medium	22.2 a	21.4 a	25.0 b
High	22.2 a	33.0 b	25.3 b

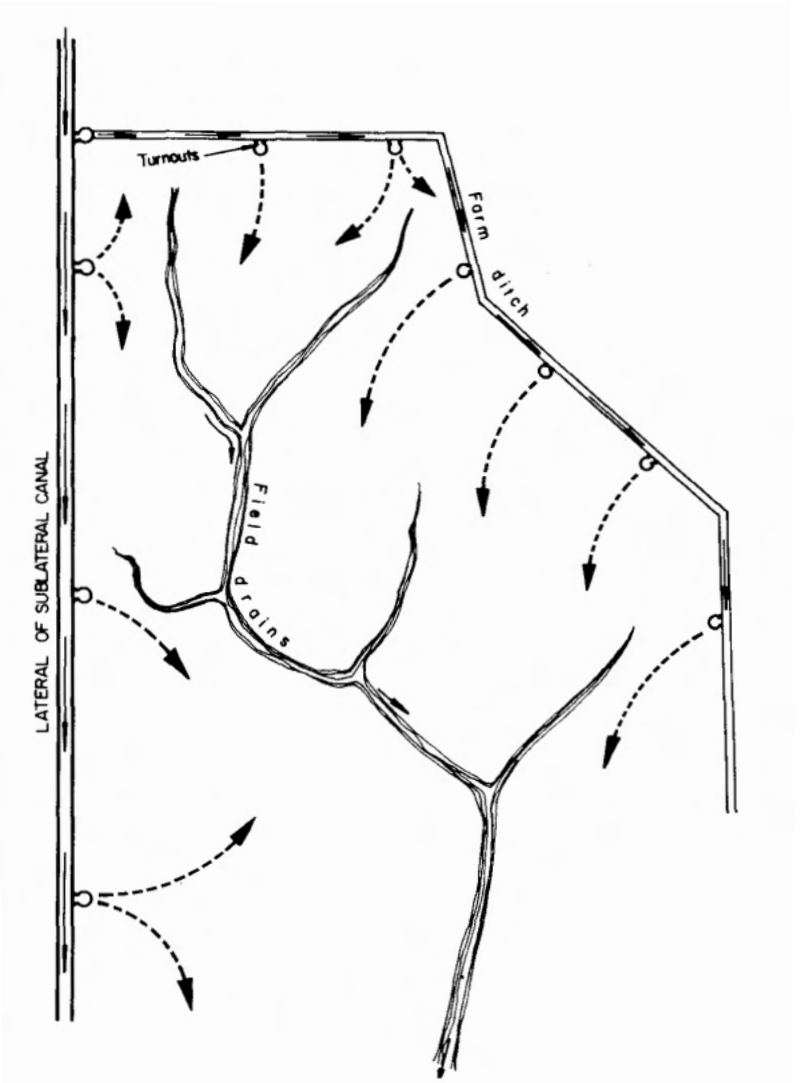
[a] Near = less than 150 m; intermediate = from 150 to 300 m; far = greater than 300 m from water source. [b] Low = less than 6.9 m/ha; medium = 6.9 to 15.5 m/ha; high = greater than 15.5 m/ha. [c] Means in the same column followed by the same letter are not significantly different at the 5% level.

Farm ditches may also have considerable value where soils are highly permeable or where the turnouts on the canals are few and widely spaced. Neither condition is common in the Philippines, however, where topography is also relatively even and well incorporated In the design and placement of distribution canals.

Therefore, it should not be surprising that farmers take considerable care to maintain certain farm ditches, and that efforts to have them construct and maintain a network justified by a theoretical optimum density, or to provide alternate water conveyance even though paddy-to-paddy movement is satisfactory, are not generally successful.

Distance of farms from their turnouts

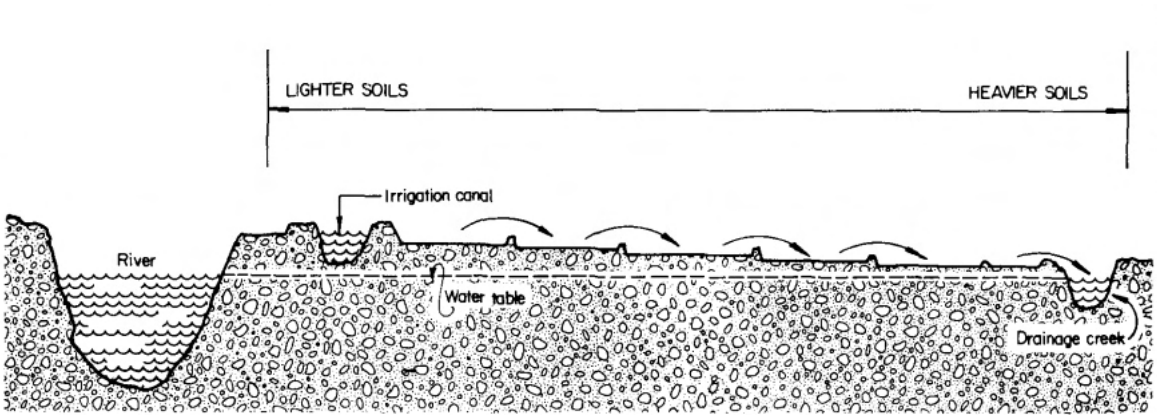
Farms that are far from their supply turnouts are generally assumed to be at a disadvantage compared with those near the canal, because of reduced water supply as it passes over the nearer fields, and the possibility of obstruction or diver-



1. The role of a specialized farm ditch in irrigating a typical area dissected by field drains.

sion of flow by farmers who have received enough water.

Data shedding some light on this question were collected in a study (Wickham, 1971) in which stress days, defined as continuously drained days in excess of three, were computed for 145 sample paddies in the wet and dry seasons of 1969-70. The sites were traditionally irrigated portions of major systems in Nueva Ecija, Bulacan, and Laguna provinces. Simple regressions of stress days on the distance of the paddies from their turnouts (determined from airphoto maps) failed to reveal even remotely significant relationships. This result was probably due to the high correlation between increasing distance and lower elevation. Farms at lower elevations usually have somewhat heavier soils, and are often closer to the water table — two factors which compensate for their distance from the water source (Fig. 2).



2. A typical cross section of paddy-to-paddy water movement.

Table 2. The percentage of farmers who agreed with selected statements on water management according to the distance of their farms from the canal. Eleven irrigated sites in Nueva Ecija, Bulacan, and Laguna provinces, Philippines, 1969-70[a]

Statement	Farmers agreeing (%)		x^2 test[c]
	Near[b]	Far[b]	
The supply of water is inadequate.	30	26	0.6 ns
Farmers are willing to pay more for supplemental pump irrigation.	56	51	0.4 ns
There are conflicts over water.	85	80	0.5 ns
Water use fee is too high.	42	23	4.1*
Farmers are willing to schedule irrigation deliveries.	95	86	3.3 ns

[a] Number of observations varies between 104 and 231 for different statements. [b] Near = within 300 m of the canal; far = more than 300 m from the canal. [c] x^2 computed from 2 x 2 contingency tables using number of agreement and disagreement responses for each statement. ns = not significant.* = significant at 5% level.

We can further explore the relationship in a regression relating stress days to the product of elevation × distance. The relationship indicates significantly more stress days for higher values of the product, but not for higher values of either distance or elevation alone.

Another analysis was conducted using responses from the farmers of the same study (G. Wickham, 1970). The farmers were divided into those farming land within 300 m of a distribution canal, and those farming more than 300 m away. Three hundred meters was used since it divided the sample approximately in two. The results indicate no significant differences in farmers' perception of water adequacy, willingness to pay more for pumped water, presence of conflicts, or willingness to rotate water use (Table 2). Only the attitude of farmers towards the fee for water use was significantly different; and farmers closer to the canals, rather than those farther away, felt most strongly that the fee was too high.

Tabbal (1975) also looked into the relationship between stress days and the overland distance of 206 sampled farms from their water sources, usually turnouts, in the Lateral C service area of the PRIS. He scaled the distances from airphotos and fitted a regression of stress days on six physical factors: farm ditch density, distances along the lateral and sublateral canals, soil texture, relative elevation of the paddy, and overland distance from the turnout. The findings, significant at the 5% level, indicate that stress days increase at the rate of 1.4 days/100 m of distance between the farm and the turnout. These findings apply to the 1974 dry season — when water was in short supply — and to an area with less than 12 m/ha of farm ditches. Since the mean overland distance was about 250 m in the study, the mean number of stress days produced by this effect was about 3.5. Depending on many assumptions relating stress days to yield (Wick-

Table 3. Mean number of stress as affected by overland distance for light, medium, and heavy soil types[a] Lateral C, Peñaranda River Irrigation System, Philippines, 1974 dry season.

Overland distance[b]	Stress days (no.)[c]		
	Light soils	Medium soils	Heavy soils
Near	12.5 a	11.8 a	25.6 a
Intermediate	15.6 a	15.0 a	17.7 b
Far	32.8 b	29.3 b	19.6 b

[a]Light = less than 40% clay; medium = from 40 to 69% clay; heavy = more than 69% clay. [b]Near = less than 150 m, intermediate = from 150 to 300 m; far = more than 300 m from water source. [c]Means in the same column followed by the same letter are not significantly different at the 5%level.

ham, 1973), 3.5 stress days might cause yield reduction between 0.1 and 0.3 t/ha.

Tabbal (1975) also stratified his dry-season sample according to those farms located close (less than 150 m) to the turnout, those at intermediate distances, and those farthest away (more than 300 m). The farthest farms showed significantly more stress days than the other two types, but only for light and medium-textured soils (Table 3).

The number of intervening farms was found to have no significant impact on incidence of stress days. Thus, the difficulty with on-farm conveyance is primarily a problem of gradually reduced supplies to the farther farms, and not the denial of water to these areas by farmers located near the turnouts.

The results of these studies, none of which were designed specifically to relate stress to on-farm distance, are mixed. Two of the studies conducted when the supply of water was sufficient showed no significant effect, but another analysis, undertaken during a dry season of very limited water, showed small but significant effects under some conditions. It is highly unlikely that significant effects could be documented for the wet season. We conclude that with Philippine topography and system layout, the on-farm movement of water is relatively efficient and its distribution is satisfactory.

Rotational irrigation at the farm level

On-farm rotational irrigation in the Upper Pampanga River Project (UPRP) is accomplished by the rotation of water among 5 units of about 10 ha each. Each unit is scheduled to receive 5 days' supply of water in 1 day. There is only one turnout with a measuring device for the entire 50 ha, but each unit is served by a main farm ditch and supplemental farm ditches (Fig. 3).

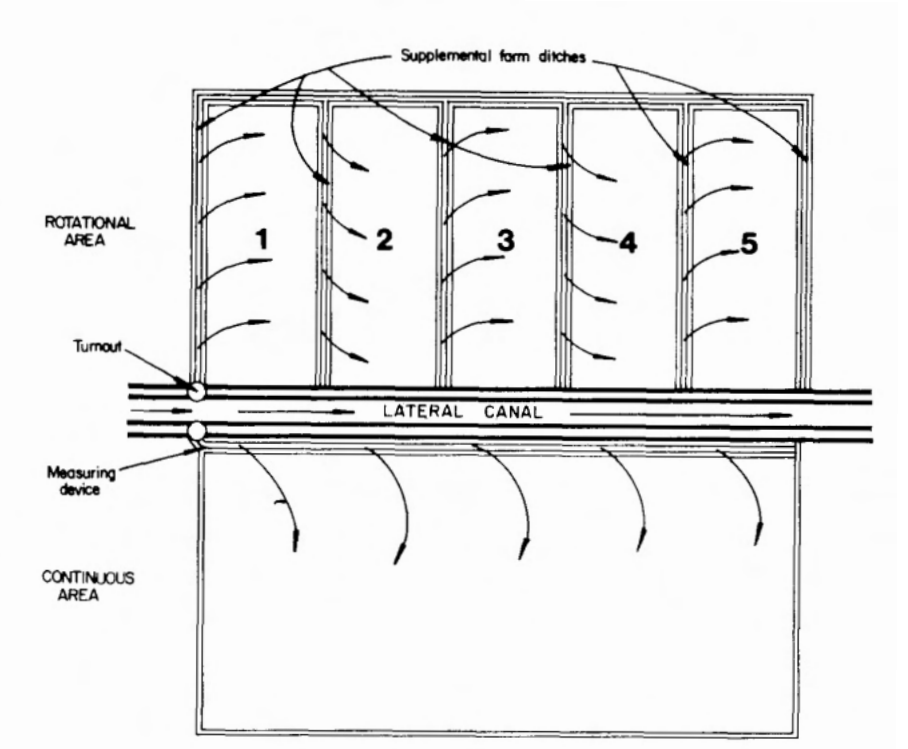
A number of problems have been encountered in implementing the rotational method in the Philippines. Irregular water supply in the system, disinterested farmers, and local drainage problems (Cerdan, 1973), along with erasure of farm ditches (Miranda, 1975), have been cited. Serious problems have also been encountered in the design and construction of the main and supplemental farm ditches, which sometimes resulted in trying to make water flow uphill (Wickham and Wickham, 1974).

Experimental studies of 7-day rotational irrigation have shown that grain yield is marginally higher with continuous or simultaneous delivery (Alvarez, 1973) than with rotation (Table 4). However, larger field comparisons are necessary to test the results and to determine if water could be saved by rotation.

Such a study was undertaken jointly by the UPRP and IRRI during the 1974 dry season at three sites in the UPRP service area (Wickham et al., 1974). At each site two adjacent irrigation areas were selected; one was assigned continuous irrigation, the other rotational. The two areas had equal but limiting rates of water supply (Fig. 3). UPRP water management technologists trained in the requirements for both types of irrigation provided equal volumes of water to the matched pairs, then monitored the progress of land preparation, water adequacy, and grain yield.

During land preparation, water was supplied essentially upon demand in all areas. The mean water depth was about the same for rotational and continuous irrigation — 482 and 467 mm, respectively — as was the mean duration to complete land preparation and transplanting — 53 and 58 days.

During crop growth we attempted to reduce



3. Comparison of rotational and continuous irrigation in two adjacent 50-ha blocks. Upper Pampanga River Project, Nueva Ecija province, Philippines, 1974 dry season.

Table 4. Grain yield for IR20 and three experimental lines. Plot experiment at Maligaya Rice Research and Training Center, Philippines, 1973 dry season.[a]

Treatment	Yield (t/ha)	
	IR20	3 experimental lines[b]
7-day interval:		
4 mm/day	5.4	5.6
6 mm/day	6.0	5.9
8 mm/day	5.9	6.1
Continuous:		
12.5 mm/day[c]	6.4	6.4

[a] Adapted from E.I. Alvarez, term paper for Agricultural Engineering 242, University of the Philippines' College of Agriculture, Los Baños, 1973. [b] IR442-2-58,IR1541-430-2, IR1529-430-2. [c] An average daily application of 12.5 mm was used to keep 4 cm of standing water.

the water supply at each location to the minimum rate compatible with high yield potential — 1.1 liters/s per ha for two locations and 2.2 for the third, which was on very light soil. Almost no drainage was observed from any area, and measures of water-use efficiency ranged from 86 to 93%.

Crop-cut yield samples at harvest showed mean yields of 3.42 t/ha from the rotational areas and 3.25 t/ha from the continuously irrigated areas (Table 5). The mean yield efficiency (kilograms of rice per cubic meter of water applied) was also slightly higher for the rotational areas, but neither this nor the yield difference was significant. It is possible that if the rate of water supply had been reduced below the levels set for the study, significant yield differences might have been found. Since the rates used were already quite low, reducing them further would probably have affected yield to some extent in both forms and would not have been realistic in operating a modern irrigation system.

Table 5. Water use, mean grain yield, and yield efflciency[a] in six pilot areas. Upper Pampanga River Project, Philippines, 1974 dry season.

Site	Total water use (mm)	Observations (no.)	Yield (t/ha)	Yield efficiency (kg rice/cu m water)	
				Water for crop growth only	Water for land preparation and crop growth
Kaliwanagan					
Rotational	1668	32	3.67	0.22	0.13
Continuous	1885	35	3.66	0.20	0.12
Gomez					
Rotational	842	35	3.45	0.41	0.23
Continuous	872	29	3.11	0.36	0.21
Santa Arcadli					
Rotational	684	22	3.14	0.46	0.24
Continuous	690	19	2.97	0.43	0.21
Mean					
Rotational	1065	89	3.42	0.36	0.18
Continuous	1149	83	3.25	0.33	0.16

[a] Differences between rotational and continuous areas are not significant at 5% level for any location or their means

Using UPRP cost estimates, we calculated that the capital costs for the on-farm system of rotational irrigation were about US$83/ha[1] more than those of continuous irrigation. This figure is not very high, considering the system's expected life, but it became apparent from the study that the yearly maintenance of the structures and earth canals would be costly. There are also additional operational costs associated with the rotational model that were not estimated in the study. Land removed from production for the rotational farm ditches amounted to about 1 ha, or 2% of the total, which represents another cost borne by the farmers.

The study showed that rotational irrigation can be implemented by UPRP personnel, and that high water use efficiencies can be achieved. No significant differences between the two irrigation forms were found for any of the performance parameters, except that the additional costs noted for the rotational model were much higher than those for the continuous model.

The most interesting finding was that both irrigation forms performed much better than did traditionally irrigated areas. We attribute the better performance to the gated and measured turnout control, which results in water deliveries closely tailored to crop and soil needs. This controlled release of water at the turnout, rather than rotation after the turnout, appears to be the key to improved water utilization.

Factors Associated with Better Water Management

Distance along distribution canals

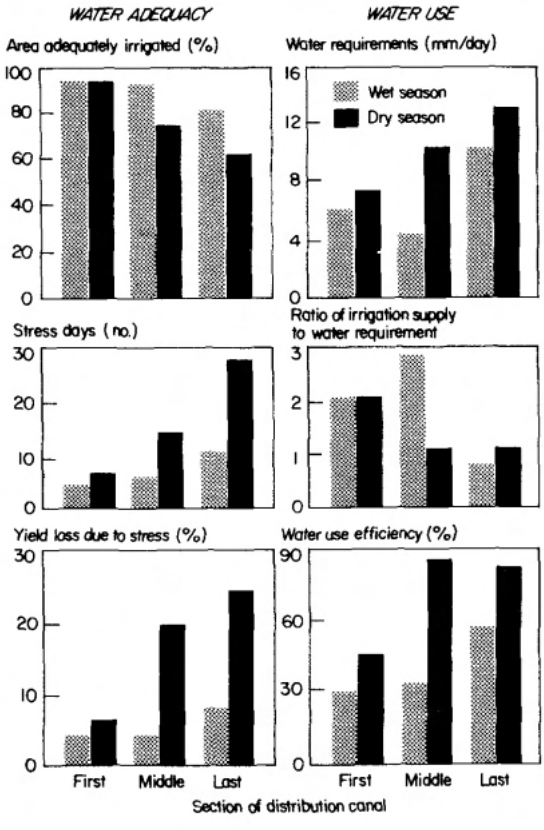
Earlier in this paper, water adequacy was related to on-farm distance of water movement after the turnout. In this section we explore the effect of relative location of farms along their supply canals.

[1] All cost and price data in this paper have been converted to US dollars at ₱7.5 = US$ 1.

Data from the study of 11 irrigated sites in the provinces of Nueva Ecija, Bulacan, and Laguna (Wickham, 1971) were grouped according to whether the sites were irrigated from the first, middle, or last section of their supply canals. We computed mean water adequacy and water-use values for each group.

Mean water adequacy was much higher for sites served from the first section of canals (Fig. 4). Stress days and predicted yield reduction due to stress were much greater for middle- and last-section farms, especially in the dry season. In the wet season, only the last section showed substantial water shortages, but in the dry season both the middle and last sections were affected. A reduction of over 25% was estimated for dry-season yields of farms located in the last section. Estimates of the water required for evapotranspiration, seepage, and percolation indicated slightly higher requirements for the last section. The slightly higher requirements may have been due to unrepresentative sampling or, perhaps, to an increased water requirement for areas that were resupplied after extended drought periods (Tabbal, 1975). Water-use efficiency approached 90% in the dry season for farms supplied by final canal sections because many of them experienced major water shortages. It appears that first-section sites were oversupplied with water and therefore showed low efficiencies, while last-section sites were short of water and had high levels of stress and yield loss.

The farmers of the 11 sites were asked their opinions about water management issues, and their responses were grouped according to whether their farms were located upstream or downstream of the midpoint of the canal (G. Wickham, 1973). A significantly higher propor-



4. Mean water-adequacy and water-use measures for 11 sites irrigated by the first, middle, or last section of distribution canals. Luzon, Philippines, 1969–70.

Table 6. The percentage of farmers agreeing with selected statements on water management according to their location (upstream, downstream) along irrigation canals. Eleven Irrigated sites in Nueva Ecija, Bulacan, and Laguna provinces, Philippines, 1969-70.[a]

Statement	Farmers (% agreeing		x^2 test[c]
	Up-stream[b]	Down-stream	
The supply of water is inadequate.	20	41	10.9**
Farmers are willing to pay more lor supplemental pump irrigation.	38	73	15.9**
There are conflicts over water.	89	76	3.8*
Water use fee is too high.	22	48	7.4*
Farmers are willing to schedule irrigation deliveries.	85	97	5.0*

[a]Number of observations varies between 104 and 231 for different statements. [b]Upstream farms are served from points upstream of the midpoint of a canal's total length; the remainder are downstream farms. [c]x^2 computed from 2 x 2 contingency tables using number of agreement and disagreement responses for each statement. * = significant at 5% level. ** = significant at 1% level.

Table 7. Area adequately irrigated on March 24, 1973, and subsequent mean grain yields by consecutive sections served from Lateral C. Peñaranda River Irrigation System, Nueva Ecija province, Philippines, 1973 dry season.

Section[a]	Production area			Planted area	
	Total (ha)	Planted (%)	With water (%)	With water (%)	Yield (t/ha)
1[b]	1559	91	82	91	2.5
2[b]	1171	82	55	67	2.2
3	873	58	20	35	1.5
4	1907	22	0	0	0.4
Total or av.[c]	5510	60	36	61	2.0

[a] Section 1 is at the beginning of the lateral and Section 4 at the end. [b] Includes 274 ha in Section 1 and 168 ha in Section 2 that were outside the command area of those sections but were fully irrigated by pumps drawing water from the lateral. [c] Weighted by area.

tion of downstream farmers than upstream farmers felt that their supply of water was generally inadequate, said that they were willing to pay more for supplemental pump irrigation, thought the water-use fee too high, and would be willing to rotate or otherwise schedule water deliveries (Table 6). The significantly greater number of conflicts reported by upstream farmers, however, indicate that mismanagement of water in the upstream reaches of a canal deprives the downstream farmers of their share of irrigation water.

Similar results were found during the 1973 dry season in the service area of Lateral C of the PRIS. The service area was divided into four consecutive sections, and sample farms were surveyed to assess the water and crop status that season (IRRI, 1973). In one of these assessments, adequate irrigation was found for more than 90% of the farms in the first section, but for only 67% and 35% of farms in the second and third sections (Table 7). No water was available to the fourth-section farms, and mean crop-cut yields of only 0.4 t/ha were recorded.

During the 1974 dry season, a similar study was made of the Lateral C area except that the daily rates of water supply were measured for each of the four sections (Tabbal, 1975). Despite a concerted attempt to provide more equitable water distribution along the canal that season, the rate of supply was 1.7 liters/s per ha for the first section, and 0.9 and 1.0 liters/s per ha for the last two sections (Table 8). But mean yields for the different sections in the areas actually planted were almost equal.

Highly significant relationships were found in the multiple regression model relating stress days during this season to the distance of the farms from the source of Lateral C and the sublateral canals. About 1.2 and 1.4 additional stress days could be expected for farms located an additional kilometer downstream in the service areas of Lateral C or its sublaterals (Tabbal, 1975).

There are a number of interrelated reasons for the tendency to overirrigate upstream farms and to undersupply the crops' needs downstream. First, siltation has reduced the carrying capacity of most of the older canals along the upstream sections. This means that water must flow at very high elevation, almost to the top of the embankments, to provide enough water for the downstream service area. Since there are many ungated turnouts — some of them unauthorized — along the canal, the water runs freely onto the fields. In fact, it is rather difficult to prevent over-

Table 8. Area planted, rate of water supply days, and grain yield for 206 farms in four consecutive sections of the Lateral C service area. Peñaranda River Irrigation System, Nueva Ecija, Philippines, 1974 dry season.

Section	Area planted (% of total)	Water supply rate[a] (1/s per ha)	Stress days (no.)	Grain yield (t/ha)
1	97	1.7	13.3	2.6
2	93	1.4	25.4	2.4
3	62	0.9	36.3	2.2
4	28	1.0	41.2	2.1

[a] Means for the whole season, including rainfall.

irrigation under these conditions.

In the lower sections, the opposite problem is encountered. Canal beds have often been scoured and eroded by floodwaters that have found their way into the canal network and eventually drained into a creek or swamp. One often finds cross-sectional areas of downstream canal reaches almost as large as those of upstream sections, despite much smaller irrigation design flows. Available water flows low in the canal and cannot easily serve the adjacent fields. Moreover, the topography downstream is usually quite flat. Farmers, therefore, open as many turnouts as possible, and resort to checking the water to build up its elevation. These practices aggravate the problem of the farther canal reaches, however, for much less water passes the checks and open turnouts.

Rotation by canal or section of canal

Although the condition of traditional canals and their turnouts limits the effectiveness of operations personnel, well-motivated field men can nonetheless do much to promote better distribution of water. Many examples of motivation have been noted: ditch tenders closing the turnouts according to a rotational schedule, or systems personnel allocating water sequentially along different reaches of a canal or among different canals (Julian, 1973; Asian Development Bank (ADB), 1973).

Rotation by years. Since the water available in a diversion system in the dry season is rarely enough to irrigate the full service area, each year priority in water use is given to designated subproject areas. To simplify management, these areas are usually served from a common canal or set of canals. Each year the priority shifts to the block that has not had priority for the longest period.

A special problem with such rotation is seen in countries such as the Philippines where farmers generally strive to plant a dry-season crop: there may be enough water for second- or third-priority farmers to transplant the crops, but not enough to sustain them in succeeding weeks. With their investments committed, these farmers can be expected to petition abandoning of the priority plan in favor of continued supply to their areas. This raises the question of whether it is better to use temporary excess water for lower priority farmers, or to refuse them irrigation altogether. The answer seems to depend on the likelihood of a continuing water surplus, which cannot be predicted with certainty although careful analysis of historical and current hydrographic data can provide some guidance.

Rotation among laterals. Different forms of rotation are used when the supply of water becomes inadequate even for the planned or priority areas. The most common in the Philippines is the allocation of all water to selected laterals while the others are closed. After several days to a week or more, depending on the severity of the shortage, the supply is shifted to the canals that were formerly closed. This operation is relatively easy to carry out, since the only points of control are the headworks of the major laterals, which are usually provided with some form of gate.

One effect of this policy is a better distribution of water among upstream and downstream farmers. If the reduced supply were to be demanded simultaneously by the entire system, only those farmers along the upper reaches of the laterals would receive water, but if rotation were arranged so that selected canals carry enough water to supply all of their planted areas, water distribution would be more even.

Such rotation also enables managers to supply water to areas that need it most, or to areas that stand to lose most if not supplied. This capability has stimulated recent research to learn at what stages of growth rice is most sensitive to drought, so that priority might be given to canals or blocks serving crops at those stages.

Experimental and field research have confirmed that rice is particularly sensitive to stress during the early reproductive period between about 60 and 30 days before harvest, during which the critical process of pollination and grain formation take place (Table 9). The data indicate that if the supply of water were not sufficient for a whole system, it would be better to give water to those crops in the reproductive period than to those in the vegetative growth period. However, periodic shifting of water back and forth between two blocks with different planting dates would probably be better than supplying all water to either one block or the other for an extended period.

The data also indicate that normally water cannot be saved by stressing a crop (Table 9). Because the soil dried out during drought and had to absorb much of the lost water when it was eventually resupplied, more water was used for either the early- or the late-stress treatment, which provided no irrigation for almost 40 days, than for continuous flooding. Furthermore, large soil cracks developed that later resulted in high losses to seepage, percolation, and drainage. Although these results were taken from small plots with large border effects, comparable findings have been reported from field studies in the PRIS Lateral C service area. To keep the number of stress days at or near zero, more than 10 times as much water was required after severe stress periods than was necessary before (Tabbal, 1975).

These findings need to be investigated further, but they indicate that it may be better to keep areas continuously saturated as long as possible than to stress them early in favor of areas with older crops. If this were done, the total water requirement of the system might be kept to a minimum, and subsequent droughts might be less likely.

Rotation among sections of laterals. Rotation is a direct attempt to distribute water equitably along the entire length of a canal. In rehabilitated canals with gated turnouts, water can be supplied through different turnouts on rotational schedules. The practice has been successful in the Philippines (Julian, 1973), but the large number of turnouts and the instability of

Table 9. Water use and grain yield of IR20 under four water treatments. IRRI, 1972 dry season.

Water treatment[a]	Days drained (no.)	Av yield (t/na)	Water use[b] (mm)	Yield productivity of water (kg/mm)
No stress	0	6.2	773	8.1
Early stress	38	4.4	788	5.6
Late stress	39	2.0	806	2.5
Late stress to harvest	54	0.5	338	1.5

[a] No stress = flooded throughout crop growth; early stress = no irrigation from 43 to 81 days after seeding; late stress = no irrigation from 63 to 102 days after seeding; late stress to harvest = no irrigation from 63 days after seeding to harvest. [b] From transplanting to about a week before harvest. Includes all rainfall.

flow in the canal make it rather difficult to carry out rigorously.

Sequential delivery along PRIS Lateral C was undertaken in the 1973-74 and 1974-75 crop years. Individual turnout control, however, was not attempted due to the poor condition of the lateral embankments and turnouts. Instead, a program of regulated checking that limited checking rights along the first quarter of the canal length to 1½ days/week was imposed by the systems' field staff. The second quarter also had 1½ days of authorized checking per week, while the third and fourth quarters were permitted 2 days each. At the end of the week, the checking rotation returned to the first quarter. Flow measurements were taken at the quarter points to monitor the amount of water diverted to each section (Valera et al., 1975). In 1974-75, the system also made a special effort to provide the third and fourth quarters with water for land preparation and transplanting before supplying the upstream sections. That was done by prohibiting any checks in the upstream sections for the first 3 weeks of water release, and blocking off the headworks of the upstream sublaterals.

The project succeeded in helping downstream farmers plant early in 1975. Previously, downstream farmers planted their wet-season crop about 1 month later than upstream farmers, and no earlier than adjacent farmers who had to depend completely on rainfall; but in 1975 farmers in both sections prepared their land simultaneously, about 1 month earlier than those with rainfed farms (Fig.5).

Carrying out the weekly sequential checking proved difficult at first, especially during the first dry season when water was most limited. In the village meetings, a PRIS technical assistant was assigned to each of the four sections to explain the plan and to promote compliance. Toward the end of the season, and throughout the following year, the schedule was generally accepted, even after dark and during periods of shortage.

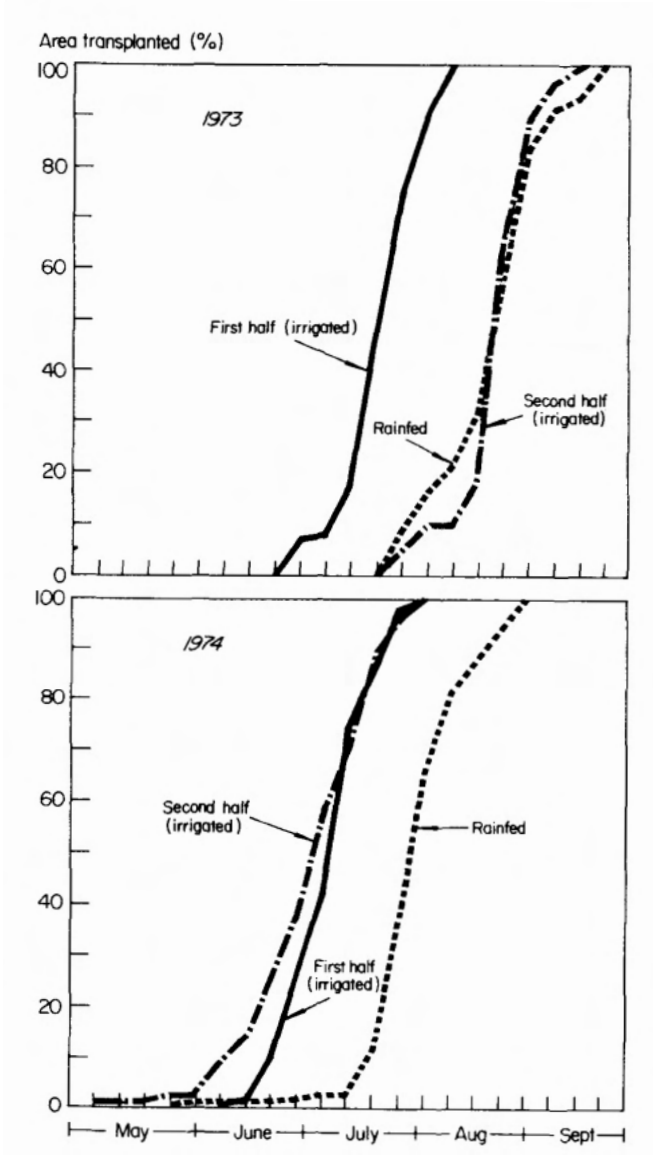
The project has not yet been carefully analyzed, but general conclusions can be drawn. In the dry season of 1973, mean yields ranged from 0.4 to 2.5 t/ha in the first and fourth quarters of the service area due to insufficient water in the downstream sections. In the 1974 dry season, mean yields varied from 2.1 to 2.6 t/ha, although there was again a serious water shortage, resulting in large areas of the downstream sections not being planted. In the 1975 dry season, a year of plentiful water, yields ranged from 2.3 to 3.0 t/ha (Table 10). The increase in rice production from the 1974 dry season to the 1975 dry season ranged from 8% in the first section to 137% in the fourth, reflecting both more water and improved canal management in the second year.

Other conclusions are that farmers in the downstream sections welcomed the plan, and those in the upstream sections accepted it provided they were assured of enough water. Thus, the project tried to reduce the tendency to overirrigate the upstream sections, but not to the point where water shortages and yield loss would result. Almost all farmers accepted the general principle that control of checking and water flows in the laterals are the responsibility of the system management, but some felt they should have some control over turnout operation.

From the result of this study, it appears that major progress can be made in more efficient and equitable water distribution even with relatively deteriorated canals and structures. However, such a management program would yield greater dividends if applied to rehabilitated canals with gated turnouts.

Conclusions: Accountability Between Farmers and Systems Personnel

The following conclusions can be made based on the research summarized above and the conditions under which it was carried out. These conditions are irrigation systems typical of the Philippines, i.e., canal systems built from 20 to 50 years ago with numerous ungated turnouts releasing water to the fields, moderate degrees of siltation, and farms with moderate topographic slope planted to two rice crops per year. Many of these features can be found in countries other than the Philippines, but it is unclear how closely these conclusions would apply there.



5. Percentages of area transplanted by date in sections along an irrigation canal and in the adjacent rainfed area. Lateral C, Peñaranda Irrigation System, Nueva Ecija province, Philippines, 1973 and 1974 wet seasons.

The on-farm distribution of water after the turnout is relatively efficient and equitable, even in the absence of many farm ditches. Farmers appear to have informal arrangements, probably worked out over many years, of sharing water with their neighbors. Rotational irrigation after the turnout does not significantly improve on-farm distribution despite the construction of many farm ditches; in some cases it causes local drainage and management problems.

Major problems are apparent in the equitable and efficient distribution of water within the system of main, lateral, and sublateral canals. To some extent these problems are caused by the need for physical rehabilitation, but they are at least equally caused by lack of effective field

Table 10. Total Irrigable area, area planted, average water depth, and average yield by sections of Lateral C, Peñaranda River Irrigation System, Nueva Ecija province, Philippines 1974 and 1975 dry seasons.

Section	Total Irrigable area (ha)	1974 dry season		1975 dry season		Increase in production[a] (%)
		Area planted (ha)	Av. yield (t/ha)	Area planted (ha)	Av. yield (t/ha)	
1	1220	1184	2.6	1110	3.0	8
2	1134	1055	2.4	1115	3.0	32
3	1988	1237	2.2	1699	2.6	62
4	1422	402	2.1	871	2.3	137
Total or av.	5764	3878	2.4	4796	2.7	39

[a] Percent Increase in production = $\frac{\text{Av. 1975 yield x area} - \text{Av 1974 yield x area}}{\text{Av. 1974 yield x area}} \times 100.$

management. The NIA has established a training program to solve these problems in its new projects; this training may be as important to good irrigation as the physical systems themselves.

A widely held belief is that poor water management is caused by negligence and uncooperativeness of farmers. From this belief stems the idea that farmers should be educated to assume more responsibility in water management, and that as they take on such responsibility, operational functions now undertaken by the systems' field staff can be turned over to them. 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.

Efficient water use calls for farmer cooperation in reducing the number of turnouts, keeping them gated, and accepting regulated checking schedules. Most farmers will cooperate provided they get a dependable supply of water. An effective system-wide management program would have two important benefits: 1) supplying water productively, and 2) eliciting the cooperation of farmers. To the extent that farmers can depend on good management within the system, they can be expected to take more initiative at the farm level. The program to encourage farmers to form irrigation associations would also be enhanced by more predictable main-system management. It is very difficult, however, to convince a farmer to build a potentially useful farm ditch if he feels that there will be no water in the canal to supply the ditch when it is completed.

Thus, the concept of transferring major responsibilities from the system to farmers should be viewed in perspective. It may eventually be possible and desirable to make this transfer, but to have farmers accept new responsibilities, the system authorities must first exercise better management in their areas of responsibility. This means that progress will come largely through system initiative and will entail more rather than fewer responsiblities for system field personnel, at least for the short term.

Although the requirements of main-system management are demanding, the NIA has many resources with which to meet the challenge. The first resource is the ditch tenders, most of whom closely identify with farmers. With strong support from their systems, they could be a vital link in managing canal flows to fit farmers'

needs. The second is the important NIA training program which concentrates on water management, crop production, and farmer relations. The third is Philippine farmers themselves, who can be counted upon to inform us quickly of irrigation problems in their areas, and to keep us alert to their interest in water management.

References Cited

Alvarez, E. 1973. Rotational irrigation in lowland rice. Term paper for Agricultural Engineering 242, University of the Philippines at Los Baños. 13 p. (mimeo.)

Asian Development Bank (ADB). 1973. Regional workshop on irrigation water management. Manila, Philippines. 325 p.

Cerdan, T. 1973. Water management plan for the Upper Pampanga River Project. Pages 78-83 *in* International Rice Research Institute. Water management in Philippine irrigation systems: research & operations. Los Baños, Philippines.

International Rice Research Institute (IRRI). 1973. Annual report for 1972. Los Baños, Philippines. 246 p.

Jucan, S. 1973. Water management innovations in the National Irrigation Administration. Pages 97-112 in International Rice Research Institute. Water management in Philippine irrigation systems: research & operations. Los Baños, Philippines.

Kampen, J. 1970. Water losses and water balance studies in lowland rice irrigation. Unpublished Ph.D. thesis, Cornell University, Ithaca, N.Y. 416 p.

Mid, S. 1975. Effects of physical water control parameters on Philippine lowland rice irrigation performance. Unpublished Ph.D. thesis, Cornell University, Ithaca, N.Y. 202 p.

Tabbal, D. 1975. Distribution of water supply and water adequacy within a gravity irrigation system. Unpublished M.S. thesis, University of the Philippines at Los Baños. 111 p.

Valera, A., D. Tabbal, R. Reyes, and R. Barker. 1975. Effect of improved water control in irrigation canals on crop production. Paper presented at National Seminar on Water Management and Control at the Farm Level, 6- I8 October 1975. Iloilo and Quezon City, Philippines. 31 p. (mimeo.)

Wickham, G. 1970. Sociological aspects of irrigation. Unpublished M.S. thesis, University of the Philippines College of Agriculture, Los Baños, Philippines. 199 p.

Wickham, G. 1973. Farmer attitudes towards irrigation and farmer potential for cooperation. Pages 219-234 *in* International Rice Research Institute. Water management in Philippine irrigation systems: research & operations. Los Baños, Philippines.

Wickham, G., and T. Wickham, ed. 1974. An evaluation of two alternatives of water-sharing among farmers. Unpublished report of consultancy to the National Irrigation Administration-Upper Pampanga River Irrigation Project. 34 p.

Wickham, T. 1971. Water management in the humid tropics: a farm-level analysis. Unpublished Ph.D. thesis, Cornell University, Ithaca, N.Y. 269 p.

Wickham, T. 1973. Predicting yield benefits in lowland rice through a water balance model. Pages 155-181 *in* International Rice Research Institute, Water management in Philippine irrigation systems: research & operations. Los Baños, Philippines.

Wickham, T., O. Giron, A. Valera, and A. Mejia. 1974. A field comparison of rotational and continuous irrigation in the Upper Pampanga River Project. Paper presented at Saturday seminar, August 3, 1974. International Rice Research Institute, Los Baños, Philippines. 24 p.

Effects of physical water control parameters on lowland irrigation water management

S. M. MIRANDA and G. LEVINE

IRRIGATION PERFORMANCE was analyzed in three diversion systems from 3,600 to 28,000 ha. Twenty-two turnout areas ranging from 5 to more than 20 ha and supplied by different irrigation techniques were monitored through both the wet and dry seasons. The results are mixed, but there is some evidence that water-use efficiency in the dry season was higher in areas served by farm-ditch rotational irrigation. Higher water-use efficiency seems to be associated with the larger and smaller sized areas, but not with the intermediate-sized areas (from 10 to 20 ha). Farmers do not practice rotational irrigation as it is practiced in Taiwan, and it does not appear to have significant value in the wet season.

The Philippines has two options to provide the irrigation needed to increase its agricultural production: to increase the available water supply, as in the government's massive irrigation infrastructure program, or to increase the efficiency of water use by improving water management in both new and existing systems. This study analyzes three parameters of water management in command areas directly served by turnouts in 1972-73.

The potential to improve water management is tremendous considering the low water-use efficiencies of present systems. Efficiency of on-farm use may average as low as 30% in areas that are well supplied with water (Kampen, 1970). At the farm level, seepage and percolation losses are small, but surface losses resulting from insufficient attention to water management and distribution are large (Kampen, 1970). Surface drainage often exceeds 50% of the total supply, especially during periods of high rainfall (Wickham, 1971). Levine (1971) stated that reducing surface drainage losses offers the greatest opportunity for increasing efficiency of water use. There are indications that water-use efficiency could be increased most by reducing losses that occur beyond the turnout.

In Philippine irrigation systems, water is most commonly distributed by the simultaneous method, i.e., water flows continuously through all canals, laterals, and sublaterals, and is simultaneously supplied to all fields. Control of flow is minimal. This method, widely used in Asia, may be conducive to excessive diversion and as generally practiced,

S.M. Miranda, Associate Professor, University of the Philippines at Los Baños and Director. Soil and Water Resources Research Division, Philippine Council for Agricultureand Resources Research, Los Baños, Laguna, Philippines; and *G. Levine*, Professor and Director of the Water Resources and Marine Sciences Center, Cornell University, Ithaca, N.Y. USA.

frequently results in unequal water distribution and low efficiency. An emergency form of rotation along laterals is sometimes practiced, especially when land is being soaked or when supply is limited, but simultaneous or continuous delivery is still practiced in the canals that supply these laterals.

Rotational water distribution, practiced with considerable success in Taiwan and introduced in the 1968-70 National Irrigation Administration-Asian Development Bank (NIA-ADB) Water Management Project, was a radical change for the Philippines (Takase, 1972). Different levels of rotation may be designated in the main canal, laterals, or sublaterals, and farm ditches. The most intensive level is rotation in the farm ditch, which has maximum potential for full water control. Intensive rotational irrigation requires facilities to measure, control, and divide the water; it also requires substantial human and managerial resources. In the pilot areas included in this study, water was rotated among units served by a farm ditch, but the conveyance and turnout of water were continuous in the main canal, laterals, and sublaterals.

Research Objectives

This study aimed to determine the relative importance of three physical parameters of water control for irrigation system performance: 1) method of water delivery, 2) degree of control at the turnout, and 3) size of the turnout area.

Each parameter was divided into three levels:

Water delivery methods

1. *Simultaneous method.* As practiced in most parts of the Philippines, this method supplies water continuously to all canals and fields.
2. *Rotation along sections of laterals* (lateral or emergency rotation). Flow in a lateral is diverted to selected turnouts for a few days, then is diverted to another set of turnouts further along the lateral. This method is sometimes practiced in traditional systems when water supply is short; it is the method adopted in the pilot divisions of the NIA-ADB Project.
3. *Rotation at farm-ditch level* (farm-ditch or planned rotation). Water is simultaneously diverted through all turnouts, but application is rotated among three to five different on-farm blocks on a 24-hour schedule for each turnout area, as in the pilot areas of the NIA-ADB Project.

Degree of control at the turnout

1. *Uncontrolled* (gap in the embankment, or turnout without gate),
2. *Medium control* (turnout with gate), and
3. *Maximum control* (turnout with gate and measuring device).

Size of turnout service area

1. *Small* (less than 10 ha),
2. *Intermediate* (from 10 to 20 ha), and
3. *Large* (more than 20 ha).

Methodology

Three national gravity irrigation systems in Central and Southern Luzon were studied. The systems provided a spectrum of distribution method as well as a degree of homogeneity. In pilot areas of each, new water-management practices had been tried through the NIA-ADB Project. Research sites composed of areas irrigated by single turnouts were located in the Angat River Irrigation System, the Peñaranda River Irrigation System, and the Santa Cruz River Irrigation System. The Angat is the largest system and has a storage reservoir; the Peñaranda System is relatively large with a diversion water supply; and the Santa Cruz System is the smallest, also with a diversion supply. Most sites were located in the Angat System because it had pilot areas reflecting the most intensive water management practices, as well as other areas with different levels of physical control and method of delivery.

All measurements and agronomic documen-

tation of the sites were made according to standard procedures detailed by Miranda (1975). The procedures were designed to permit accurate measurements but to interfere as little as possible with the existing forms of water management. New technological ideas were deliberately excluded so as not to bias results.

When the research sites were selected, the three physical parameters of water control were thought to be represented. However, actual operations differed from the anticipated forms.

Farm-ditch rotation varied in the three systems and was unlike that in the Taiwan model. In study sites from the Angat NIA-ADB pilot area,[1] water was rotated on an informal schedule prepared by the water management technician and the farmers. Flow in the turnout was not continuous; instead, water was available on demand, with several parcels simultaneously receiving it. Rotation began with the parcel closest to the turnout and ended with the parcel farthest downstream. Individual farmers, rather than a common irrigator, managed water along the ditch. In one site from the Santa Cruz pilot area, the flow through the turnout was continuous; not even an informal schedule was followed. Because the measuring device was defective, a staff gauge was installed and calibrated to measure the flow. In sites within the Peñaranda pilot area, the methods used were a combination of those at Angat.

A clear pattern of water distribution was noted in turnout areas selected from areas with lateral rotation capability.[2] Ditch tenders and farmers in these areas were aware of improved water management technology because of the efforts of prior water management projects in their areas (Valera et al., 1975). Lateral rotation was never necessary during the study, but some form of rotation along the laterals in both systems was practiced without scheduling or announcement.

Research Sites

General description of research turnout areas

Data were gathered from 22 turnout areas: 4 from Santa Cruz, 11 from Angat, and 7 from Peñaranda. The number of turnout areas chosen for each system was based primarily on the apparent levels of physical water control available and partly on the size of the system. Eight turnout areas used simultaneous delivery, seven used lateral rotation, and seven used farm-ditch rotation. Eleven areas were served by turnouts without gates, six had gates, and five had both gates and measuring devices. Each turnout served an area ranging from 4.7 to 68.1 ha. Nine of these areas were considered small (less than 10 ha), six were intermediate (from 10 to 20 ha), and seven were large (more than 20 ha) (Table 1).

To document actual management of the selected turnouts, the percentage of time (days) that water was turned in during the dry season was computed (Table 2). Water flowed almost all the time to the Santa Cruz site with rotational delivery (coded 322) as expected. The percentage of turn-in time varied noticeably among the three Santa Cruz turnouts, reflecting the variable supply of water along the lateral. The low percentage of flow times for the Angat turnouts with farm-ditch (planned) rotation was the result of the deliberate and intermittent supply of irrigation on demand, referred to as rotation by turnout. The relatively high percentage of flow time for the Angat site with farm-ditch rotation and large service area (coded 333) suggested that larger distribution times were needed for these conditions. Indications of decreasing water supply toward the lower reaches of the laterals were clear for typical canals with simultaneous supply, and for the Angat and Peñaranda canals with farm-ditch rotation. One Peñaranda site reportedly using farm-ditch rotation

[1] The pilot areas of all three systems were those areas in which more intensive water management practices had been tried by the NIA-ADB pilot project. Many study sites were therefore selected from those areas.

[2] Areas with rotation along laterals were found in two pilot divisions, one in the Angat System and one in the Peñaranda, for which this method of irrigation had been implemented.

Table 1. Distribution of research turnout site according to the various levels of physical parameters of water control. Selected turnout areas in three national irrigation systems, Philippines, 1972-73.

Turnout site[a]	Water delivery method[b]			Degree of control[b]			Size of turnout service area[c]		
	Simultaneous supply	Lateral rotation	Farm-ditch rotation	Uncontrolled, ungated turnout	Med. control, gated turnout	Max. control, gated turnout with measuring device	Small (less than 10 ha)	Intermediate (10 to 20 ha)	Large (more than 20 ha)
Santa Cruz River Irrigation System									
322			✓[d]		✓			12.6	
113	✓			✓					21.9
111	✓			✓			4.7		
111	✓			✓			7.3		
Angat River Irrigation System									
331			✓			✓	5.9		
331			✓			✓	6.3		
333			✓			✓			39.1
213		✓		✓					22.2
221		✓			✓		10.0		
223		✓			✓				42.1
113	✓								22.0
122	✓				✓			13.5	
111	✓			✓			6.8		
111	✓			✓			5.7		
113	✓			✓					25.3
Peñaranda River Irrigation System									
312			✓	✓				19.8	
332			✓			✓		13.0	
331			✓			✓	9.3		
213		✓		✓					68.1
211		✓		✓			6.6		
222		✓			✓			18.4	
222		✓			✓			10.5	

[a] First digit = method of delivery: 1 = simultaneous supply; 2 = lateral rotation; 3 = farm-ditch rotation. Second digit = degree of control: 1 = uncontrolled, ungated turnout; 2 = medium control, gated turnout; 3 = maximum control, gated turnout with measuring device. Third digit = size of turnout service area: 1 = less than 10 ha; 2 = from 10 to 20 ha; 3 = more than 20 ha. [b] ✓ represents sites for each category. [c] Turnout service area, corrected by field observation, from irrigation systems records. [d] Flow was actually continuous, without even an informal schedule.

actually used continuous flow, while two other areas used intermittent flow based on demand.

Farm supply and drainage ditch density

The average farm ditch density of the various turnout sites was about the same as or higher than that of the Angat lateral-rotation areas (Table 3). The simultaneous-supply area of Angat had the lowest average value, 19.5 m/ha. It was almost flat, with a gradual and even slope. The values for the other relatively flat areas, especially the Angat and Peñaranda farm-ditch rotation areas, were greater than average because of additional farm-ditch construction through the NIA-ADB project. All the rolling areas had high farm-ditch densities, probably because more farm ditches were necessary to distribute water where topography was rolling.

Table 2. Number and percentage of days during which water was turned in after transplanting. Selected turnout areas in three national irrigation systems, Philippines, 1972-73 dry season.

Turn-out site[a]	Irrigation days (no)	Duration of Irrigation period (days)	Days water was turned in (%)
Santa Cruz River Irrigation System			
322	110	112	98
113	73	110	66
111	b	b	b
111	35	90	39
Angat River Irrigation system			
331	29	95	31
331	27	88	31
333	58	109	53
213	40	68[c]	59
221	32	80[c]	40
223	38	85	45
113	74	96	77
122	65	96	68
111	48	97	49
111	47	107	44
113	38	99	38
Peñaranda River Irrigation System			
312	36	82	44
332	80	81	99
331	35	81	43
213	41	60[c]	68
211	b	b	b
222	37	102	36
222	27	90	30

[a] See Table 1 for turnout site code. [b] Data not available
[c] Data obtained for only part of the season

The pressure for new ditches did not seem great in the flatter areas where water can easily flow from paddy to paddy. Farmers even resisted the construction of ditches that they believed were not needed.

The density of drainage ditches in the farm-ditch (planned) rotation areas was low and difficult to estimate. However, almost all turnout sites were bordered on at least one side by creeks or drainage outlets.

Characteristics of paddy areas within the turnout sites

Average paddy areas. The average area per paddy field in the research sites ranged from 0.07 to 0.19 ha (Table 4). The size was related to topography, with flatter terrain having larger areas. Among the systems, Santa Cruz had the smallest paddy areas.

Dimensions and conditions of paddy dikes. The Santa Cruz areas had the lowest and narrowest dikes (Table 4). Those of the Angat and Peñaranda areas did not differ much, although the Peñaranda dikes were higher. The height and width of the paddy dikes seemed to be related to water storage capacity and water tightness, respectively. The values tend to indicate that these dimensions were less important in the Santa Cruz areas, perhaps because of the more even rainfall distribution. The dikes in the pilot areas were better maintained than those in the other areas.

Paddy dike spillways. Farmers adjusted the heights of paddy spillways over the cropping season to allow water to flow into and from paddies. The heights of dike spillways varied from 5.3 to 10.3 cm, with the lowest in the Santa Cruz areas (Table 4). These values approximated the depth of water, including rainfall, that can be stored in the paddy.

Land area occupied by paddy dikes. The area utilized for paddy dikes varied directly with the roughness of the terrain; more and wider paddy dikes were constructed on rougher terrain (Table 4). The values varied from 1.6 to 5.0% of the total area, which in a 50-ha area results in 0.8 to 2.5 ha of nonproductive land.

Results and Discussion

The study results are discussed in two parts: water use for land soaking and preparation, and crop water use after transplanting. Cultural practices of farmers, crop yields, and equity of water distribution are also discussed.

Land soaking and preparation

Starting date. The start of land soaking for the wet season differed from system to system and within systems, and depended on the water supply. Land soaking in the Angat System started earliest, before the onset of the wet season. In the better-situated Angat pilot areas (with farm-ditch rotation), water was turned in as early as mid-April. For the Angat pilot divi-

Table 3. On-farm irrigation and drainage ditch densities in turnout sites. Selected turnout areas in three national irrigation systems, Philippines, 1972-73.

Turnout site [a]		Farm ditch density (m/ha)	Drainage ditch density (m/ha)	Natural creek drainage density (m/ha)	Topography
		Santa Cruz River Irrigation System			
322		90.8	19.0	6.3	Slightly undulating
113		40.0	*b*	55.7	Relatively flat
111		109.0	22.5	*b*	
111		35.7	*b*	*b*	
	Mean	68.9			
		Angat River Irrigation System			
331		28.0	44.0	*b*	Relatively flat
331		48.7	22.1	*b*	
333		78.8	16.0	18.0	
	Mean	51.8			
213		37.8	*b*	86.2	Rolling
221		80.3	*b*	18.2	
223		49.3	*b*	39.6	
	Mean	55.8	*b*	b	
113		12.8	*b*	18.8	
122		4.9	*b*	16.6	Flat
111		13.1	*b*	31.2	
111		38.8	*b*	17.8	
113		28.1	*b*	42.1	
	Mean	19.5			
		Peñaranda River Irrigation System			
312		52.4	*b*	29.8	
332		95.0	22.4	16.6	Flat
331		19.3	*b*	19.7	
	Mean	55.6			
213		58.0	*b*	24.6	
211		53.0	*b*	56.6	Rolling
222		16.4	*b*	*b*	
222		79.5	*b*	*b*	
	Mean	51.7			

[a] See Table 1 for turnout site code. [b] Data not available.

sion (with lateral rotation) and for all other canals, land soaking began in the second week of May. The Santa Cruz pilot areas received water in late July, but the rest of the system first had water in mid-June (Table 5). In all systems, from 100 to 200 mm of rainfall fell in May. For the dry season, land soaking began simultaneously (during October) at almost all Angat and Peñaranda sites. The Santa Cruz sites started later, in the second week of December (Table 6).

Duration. The duration of land soaking and preparation for each turnout area, from the first day of water release to the median date of transplanting, ranged from 24 to 52 days for the wet-season crop, and from 26 to 62 days for the dry-season crop. The average was 39 days for the wet and 41 for the dry seasons. The shortest preparation period for both cropping seasons was in the Santa Cruz site with simultaneous supply, where the 12-day *dapog* method of preparing seedlings was

Table 4. Average paddy parameters in research sites served by similar water delivery methods. Selected turnout areas in three national irrigation systems, Philippines, 1972-73.

Delivery method	Sites (no.)	Paddy area as dikes (%)	Paddy spillway height[a] (cm)	Dike dimensions		Area per paddy (ha)	Topography
				Width (cm)	Height (cm)		
Santa Cruz River Irrigation System							
Simultaneous supply	3	1.6	5.3	24.1	9.3	0.09	Relatively flat
Farm-ditch rotation	1	2.0	6.0	23.0	11.1	0.07	Slightly undulating
Angat River Irrigation System							
Simultaneous supply	5	2.3	7.7	35.1	12.9	0.19	Flat
Lateral rotation	3	4.7	8.3	40.8	12.9	0.08	Rolling
Farm-ditch rotation	3	2.9	6.7	41.9	11.5	0.11	Relatively flat
Peñaranda River Irrigation System							
Lateral rotation	4	5.0	10.3	36.7	18.3	0.07	Rolling
Farm-ditch rotation	3	2.1	7.0	32.6	11.5	0.15	Flat

[a] Excluding those without spillways.

Table 5. Duration and water use for land soaking and preparation. Selected turnout areas in two national irrigation systems, Philippines, 1972-73 wet season.

Turnout site[a]	Beginning and ending dates	Duration (days)	Water applied (mm)	Total rainfall (mm)	Total[b] wateruse (mm)	Evaporation[c] plus percolation (mm)	Saturation[d] requirement (mm)	Water[e] required (mm)	Gross[f] efficiency (%)
Santa Cruz River Irrigation System									
322	26 July- 9 Sept.	45	61	470	531	175	150	325	61
113	12 June- 6 July	24	181	310	491	88	150	238	48
Angat River Irrigation System									
331	27 April-30 May	34	537	113	650	230	150	380	58
331	16 April-31 May	46	928	147	1075	319	150	469	44
333	28 April- 5 June	39	484	184	668	265	150	415	62
221	9 May-13 June	36	877	327	1204	250	150	400	33
333	3 May-23 June	52	212	355	567	358	150	508	90
113	8 May-13 June	37	255	308	563	233	150	383	68
122	6 May-18 June	44	815	329	1144	282	150	432	38
111	8 May-16 June	40	276	308	584	252	150	402	69

[a] See Table 1 for turnout site code. [b] Sum of water applied and total rainfall. [c] Evaporation obtained from USWB class A pan; percolation obtained from spot measurements by Kampen (1970) and from measurements in the pilot areas by the NIA-AD6 project. [d] Values reported by Julian (1973). [e] Sum of evaporation, percolation, and saturation requirements. [f] Water required divided by total water.

practiced. The size of turnout area did not influence duration of the process, as the mean duration for area categories ranged only from 37 to 41 days.

The duration of land preparation was shortest in areas of simultaneous delivery supply and longest in those of lateral (emergency) rotation (Table 7), possibly because more water was available to the areas served by simultaneous distribution.

Table 6. Duration and water use for land soaking and preparation. Selected turnout areas in three national irrigation systems, Philippines, 1972-73 dry season.

Turnout site[a]	Beginning and ending dates	Duration (days)	Water applied (mm)	Total rainfall (mm)	Total[b] water use (mm)	Evaporation[c] plus percolation (mm)	Saturation[d] requirement (mm)	Water[e] required (mm)	Gross[f] efficiency (%)
				Santa Cruz River Irrigation System					
322	26 Dec.-29 Jan.	35	397	45	442	164	120	284	64
113	15 Dec.- 9 Jan.	26	516	25	541	123	120	243	45
111	9 Dec.-12 Jan.	35	408	100	508	164	120	284	56
				Angat River Irrigation System					
331	4 Oct.-18 Nov.	46	431	66	497	248	120	368	74
331	13 Oct.-16 Nov.	35	462	62	524	217	120	337	64
333	4 Oct.-20 Nov.	48	368	66	434	259	120	379	87
223	17 Oct.- 6 Dec.	51	300	147	447	292	120	412	92
113	17 Oct.-24 Nov.	39	443	85	528	202	120	322	61
122	17 Oct.-23 Nov.	38	344	80	424	198	120	318	75
111	3 Oct.-15 Nov.	44	401	89	490	220	120	340	69
				Peñaranda River Irrigation System					
312	25 Oct.- 4 Dec.	41	460	97	557	203	120	323	58
332	5 Oct.- 5 Dec.	62	421	104	525	212	120	332	63
331	26 Oct.- 7 Dec.	43	539	138	677	328	120	448	66
222	1 Dec.-31 Dec.	31	462	47	509	149	120	269	53

[a] See Table 1 for turnout site code. [b] Sum of water applied and total rainfall. [c] Evaporation obtained from USWB class A pan; percolation obtained from spot measurements by Kampen (1970) and from measurements in the pilot areas by the NIA-ADB project. [d] Values reported by Julian (1973) [e] Sum of evaporation, percolation, and saturation requirements. [f] Water required divided by total water.

Table 7. Mean duration of land preparation for sites with three water delivery methods. Selected turnout areas in three national irrigation systems, Philippines, 1972-73 wet and dry seasons.

Delivery method	Total turnout sites (no.)	Mean duration (days) of land preparation	
		Wet season	Dry season
Simultaneous supply	8	30	34
Lateral rotation	7	44	51
Farm-ditch rotation	7	39	42

Water use and efficiency. Total rainfall was considered effective for both the wet and dry seasons in all the areas because heavy rains did not start until early July after completion of land preparation. Total water use ranged from 491 to 1,204 mm during the wet season (Table 5) and from 424 to 677 mm during the dry season (Table 6). The lower figures during the dry season tend to confirm results of an earlier investigation indicating that farmers used more care in

water control during the dry season (Wickham, 1971). An examination of the water control parameters provides a more complete picture:

1. *Water delivery method.* The delivery method for the wet-season crop did not influence efficiency of water use (Table 8). However, efficiencies for farm-ditch rotation were somewhat higher than those for the other methods during the dry season. The simultaneous and the lateral-rotation methods had the same efficiency, but actual water delivery practices were similar in these sites.

The efficiencies were relatively high, averaging 56% for the wet season and 65% for the dry. In almost all cases, high efficiencies appeared to be the result of limited rainfall, most of which was effective during the period. Water requirements including evaporation and percolation also resulted in higher efficiencies than are customary when only the soaking requirements of 150 and 120 mm are used as the useful portion of the delivered water.

2. *Degree of control at turnout level.* The degree of control at the turnout level did not significantly affect water-use efficiency for land soaking and preparation in the wet season (Table 8). Better facilities of physical control did seem however to improve water use efficiency in water management during the dry season when water became scarce.

3. *Size of turnout service area.* During the wet season, water use was not efficient for large turnout areas (Table 8). Water-use efficiency for land soaking and preparation seemed to be independent of the size of turnout area during the dry season.

Crop water use after transplanting

Water use and efficiency. Crop water use was recorded from the median date of transplanting to 2 weeks before the median harvest date, or to the last irrigation date, whichever came later. The duration of crop water use ranged from 87 to 120 days (median of 100 days) in the wet season, and from 21 to 112 days (median of 96 days) in the dry season. Total water use varied from 1,019 to 3,184 mm (median of 2,761 mm) in the wet season, and from 455 to 1,617 mm (median of 825 mm) in the dry season. Average daily use ranged from 10.2 to 31.8 mm (median of 27.6 mm) in the wet season and from 5.6 to 14.7 mm (median of 10.2 mm) in the dry season. The daily rate of estimated crop transpiration was 4.0 mm in the wet season and 4.7 mm in the

Table 8. Mean efficiency of water use during land preparation for sites with common delivery methods, degree of water control, and size of turnout service areas. Selected turnout areas in three national irrigation systems, Philippines, 1972-73 wet and dry seasons.

Physical parameters of water control	Sites (no.)	Mean efficiency of water use (%)	
		Wet season	Dry season
Delivery method			
Simultaneous supply	8	56	65
Lateral rotation	7	57	65
Farm-ditch rotation	7	56	73
Degree of water control			
Uncontrolled (gap or turnout without gate)	11	62	58
Medium control (turnout with gate)	6	53	66
Maximum control (turnout with gate and flow-measuring device)	5	55	71
Size of turnout service area			
Small (less than 10 ha)	9	51	65
Intermediate (from 10 to 20 ha)	6	50	64
Large (more than 20 ha)	7	65	66

Table 9. Water use after transplanting. Selected turnout areas in three national irrigation systems, Philippines, 1972-73 wet season.

Turnout site[a]	Beginning and ending dates	Duration (days)	Water applied (mm)	Total rainfall (mm)	Total water use[b] (mm)	Effective rainfall[c] (mm)	Evapo-ration (mm)	ET[d] (mm)	Perco-lation[e] (mm)	Water required[f] (mm)	Gross efficiency[g] (%)	Net efficiency[h] (%)
					Santa Cruz River Irrigation System							
322	2 Sept- 6 Dec	96	423	596	1019	527	407	382	100	482	47	51
113	6 July- 2 Nov	120	902	1477	2379	790	521	488	62	550	23	32
111[i]	2 Aug- 9 Nov	100	569	757	1326	570	459	426	52	478	36	42
111[i]	7 Aug- 4 Nov	90	733	799	1532	689	435	405	51	456	30	32
					Angat River Irrigation System							
331	31 May- 7 Sept	100	139	2622	2761	730	445	414	78	492	18	57
331	1 June- 8 Sept	100	214	2608	2822	729	443	410	78	488	17	52
333	6 June- 3 Sept	90	178	2549	2727	716	384	369	70	439	16	49
221	14 June-21 Sept	100	346	2838	3184	703	422	396	150	546	17	52
223	24 June- 1 Oct	100	0	2727	2727	704	416	393	130	523	19	74
113	14 June-21 Sept	100	73	2738	2811	722	430	403	70	473	17	60
122	19 June-24 Sept	98	111	2763	2874	753	408	385	69	454	16	52
111	18 June-25 Sept	100	359	2784	3143	765	422	396	52	448	14	40
111	17 June-11 Sept	87	210	2649	2859	637	350	329	45	374	13	44
113	18 June-25 Sept	100	0	2784	2784	765	422	393	70	463	17	61
					Peñaranda River Irrigation System							
332[i]	5 July-12 Sept	70	66	1912	1978	549	287	272	36	308	16	50
222	3 July-10 Oct	100	0	2120	2120	720	442	413	52	465	22	65
222	6 July-13 Oct	100	0	2143	2143	700	443	416	52	468	22	67

[a] See Table 1 for turnout site code. [b] Sum of water applied and total rainfall. [c] Using Asian Development Bank (ADB, 1973) method, 80 mm as effective for 10 days. [d] Evapotranspiration during the vegetative stage: ET = 0.84 E + 0.35 (r = 0.94); and during reproductive stage: ET = 0.91 E + 0.17 (r = 0.90), where ET = evapotranspiration; E = evaporation from USWB class A pan. [e] Values obtained from spot measurements by Kampen (1970) and from measurements in the pilot areas by the NIA-ADB project. [f] Sum of ET and percolation.

[g] Gross efficiency $= \frac{\text{water requirement} \times 100}{\text{total rainfall} + \text{water applied}}$ [h] Net efficiency $= \frac{\text{water requirement} \times 100}{\text{effective rainfall} + \text{water applied}}$

[i] Data obtained for only part of the cropping season.

Table 10. Water use after transplanting. Selected turnout areas in three national irrigation systems, Philippines, 1972-73 dry season.

Turnout site[a]	Beginning and ending dates	Duration (days)	Water applied (mm)	Total rainfall (mm)	Total[b] water use (mm)	Evapo-ration (mm)	ET[c] (mm)	Perco-lation[d] (mm)	Water required[e] (mm)	Gross efficiency[f] (%)
				Santa Cruz River Irrigation System						
322	30 Jan-21 May	112	1318	81	1399	577	578	112	690	49
113	10 Jan-29 April	110	1537	80	1617	518	523	57	580	36
111	13 Nov-12 April	90	648	63	711	410	418	47	465	65
				Angat River Irrigation System						
331	19 Nov-21 Feb	95	535	69	604	420	427	74	501	83
331	17 Nov-12 Feb	88	436	69	505	404	413	69	482	95
333	21 Nov- 9Mar	109	581	69	650	519	526	85	611	94
213[g]	18 Dec-23 Feb	68	805	10	815	271	286	61	347	43
221[g]	5 Dec-22 Feb	80	862	14	876	309	321	120	441	50
223	7 Dec- 1 Mar	85	510	13	523	346	354	110	464	89
113	25 Nov-28 Feb	96	1167	42	1209	362	378	67	445	37
122	24 Nov-27 Feb	96	897	48	945	352	366	67	433	46
111	22 Nov-26 Feb	97	1049	52	1101	342	379	50	429	39
111	16 Nov- 5 Mar	107	966	52	1018	416	429	56	485	40
113	9 Nov-15 Feb	99	560	75	635	366	377	69	446	70
				Peñaranda River Irrigation System						
312	5 Dec-24 Feb	82	675	24	699	372	378	43	421	60
332	6 Dec-24 Feb	81	805	21	826	368	373	42	415	50
331	8 Dec-26 Feb	81	433	22	455	374	378	42	420	92
213	3 Feb- 3 Apr	60	623	8	631	316	319	103	422	67
211	9 Mar-29 Mar	21	252	6	258	116	119	11	130	50
222	27 Dec- 7 April	102	1289	8	1297	496	509	53	562	43
222	1 Jan-11 Mar	90	1438	8	1466	423	431	46	477	33

[a]See Table 1 for turnout site code. [b]Sum of water applied and total rainfall. [c] Evapotransplration during the vegetative stage: ET = 0.87E + 0.52 (r = 0.88); and during the reproductive stage: ET = 0.94E + 046 (r = 0.91), ET = Evapotranspiration, E = evaporation from USWB class A pan. [d]Values obtained from spot measurements by Kampen (1970) and from measurements in the pilot areas by the NIA-ADB. [e] Sum of ET and percolation
[f] Gross efficiency = $\frac{\text{water requirement x 100}}{\text{total rainfall + water applied.}}$ [g]Data obtained for only part of the cropping season

dry season (Table 9, 10).

The gross efficiency of water use in the wet season varied from 13 to 47% (median of 18%), while net efficiency varied from 32 to 67%[3] (Table 9).

The effects on water use efficiency of each of the three physical parameters of water control are discussed in the succeeding sections.

1. *Water delivery method.* Differences in efficiency of water use among the three water-delivery methods were not significant in the wet season. Assuming 80 mm effective rainfall[4] in computing net efficiency, lateral rotation appeared slightly more efficient than the two other methods. That can be explained, however, by the fact that three of the four turnout sites with lateral rotation did not receive any irrigation during the wet season. They were totally dependent on rainfall, resulting in abnormally high net efficiencies (Table 9).

[3] Gross efficiencies include all rainfall; net efficiencies include a maximum of only 80 mm of effective rainfall.

[4] Estimate is taken from Asian Development Bank (1973).

In the dry season, efficiencies were much higher for the farm-ditch (planned) rotation than for the simultaneous and lateral-rotation methods (Table 11), indicating better water control and management with farm-ditch rotation. The insignificant difference between the lateral-rotation and simultaneous methods is expected because the actual distribution of water in the two methods was similar.

2. *Degree of control at turnout.* Analysis of water-use efficiency was limited to the dry season because of the unusually heavy rainfall during the wet season. Efficiencies were similar for the uncontrolled and medium-control levels, but were markedly higher for the maximum-control levels (Table 11). This indicates that gated turnouts without measurement facilities do not necessarily improve water management. In some instances the flow through gateless turnouts was controlled by plugging the concrete pipes with grass and mud, or by installing temporary checks in the farm ditches immediately below the concrete pipes. Controllable gates that were defective either remained open throughout the season or were only controlled by plugging. Where gates were in use and in good condition, the absence of flow measuring devices made it impossible to determine the proper amounts of water to be supplied. Estimates of delivery needs were based primarily on the height of water in the farm ditches. It is apparent that to consistently improve water-use efficiency, some form of measuring device should be incorporated into or near the point of flow control.

3. *Size of turnout service area.* The average efficiency for all rotational areas combined (Table 11) and values for all systems except Santa Cruz (Table 12) indicate comparable water use efficiencies for small and large turnout areas. Efficiency of the intermediate-size areas was significantly lower for both the Angat and Peñaranda systems but not for the mean of all systems.

Mean efficiency data for the small areas indicate that paddy-to-paddy distribution apparently can serve these areas well, even without an intensive network of farm ditches. Water needed anywhere in the area can be delivered quickly when the area is small and farmers are relatively few. Farmers thus are confident that if water is

Table 11. Mean efficiency of water use after transplanting for sites with common delivery methods, degree of water control, and size of turnout service areas. Selected turnout areas in three national irrigation systems, Philippines, 1973 dry season.

Physical parameters of water control	Sites (no.)	Mean efficiency of water use (%)
Delivery method [a]		
Simultaneoussupply	8	51
Lateral rotation	7	54
Farm-ditch rotation	7	75
Degree of control		
Uncontrolled (gap or turnout without gate)	11	51
Medium control (turnout with gate)	6	52
Maximum control (turnout with gate and flow-measuring device)	5	83
Sizeofturnout area		
Small (less than 10 ha)	9	65
Intermediate (from 10 to 20 ha)	6	47
Large (more than 20 ha)	7	62

[a] Corresponding values for the three successive delivery methods in the wet season are 20, 20, and 23%, respectively.

Table 12. Mean efficiency of water use for three sizes of turnout service areas. Selected turnout areas in three national irrigation systems, Philippines, 1973 dry season.

Size of turnout area	Santa Cruz River Irrigation System		Angat Rwer Irrigation System		Peñaranda River Irrigation System		All systems[a]	
	Sites (no.)	Efficiency (%)	Sites (no.)	Efficiency (%)	Sites (no.)	Efficiency (%)	Sites (no.)	Efficiency (%)
Small (less than 10 ha)	2	64	5	63	2	71	9	65
Intermediate (from 10 to 20 ha)	1	49	1	46	4	47	6	47
Large (more than 20 ha)	1	36	5	67	1	67	7	62

[a] Weighted by number of sites in each system.

available at all they can secure it before their crops suffer.

Most of the large areas were long and narrow with good networks of farm ditches. Because the embankments of the primary laterals were relatively high for most of them, it was almost impossible for farmers to turn water out illegally without being detected and subject to sanctions. Thus, they were forced to obtain water from only one turnout, and the farm ditch in effect became a sublateral with several openings serving smaller portions of the area. effective responsibility for water control was thus transferred to farmers. This situation provides an opportunity for better ditch-tender control of the larger area, and calls for coordination, cooperation, or informal organization among farmers.

The intermediate-size areas (from 10 to 20 ha) may fall between the two discussed above. For them, coordination and cooperation among farmers may not be urgent because paddy-to-paddy distribution is reasonably adequate most of the time, or because unauthorized turnouts are possible for these areas, or both.

General discussion

The results indicate that farm-ditch rotation increases efficiency of water use in the dry season. Although the rotation methods differ from those developed in Taiwan, they show promise of being effective. In the wet season, the rotational method was less advantageous because of generally abundant irrigation and rainfall. Gated turnouts with flow-measuring devices provide a reliable and credible basis for directing flow.

These results should be recognized as only being indicative because the numerical relations between the physical control parameters and efficiency of water use were based on a limited set of test sites, and did not include estimates of social factors. An especially energetic ditch tender (as found in two of the Santa Cruz study sites) can significantly affect system performance.

To have more complete control over water and fewer problems with large service areas per turnout, the ditch tender should attend to fewer turnouts. But that would increase the responsibility and, thus, the interdependence of farmers in water management. Farmers may revert to their accustomed and independent ways if they find difficulty in adjusting to the new relationship or if the physical situation encourages their making illegal openings along the canals. Narrow canal embankments and the absence of definitive penalties tend to encourage this behavior.

To increase wet-season efficiencies, a mechanism is needed to reduce the flows in relation to rainfall. This suggests that rainfall monitoring and controlling, and scheduling water releases at various levels all the way to

the diversion gates at the main headworks or dam site would be useful. However, essentially no records of flow diversions were kept, except at the main headgate. Daily reading of the gauges at the headgates of the laterals was instituted to determine the availability of water for the laterals, but except in one lateral and part of another, only sporadic readings were received from the gatekeepers. It is not clear why these data were difficult to obtain. System managers knew only what was being diverted to the main canals. No record was kept on how water was divided and distributed, making it impossible to evaluate a system's operation. Thus, claims by farmers that they do not receive water, or are oversupplied with it, cannot be verified.

A basic requirement is that physical facilities for controlling and measuring water be properly designed and constructed. Accurate topographic maps are needed for careful engineering design, and appropriate flow regimes must be considered in the conveyance channels. Designers should take advantage of local farmers' familiarity and experience with the area of a proposed turnout to select the best site for a turnout structure, and to lay out the supply and drainage ditches. The turnout and other terminal facilities might be better used if farmers were involved in the decision process. Farmers might accept reduced water supplies if they are assured of timely delivery, and if it is demonstrated that reduced but adequate water supplies do not negatively affect their yields. Hence, the assurance of water supply should be complemented by the simultaneous introduction of improved cultural practices to help farmers increase their yields and give them incentives for their extra effort in managing water. Reliable agricultural technicians are needed to introduce farming innovations, and some type of informal association or organization may also be necessary to reduce friction and promote cooperation.

Water masters and ditch tenders identified irrigation problems and made suggestions for their solution. Among the problems mentioned are poor condition of canals and embankments; lack of necessary terminal facilities; and inadequate cooperation among farmers, between farmers and irrigation system personnel, and among system personnel. Communication is clearly poor. Scheduling of water as well as repairs and maintenance is necessary to provide more confidence in and satisfaction with the capability of the systems.

Also mentioned is the need for farm-to-market roads within the command area of the irrigation system to facilitate the transportation of necessary inputs and farm produce. The roads would also permit improved supervision and better operation and maintenance by irrigation system personnel, and would enhance the introduction of allied agricultural technology.

Conclusions and Implications

The conclusions reached follow:

1. The water delivery methods thought to be present differed from those actually observed, especially in the case of the farm-ditch (planned) rotation method. Farm-ditch rotation was different from that used in Taiwan, and was a modification of the demand method, with intermittent closure of turnouts and a form of mixed rotational and simultaneous distribution. Distribution started at the upper parcels and sequenced to the lower reaches. A second modification provided continuous flow at the turnout — with or without a prepared schedule of water delivery — and some form of mixed rotation and simultaneous application.

2. While there was a deliberate attempt to have maximum homogeneity among research sites, significant sources of variation were present in the available water supply, distribution of area per turnout, and general topography.

3. Unusually heavy rainfall caused extensive flooding in Central Luzon and outbreaks of bacterial blight and tungro during 1972. Thus, definitive conclusions could not be made for the wet-season crop. The efficiency of water use for either land preparation or crop growth during that season was not found to be significantly related to water

delivery method, turnout control, or size of turnout area.

4. In the dry season, improved water-delivery methods such as rotational irrigation management were positively correlated with high water-use efficiency during both the land preparation and cropping periods. The degree of water control, which correlated significantly with water delivery method, was also positively correlated with efficiency of water use. But efficiency with medium control and without control differed only slightly. Efficiency patterns differed among turnout service areas of different sizes, with small or large areas having high efficiencies for crop water use after transplanting, and intermediate-size areas having the lowest. Social relationships may explain this pattern.

5. Water-use efficiencies for land preparation were higher for the dry-season crop. But the average duration of land preparation was the same for both seasons, about 40 days.

6. Among the three systems, the turnout areas with highest efficiency of water use were those in Angat, especially those areas with farm-ditch (planned) rotation where previous efforts in water management had been most intensive.

7. If the increasing demands on the systems are to be met and agricultural production increased, dedicated irrigation personnel must be better qualified and trained, and farmers must have greater skill and faith in improved water management. Extensive training in water technology, rice production, and social organization is needed for irrigation personnel and farmers. If such needs are met, reduced water waste at the farm level will increase the efficiency of water use.

References Cited

ADB (Asian Development Bank). 1973. Regional workshop on irrigation water management. Philippines, Thailand and Indonesia, January 1973. 324 p.

Julian, S.I. 1973. Water management innovations in the National Irrigation Administration. Pages 97-112 *in* International Rice Research Institute. Water management in Philippine irrigation systems: research and operations. Los Baños, Philippines.

Kampen, J. 1970. Water losses and water balance studies in lowland rice irrigation. Ph.D. dissertation, Cornell University, Ithaca, N.Y. 416 p.

Levine, G. 1971. The water environment and crop production. Pages 378-395 *in* K.L. Turk, ed. Some issues emerging from recent breakthroughs in food production. Cornell University, Ithaca, N.Y.

Miranda, S.M. 1975. The effects of physical water control parameters on Philippine lowland rice irrigation system performance. Ph.D. dissertation, Cornell University, Ithaca, N.Y. 202 p.

Takase, K. 1972. NIA-ADB Water Management Project. FAO Irrigation Drainage Paper 12: 173-181.

Valera, A., D. Tabbal, R. Reyes, and R. Barker. 1975. The effect of improved water control in irrigation canals on crop production. Paper presented to the Two National Seminars on Water Management and Control at the Farm Level, sponsored by FAO/NIA, 6-11 October, Iloilo, and 13-18 October 1975, Quezon City. 31 p. (mimeo.)

Wickham, T.H. 1971. Water management in the humid tropics: a farm level analysis. Ph.D. dissertation, Cornell University, Ithaca, N.Y. 269 p.

Effects of location and water supply on water shortages in an irrigated area

D. F. TABBAL and T. H. WICKHAM

THE EFFECTS OF LOCATION and hydrologic factors on drought occurrence in the 5,700-ha command area of a lateral in the Philippines' Peñaranda River Irrigation System were studied. Greater moisture stress was observed on fields located further along major canals. Minimum water requirements for rice increased substantially when fields were allowed to dry out and crack during periods of water scarcity because of increased seepage and percolation through the cracks when water was resupplied.

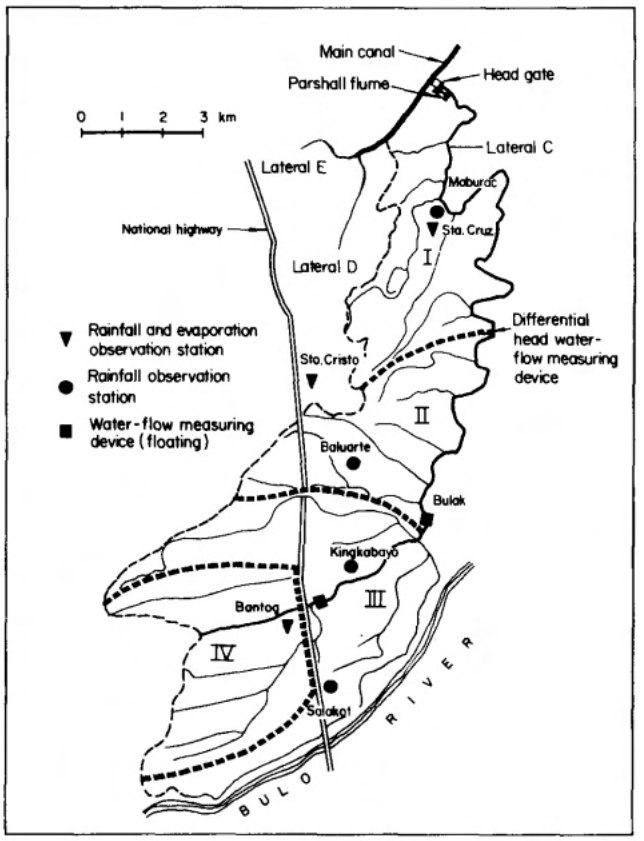
Almost all gravity irrigation systems in the Philippines are run-of-the-river type and were designed mainly to assure the success of the wet-season crop, which is often affected by insufficient rainfall or its untimely occurrence (Regalado et al., 1963). The amount of water that can be diverted from the source into the canal networks and onto farms served by these systems varies greatly from season to season, but is very low during the dry months. On the other hind, development of new production technology has accelerated rice production. Many farmers have shifted to diversified cropping or double-cropping, while others have expanded their areas of production. In either case, more irrigation water is now required to ensure favorable crop growth in those areas. Although the yearly supply of available water in most systems has not changed, the demand for it has increased; hence, the water deficit has become acute. This deficit, aggravated by the low efficiencies at which most system operate, further reduces the water available for crop production. These conditions have prevented most existing systems from satisfying crop water requirements in their service areas.

To overcome the water shortage in systems and thus ensure increased agricultural production, the National Irrigation Administration (NIA) and other agencies are undertaking major projects of integrated water resources development. These projects may consist of reservoir construction, rehabilitation of old systems, adoption of rotational irrigation and land consolidation, as well as the improvement of agricultural production techniques.

Background and Study Objectives

In view of these developments, the Agricultural Economics Department of the International Rice Research Institute (IRRI) and the NIA undertook a joint pilot project on water

D.F. Tabbal, Instructor, Camarines Sur Agricultural College, Pili, Camarines Sur; *T.H. Wickham,* Agricultural Engineer, International Rice Research Institute, Los Baños, Laguna province, Philippines.



1. Command area of Lateral C, Peñaranda River Irrigation System, Philippines, showing sections (I to IV) based on distance from water source.

management during the agricultural years 1973-74 and 1974-75.[1] The project aimed to develop, implement, and evaluate a package of management practices for improved distribution of water along a lateral canal. The management practices involved the rotation or sequencing of water deliveries among sections of the lateral by systematic operation of checks and flashboards in the canals. The project was implemented in Lateral C of the Peñaranda River Irrigation System (PRIS), which serves an area of approximately 5,700 ha (Fig. 1). The project was expected to decrease the tendency to over-irrigate in the upper reaches of the canal, and to provide more water in the lower reaches (Valera et al., 1975). Engineering and economic studies (Obedoza, 1976) were conducted to evaluate the degree to which the anticipated effects were realized. This paper[2] is concerned with the engineering aspects, and was designed to determine the effects of location, hydrologic, and management factors on the occurrence of drought within the command area of Lateral C (Fig. 2).

The location factors studied include soil type T; relative elevation E_r; distance of farm along the lateral canal D_l, measured from its headgate; distance of farm along sublateral canal D_s, measured from its headgate; overland

[1] Only the results of the 1973-74 project are reported here. For a fuller description of the project, see Wickham and Reyes (1974).

[2] Adapted from Tabbal (1975).

distance of farm from turnout D_o; farm ditch density *FD;* and number of intervening farms *Nf.*

The hydrologic factors include the amount of irrigation water flow *Q,* rainfall *RN,* and evaporation *EV.* They reflect the amount of water available in the system and hence the buildup and distribution of drought in the service area.

Management factors include the distribution and scheduling of water to different parts of the system. The most important management practice was periodic checking, or temporary obstruction of water flow by placing wooden boards in specialized canal structures to raise the upstream level of water.

The major objectives of the study were to assess the incidence of drought in different parts of the Lateral C service area and to explain variability in drought incidence by the location, hydrologic, and management factors. Although these factors are interrelated, location and hydrologic effects were quantified separately. The effects of management practices were not included in this analysis because the practices used by the ditch tenders and farmers appeared uniform over the entire area.

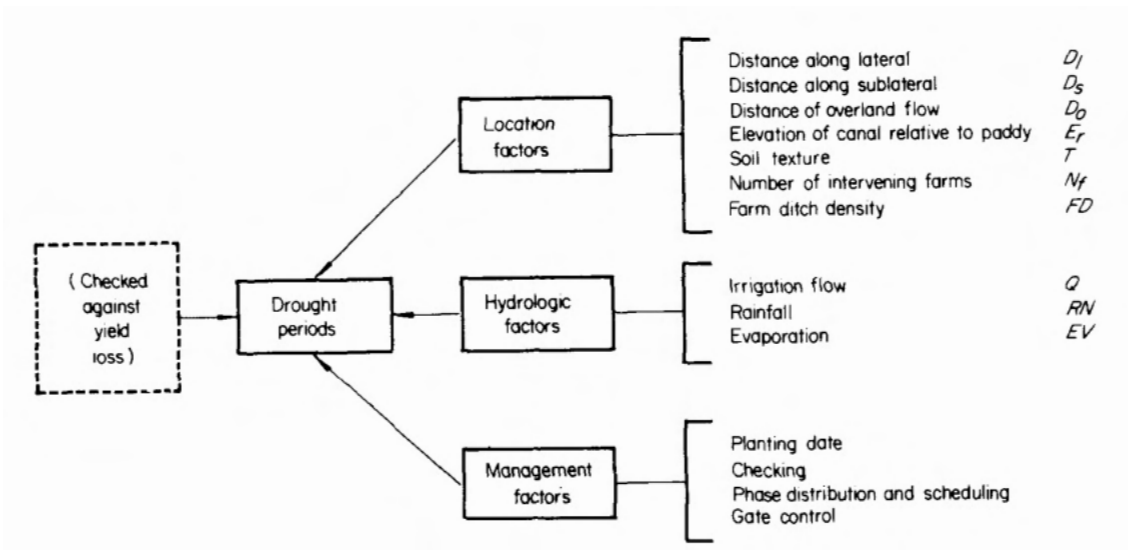
Methodology

The service area of Lateral C was stratified into four sections (I to IV) according to conveyance of water from source to paddy. The boundaries were at points about 25, 50 and 75% of the distance along the canal, measured from the headgate down to the tail end (Fig. 1).

A total of 411 sample paddies within the area were selected and used as the unit of observation and analysis. They were selected on a grid basis with 360 m spacing, or one paddy for roughly every 13 ha.

The occurrence of drought in each paddy was assessed three times a week throughout the wet and dry growing seasons of 1973-74 with the help of PRIS field personnel. The water depth above or below soil surface was measured in a short piezometric tube, and the data were converted to stress days, or days when the paddy is continually without standing water (Wickham, 1973).

The elevation of each paddy relative to the canal bed at the turnout was determined by running a differential leveling survey. The soil texture was estimated from a soil classification



2. Factors that affect the severity and distribution of drought periods in canal-irrigated areas.

report and an accompanying map. The distance of each paddy from its source of water was scaled from detailed air photo maps, and the number of intervening farms between the turnout and the sample paddy was determined through farmer interviews.

Farm ditches were surveyed by flights over the service area of the lateral, during which the ditches were sketched onto detailed air photo maps. The sketched ditches were examined for accuracy by spot checks on the ground. The length of the ditches was scaled from the maps and then divided by the area that they served to determine farm ditch density.

The irrigation water flow at the headworks of the lateral canal was measured with a 3.66 m (12 foot) Parshall flume equipped with continuous recorders. The amount of water turned into each section of the lateral was determined by different flow-measuring devices with continuous recorders at the boundaries of each section along the canal (Fig. 1). The depths of water applied to each section were then computed by dividing the rate of water flow (cu m/s) by the area (sq m) served. These values were later expressed as water depth (mm) on a weekly basis.

Rainfall was measured in six places, and evaporation by class A pans in three locations within the command area. The measurements were taken daily with the help of NIA field personnel assigned in the area and converted to mean weekly sums of rainfall and evaporation (mm) for each section.

Results and Discussion

Effects of location factors on stress days

Multiple regression analysis was used to determine the combined and relative effects of each of the following location factors on the buildup of stress days:

1. distance of the farm from the source of water (in 100 m);
   a. distance along the lateral canal D_l
   b. distance along the sublateral canal D_S
   c. overlanddistance from the turnout D_o
2. farm ditch density FD (m/ha);
3. soil type T (percent clay-size particles); and
4. relative elevation E_r (m).

The model used was

$$SD = a + b(T) + c(E_r) + d(D_l) + e(D_s) + f(D_o) + g(FD)$$

where SD is the number of stress days (the number of days that the paddy has no standing water between the date of transplanting and 25 days before harvest).

The analysis for the wet season resulted in an equation with a very low coefficient of determination because of heavy rainfall, which had uniform distribution throughout the service area. Hence, hardly any stress developed anywhere in the system during that season.

The dry-season analysis (Table 1) showed that the most significant location factors were D_l, D_s, and D_o.

The buildup of stress at increasing distances along the lateral and sublateral canals is almost the same, 0.12 and 0.14 stress days/100 m, respectively; but for D_o there is an increase of 1.42 stress days/100 m. The coefficients indicate that stress buildup per 100-m distance of water flow is greatest for D_o, although the mean distances of such movement are much less than those along D_l and D_s. But as will be discussed later, this does not mean that total stress days caused by overland flow are as many as those caused by D_l and D_s.

The results indicate that more water is applied to farms served by upper portions than to those served by lower portions of lateral or sublateral canals, and that farms located near the turnout have greater access to water than those far from it. The unequal distribution of water is caused by

1. Unscheduled checking, frequently done at night, which farmers in the upper sections resort to during periods of water scarcity;
2. Lack of control gates at the sublateral headworks and on turnouts, which cause water to flow freely through those openings even though their service areas may already have been oversupplied;
3. Presence of numerous unauthorized turnouts along the lateral and sublateral canals, which divert considerable quantities of water, especially in conjunction with unregulated checking. Their number greatly exceeds that of the authorized ones;

4. Partial silting of canal beds, which results in overflows at embankments of upstream sections, but only moderate flows and depths downstream;

5. Presence of numerous pumps drawing water from the first two sections of the lateral to irrigate adjacent rainfed areas, which further reduces the water available to downstream reaches of the canal;

6. Better control over water by farmers nearer the turnout than by those farther away. In times of scarcity, the farmer nearer the turnout may not allow the farmer next to him to receive water until his own needs have first been satisfied;

7. Water losses through surface drainage, seepage, and percolation, which are largely due to irrigation oversupply; and

8. Paddy-to-paddy water movement on irregular topography, which tends to result in water lost as surface drainage.

The effect of farm ditch density on the occurrence of stress days was ambiguous in the regression analysis (Table 1). In fact, the sign of the coefficient was positive, suggesting increased stress incidence with greater farm ditch density, but the coefficient was not significant. However, the simple correlation between farm ditch density and stress days was negative, as expected, but not significant.

A preliminary regression trial in which the number of intervening farms N_f from the turnout was included in the model indicated that *SD* was not significantly affected by N_f. This implies that *SD* is more closely associated with D_o than with N_f.

When mean measured values were substituted for the location variables D_l, D_s, and D_o, the mean stress days estimated by the regression model of Table 1 were 12.5 for section I, 26.3 for II, 34.9 for III, and 35.4 for IV. Mean stress days from field observations were 13.3, 25.4, 34.3, and 36.4 for the same sections, indicating that the model and its distance variables account very well for field incidence of stress (Table 2). Yield reduction associated with those stress days is about 0.2, 0.4, 0.6, and 0.7 t/ha for the four sections. based on the model Y = 2.70 - 0.0 17*SD*. Weighting each section by its planted area, we can compute a mean of 25.8 stress days for the entire system, and a mean yield loss of 0.5 t/ha.

Table 1. Estimated coefficients and means of regression equations[a] relating stress days to location factors. Lateral C, Peñaranda River Irrigation System, Central Luzon, Philippines, 1974 dry season

Variable	Coefficient	t-values[b]	Means	Standard deviations of the mean
Stress days *SD* (no.)			25.97	1.44
Constant a (days)	–5.380			
Percent clay *T* (%)	+0.068	0.84	61.66	1.28
Relative elevation E_r (m)	–1.13	–1.06	0.39	0.09
Distance along lateral D_l (hundred m)	+0.12	5.92**	155.30	4.80
Distance along sub-lateral D_s (hundred m)	+0.14	2.64**	23.45	1.83
Overland distance D_o (hundred m)	+1.42	1.98*	2.47	0.13
Farm ditch density *FD* (m/ha)	+0.18	1.70	11.68	0.84
Observations (no.)	206			
R^2	0.27			
F-test		12.19**		

[a]For the model $SD = a + b(T) + c(E_r) + d(D_l) + e(D_s) + f(D_o) + g(FD)$. [b]*significant at 5% level; ** significant at 1% level.

Table 2. Computed stress days[a] and yield reduction[b] by section, Lateral C, Peñaranda River Irrigation System, Central Luzon, Philippines, 1974 dry season.

Section	Item	Effects of distance				
		Along lateral (D_l)	Along sublateral (D_s)	Over-land (D_o)	Total	Measured stress days (no.)
I	Stress days (no.)	6.6	2.1	3.8	12.5	13.3
	Yield reduction (t/ha)	0.1	0.0	0.1	0.2	
II	Stress days (no.)	20.4	2.4	3.5	26.3	25.4
	Yield reduction (t/ha)	0.3	0.0	0.1	0.4	
III	Stress days (no.)	24.5	5.8	4.6	34.9	34.3
	Yield reduction (t/ha)	0.4	0.1	0.1	0.6	
IV	Stress days (no.)	28.4	3.2	3.8	35.4	36.4
	Yield reduction (t/ha)	0.5	0.1	0.1	0.7	
Weighted av.						
	Stress days (no.)	18.3	3.5	4.0	25.8	25.7
	Yield reduction (t/ha)	0.3	0.1	0.1	0.5	

[a] Computed by the model $SD = 0.49 + 0.12\ D_l + 0.14\ D_s + 1.42\ D_o$. [b] Computed by the model $Y = 2.70 - 0.017SD$.

The number of stress days in the entire system attributable only to D_l is 18.3, while that attributable to D_s and D_o are 3.5 and 4.0, respectively (Table 2). Similarly, yield reduction with D_l, D_s and D_o are 0.3, 0.1, and 0.1 t/ha, respectively. It is apparent that water movement along the lateral canal is more of a constraint to equitable water distribution and high yields than is overland water movement from the turnout to the fields, even though overland flow is from paddy to paddy, and has a higher stress incidence per 100 m of travel. Overall yield reduction and stress days associated with D_l were more than four times that with D_s or D_o.

These findings indicate that first priority should be given to managing the primary canals of an irrigation system and providing equitable water flows to the lower reaches, rather than focusing on on-farm water movement, which is often the subject of current improvement schemes. Care for on-farm water distribution can also be expected to give high returns, but only after water distribution in the main system is reasonably equitable.

Effects of hydrologic factors on stress days

The effect of irrigation flow VQ, rainfall *RN*, and evaporation *EV* on stress days *SD* was evaluated using multiple regression analysis as in the previous section. The first approach was made with the model

$$SD_i = a + b(Q_i) + c(RN_i) + d(EV_i)$$

where SD_i is the weighted average number of stress days per paddy in the ith week for each of the four sections. Weighted average stress days over a section was used because the irrigation flow Q could only be measured for whole sections, and not for each paddy. Q_i, the weekly average irrigation depth in the ith week (mm/wk), was computed by dividing the irrigation flow to each of the four sections by the area planted. RN_i and EV_i are depths of rainfall and evaporation in the ith week (mm/wk).

The analysis showed that only evaporation EV_i had a significant effect on stress days for the first three sections (Table 3). In the fourth section both Q_i and EV_i significantly affected stress days.

The significant relationship between evapora-

Table 3. Regression equations relating stress days to water flow, rainfall, and evaporation by section of canal, Lateral C, Peñaranda River Irrigation System, Philippines, 1974 dry season.

Section	Regression equation[a]	R^2	Observations (no. of wk)
I	SD = 3.57 - 0.013 Q - 0.0064 RN + 0.12EV (−1.68) (−0.54) (2.78)*	0.54	18
II	SD = 3.48 - 0.011 Q + 0.0062 RN + 0.14EV (−1.64) (0.29) (4.71)*	0.51	21
III	SD = 6.10 + 0.0059 Q - 0.012 RN + 0.020 EV (0.59) (— 1.17) (4.09)**	0.48	29
IV	SD = 5.31 - 0.049 Q + 0.057 RN + 0.22EV (2.34)* (2.05) (3.21)**	0.57	21

[a] Q is irrigation flow, RN is rainfall and EV is evaporation, all in millimeters per week. The computed *t*-value for each coefficient is shown below the coefficient. * significant at 5% level; ** significant at 1% level.

tion and stress days should be interpreted with caution. The seasonal trend shows evaporation rates and stress-day buildup to be correlated, but only indirectly. Stress-day buildup accelerated as soils gradually dried out; the drying out was associated directly with reduction in available water supply and indirectly with higher evaporation rates that occurred late in the dry season. Evaporation thus tended to increase as water supply became scarce and rainfall diminished. These factors, coupled with increased evaporation due to high solar radiation, severely depleted moisture stored in the paddy, especially in the last three sections.

We therefore refined the model with the use of an excess-water term EX_i:

$$SD_i = a + b(EX_i)$$

where $EX = (Q + RN - EV)$ is the excess water supplied $(Q + RN)$ less the evaporative demand (EV). The term EX can be used as an index of the quantity of water available for crop production. EX does not take into account water lost by seepage and percolation; hence, at small EX values some stress days are expected.

The preliminary results of the model were not satisfactory because the response in stress days was observed to lag behind major changes of excess water; also, after a long period of water stress, a much larger quantity of water was required to give an equivalent reduction in stress days.

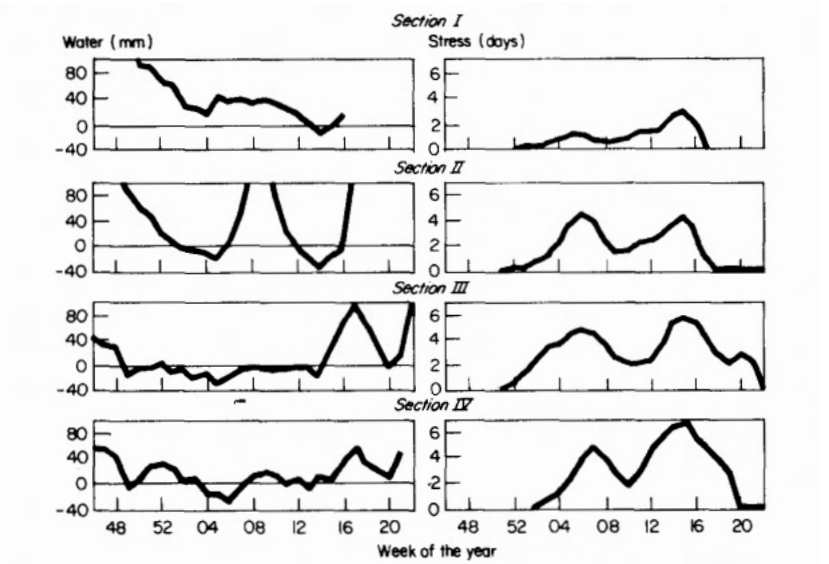
In a final analysis, a 3-week moving average was computed for both stress days (SD_i) and excess water (EX_i). The values were plotted (Fig. 3) and examined to get a clearer idea of the relationship. It was then decided to fit the model:

$$SD_i + 1 = a + b(EX_i)$$

where $SD_i + 1$ is the number of stress days for the $_ith + 1$ week.

The equation was computed separately for each of the two periods of stress. The first period began at transplanting and continued until there were indications of severe moisture deficit or stress (Fig. 3). The second period extended from this point until harvest. The regression analysis, was made using different boundaries between the two stages to determine which gave the best coefficient of determination. A two-stage model is used because prior to significant stress buildup there was reserve water in the soil; this reserve water did not exist in the second stage because the soil moisture content had been depleted. In addition, the wide soil cracks that developed during the earlier stress period increased subsequent water requirements.

The analysis indicates that for all sections the intercept term in the model is greater for the second period than for the first (Table 4). More EX was required in the second than in the first stage to reduce the stress days to zero for the last three sections.



3. Weekly values of excess water (irrigation + rainfall - evaporation) and stress days (mean days per week the area is not flooded) for four sections of Lateral C, Peñaranda River Irrigation System, Philippines, 1974 dry season.

The amount of water required to reduce *SD* to zero in the second period for the three sections was more than 200 mm/week, compared with only 67 mm/week in the first section. These values were from 4 to 20 times greater than the corresponding levels of *EX* in the first stage for the last three sections, but for section I there was little difference between the two stages. The reason is that there were more stress days in the last three sections than in the first, causing the soils to dry and crack. Thus, more water was lost through seepage, percolation, and drainage when water was reapplied in the second period. In section I there was not much difference between the first and second stages because stress incidence was relatively minor, and the soil moisture condition was nearly constant throughout the season.

Conclusions

The distribution of stress days depends on location, hydrologic, and management factors. Their effects cannot be entirely separated

Table 4. Regression [a] coefficients and predicted values of excess water needed to reduce the number of stress days to zero for two periods [b] by section of Lateral C, Peñaranda River Irrigation System, Philippines, 1974 dry season.

Parameter	Section I		Section II		Section III		Section IV	
	1	2	1	2	1	2	1	2
Intercept [a]	1.39	2.34	1.42	3.43	1.69	3.55	1.64	4.46
Slope [b]	- 0.02	- 0.03	- 0.03	- 0.02	- 0.03	- 0.01	- 0.07	- 0.02
R^2	0.73	0.87	0.65	0.85	0.76	0.14	0.85	0.05
Observations (no. of wk)	5	11	5	12	5	17	4	13
Excess water required to reduce SD to zero (mm/wk)	70	67	49	202	13	273	25	297

[a] For the model $SD_i + 1 = a + b\ (EX_i)$. [b] Period 2 follows the first major period of drought.

because they are interrelated and sometimes overlap.

The most important location factors that affect the incidence of drought within an irrigation system are 1) location of the farms along the lateral canal, 2) location of the farms along the sublateral canal, and 3) overland distance from the turnout to the farm. The farms experienced an average of 0.12 and 0.14 stress days, respectively, for every additional 100-m distance along the lateral and sublateral canals, and about 1.42 stress days for every 100 m of overland distance between the turnout and the farm.

Stress-day buildup tended to be concentrated in two periods. The first period was from transplanting to a time of severe soil moisture stress causing the soil to crack; the second period then followed. These periods roughly correspond to the vegetative and early reproductive growth stages of the crops in Lateral C during the 1974 dry season.

Farms in the first section of Lateral C did not experience severe stress, so the average water requirements did not vary much during the season. In the other three sections, the amount of water needed to minimize the number of stress days was between 4 and 20 times greater after the first stress period than before. That is because there is less stored moisture in the soil, and because more water is lost to seepage and percolation after severe stress periods during which the soil cracks.

These results are important in deciding which areas to give priority to when water flow is insufficient to irrigate the entire planted area. The usual recommendation is to irrigate the areas with crops in the early reproductive growth stage because rice plants at that stage (60 to 25 days before harvest) have been found much more sensitive to water stress than plants at vegetative growth (IRRI, 1973). However, this study documents greatly increased water requirements after a stress period. If the stress period occurs in newly planted fields, the increased requirement would have to be provided for a longer time than would be necessary if the stress occurred in plantings of advanced maturity. The policy of imposing emergency water stress on young crops would thus result in greater total water requirements for the entire season than would a policy of stressing older crops. The greater need for water over several months would increase the risk of additional stress later in the season.

It should be noted that these findings are influenced by the conditions of the study: traditional canals with numerous ungated turnouts, rather deteriorated canal sections, and relatively steep on-farm topography. It is recommended that research be carried out on irrigation systems operating under a range of conditions, to provide conclusions about the effects of water shortages for those conditions.

References Cited

International Rice Research Institute. 1973. Annual report for 1972. Los Baños, Philippines. 246 p.

Obedoza, R. 1976. Water adequacy at the farm level: its influence on input use and rice yield. Unpublished MS thesis, University of the Philippines at Los Baños, Laguna, Philippines.

Regalado, F.N., P.C. Camanga, and M.P. Leuterio. 1963. Management and operation of irrigation and drainage systems in the Philippines. 12 p. (mimeo.)

Tabbal, D.F. 1975. The distribution of water supply and water adequacy within a gravity irrigation system. Unpublished MS thesis, University of the Philippines at Los Baños, Laguna, Philippines.

Valera, A., D. Tabbal, R. Reyes, and R. Barker. 1975. The effect of improved water control in irrigation canals on crop production. Paper presented at the National Seminar on Water Management and Control at the Farm Level, October 6-18, 1975, Iloilo and Quezon City, Philippines. (mimeo.)

Wickham, T. 1973. Predicting yield benefits in lowland rice through a water balance model. Pages 155-181 *in* International Rice Research Institute, Water management in Philippine irrigation systems: research and operations. Los Baños, Philippines.

Wickham, T., and R. Reyes. 1974. An extensive pilot project on water management. Paper presented at the Saturday seminar, August 3. International Rice Research Institute, Los Baños, Philippines. 15 p. (mimeo.)

The water management training program of the Upper Pampanga River Project, National Irrigation Administration, Philippines

B. BAGADION, R. GAMBOA, L. ABESAMIS, and R.C. LAZARO

THE CURRICULUM FOR THE NEW TRAINING PROGRAM for water management technologists in the Philippines deals with irrigation water management, rice crop production, and group action related to irrigator behavior. The training program is divided into five phases: a 4-week orientation-field experience, a 3-week live-in seminar, two seasons of on-the-job field training, 2-week evaluation and planning workshops after each season, and an evaluation of the performance of trainees during the first 2 years in their field assignments. The paper includes an evaluation of the first year of the program.

The Upper Pampanga River Project (UPRP) is the largest irrigation system in the Philippines. The original plan was to irrigate about 77,000 ha of rice land with water from the Pantabangan dam and reservoir. But with the Aurora Transbasin Diversion Project supplying additional water to the reservoir and the consequent integration of the Peñaranda River Irrigation System into the UPRP, the total irrigation service area will be about 102,000 ha.

Efficient water management is essential for the success of this large project. Toward that end, water measurement devices, gated turnouts, and farm ditch networks were provided for rotational irrigation delivery. Each rotational area covers about 50 ha and is divided into subunits of about 10 ha.

Before the Pantabangan Dam was completed, pilot areas for improving water management had been established. Early experience with the pilot projects suggested, however, that in addition to the installation of terminal facilities, two conditions for efficient water distribution had to be met:

1. Availability of personnel who could manage efficiently water deliveries in relation to farming operations, crop requirements, and weather conditions; and
2. Acceptance by farmers of water delivery schedules, practices, and farming methods that would conserve irrigation water.

These preliminary findings were confirmed

B. Bagadion, Assistant Administrator for Special Projects; *R. Gamboa,* Irrigation Engineer, Water Management Training, Upper Pampanga River Project; *L. Abesamis,* Acting Program Director, Water Management Training, Upper Pampanga River Project; and *R. Lazaro,* Agricultural Director, Office of Special Projects; all of National Irrigation Administration, Greenhills, San Juan, Rizal, Philippines.

in a sociological study of the pilot areas (Wickham and Wickham, 1974), which concluded that farmers' acceptance of improved irrigation practices would follow if terminal irrigation facilities are adequate and if the farm-level personnel of the systems have the skills needed to achieve efficient water management and effective relations with farmers. Consequently, a proposal to improve the skills of irrigation personnel through practical in-the-field and on-the-job training was prepared and submitted for funding to the World Bank (National Irrigation Administration [NIA], 1975). The project was approved and, in June 1975, the first trainees reported for instruction.

Program Objectives

The training program is geared principally toward the professional development of effective water management technologists (WMT) to help realize the goals of the UPRP. It entails training 325 WMT in groups of 60 to 70 during each of 5 years. After that period, the plan is to train staff from other irrigation projects.

The training program aims to 1) provide the UPRP with WMT who know the operational aspects of irrigation water management, irrigated crop production, and human resource development; 2) enable the WMT, in coordination with farmer-irrigators, to plan and implement the rotational delivery of irrigation water according to previously developed cropping patterns and farming schedules; 3). enable the project, mainly through the WMT and farmers, to increase water-use efficiency from about 25 to about 75%; and 4) increase irrigated rice yields from 2.2 to 3.8 t/ha for the wet season and from 2.6 to 4.2 t/ha for the dry season.

The training materials and teaching-learning activities were developed in specific relation to the WMT job description contained in the UPRP progress report (1975). The "performance discrepancy model for training design" (Hickerson and Middleton, 1975; Lazaro, 1975), in which the gap between desired on-the-job performance and actual performance of staff is first identified, was followed. A training program was then designed with the specific objective of closing the gap.

Training Facilities and Staff

The main building of the Water Management Training Program is within the 3-ha UPRP-NIA complex at the Central Luzon State University reservation in Muñoz, Nueva Ecija. It contains two offices, two small-group discussion rooms, a recreation room, an auditorium with 120 seats, two audiovisual rooms, a canteen with space for 120 persons, and a 26-room dormitory. The center has a built-in sound system and intercom, and is provided with movie, slide, and opaque projectors and two minibuses.

Pilot training areas of about 500 ha each have been established in each of the four districts of the UPRP. One such training area was also set up in the Tarlac Irrigation System Improvement Project, a special project of NIA attached to UPRP.

Within each pilot area is a district training center with 176 sq m of floor space for office, conference, storage, living rooms, and an assembly hall. Each center is supplied with one pickup truck, two motorcycles, two bicycles, typewriters, calculators, and meeting tables. The centers can respond to requests from the district for other equipment such as hydro-meteorological instruments, public address systems, tape recorders, rice threshers, and hand tractors.

The training center staff in Muñoz includes a program director, a rural sociologist or psychologist, two agricultural specialists, a water management specialist, a farm manager, an agricultural information specialist, and a line of support staff.

The center staff plans and manages the activities of the trainees during their live-in seminar training (Phase II), and the evaluation and planning workshop (Phase IV), and any other training activities held in the center. During on-the-job training (Phase III), center specialists, with assistance from the district training staff, monitor the field activities and

performance of trainees and prepare training plans and reports.

The district training centers are staffed with a district training coordinator, a crop production and protection specialist, a water management specialist, a driver or utility man, and a records clerk.

The staff in each district plans and manages the on-the-job training activities in its pilot area and provides guidance to its trainees. District staff members also assist the center staff when their trainees are at the center.

Nature of Training Program

Program scope

Training is focused mainly on irrigation water management, irrigated rice crop production, irrigator behavior, and group action. It involves both knowledge and application of such subjects as

1. Reading and recording data from water-measuring devices; determining and computing water requirements; accounting for water utilization through water-balance analysis; collecting simple data as rates of rainfall, evaporation, seepage, and percolation; controlling and supervising field deliveries of water; and controlling surface drainage losses;
2. Irrigated rice crop production and its cultural requirements, including pest and disease control, weed control, fertilizer management, farm credit, and other inputs; and
3. Organization of irrigators' groups, farmer involvement in cooperative action, human relations, and leadership and management of human resources.

Methodology and phases

The training program focuses on practical information and processes. Program implementation is divided into five phases:

Phase I - Orientation-field experience. Phase I is a 4-week field exposure and frustration period. Each trainee receives an area assignment, observes and calls farmers' meetings, and works as a water tender. He must react to such field-simulated crises as water stress, floods, and dirty ditches. He also makes farm inventories and gathers other data from his area and its fanners.

Phase II – Live-in seminar training. Phase II is 3 weeks long. It consists of half days of "tell-show-do" activities in the classroom and half days of work involving irrigation water management, irrigated crop production, and human relations.

Phase III – On-the-job training. Phase III covers two seasons of field experience in district centers. Each trainee is assigned a specific area for which he plans, programs the work, and implements the schedules. He also gathers, analyzes, and uses field data dealing with water management, rice production, farmer behavior, and group action.

Phase IV – Evaluation and planning workshop. After the first period of on-the-job training, the trainees and trainers meet for 2 weeks at the Center to evaluate the season's activities and plan for the next season.

Phase V – Performance evaluation. After the above training, which lasts 1 year, the trainees are posted to their normal field assignments of about 600 ha each. Each plans and implements water management activities in his area. During this 2-year phase, the trainees receive minimum supervision by the training program staff. Their on-the-job performance is evaluated to gain insights for possible changes in the training program that may make it more responsive to the needs of UPRP.

Administration and logistics

The training program director has overall responsibility for management, control, and supervision of the training program. Trainees are under the administrative and supervisory control of the program management through the district training coordinators. The program provides salaries for the training staff, while the UPRP district offices provide salaries for their trainees.

Implementation of Training Program, 1975-76

The first training program began in June 1975 with 53 trainees. This section briefly

reviews the trainees' and trainers' evaluation of the program.

Phase I — Orientation-field experience

The field exercise during Phase I was implemented with little explanation of its purposes. During participation in the exercise, most trainees felt frustrated. In retrospect, however, they found it useful, particularly because it enabled them to personally experience some of the difficulties that their subordinates commonly face.

The trainees recommended:

1. That the next group of trainees be informed in more detail of the objectives of Phase I and its relation to the other phases of the training program; and
2. That this phase be reduced from 4 to 2 weeks to give more time to Phase II.

Phase II — Live-in seminar training

At the start of Phase II, the trainees were given an examination to determine the topics that should be emphasized in the classroom and in the field. The trainees' profiles were also explored. A second examination at the end of Phase II determined the extent to which its teaching-learning objectives were met. The mean score on the examination increased from 37 to 78% after Phase II, reflecting substantial value from it.

Among the recommendations derived from the trainees' evaluation of Phase II were the following:

I. Devote more time to discussing common field problems;

2. Rearrange the presentation so that human resource development comes in the first week, rice production in the second, and water management in the third;

3. Give refresher courses that focus on areas of weakness of individual trainees; and

4. Assess more carefully the trainees' intelligence levels and relate the scores with their performance during Phase II.

Phase III — On-the-job training (first session)

The only evaluation results available are for the District II training area of 658 ha during the 1975 wet season. The trainees in this area collected data to better understand the irrigation requirements. The results follow:

Land preparation. Land soaking took 23 days and land preparation 30 days (Table 1). Total water use was 236 mm or an average of

Table 1. Assessment of water requirements and management at District II Pilot Training Area, Upper Pampanga River Project, Philippines, 1975 wet season.

Item	Activity		
	Land soaking	Land preparation	Normal crop growth
Duration of farming activities[a] (days)	23	30	88
Assume rainfall effectivity (% of total rainfall)	100	68	94
Effective rainfall (% of total water use)	62	62	48
Total water use (mm)	236	249	802
Av water applied (mm/day)	10.2	8.3	9.1
Estimated av. water required (P + ET)[b] (mm/day)	6.2	5.9	6.2
Farm-level water-use efficiency[c] (%)	61	71	68

[a] Transplanting the entire area spanned 21 days. [b] P = percolation; ET = evapotranspiration
[c] Efficiency = Av. water required c Av. water applied.

Table 2. Average daily water applied and required, Upper Pampanga River Project study sites and District II Pilot Training Area, Philippines, 1971-75 wet season.

Site	Year	Area (ha)	Av. water applied (mm/day)	Av. water required[a] (mm/day)	Farm-level efficiency[b]
Pamaldan Cinco-Cinco Rotational Area	1971	29	17.9	6.0	34
Gen. Ricarte Rotational Area	1973	509	13.5	8.5	62
District II Training Area	1975	658	9.2	6.1	67

[a] Based on lysimeter tank observations from another location.
[b] Farm-level efficiency = Av. water required + Av. water applied.

10.2 mm/day for soaking, and 249 mm or an average of 8.3 mm/day for the entire land preparation process. Of the water used during these periods, 62% came from rainfall. The rainfall during land soaking was assumed to be 100% effective, while rainfall during land preparation was 68% effective.

Normal crop growth. For normal crop growth, 802 mm of water, or an average of 9.1 mm/day, was used. Forty-eight percent of the water was from rainfall; 94% of it was assumed to be used effectively.

The percolation and evapotranspiration (P + ET) requirements were 6.2 mm/day during land soaking, 5.9 during land preparation, and 6.2 during normal crop growth. Using the equation

$$\text{Water use efficiency (\%)} = \frac{P + ET}{\text{water applied}} \times 100$$

resulted in mean water-use efficiencies of 61% for land soaking, 71% for land preparation, and 68% for normal crop growth, or an average of 67% for the whole season.

Water-balance studies had also been conducted in two areas of the UPRP in which no changes in farmers' water-management practices were introduced. The results from those two earlier studies were compared with those from the District II training area (Table 2).

The average water requirement for the General Ricarte Rotational Area was 8.5 mm/day. It is substantially greater than that for the two other sites because of its coarser textured soils and, therefore, higher percolation. The average daily water application varied from 9.2 mm/day in the training area to 17.9 mm/day in Pamaldan Cinco-Cinco Rotational Area. Efficiency of water use varied from 34% in the Pamaldan Cinco-Cinco Rotational Area to 67% in the training area (Table 2). The difference can be attributed largely to the training area's improved irrigation management.

Farming information gathered from the pilot training areas provided a bench mark for later stages in the training program. About 2,000 farmers cultivated the 2,235 ha in the pilot training areas. They planted 29 rice varieties, about 98% of which are modern varieties; 97% of the farmers used fertilizers. The average yield of the 1975 wet-season crop was 3.0 t/ha.

The trainees expressed the following observations concerning farmer participation in distributing water and repairing and maintaining on-farm facilities and structures:

1. Most farmers who were properly informed complied with their responsibilities. The irrigators' groups were used to discipline

erring members;

2. Farmers generally had a "wait and see" attitude toward the new scheme of rotational water distribution;

3. Farmer cooperation was achieved on only those issues for which needs were felt;

4. About 95% of the farmers believed that responsibility for on-farm water distribution should be given to the chairmen of the irrigators' groups;

5. About 95% of the farmers were willing to participate in the repair, improvement, and maintenance of farm facilities and structures if they thought that such participation would facilitate water distribution; and

6. About 73% of the farmers preferred that farm ditches be maintained by groups rather than by individuals.

Phase IV — Evaluation and planning workshop

The field performance of trainees was evaluated by the trainers, and the trainers' field performance was evaluated by the trainees. The action programs undertaken in the district training areas were also evaluated. Revisions of district action programs were made and presented to the group for evaluation and criticism.

Recommendations from the evaluation and planning workshop were as follows:

1. Develop final WMT job descriptions to be used as a basis for improved training objectives;

2. Enrich the material in human resource management and relate it more closely to materials in water management and irrigated rice production;

3. Improve instruction on communication;

4. Improve facilities at the district training centers and provide mini-libraries;

5. Improve managerial skills of trainers through management training outside the agency; and

6. Provide regular in-service training for trainers.

The training program outlined in this paper is expected to undergo many changes to benefit from experience gained during its first year. With such changes, it is hoped that the program will provide the field staff of the UPRP with the necessary motivation and qualifications to provide water for modern and productive agriculture in the area.

References Cited

Hickemon, F.J., and J. Middleton. 1975. Helping people learn: module for trainers. East-West Center. Honolulu. 50 p. (mimeo.)

Lazaro, R.C. 1975. In-service training program development for mid-level managing personnel. (unpubl.)

National Irrigation Administration (NIA). 1975. Proposed training program in implementation scheme for the water management technologist in the Upper Pampanga River Project. Proposal to the World Bank. (unpubl.)

Upper Pampanga River Proiect (UPRP). 1975. Water management training program progress report. Unpublished report to the UPRP management. 12 p.

Wickham, G.Y., and T.H. Wickham, ed. 1974. An evaluation of two alternatives of water-sharing among farmers. Unpublished mimeographed report to the UPRP management. Vol. I. 34 p.

ECONOMIC ANALYSES OF IRRIGATION

Financing irrigation services in the Pekalen Sampean Irrigation Project, East Java, Indonesia

D.C. TAYLOR

THE UNDERLYING ISSUE of the study is whether irrigation charges should be increased in the 274,000-ha river-diversion Pekalen Sampean Irrigation Project in East Java, Indonesia. The study shows that even though Indonesia has no nominal water tax, farmers are already paying more for irrigation water than what is being spent on operations and maintenance in the project. While farmers receive economic benefit from irrigation, farm sizes are so small that annual agricultural incomes in irrigated areas are only about $20 per capita. These findings, plus the fact that government, agro-industries, and the food-consuming public also benefit substantially from irrigation, suggest caution in approaching the possibility of increasing the water charges payable by farmers.

This paper examines various issues in financing irrigation services in the Pekalen Sampean Irrigation Project (PSIP) in East Java, Indonesia.[1] The first of five sections provides background information on the nature of the PSIP and some perspective on the study. The second examines the irrigation benefits to farmers and offers a basis for determining the ability of farmers to pay for water. The third examines the nature and extent of farmers' current payments for irrigation. The fourth deals with current and prospective expenditures for operation and maintenance (O&M). The final section draws on these findings and examines financial policy options for future irrigation development in the PSIP. The options include the possibility that farmers might be assessed higher water rates and that these rates might be in the form of direct payments for water rather than the present system of indirect land taxes.

Background

The PSIP is one of Indonesia's oldest and largest irrigation projects. Its first infrastructure was constructed as early as 1781 to provide irrigation for the export crop sugarcane. Later facilities were developed for additional sugarcane and for the irrigation of rice and upland crops. The present command area of the project is about 274,000 ha.

D. C. Taylor, Associate, Agricultural Development Council, 20 Jalan Cangkat Damansara, Kuala Lumpur 10-05, Malaysia.

[1]For a more detailed version of this paper, including an outline of conceptual issues in the formulation of financial policies in Asian gravity-flow irrigation systems, see Taylor (1976).

The PSIP involves gravity-flow, run-of-the river diversion of water into 139 more or less independent (regarding water source) irrigation systems ranging in size from 27 to 17,770 ha and averaging about 2,000 ha each. The systems include primary, secondary, and tertiary blocks, with each tertiary block commonly covering from 100 to 200 ha.

As in other Indonesian irrigation projects, the Provincial Irrigation Service has responsibility for the main irrigation systems (headworks and primary and secondary channels), and the local communities are responsible for the terminal systems (tertiary channels and other infrastructure reaching down to the farm).

Administratively, the PSIP consists of three irrigation districts, within which there are 11 irrigation sections. Below the sections are subsections and sub-subsections. The head of the sub-subsection is the *Juru-Pengairan,* a key figure in the allocation and distribution of irrigation water and the government's link with the community irrigation representatives, the village ditch tenders, *ulu-ulu desa.*

The project area has two distinctive seasons: the west-monsoon wet season lasting from October to April, and the east-monsoon dry season from May to October. Annual rainfall varies from 1,500 mm to more than 2,000 mm in certain parts of the area. Only paddy is grown during the wet season. Paddy may also be grown during the dry season, but crops such as soybeans, maize, and tobacco are common.

The basic irrigation infrastructure of the PSIP has deteriorated considerably, especially since World War II. A major rehabilitation of the project was therefore initiated in the early 1970s, with partial support from a World Bank-International Development Association (IDA) loan. In accepting the IDA loan, the Indonesian government agreed that charges would be assessed on the irrigable land served by the PSIP, or on the users of such land, in an amount sufficient to offset the O&M expenses required by the project after rehabilitation.

The government, through its Ministry of Agriculture, asked the Agro-Economic Survey (AES) to undertake a research project to determine a level of water rate sufficient to offset expected O&M expenses, but which would also be commensurate with farm benefits derived from irrigation. The research involved a 1973-74 study of six irrigation systems in the Rawatamtu and Jember sections of the Bundowoso Irrigation District. In each irrigation system, two tertiary blocks were selected and within each tertiary block, 15 farmers and all irrigation personnel were interviewed. Data were also collected from certain higher levels within government administration.

The overall results of the research are officially reported in the AES (Agro-Economic Survey) (1975). The present paper draws on, and in some cases goes beyond, the findings presented in that report. It includes findings from related studies.

Benefits from Irrigation

The terms of reference for the research called for an estimate of the benefits from rehabilitating the project, with the assumption that the benefits would represent farmers' ability to pay for irrigation. In addition, the research estimated the benefits from the use of irrigation water in the project area because the ability of farmers to pay for water depends fundamentally on the benefit currently derived from its use, not just the benefits from a one-time improvement made on the irrigation infrastructure.[2]

Rehabilitation Benefits

In measuring the benefits of rehabilitation, three types of irrigation systems were identified:

1. Type H, with the highest rehabilitation expenditure per hectare, to represent the most extreme before-rehabilitation situation;
2. Type L, with the lowest rehabilitation expenditure per hectare, to represent the after-rehabilitation situation; and
3. Type M, with intermediate expenditure, to represent the average before-rehabilitation situation.

[2] With the limited time and other restrictions of the study, no explicit attempt was made to measure indirect benefits of irrigation, or nonirrigation benefits such as flood control. However, some data suggesting the extent of indirect benefits from irrigation were generated as a side effect of the effort to estimate direct benefits.

Efforts were made to pick irrigation systems and tertiary blocks that were as uniform as possible in their ecological environments and agrisupport services. Comparable groups of farmers who were not receiving irrigation water (Type N) served as control in estimating returns resulting from the use of irrigation water.

Individual crop performance in each of the two tertiary blocks within an irrigation system, as well as for the N situation, was monitored for a year, with attention given to production expenditures, yields, and gross returns. Net income (NI) per hectare was assessed for each crop in each season and also for each block for the period of a full year.[3] The benefit due to rehabilitation was then computed:

$NI_L - NI_M$ as an estimate of average expected benefit; and

$NI_L - NI_H$ as an estimate of maximum expected benefit.

The overall benefit to irrigation was computed:

$NI_M - NI_N$ as an estimate of average expected benefit; and

$NI_L - NI_N$ as an estimate of maximum expected benefit.

The results showed that rehabilitation had no immediate impact on production. In fact the mean net income was highest for the high rehabilitation-cost situation (H). Why there was no evidence of benefit from rehabilitation is not known for sure, but possible explanations include the following:

1. Factors other than the need for rehabilitation may not have been equal among the sampled systems and tertiary blocks. For example, systems with the highest rehabilitation expenditures may be in difficult terrains where more control structures and, hence, higher costs per hectare were required. Another possibility is that soils are more productive in the H tertiary blocks. Some empirical evidence is available to support this point of view.

2. The availability of regular supplies of irrigation water may have differed for the different blocks during the study period. Fairly substantial empirical evidence is available on that, but it shows the least regular supply to the H blocks that had the highest net incomes.

3. More intensive O&M may have been undertaken in H blocks to make up for defects in their basic irrigation infrastructure.[4] That has been documented for three of the four O&M measures monitored in the study (AES, 1975, pp. 47-49).

4. A primary benefit of rehabilitation is undoubtedly the prevention of a major disaster, which might take place if rehabilitation were not undertaken. Thus, the infrastructure may have partially deteriorated, but not to the point where regular and assured water deliveries could not be made. If attention were not given to the system, deterioration would intensify and as a result negatively affect the irrigation and agricultural performance of the system.[5] The study methodology took no account of this possibility, for to do so would have involved a more elaborate research design, with special attention to the monitoring of hydrologic and engineering performance of the system.

Benefits from overall use of irrigation water

In estimating benefits from the overall use of irrigation water, the average H-M-L situation represented a typical with-irrigation circumstance and the N situation the without-irrigation circumstance.

The impact of irrigation on individual crop performance was considered through data on the economic performance of irrigated and nonirrigated crops in two seasons (Table 1). The most striking outcomes of the analysis follow:

1. The net income of farmers growing irrigated crops is generally not greater than that of farmers without irrigation. In fact, for maize and

[3] This computation reflects the surplus of receipts over cash production expenditures, and represents a return to farmers' owned capital, family labor, and management. Particularly with respect to the land component of owned capital, and probably for family labor as well, this procedure biases upward the estimates of real benefits to irrigation.

[4] An additional possibility is that farmers may also adjust to circumstances, with those under difficult circumstances "tightening their belts" more to protect minimum levels of subsistence production and income.

[5] Thus, the failure to identify an immediately observable production benefit from rehabilitation does not imply that the rehabilitation will not serve a useful, long-term purpose.

Table 1. Returns, expenditures, and net farm income under irrigated and nonirrigated conditions for selected crops. Pekalen Sampean Irrigation Project, Indonesia, 1973-74.[a]

Crop, season	Returns			Expenditures ($/ha)				
	Yield (tha)	Price ($/t)	Gross return ($/ha)	Hired labor	Materials	Other	Total	Net income ($/ha)
Paddy — wet season								
Irrigated	3.91	82	321	118	42	16	176	145
Nonirrigated	2.56	80	202	16	46	3	65	137
Ratio[b]	1.55	1.0	1.6	7.4	0.9	5.3	2.7	1.1
Paddy — dry season								
Irrigated	2.38	96	228	114	37	14	165	63
Soybean — dry season								
Irrigated	0.55	254	140	41	25	6	72	68
Nonirrigated	0.37	236	87	12	0	2	14	73
Ratio[b]	1.49	1.1	1.6	3.4	–	3.0	5.1	0.9
Maize — dry season								
Irrigated	0.60	113	68	40	8	2	50	18
Nonirrigated	0.46	123	57	20	6	2	28	29
Ratio[b]	1.30	0.9	1.2	2.0	1.3	1.0	1.8	0.6
Tobacco — dry season								
Irrigated	0.42	753	316	112	64	8	184	132
Nonirrigated	0.27	1085	293	25	32	4	61	232
Ratio[b]	1.56	0.7	1.1	4.5	2.0	2.0	3.0	0.6

[a] Based on data in Agro-Economic Survey (1975, pp. 96-114). All data converted to US$ at Rp 415 = US$1

[b] Ratio of irrigated to nonirrigated conditions.

tobacco the net income per hectare from irrigated production is only about 60% of that from nonirrigated production.

2. Despite the lower net income of irrigated farms, their yields were from 30 to 56% higher than those of nonirrigated farms. Average gross returns per hectare were from 10 to 60% greater for crops grown with irrigation. But in general the costs of irrigated crop production increased more substantially than did gross returns. For example, during the wet season irrigated paddy produced 1.6 times as much gross returns as nonirrigated paddy, but its production expenditure was 2.7 times as much. For soybeans, the gross return also increased by 1.6 times, but the cash expenditure increased by more than 5 times. The expenditure item that increased most was hired labor. For some crops like soybeans and tobacco, expenditures for materials also increased but not nearly as much as expenditures for hired labor.

3. This analysis, reinforced by higher cropping intensities made possible by irrigation, suggests that substantial benefits of irrigation accrue to:

a. the general public, in the form of much larger quantities of domestic food available in the market at prices lower than would otherwise have prevailed.[6]
b. the government, in that greater domestic food production and expanded employment opportunities help insure political stability, while the former also reduces the extent of foreign exchange required to import food; and
c. hired labor, because of expanded work opportunities.

The analysis now shifts from a per-crop per-season basis to a total-production-per-year basis, which permits consideration of changes in cropping intensities that result from irrigation. The

[6] Expanded levels of production made possible over time by large-scale irrigation in the region imply downward pressure on the prices of the crops produced with irrigation.

mean annual net incomes[7] per hectare were $300 with irrigation and $100 without irrigation, giving a $200 annual benefit from irrigation.[8]

The higher annual net income from irrigation is consistent with the findings of neutral or negative impact of irrigation on individual crop performance unless cropping intensities with irrigation are greater. Data on cropping intensities without irrigation are not available, but those on annual cropping intensities with irrigation are. On the average, 2.56 crops per year were grown in the tertiary blocks studied; for 7 of the 12 sample blocks, cropping intensities were between 2.8 and 3.0. These cropping intensities are high by any standard, and certainly are higher than those for noninigated land in the PSIP. It seems clear that the advantage of irrigation of a farm arises not from higher individual crop revenues, but from more intensive use of land throughout the year, especially during periods when rainfall is insufficient to support good crop growth.

This finding on high cropping intensities is one reflection of intensive and rational use of land and water resources in the PSIP. Another is the relatively frequent but small applications of irrigation water to secondary crops.[9]

Farmer Payments for Irrigation

It is known that Indonesian farmers pay the local village government for terminal irrigation services. But, because they do not pay directly for the main irrigation systems, it is often assumed that farmers are not paying for irrigation water. It is often recommended that farmers should bear more of the costs of irrigation, at least enough to pay for the annual O&M expenses. The feasibility report on the rehabilitation of the PSIP (Harza, 1971, section 4.5(2) states:

> . . . As each of the Irrigation Systems is rehabilitated, the Borrower, through the Province of East Java, shall adopt and thereafter maintain and enforce appropriate legislation for the levy and collection of charges on irrigable agricultural land served by such Irrigation System, or on the users of such land, and shall commence to collect such charges within one year after each such system is rehabilitated. Within two years of when such Irrigation System is rehabilitated such charges shall have reached, and thereafter such charges shall be maintained at, levels adequate to provide the Province of East Java with revenues sufficient to cover the operation and maintenance costs of the Province attributable to such lrrigation System . . .[10]

Commenting on Indonesia as a whole, the Asian Development Bank (1973, p. 254) reports that:

> . . . To date there is no irrigation charge in Indonesia. The fund of the provincial government for operation and maintenance of irrigation systems comes from the land tax; however, this is never adequate for the purpose . . .

Since the forms of institutionalization and the levels of payments for irrigation at the terminal level and the main system differ, the following discussion focuses separately on those two components.

Terminal systems[11]

Payments in the PSIP for terminal-level O&M are of two types: I) payment to local ditch tenders for their services in operating the systems, and 2) contribution of cooperative labor, *gotong royong,* to maintain the systems.

Payments to the village ditch tenders are

[7] All cost and price data in this paper have been converted to US dollars at Rp 415 = US$1.

[8] The with-irrigation figure takes no account of extra effort to locate, manage, and supervise the additional hired labor, agricultural inputs, and credit required with irrigation. Nor does it take into account the fact that a farmer and his family may have to work harder, especially in the dry season, as a result of irrigation. In these two senses, the reported annual benefit from irrigation overstates the real benefits realized by farmers.

[9] For a more detailed discussion, plus an elaboration of the rather sophisticated approaches in deciding how to allocate expected supplies of irrigation water to alternate cropping patterns and how decisions to adopt varying degrees of rotational irrigation are taken during unexpectedly dry periods, see Pasandaran and Taylor (1976), pp. 9-23, 41.

[10] From informal discussions in Indonesia, the author understands that the external agency that lent funds for the PSIP rehabilitation also encouraged the government to implement charges against farmers in the form of a direct nominal water rate. Such an approach, however, may imply constitutional difficulties, because the Indonesian Constitution describes irrigation water as a free gift of nature.

[11] During the 1970s two federal subsidies for rural development were introduced: village subsidy, *subsidi desa,* and district "impres", *impres kabupaten.* One use for the funds is irrigation. For useful discussions of the subsidy programs, see de Wit (1973). Hafid (1976), and van Leuwen (1975).

Table 2. Farmers' payments for operations and maintenance at the terminal level. Pekalen Sampean Irrigation Project, Indonesia, 1973-74.

Season	Farmers' payment (US$/ha)		
	Operations (O)	Maintenance (M)	Total (O&M)
Wet	3.60	0.95	4.55
Dry	3.85	0.70	4.55
Total (annual)	7.45	1.65	9.10

Table 3. Yield and farmer payments (yield equivalents and $) to village ditch tender by season and crop. Pekalen Sampean Irrigation Project, Indonesia, 1973-74.

Season and crop	Yield (t/ha)	Amount of payment		
		Yield equivalent (kg/ha)	Fraction of yield (%)	Value ($/ha)
Wet season				
Paddy	3.91	39	1.0	3.20
Dry season				
Paddy	2.38	33	1.4	3.15
Maize	0.59	14	2.4	1.45
Soybean	0.54	12	2.2	2.90
Tobacco	0.42	6	1.4	4.25

"gratuity" or "feeling" payments.[12] The amounts traditionally depend on the feelings of individual farmers and on the outcome of harvests. In the areas studied, village ditch tenders are almost always paid in kind at the time of harvest for the irrigation of paddy. But for secondary crops, *palawija,* the ditch tenders are generally paid in cash when they perform their services. Farmers who are unable to make such payments at that time do so in kind at harvest.

Table 2 shows the amount of tertiary-level O&M payments made during 1973-74. These payments incorporate imputed values for in-kind payments and cooperative labor contributed by farmers. Data are shown separately by season, with their totals reflecting the total yearly payment per hectare.

The total terminal level O&M payment is $9.10/year. The wet season has slightly higher maintenance payments than the dry season, and slightly compensating lower operations payments. Operations for the year account for more than 80% of the total O&M cost at the terminal level.

Table 3 shows added detail with respect to crop and season for operations payments to village ditch tenders and draws attention to the effect of crop yield on the payments. Dry-season paddy yields are substantially less (about 40%) than wet-season yields. They may reflect less well-prepared land or some degree of water stress. Physical amounts of payment are somewhat, but not correspondingly, less in the dry season. On the other hand, the monetary value of the dry-season paddy payment is almost identical with that of the wet-season paddy payment. That would show that terminal-level O&M payments may be more of a monetary valuation for irrigation services than proportions of yields

[12] The Indonesian word for the payment to village ditch tenders for the irrigation of paddy is *pangrasa,* literally "feeling."

as has generally been believed.

Rates of payments as percentages of yield are more than twice as high for secondary food crops as for paddy. In the area, a crop of maize typically received three applications of irrigation water, but soybeans received six (Pasandaran and Taylor, 1976). The greater payment for irrigation services to these crops could mean that the farmers perceived a greater value in the more time-consuming, intermittent irrigation service provided to the secondary crop by ditch tenders than in the simpler, continuous irrigation service provided to paddy.

A third finding (Table 3) is the substantially larger payment for the irrigation of tobacco than for other secondary crops. Irrigation water is applied to tobacco about 15 times/season (Pasandaran and Taylor, 1976), a fact that again could justify higher levels of payment roughly commensurate with the effort required of the ditch tenders.

In these three respects, then, there is evidence of an underlying economic calculus rather than just "feeling," which helps to determine the level of payment Indonesian farmers make to ditch tenders. Although the nominal institution through which ditch tenders are paid is highly traditional, it seems to have rather substantial modem economic content.

Main system

While Indonesian farmers do not pay for irrigation water in the form of direct nominal water charges, in effect they pay for it through the system of land development taxes, commonly abbreviated as IPEDA (the acronym for Iuran Pembangunan Daerah)[13]. The level of IPEDA payments assessed against paddy land, *tunah sawah,* is higher than that assessed against dry land, *tanah darat,* because paddy land has irrigation facilities and dry land does not.

In practice, of course, the introduction and use of irrigation induce additional government activities — extension, credit programs, input distribution, and marketing — to support agriculture. Thus, the differential in IPEDA payments between paddy and dry land does not solely reflect a payment for irrigation. Disregarding the question of the exact proportion of all government services represented by irrigation, we consider irrigation as an instrumental input that represents a substantial proportion of total government services provided to farmers.

The Federal Government decides on the level of IPEDA assessments. Provinces may stipulate general guidelines in the allocation of IPEDA funds. In East Java, the districts are to allocate IPEDA funds as follows: 10% for the province, 10% for the Regional Development Bank, 40% for the development of district town infrastmcture, and 40% for the agrarian sector, including irrigation (AES, 1975, p. 38). In urgent cases, however, the heads of the districts, *Bupati,* may alter the allocations. Responsibility for the collection and ultimate use of IPEDA funds rests primarily with the district.

The precise use of IPEDA funds is difficult to describe because information on spatial and temporal variations in allocations is not always readily available. In general, however, it appears that IPEDA funds allocated to irrigation

Table 4. Land development taxes paid by farmers for different land and land-use classes Pekalen Sampean Irrigation Project, Indonesia, 1973-74.

Land class[a]	Taxes (US$/ha per year)		
	Paddy land	Dry land	Difference between paddy and dry land
I	14.30	2.40	11.90
II	12.10	1.45	10.65
III	11.30	1.40	9.90
IV	[c]	1.50	[c]
Weighted av.[b]	12.80	1.95	10.85

[a] Classes I to IV are listed in order of decreasing fertility.
[b] Weighted by the respective area in each class of land.
[c] Data not avaliable

[13] In November 1965, Indonesia's land development tax was changed in name from *Pajak Hail Bumi,* literally Land Output Tax, to Iuran *Pembangunan Daerah,* meaning Regional Development Contribution. In changing the name, it was hoped that assessments would no longer have connotations of colonial taxes but rather more positive connotations of farmer contributions to local and regional development. IPEDA is now under the Directorate General of Finance within the Ministry of Finance, and not the Directorate General of Taxation (Booth, 1974, pp. 59-60). The article by Booth (1974, pp. 55-81) provides an excellent recent analysis of IPEDA in Indonesia and is the basis for part of the following discussion.

are turned over to the local irrigation service for funding O&M and, possibly, for some repair and minor rehabilitation of main irrigation systems.

Data on levels of IPEDA payments made by the sample farmers in 1973-74, by class of land, are shown in Table 4. On the average, farmers pay $10.85/ha more per year for paddy land than for dry land; the difference is slightly greater for more productive classes of land. Subject to adjustment for nonirrigation government services, this sum reflects the indirect payment by farmers for main-system O&M. [14]

Since the principal concern of this paper is to examine the implications of charging more for irrigation water, it seems useful to inquire into changes in the levels of IPEDA assessments during the recent years. Booth (1974, pp. 60-62) reports that the IPEDA assessment against the rural sector in all of Indonesia increased by 4 times in 1967 and that the assessment in 1973 was 3.3 times that of 1968. [15] The AES Report (1975, pp. 116-120) shows data on IPEDA assessments in the central district of the PSIP study area, Jember District of East Java, from 1970 to 1974. It shows an increase over time similar to that in Booth's study, and, in addition, a further 50% increase in the 1974 assessment over that of 1973. In considering further possible rises in assessments against PSIP farmers, it would seem important to bear in mind this rapid escalation (an almost twenty fold increase) in IPEDA assessments over the 8-year period of 1967-1974. [16]

An additional factor that should be considered regarding water rate policy is the relative importance of IPEDA as a source of district revenue. Booth's study (1974, pp. 76-77) shows the principal sources of revenue in 23 districts in 10 provinces. The sources include IPEDA, subsidies from the province, e.g., salaries and wages of district officials, district taxes, and "retributions", e.g., fees charged to the users of markets, hospitals, polyclinics, bus stations, and other public facilities under district control. The only province from which all districts studied derive more than 50% of local revenue from IPEDA is East Java. Of the districts in East Java, Jember has the highest percentage (67%). Relative to other areas in Indonesia, then, the PSIP project area already seems to rely very heavily on IPEDA as a source of local revenue.

Expenditures on Operations and Maintenance

Expenditures on O&M at the tertiary level are identical to payments by farmers for terminal-level O&M. In 1973-74 this expenditure was $9.10/ha per year (Table 2).

This section gives primary attention to O&M expenditures on the main system. The data reflect full direct expenditures at the subsection — *cabang seksi pengairan* — and the sub-subsection — *kemantren* — levels, and portions of higher level backup or overhead expenditures at the province, district, and section levels.

The total main-system O&M expenditure during crop year 1973-74 was $2.00/ha, more than 90% of which was used for salaries of personnel and the remaining amount divided equally between equipment and materials.

Since many observers of Indonesian irrigation believe that recent levels of O&M have been inadequate, likely future levels of main-system O&M were explored. In principle, an attempt was made to project a future level of O&M expenditure sufficient to permit satisfactory performance of the irrigation project on a sustained basis, and to preclude the necessity for rehabilitating the project again after only a few years.

The future projected level of main-system O&M expenditure was based on the equation used for that purpose by the Indonesian Directorate General of Water Resources Development. The equation involves the determination of ex-

[14] The overall PSIP area has almost equal areas of paddy land and dry land, so that the presupposition of this argument at the microlevel area holds up within the macrogovernment revenue-expenditure context.

[15] Of the five sectors contributing IPEDA payments (rural, urban, estate, mining, and forestry), only the rural sector showed an increase in its relative importance to the total IPEDA assessment between 1968 and 1973 (Booth, 1974, p. 61).

[16] During the same period, paddy prices increased by approximately 14 times.

penditures for personnel, equipment, and materials with the help of coefficients reflecting ecological conditions of the watershed, numbers of irrigation control structures and service personnel, and backup factors covering overhead administrative support.[17] The level of main-system O&M expenditure was thereby projected at %.75/ha per year.

Financial Policy Options for Future Irrigation Development

The primary reason for the financial analysis of irrigation in the PSIP was to generate insights to be considered in possible modifications of financial policies in the project. This section therefore gives attention to various financial policy options for further development of the PSIP. It outlines some views that might be considered by policy makers. It is not intended to suggest final decisions that would obviously require deeper understanding of the technical, economic, cultural, and political environment than that possessed by any "outsider to the system."

First, let us make explicit the possible alternative financial policies in the PSIP:

1. increase the assessments against farmers for land and water;
2. charge farmers directly for water rather than indirectly through IPEDA as at present;
3. reallocate O&M expenditure to improve farm water management; or
4. replace the traditional village ditch tender system of payment for local irrigation services with a system embodying more direct economic content.

Before considering these alternative policies, it may be helpful to summarize the major points emerging from the three preceding sections. Summary points S-l to S-9 concern various aspects of irrigation benefits; S-10 to S-14 concern expenditures on and payments for O&M; and S- 15 to S- 19 cover a variety of other factors.

[17] See AES (1975, pp. 126-132) for details of the equation and the computational procedures involved in applying it.

Benefits

Benefits from more intensive agricultural production can be viewed in terms of

1. The rehabilitation of the basic irrigation infrastructure:

S-1. No evidence of a direct production benefit.

2. The overall presence and use of irrigation water:

A 30 to 55% increase in yield and an increase in cropping intensity to more than 2.5 crops per year with irrigation.

S-2. General consuming public enjoys larger quantities of domestically produced food, which is thus available at lower prices than otherwise would have prevailed.

S-3. Government imports less food than otherwise and therefore spends less foreign exchange; government also enjoys a more stable political environment because of greater self-sufficiency in the production of food, especially rice.

3. A more than twofold increase in the hired labor requirements for crops grown under irrigation, coupled with increased cropping intensity under the irrigation:

S-4. Laborers have expanded employment opportunities.

S-5. Government with fewer pressures from unemployment enjoys a generally more productive economy and more stable political environment.

S-6. Agricultural net income rises by about $200/ha per year.

S-7. The net agricultural income above-cash costs of production from crops produced under irrigation is about $300/ha per year. Typical farms in the PSIP are less than 0.5 and have six to nine family members, implying an annual per-capita net income from agriculture of about $20.

S-8. No attempt has been made to measure indirect benefits of irrigation to the manufacturers, agricultural businessmen, and merchants in and near the project area, nor to estimate the taxes assessed against them because of their larger volumes of business.

S-9. No attempt has been made to measure the nonirrigation benefits, such as added protection against flooding.

Payments by farmers

Farmers make two kinds of payments:

S-10. Terminal-level O&M is $9.10/ha per year.

S-11. Main-system O&M expenses are covered by indirect payments of $10.85/ha per year. That needs to be adjusted by the extent of additional nonirrigation government services received by farmers with irrigation, and by some repairs and minor rehabilitation also possibly funded by the payment.

O&M expenditures

Current and projected O&M expenditures follow:

S-12. Terminal level is $9.10/ha per year.

S-13. Main-system level is $2.00/ha per year.

S-14. Projected expenditure on main system O&M is $6.75/ha per year.

Other points

S-15. An East Java provincial guideline states that 40% of land development taxes collected are to be allocated to the agrarian sector, including irrigation. This allocation of the IPEDA tax on paddy land amounts to $5.10/ha per year.

S-16. Land-development tax assessments against farmers have increased almost twenty-fold during the 8-year period 1967-74.

S-17. Indonesia's current reliance on land development taxes relative to other sources of revenue is highest in the province of East Java, and within East Java it is highest in Jember district, the central district in the PSIP.

S-18. Remarkably efficient use of scarce land and water resources is reflected in high cropping intensities, carefully monitored and modest application of irrigation water to secondary crops, and generally careful decision-making on the allocation and distribution of irrigation water in the project area.

S-19. The traditional village system of paying for local ditch tender services is becoming more institutionalized and economically based.

Should charges for land and irrigation water assessed against farmers in the PSIP be raised?

Possible rationale for increasing the charges to farmers would be to raise more revenue for development, and to make irrigation water more precious, thus reducing its wastage.[18] In considering this possibility, one should note that current payments by farmers substantially exceed current expenditures on O&M (S-11 vs. S-13). The current allocation of local IPEDA revenue to irrigation is less than that recommended by the East Java Provincial Government (S-13 vs. S-15), unless it is presumed that less than 40% of the IPEDA allocation to the agrarian sector goes to irrigation. It is clear, then, that current charges against farmers are more than sufficient to cover O&M. There is a need, however, to allocate a larger proportion of existing local revenues to O&M so that district revenue allocations meet the broad guidelines for IPEDA allocations provided by the East Java Provincial Government.

In considering the possibility of future increases in assessments for land and irrigation water, the following facts and issues seem important:

1. Farmers' land taxes in the PSIP increased almost 20 times from 1967 to 1974 (S-16). Furthermore, in the PSIP at present, IPEDA provides a larger proportion of local tax revenues than it does in other areas of Indonesia (S-17).

2. Although neither the indirect benefits of irrigation nor the benefits of nonirrigation to the PSIP are precisely known, rough evidence suggests that substantial indirect benefits are

[18] The author believes the only way that raising water rates can be expected to cut down on water wastage, however, is if the rates are charged volumetrically, i.e., according to rates and durations of flow. If water is priced volumetrically, each increment of water used involves an additional increment in the charge for irrigation. With an area-based system of water rates, on the other hand, once a farmer pays his water rate, the cost of water application to his fields becomes fixed, and additional increments of water applied to his land are essentially free and, therefore, of no additional cost to him.

realized, especially by the general consuming public and the government (S-2 to S-5). To the extent that such benefits exist, and unless income transfers from irrigation users to other groups in Indonesia are intended, the full O&M costs (S-12 to S-14) should not have to be paid by farmers (S-10 and S-11).

3. It should also be explicitly recognized that existing provincial guidelines for allocation of IPEDA (S-15) involve a substantial income transfer from the irrigation and agricultural sector to other sectors. Altering the allocation of IPEDA collection to irrigation is one direct means of altering the direction or amount, or both, of income transfers among sectors of the society.

4. The effect of higher water charges on poverty levels and possible income redistribution also requires consideration. Although irrigated farms may produce income that exceeds the cash costs of production, the margin of surplus relative to farm size and family size may be so small as to imply per-capita agricultural incomes of only $20/year (S-7). While systematic data on the extent of nonagricultural incomes to PSIP farmers, or on the relative poverty of other groups in Indonesia are not available to the author, it would seem that raising charges to PSIP farmers would place added burdens on people already in relatively deep poverty.

In short, the author is cautious about the possibility of raising existing charges for land and irrigation water assessed against farmers in the PSIP.

Should the systems of farmers' payments for irrigation water be changed from indirect water payment through IPEDA to direct nominal water charges?

A primary possible advantage of direct nominal charges for water is increase in efficiency of water use. A direct charge is visible; users of a directly taxed input may have special incentives to make full use of the input.

Available evidence in the PSIP, however, suggests that with the existing institutional arrangement the project's land and water resources are already used in a remarkably efficient way (S-18). There may be only limited possibilities, then, for achieving higher levels of efficiency. Furthermore, if a system of direct water charges were introduced, the cost of collecting the charges would increase substantially because a whole new administrative structure and staff would be required.

It is not at all clear, therefore, that there would be net gains from changing to a system of direct nominal water charges.

Should O&M expenditures be reallocated to make possible relative improvements in farm level water management?

Many observers of irrigation in Asia believe that water management at the farm level needs considerable improvement (FAO, 1972; Peterson, 1974). The findings from this study, however, suggest that such a need may not have the highest priority in the PSIP. For example, present expenditures at the terminal level are more than 4½ times the O&M expenditures in the main irrigation systems (S-12 vs. S-13). Furthermore, using the equation of the Directorate General of Water Resources Development to project future main-system O&M expenditure results in a level more than three times the current one (S-13 vs. S-14). These two results suggest that the current need for added attention to water management is much greater in the main system than at the terminal or farm level. In the immediate future, then, it seems advisable that main-system O&M expenditures be increased. Depending on the effects of such increases, later modifications may also need to be considered for O&M expenditures at terminal levels.

Should the traditional village ditch tender system of payment for terminal irrigation services be changed to one with direct economic content?

Evidence from our study shows that the traditional village ditch tender system has become institutionalized to a considerable extent and that it has a substantial underlying economic basis (S-19). Furthermore, its emphasis on shared in-kind payments provide a type of informal income insurance to relatively poor

farmers. Since the system is already well-established and accepted, there seems to be reason for caution in attempting to modify it so that it deals more explicitly with economic issues.

Summary and Conclusions

This study shows that farmers are, in effect, paying much more than is being spent for irrigation O&M and that, while there is a definite benefit from irrigation, farm sizes in the project area are so small that levels of net agricultural income are still extremely modest, about $20/capita per year. This evidence, coupled with the fact that payments by farmers for land and water have increased almost 20 times in the past 8 years, would seem to raise serious questions about the advisability of the Indonesian government adopting a higher water rate in the PSIP.

Government policies concerning the allocation of local land and water revenues, however, may well deserve additional consideration. Existing East Java provincial guidelines for the allocation of such revenues implicitly involve a substantial transfer of income from the irrigation-agricultural sector to nonagricultural sectors. Particularly in view of recent substantial increases in government revenue from petroleum in Indonesia, the extent of this income transfer may merit review. Apart from such considerations, it should be recognized that at present actual allocations to irrigation are substantially lower than the allocation suggested in provincial guidelines.

The study also shows that land and water resources in the PSIP are already being used in a remarkbly efficient manner. To change from the current system of collecting water charges as a component of land development taxes, to a system of direct nominal water charges might not, therefore, produce much gain. Since a new system would increase administrative costs for collecting the charges, the government would seem to be particularly well-advised to be cautious in adopting a direct water charge.

In conclusion, the author would make explicit his belief that the policy implications of this study cannot be generalized to other irrigation projects. The economic-financial environment surrounding an individual irrigation project is too location-specific to warrant broad generalizations. Any broader value of the study, then, is limited to its providing an illustration of a type of financial analysis that might be undertaken in irrigation projects in which policies and procedures for repayment are under review.

References Cited

Agro-Economic Survey (AES). 1975. Research on Irrigation water rates in Pekalen Sampean, East Java (Penelitian Iutan Air lrigasi di Pekalen Sampean, Jawa Timur). Report No. 07/75/L, Jakarta.

Asia Development Bank (ADB). 1973. Regional workshop on irrigation water management. Manila.

Booth, A. 1974. IPEDA - Indonesia's land tax. Bull Indones. Econ. Stud. 10(1): 55-81.

Food and Agriculture Organization (FAO). 1972. Farm water management seminar, Manila. Report of FAO/UNDP Seminar on Measures to Accelerate Benefits from Water Development Projects by Improved Irrigation, Drainage and Water Use at the Farm Level, Quezon City/Manila, Philippines, 7-16 October 1970. Irrigation and Drainage Paper 12, Rome.

Hafid, A. 1976. An economic analysis of developing irrigation infrastructure by mobilizing local resources: the Indonesia Swadaya case. Unpublished M.S. thesis, University of the Philippines at Los Baños, College, Laguna, Philippines.

Harza. 1971. Feasibility report: Pekalen Sampean Irrigation Rehabilitation Project, East Java; Irrigation Rehabilitation Program, for Directorate General of Water Resource Development, Ministry of Public Works, Electricity and Power. Harza Engineering Company International, Chicago.

van Leuwen. R. 1975. Central government subsidies for regional development. Bull. Indones. Econ. Stud. 11(1): 66-75.

Pasandaran, E., and D.C. Taylor. 1976. The management of Irrigation system in the Pekalen Sampean Irrigation Project, East Java, Indonesia. Research Note No. 01/76/RN. Agio-Economic Survey, Jakarta.

Peterson, D.F., ed. 1974. Research needs for on-farm water management. Proceedings for an international symposium, sponsored by USAID, Utah State University, Logan.

Taylor, D.C. 1976. Financial policies in Asian gravity-flow irrigation with an Indonesian case study application. Paper prepared for the Water Resources Branch, Center for Natural Resources, Energy and Transportation. United Nations, New York.

de Wit, Y.B. 1973. The Kabupaten program. Bull. Indones. Econ. Stud. 10(1): 65-85.

Mobilizing local resources for irrigation development: the subsidi desa case of Indonesia

ANWAR HAFID and Y. HAYAMI

THE IMPACT OF NATIONAL SUBSIDIES on the rehabilitation of two small-scale river-diversion irrigation systems in Indonesia is examined. One system is in West Java and the other in South Sulawesi; both serve less than 100 ha. The rehabilitation involved the repair and raising of the diversion dams and the lining of some canals. The study shows that the subsidies were substantial inducements to the mobilization of local resources, and that as a result high rates of return on the rehabilitation projects were achieved.

Conversion of potential savings in the rural sector in the form of underemployed labor into productive capital such as roads and irrigation systems has been recognized as a potent means of agricultural and economic development in Asia.[1] But the success of this strategy depends on effective organization of labor at the village level.

This paper presents case studies on the use of communal labor to rehabilitate irrigation projects in two Indonesia villages. Both projects were supported by the Village Subsidy *Subsidi Desa* program, a national program to facilitate mobilization of local resources. The effectiveness of the program is analyzed in terms of the amount of local resources mobilized relative to the amount of outside assistance, the rate of returns to total investment, and the shadow price for communal labor.

Anwar Hafid, Research Scholar, and *Yujiro Hayami,* Agricultural Economist, International Rice Research Institute, Los Baños, Laguna, Philippines.

Subsidi Desa Program

Before proceeding to the case studies, we present a brief review of the *Subsidi Desa* program.[2]

A program of providing village subsidies to encourage community work in the construction of rural infrastructure was begun in 1969. The funds were used for the construction of irrigation systems, roads, and markets. Initially designed on a 1-year pilot basis, the program has since become nationwide with continuing budget appropriations.

Under the program, villages prepare project proposals that are sent through the subregency *kecamatan* to the community development offices of the municipalities *kabupaten* for assessment. Proposals approved by the *kabupaten* heads are sent to the provincial governors for final approval.

[1] For a classical review, see Nurkse (1953).

[2] For additional information on the *Subsidi Desa* program, see Prabowo (1973).

Table 1. Government subsidy, locally mobilized resources, and irrigation investment under the *Subsidi Desa* program. Indonesia, 1969-70 to 1973-74.[a]

Period	*Subsidi Desa* (million US$)			Irrigation Investment (million US$)	Percentage of total *Subsidi Desa*	Inducement coefficient[b]
	Government subsidy	Locally mobilized resources	Total			
1969-70	11.2	27.1	38.3	18.0	47.0	3.4
1970-71	13.5	15.3	28.8	13.2	45.8	2.1
1971-72	12.7	13.2	25.9	11.0	42.5	2.0
1972-73	12.7	13.3	26.0	9.3	35.8	2.0
1973-74	9.2	9.1	18.3	6.5	35.5	2.0
Total	59.3	78.0	137.3	58.0	42.2	2.3

[a] Source: Unpublished data from the Community Development Office, Department of Interior, Republic of Indonesia.
[b] The sum of government subsidy plus locally mobilized resources divided by government subsidy.

The subsidy for each project was initially US$250[3], but the amount was raised to $500 in 1973 and $750 in 1975. The funds appropriated for the *Subsidi Desa* program by the central government come from the Community Development Office, Department of Interior, and are channeled to the villages through the local administrative hierarchy.

Between 1969-70 and 1973-74, total government subsidies amounted to $59 million and locally mobilized resources to $78 million (Table 1). The mean investment-inducement coefficient — the ratio of the total project cost to the government subsidy (Ishikawa, 1967) — was about 2.3 during this period, indicating that, on the average, $1 of government subsidy induced the mobilization of $1.30 of local resources.

These statistics suggest that the *Subsidi Desa* program was quite successful in mobilizing local resources of low opportunity cost for the construction of rural infrastructure. However, these data were taken from the *kabupaten* reports of community development and should be viewed with reservation. Because *kabupaten* offices process more than 100 project proposals each year, it is hardly possible for them to conduct substantive preproject and postproject appraisals. Without adequate data, some local officials may inflate achievement levels in their official reports. In addition, estimates of social benefits of *Subsidi Desa* projects are generally not made.

Evaluating the effectiveness of the *Subsidi Desa* program therefore requires the collection of village-level data. Case studies of the rehabilitation of two communal irrigation systems were thus undertaken. Irrigation projects were chosen because the major share (about 42%) of Subsidi Desa investments has been used for irrigation (Table 1), and because it is relatively easy to measure irrigation benefits.

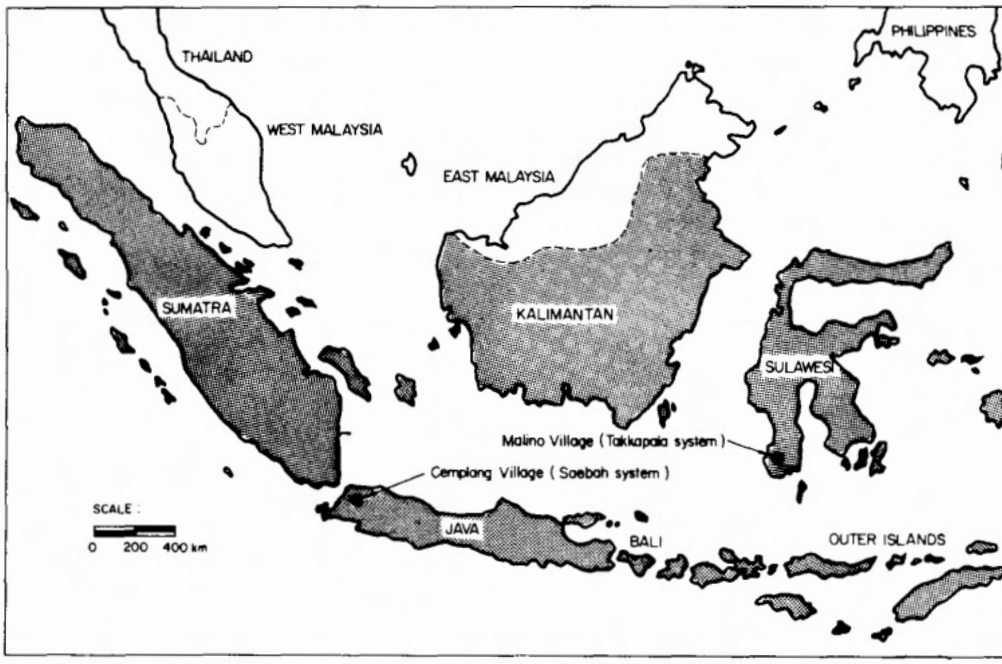
The Study Areas

The cases selected for study were the Saebah Communal Irrigation System in Desa Cemplang, West Java, and the Takkapala Communal Irrigation System in Desa Malino, South Sulawesi[4] (Fig. 1). Both systems involve gravity irrigation by river diversion, which is operated and maintained by village communities. [5]

[3] All cost and price data in this paper have been converted to US dollars at Rp400 = US$1.

[4] Irrigation systems in Indonesia are usually classified into technical irrigation systems *pengairan technis;* semi-technical irrigation systems *pengairan semi technis;* and village or communal irrigation systems penguiran desa. The first two are national systems operated and maintained by the government, while the third are communal systems managed by villagers. The areas covered by the technical, semitechnical, and communal systems in 1972 were 1.54, 1.02, and 1.51 million ha, respectively. Both the Saebah and Takkapala systems are *penguiran desa.*

[5] Locally elected village ditch tenders *ulu-ulu desa* manage the systems, utilizing communal labor for operations and maintenance.



1. Major islands of Indonesia.

The Saebah system was rehabilitated under the *Subsidi Desa* program with $250 subsidies in both 1971 and 1972. During 1971, its rock-and-gravel diversion dam was renovated and heightened. In 1972, lining of critical canal reaches with concrete improved the water distribution system. The rehabilitation was undertaken during the slack agricultural season (June to August) by mobilizing 30 villagers each for 45 effective working days in the first year, and each for 30 effective working days in the second year.

Rehabilitation of the Takkapala system, which was undertaken with a $250 subsidy in 1971, also involved concrete lining of dam and canals. The village received the government subsidy in September, and the project was carried out during September and October through the mobilization of 40 villagers for 45 effective working days.

Systems in these two areas of Indonesia were selected to reflect contrasts in population density and the share of total *Subsidi Desa* funds used for irrigation. The values for both criteria were substantially higher in West Java (469 persons/sq km and 54%) than in South Sulawesi (76 persons/sq km and 168). Cemplang, West Java, also represents villages near urban areas with many off-farm employment opportunities. Malino, South Sulawesi, is an isolated village with few nonfarm employment opportunities.

Cemplang is on a highway about 30 km west of Bogor, the center of agricultural education and research in Indonesia. The village is made up of 53 neighborhood organizations *rukun tetangga* and 8 unions of *rukun tetangga* called *rukun* kampung. At the time of the survey, the village had 750 households with 5,048 inhabitants, many of whom were employed in construction and other trades in Bogor and Jakarta. The total agricultural land area is 415 ha, of which 360 ha are lowland rice fields. Rainfall is high and relatively evenly distributed throughout the year (Fig. 2).

Malino is 64 km south of Ujung Pandang, the provincial capital of South Sulawesi. It is relatively isolated with no improved roads

connecting it to any urban center, and consists of 71 *rukun tetangga* and 11 *rukun kampung* with 1,781 households and 9,828 inhabitants. Of the total 10,000 ha area, 610 ha are lowland rice fields, 2,645 ha are upland rice fields, and 6,845 ha are forest lands. Rainfall in Malino is also high and relatively evenly distributed (Fig. 2).

Surveys of the Saebah and Takkapala systems were conducted from March 15 to June 6, 1975. Random samples of 30 respondents from the list of 90 irrigators in the Saebah system and 34 respondents from 125 irrigators in the Takkapala system were taken. Data were collected on benefits and costs of rehabilitation and on the motivation of villagers to participate in rehabilitation.

Economic Evaluation of the Projects

General characteristics

A major difference in the socioeconomic characteristics of farmers in the Saebah system and in the Takkapala system is the proportion of family members of working age (15 to 65 years) who work on farms (Table 2). In Saebah, only 1.2 of 4.1 family members worked on farms, while in Takkapala 2.3 of 3.8 did. This difference arises because Takkapala has fewer off-farm employment opportunities and larger farms.

While the area commanded by the Saebah system was used exclusively for lowland rice production, the Takkapala area had a mixture of lowland rice and upland crops. In Saebah, most respondents were tenants while in Takkapala most were owner-operators.

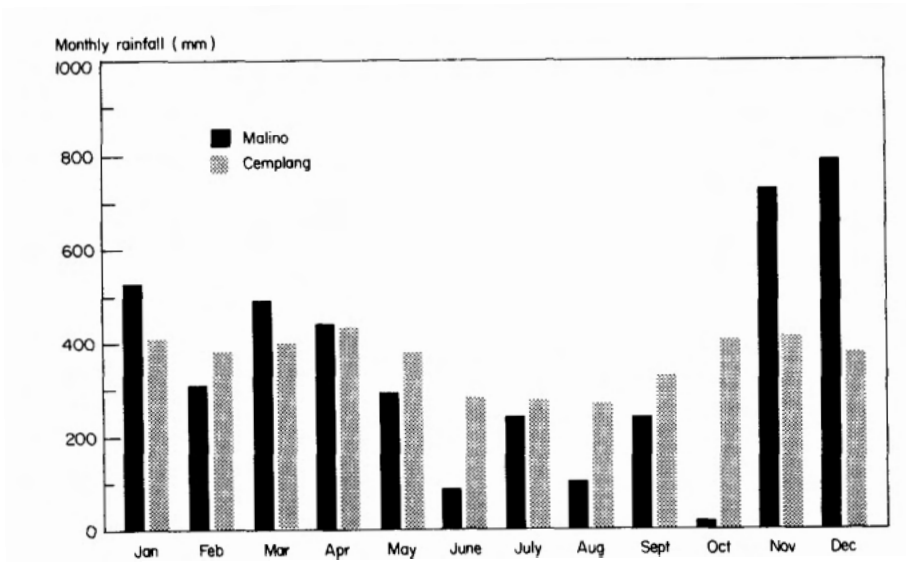
Only 2 of 30 respondents in Saebah own carabaos; the rest hire animals for the traditional means of land preparation. Farmers in Takkapala, on the other hand, average one draft animal each, and many invest earnings in animals rather than keeping cash or gold.

The Saebah respondents had less education than those from Takkapala, again reflecting Saebah's greater exposure to the infrastructure and economic opportunities of nearby urban areas.

Locally mobilized resources

The first criterion for assessing the effectiveness of the *Subsidi Desa* projects is the extent of local resources, especially communal labor, mobilized for the projects.

The estimated capital costs required for the rehabilitation are computed from material con-



2. Monthly rainfall in Malino (Ujung Pandang Extension Service) and Cemplang (Central Research Institute for Agriculture). Indonesia, 1973–74.

Table 2. Characteristics of sample respondents [a] for the Saebah and the Takkapala Irrigation Systems. Indonesia, 1975.

Characteristic	Saebah, W. Java		Takkapala, S Sulawesi	
	Mean	Range	Mean	Range
Family size (no.)	6.1	2-11	5.3	3-10
Family members aged 15 to 65 (no.)	4.1	3-9	3.8	2-8
Family members working on farms (no.)	1.2	1-3	2.3	1-6
Age of family head (yr)	40	27-62	37	25-57
Age of family members (yr)	22	2-30	22	11-34
Education of family head (years of schooling)	4.5	0-9	3.4	0-9
Farm size (ha) [b]				
Irrigated rice land				
Owned	0.2	0.2-0.3	0.6	0.2-1.5
Tenanted	0.8	0.5-2.0	0.1	0.0-0.6
Upland	0	0	0.7	0.5-2.5
Total	1.0	0.4-2.0	1.4	0.4-2.0
Carabaos (no.)	0.1 [c]	0-1	6.8	3-13
Horses (no.)	0	0	0.7	0-4

[a] Based on 30 respondents from Saebah and 34 from Takkapala. [b] After rehabilitation. [c] Two farmers owned one carabao each.

Table 3. Capital costs of rehabilitating the Saebah and the Takkapala irrigation systems. Indonesla, 1971 -72.

Costs	Capital costs of rehabilitation			
	Saebah, W. Java		Takkapala, S. Sulawesi	
	US$	%	US$	%
Government subsidy				
Administrative costs	85	3.9	12	0.9
Construction materials	382	17.6	92	6.9
Hired labor	32	1.5	145	10.6
Subtotal	499	23.0	249	18.4
Locally mobilized resources				
Construction materials	0	0.0	95	6.9
Communal labor [a]	1407	64.8	1012	74.7
Cash payment for hired labor	265	12.2	0	0.0
Subtotal	1672	77.0	1107	81.6
Total Investment	2171	100.0	1356	100.0
Investment inducement coefficient [b]	4.4		5.4	
Community labor mobilization coefficient [c]	4.5		7.2	

[a] Computed from 2250 man-days of communal labor at the local farm wage rate of US$0.62/man-day for Saebah, and 1880 man-days at US$0.56/man-day for Takkapala. [b] Total investment divided by government subsldy. [c] Total man-days of communal labor divided by government subsidy (man-days/US$).

tributions valued at market prices (Table 3). Communal labor contributions were imputed using the local farm wage rates of $0.62/man-day for Saebah and $0.56/man-day for Takkapala.

The proportion of locally mobilized resources was 77% for Saebah and 82% for Takkapala. Estimates of the investment inducement coefficient, the ratio of the value of total resources invested to the government subsidy, were 4.4 for Saebah and 5.4 for Takkapala. These estimates are substantially higher than the national average (Table 1), indicating that the projects under study are relatively successful.

Because the wage rate used for imputing the value of communal labor in the two systems differed, a physically based criterion was also computed. This community labor mobilization coefficient is the ratio of man-days of community labor to the value of the government subsidy. The respective coefficients for Saebah and Takkapala are 4.5 and 7.2 man-days/$1, showing a wider difference in real labor mobilization between the two irrigation systems than that reflected by the monetarily based inducement coefficient.

Profitability of the projects

Economic efficiencies of the Saebah and Takkapala rehabilitation projects were analyzed through benefit-cost (B-C) ratio and internal rates of return (IRR) analyses.

Benefits from the projects consist of increases in irrigated areas and in yields per hectare. This analysis is conservative, however, because it includes only those benefits stemming from increased area of irrigation. In the Saebah system, the area of rice increased from 70 to 100 ha during the wet season and from 50 to 90 ha in the dry season. The corresponding figures for the Takkapala system are 60 to 80 and 0 to 70 ha, respectively.

The first step in determining the annual flow of benefits was a farm budget cost and returns analysis (Table 4). Two extreme conditions were designated, Case A and Case B. The cost of man and animal power were assumed to be zero in Case A, and to reflect the prevailing wage rates in Case B. Because the increase in cropped area due to rehabilitation took place mainly in the dry season, the opportunity costs for labor would be much lower than the market wage rates, but not nil. Cases A and B therefore represent extremes between which reality lies.

Table 4. Costs and returns for rice production in the Saebah and the Takkapala irrigation systems.[a] Indonesia, 1974-75.

	Costs and returns (US$/ha)	
	Saebah, W. Java	Takkapala, S. Sulawesi
Output[b]	240	178
Total costs	212	101
Paid-out costs	106	37
Paid-out costs in cash	57	19
Fertilizer	37	4
Seed	10	8
Chemicals	0	1
Animal rental	6	0
Others	4	5
Paid-out costs in kind (hired labor)	49	18
Imputed farm factor costs	106	64
Family labor[c]	105	59
Animal costs	0	5
Net farm returns:[d]		
Case A: Output value minus paid-out costs	134	141
Case B: Output value minus total costs	28	77

[a]Data assumed to apply equally to wet and dry seasons. [b]Based on yields at 3.20 and 1.78 t/ha for Saebah and Takkapala, respectively, and price of US$100/t. [c]Based on 170 man-days at US$0.62/man-day for Saebah and 105 man-days at US$0.56/man-day for Takkapala. [d]The opportunity costs of man and animal power in Case A are assumed to be zero; in Case B they are assumed equal to the market wage rates.

The next step was to apply the farm budget data to the changes in the areas irrigated because of rehabilitation (Table 5). Common prices for inputs and outputs were used in the before- and after-rehabilitation analyses. Discount rates of 12 and 18% were also used.[6]

The final step in calculating B-C ratios and

[6] The highest interest rate of Indonesian government investment loans is 24%. Because the rate of inflation exceeds 20%/year, however, the real interest rate is less than 5%. This analysis therefore assumes discount rates much higher than the common real interest rate in the country.

Table 5. Benefits from rehabilitating the Saebah and the Takkapala irrigation systems.[a] Indonesia, 1974-75.

	Saebah, W. Java		Takkapala, S. Sulawesi	
	Case A	Case B	Case A	Case B
Value of rice output (US$/ha)	240	240	177	177
Rice production costs (US$/ha)	107	212	37	102
Net return (US$/ha)	132	27	140	75
Annual rice area (ha)				
Before rehabilitation	120	120	60	60
After rehabilitation	190	190	150	150
Annual farm returns before rehabilitation (thousand US$)				
Rice production[b]	15.9	3.3	8.4	4.5
Vegetable productton	0.8	0.6	5.2	5.2
Total	16.7	4.1	13.6	9.7
Annual farm returns after rehabilitation (thousand US$)[c]	25.1	5.1	21.0	11.2
Annual benefit of rehabilitation (thousand US$)[d]	8.4	1.0	7.4	1.5
Capitalized value of benefit (thousand US$)[e]				
12% discount factor	45.2	6.1	39.2	7.9
18% discount factor	36.5	4.9	31.6	6.4

[a] The opportunity costs of man and animal power in Case A are assumed to be zero, in Case B they are assumed equal to the market wage rates. [b] The product of the net return per hectare times the rice area before rehabililtation [c] The product of the net return per hectare times he rice area after rehabilitation. [d] The difference in total farm returns before and after rehabilitation, excluding possible yield differences due to rehabilitation. [e] Assumes a usable life of 9 years beginning in 1971 -72.

IRR was to introduce data on system costs (Table 6). The capital costs were based on data from Table 3, with the second year of the Saebah costs discounted to the present.[7] The annual operations and maintenance (O&M) costs were based on information from village officials. Annual O&M required 120 man-days of communal labor in the Saebah system, and 320 man-days in the Takkapala system.

Even with the conservative assumption of Case B, the B-C ratios are greater than 2 and the IRR greater than 50% for both the Saebah and Takkapala systems. Since the opportunity costs of family labor are lower than the market wage rates, the real profitability of the projects is substantially higher than the estimates of Case B. These results show that community rehabilitation projects are lucrative investment opportunities. It must be remembered, however, that the use of the *Subsidi Desa* program for the two irrigation systems covered in this study was considerably more favorable than the national average.

Rates of return to communal labor

From the standpoint of village communities, perhaps the most relevant criterion for appraising the value of work programs is the return to village labor contributed to the rehabilitation. In this study, a shadow price of communal labor was computed to reflect the value of that labor.

The shadow price was estimated as an average return per man-day of labor for initial capital construction, and for initial construction combined with O&M. The average return was calculated by substracting noncommunal labor costs from total benefits and dividing the resulting figures by the total man-days of communal labor. The ratios of shadow prices to market wage rates were also computed.

These calculations were made not only for the two types of communal labor, but also for the two wage rates assumptions, and for 12 and 18% discount rates, as in the B-C and IRR

[7] Discount rates of 12 and 18% and a usable life of 9 years were assumed.

Table 6. Benefits and costs associated with rehabilitating the Saebah and the Takkapala irrigation systems.[a] Indonesia, 1971-72.

	Saebah, W. Java				Takkapala, S. Sulawesi			
	Case A		Case B		Case A		Case B	
	12%[b]	18%[b]	12%	18%	12%	18%	12%	18%
Capital cost (CC) (thousand US$)	2.1	2.0	2.1	2.0	1.3	1.3	1.3	1.3
Capitalized value of operation and maintenance (O&M) (thousand US$)	0	0	0.3	0.2	0	0	0.9	0.8
Capitalized value of benefit (B)[c] (thousand US$)	45.2	36.5	6.1	4.9	39.2	31.6	7.9	6.4
Benefit-cost ratio: $\frac{B}{CC + O\&M}$	21.7	19.7	2.5	2.1	28.9	23.3	3.5	3.0
Internal rate of return (%)	610		58		530		89	

[a] The opportunity costs of man and animal power in Case A are assumed to be zero; in Case B they are assumed to be the market wage rate. [b] Discount factor. [c] Data from Table 5.

Table 7. Estimated shadow price of communal labor mobilized for rehabilitating the Saebah and Takkapala irrigation systems.[a] Indonesia, 1971-72.

	Saebah, W. Java				Takkapala, S. Sulawesi			
	Case A		Case B		Case A		Case B	
	12%[b]	18%[b]	2%	18%	12%	18%	12%	18%
Capitalized value of benefit (thousand US$)	45.2	36.5	6.1	4.9	39.2	31.6	8.0	6.4
Capital cost excluding imputed value of communal labor (thousand US$)	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3
Capitalized value of O&M cost (thousand US$)	0	0	0.3	0.2	0	0	0.9	0.8
Total return to communal labor (thousand US$)[c]								
For construction only	44.5	35.8	5.4	4.2	38.9	31.3	7.7	6.1
For construction and O&M	44.5	35.8	5.0	3.9	38.8	33.8	6.7	5.3
Communal labor (man-days)								
For construction	2250	2250	2250	2250	1800	1800	1800	1800
For O&M[d]	1080	1080	1080	1080	2880	2880	2880	2880
Total	3330	3330	3330	3330	4680	4680	4680	4680
Shadow price of communal labor (US$/day)[e]								
Construction only	19.80	15.90	2.40	1.90	21.60	17.40	4.20	3.40
Both construction and O&M costs	13.40	10.80	1.50	1.20	8.30	7.20	1.40	1.10
Ratio of shadow price to farm wage rate[f]								
Construction only	31.9	25.7	3.8	3.0	38.5	31.1	7.5	6.1
Both construction and O&M costs	21.6	17.3	2.4	1.9	14.8	12.9	2.6	2.0

[a] The opportunity costs of man and animal power in rice farming and of labor in O&M are assumed to be zero in Case A and equal to the market wage rates in Case B. [b] Discount factor. [c] The return to communal labor used in construction is the capitalized benefit minus both the above costs. The returns to communal labor used in both construction and O&M do not involve the subtraction of the capitalized O&M cost. [d] Nine years of O&M at 120 and 320 man-days/year for Saebah and Takkapala, respectively. [e] Shadow prices are computed by dividing the total return to communal labor by the corresponding man-days of communal labor. [f] Farm-wage rates for the Saebah and Takkapala systems are US$0.62 and US$0.56/man-day, respectively.

analyses. A wide range of estimates resulted, as illustrated by shadow prices ranging from $1 to over $20/man-day (Table 7). Even the lowest estimates — which are unrealistically conservative because the rehabilitation was undertaken primarily during slack agricultural seasons — show a very satisfactory economic return to communal labor.

Organization of Community Resource Mobilization

We now consider what are probably the main determinants of success with the rehabilitation projects: village leadership and community organization.

In accordance with the guidelines of the *Subsidi Desa* program, the requests for project proposals originated with the village heads in Cemplang and Malino. The village heads first consulted intensively with the heads of their *rukun kampung* and *rukun tetangga* and then convened village meetings. The formal project proposals that emerged from the meetings were submitted to and approved by their respective *kecamaten, kabupaten,* and provincial offices. In executing the projects, the village heads, in consultation with heads of rukun *kampung* and *rukun tetangga,* prepared schedules to mobilize villagers for the work.

A major organizational difference between Cemplang and Malino was the relationship between the official village administration and the unofficial community organizations such as *rukun kampung* and *rukun tetangga.* In Cemplang, the village head took the major initiative in planning and organizing the projects. Even though he consulted with the heads of the lower organizational units, his requests for participation in the communal project were delivered directly to the villagers. Also, he often supervised the rehabilitation work directly at the project site. In contrast, the head of Malino left major decisions to the heads of the *rukun kampung* and *rukun tetangga.* The leaders of these smaller community units thus took responsibility for scheduling and supervising the work. The study respondents noted these differences in decision making between the two projects (Table 8).

Table 8. Villagers' perception of major decision makers who determine which subsidi desa projects to undertake in Cemplang (West Java) and Malino (South Sulawesi). Indonesia, 1975.

Decision makers	Respondents			
	Cemplang		Malino	
	No.[a]	%	No.[a]	%
Head of *desa*	25	56	6	15
Head of *rukun kampung*	15	33	7	17
Head of *rukun tetangga*	5	11	20	50
Ditch tender *(ulu-ulu)*	0	0	3	8
Individual farmers	0	0	4	10
Total	45	100	40	100

[a] Some respondents identified more than one category of persons.

The differences may have resulted partly from the difference in size and population density of the *desas* (750 households in Cemplang and 1,781 in Malino). But the more basic reason appears to be the stronger community ties in Malino, because that village was more isolated and self-contained. Indigenous community organizations in Cemplang were relatively weak, and official village administration was relatively strong.

These differences are also reflected in the characteristics of the leaders of the two villages. The head of Cemplang had accumulated wealth as a trader and was elected in 1970 for his administrative capability. But in Malino, the village head was an ordinary farmer respected for his dedication to the community and for his piety. He had been in office since 1945, the year of national independence, and was more a symbol of village unity than of administration. These characteristics are consistent with the villagers' preferences in Cemplang and Malino (Table 9).

Despite differences in village leadership for the two rehabilitation projects, economic analysis showed both projects as successful. Not only were substantial amounts of communal labor mobilized for construction, but the systems also appear to have been properly maintained after rehabilitation. Other similar

Table 9. Attributes of community leadership preferred by villagers in Cemplang (West Java) and Malino (S. Sulawesi). Indonesia. 1975.

Preferred leadership attributes	Respondents			
	Cemplang		Malino	
	N0.[a]	%	No.[a]	%
Community dedication	3	8	34	55
Religiousdevotion	0	0	15	24
Administrative ability	30	79	7	11
Technical ability	0	0	6	10
Educational qualifications	5	13	0	0
Total	38	100	62	100

[a] Some respondents identified more than one category of persons.

US$100/t. [c] Based on 170 man-days at US$0.62/man-day for Saebah and 105 man-days at US$0.56/man-day for Takkapala. [d] The opportunity costs of man and animal power in Case A are assumed to be zero; in Case B they are assumed equal to the market wage rates

Table 10. Prlmary motives of villagers participating in the rehabilitation of the Saebah and Takkapala irrigation systems Indonesia, 1971-1972.

Primary motive	Respondents			
	Saebah, W Java		Takkapala, S. Sulawesi	
	No	%	No.	%
Social obligation	30	100	24	71
Economic benefits	0	0	10	29
Total	30	100	34	100

projects may have been less successful because their lifetimes were shorter due to inadequate maintenance or poor technical design — not necessarily because of insufficient mobilized labor.

The success of the two projects, in spite of different community structures and leadership, suggests that both villages had appropriate leadership for their undertakings. In Malino, where neighborhood community ties are strong, leaving major decisions to the local community undoubtedly provided incentives for villagers to participate in the project. But in Cemplang, where community ties are somewhat weaker, the strong initiative of the administratively capable village head was probably necessary to effectively mobilize local resources.

Differences in community structures also reflect differences in the motivation of villagers to participate in the projects. In Cemplang, all respondents identified "social obligation" as the major motive for participation, while in Malino, some respondents referred to ''economic benefits" (Table 10). Perhaps when the villagers of Malino made decentralized decisions, they discussed the benefits they could expect from the project within their neighborhood communities.

Conclusions

National policy to promote the mobilization of low opportunity-cost resources — chiefly labor — at the village level by subsidizing the community construction of social and production infrastructure can be highly successful. It must be emphasized, however, that the projects investigated in this study are not fully representative of all such projects in other countries or even in Indonesia. Many unsuccessful projects have undoubtedly suffered from inadequate local leadership and attention to technical detail.

The nature of the projects in this study is somewhat special. Both involved the rehabilitation of certain components of irrigation infrastructure to enable the restoration of original water delivery capacities and, hence, original agricultural potentials. Because the benefits from such rehabilitation are apparent to the community, and because the projects do not involve dislocation of people or construction of the complete system (as many other projects do), villagers can be expected to participate actively.

Finally, we are impressed with the importance of village leadership in identifying and organizing viable community projects. The villages in this study had quite different socioeconomic environments, community structures, and types of leadership. Yet the projects in both were highly successful,

suggesting that national and local government agencies should use different approaches for different communities. Additional studies of both successful and unsuccessful cases would help identify appropriate approaches to mobilize underutilized local resources for economic and social development.

References Cited

Central Research Institute for Agriculture, Agroclimatology Unit, West Java. 1974. Monthly rainfall records for 1973.

Ishikawa, S. 1967. Economic development in Asian perspective. Tokyo, Kinokuniya. 488 p.

Nurkse, R. 1953. Problems of capital formation in underdeveloped countries. Oxford University Press, New York. 162 p.

Prabowo, D. 1973. The impact of government subsidy upon villages, Yogyakarta. Gajah Mada University.

Ujung Pandang Extension Service, South Sulawesi. 1973. Monthly rainfall records for 1972.

Mobilizing local resources for irrigation development: a communal system in Central Luzon, Philippines

G. DOZINA, Jr., M. KIKUCHI, and Y. HAYAMI

THE REHABILITATION of the 90-ha riverdiversion Cavite Communal Irrigation System in Zambales province, Philippines, involved replacing a washed-out temporary dam with a concrete structure and improving portions of the system's primary canal network. The case study showed high rates of return to the communal labor working on the project and to the total package of resources used in the rehabilitation. A relatively greater share of the benefits of rehabilitation accrued to farm laborers than to farm operators or landlords.

This paper reports the case study of the rehabilitation of the Cavite Communal Irrigation System (CCIS) in the village of Nagbayan, Castillejos municipality, Zambales province, Philippines (Fig. 1). The study was designed to examine the local resources and condition in a rural community that could be effectively mobilized for capital formation.

The CCIS taps the Kiling River, which flows from the Zambales mountain range. The system consists of a simple diversion dam with about 2 km of canals (Fig. 2). It commands about 90 ha, a third of the total rice area in Nagbayan.

The village council is responsible for the operation and maintenance (O&M) of CCIS. Each farmer is responsible for the cleaning of farm ditches. The dam and canals are desilted and cleaned twice a year by communal labor arranged by the village council, which also prepares the schedule for water distribution. Farms along the first third of the canal are irrigated on Monday and Tuesday, those along the second third on Wednesday and Thursday, and those along the last third from Friday to Sunday.

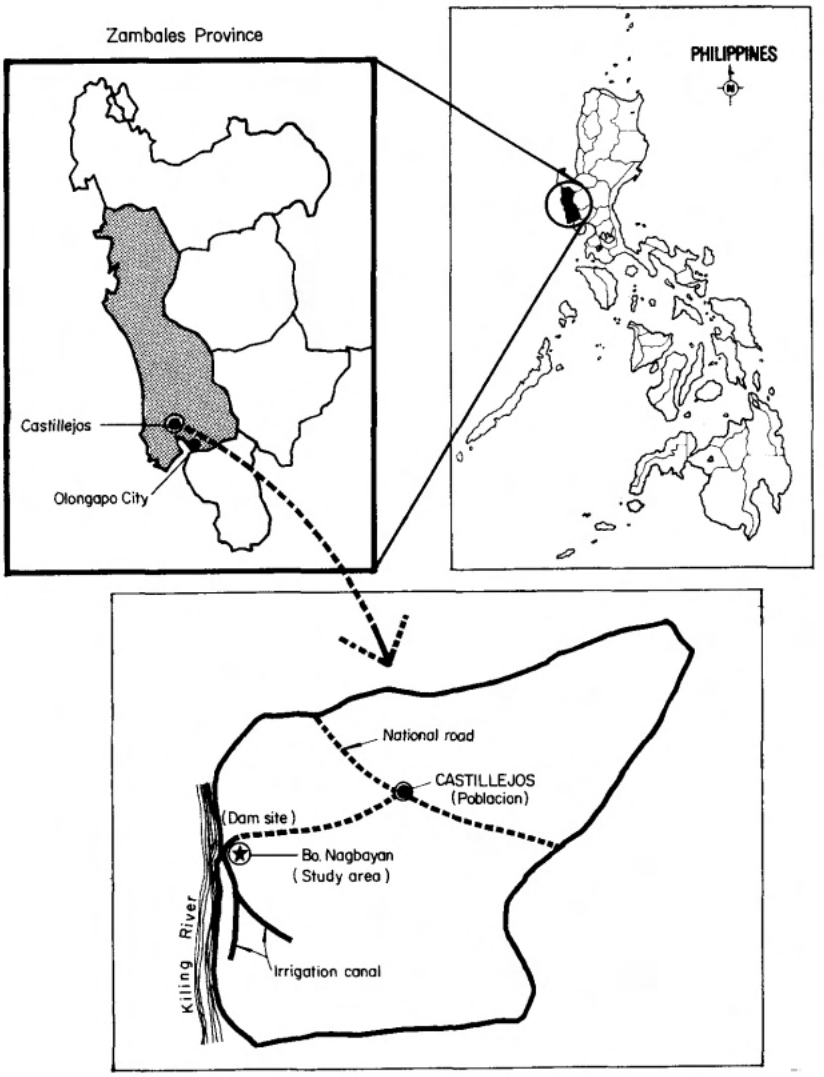
Project Rehabilitation

The CCIS diversion dam, which originally consisted of log piles held together by cement, was destroyed by a flood in 1972. The village council therefore adopted a resolution to rehabilitate the system with combined community and external resources.

The council requested assistance from Congress, through the Castillejos mayor and the con-

G. Dozina, Jr., Research Assistant; *M. Kikuchi*, former Research Scholar; and *Y. Hayami*, Agricultural Economist, International Rice Research Institute, Los Baños, Laguna, Philippines.

[1] Some of the materials presented in this paper were published with a different focus and a different organization in M. Kikuchi, G. Dozina, and Y. Hayami, "Economics of Community Work Programs: A Communal Irrigation Project in the Philippines," *Econ. Dev. Cultural Change* 26(2) (January 1978), pp. 211-225.

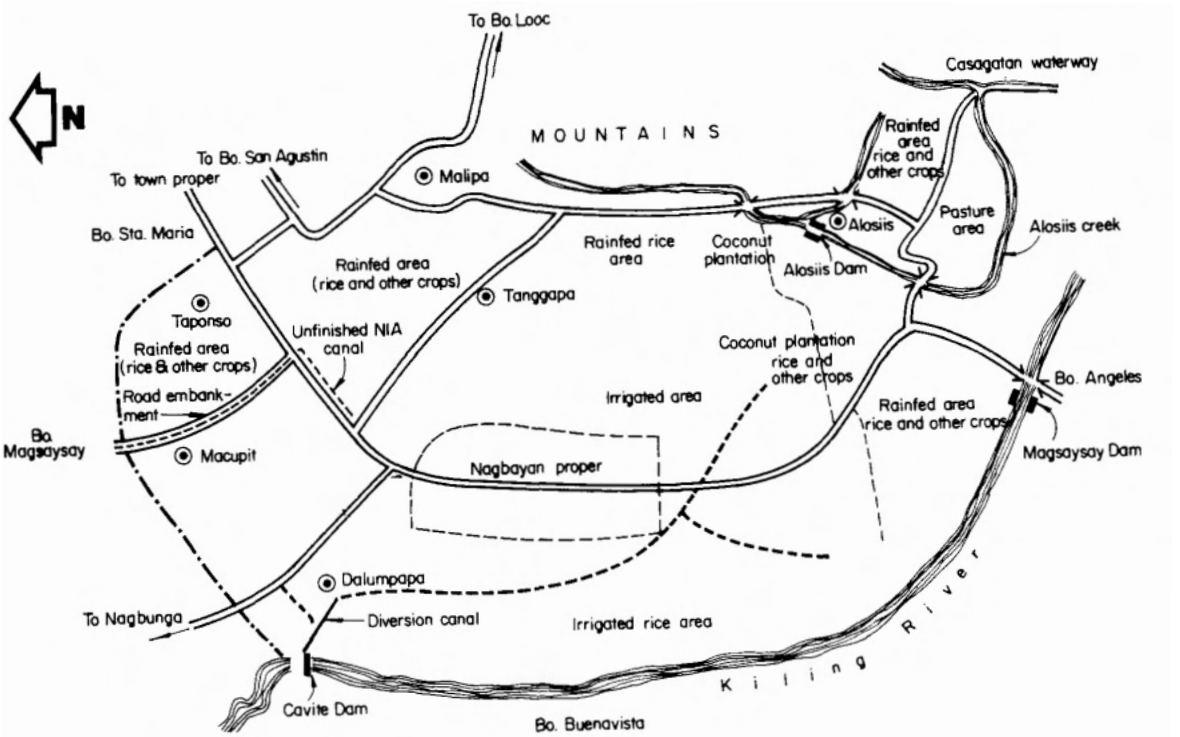


1. Location of the Cavite Communal Irrigation System in the village of Nagbayan, Castillejos, Zambales province, Philippines.

gressman of the electoral district. Through Republic Act No. 5979, the Philippine Congress appropriated about US$1,330[2] for the National Irrigation Administration (NIA) to provide technical assistance and construction materials. The Department of Social Welfare Administration and the Catholic Relief Services gave foodstuffs, which were used as incentives to local labor. Cement was acquired from the Presidential Assistant for Community Development (PACD) and through the provincial government's share of the national government calamity fund.

Through a series of meetings the village council organized the local community for work on the project. The effort was highly successful: it mobilized 1,010 man-days of voluntary labor from 100 participants. The participants included all but 10 of 98 farmers with land in the CCIS command area (some farmers lived outside Nagbayan), 5 farmers who rented some land within the system for the dry season only, and 7 participants who had no land in the command area

[2] All cost and price date in this paper have been converted to US dollars at ₱7.5 = US$l.



2. Village of Nagbayan, Castillejos, Zambales province, Philippines.

(Table 1). The latter seven anticipated that the improvement in irrigation would increase their employment opportunities in the dry season.

The major construction work was carried out during the labor-slack months of August and September. It involved the construction of a concrete dam and some improvements in the water-delivery system. Voluntary laborers were grouped into seven teams; each worked 1 day/week on a variety of tasks (Table 2).

Our case study of the CCIS rehabilitation project included a complete enumeration in July 1975 of the participants in the rehabilitation work and of the nonparticipants with land in the system's command area (Table 1). Information was also collected on the farmers' contributions of labor and materials to the project, as well as their farm inputs and production. Other relevant information was obtained from village officials and the NIA engineer who supervised the project.

Table 1. Participation of communal labor mobilized for rehabilitating the Cavite Communal Irrigation System Castillejos Zambales province. Philippines, 1974-75.

Type of participants	Participants (no)	Communal labor mobilized: Total man-days (no.)	Communal labor mobilized: Av man-days (no.)
Farmers with land inside the system[a]	88	904	10.3
Seasonal farmers[b]	5	45	9.0
Participants with no land inside the system	7	60	8.6
All participants	100	1009	10.1

[a]Seven additional farmers had land inside the system but did not participate in the project [b]Temporary tenants for dry season only.

Evaluation of the Project

The capital costs of rehabilitation were estimated with two wage rates assumed for communal labor: case A estimates were based on the wages of construction workers ($1.07/day) and case B on the wages of hired farm workers ($0.59/day). Material contributions were valued at their market prices. Implements were valued at their rental rates if information was available

Table 2. Allocation, by task, of communal labor for rehabilitating the Cavite Communal Irrigation System. Castillejos, Zambales province, Philippines 1974-75.

Task	Man-days (no.)
Reservoir cleaning	216
Reconstruction of reservoir embankment	163
Hauling of sand, gravel, and boulders	122
Mixing cement	152
Posting	214
Widening canals	110
Others [a]	33
Total	1010

[a] Includes indirect services such as supervision and transportation of food rations for laborers.

(as for carabaos and carts), or at 5% of acquisition costs if information was not available (as for hoes and shovels).

The value of locally mobilized resources as percentages of total capital construction costs in rehabilitation was 43% for case A and 33% for case B (Table 3). Stated in other terms, the value of locally mobilized resources ranged from about 50 to 75% of the outside assistance provided, Of the locally mobilized resources, communal labor was predominant.

The profitability of the CCIS rehabilitation project was evaluated through benefit-cost *(B-C)* and internal rate of return *(IRR)* analyses.

Benefits from rehabilitation can be expected from increases in both irrigated area and yields. This analysis considers only the benefit from an increase in the dry-season irrigated area, and therefore makes a conservative estimate.

Rehabilitation of the irrigation system resulted in a 38-ha (from 36 to 74 ha) increase in the rice-cropped area in the dry season. The increase in farm income per hectare in the dry season — the result of the shift from unirrigated crops to irrigated rice — was estimated by subtracting both the cost of rice-production inputs, such as fertilizer, and the forgone income from the crops that might have been planted without irrigation from the value of rice output. To make our benefit estimate conservative, we assumed that sweet potatoes, the most profitable unirrigated crop in the area, were planted in all 38 ha to which irrigation service was extended, even though a substantial portion of the area had actually been left idle during the dry season before the system was rebuilt.

The following assumptions were made about farm production: the cost of rice production in-

Table 3. Capital costs of rehabilitating the Cavite Communal Irrigation System. Castillelos, Zambales province, Philippines, 1974-75.

Item	Case A [a]		Case B [a]	
	US$	%	US$	%
Outside assistance				
Construction materials	477	14.3	477	16.8
Technical assistance and supervision	97	2.9	97	3.4
Professional construction labor	895	26.9	895	31.5
food rations	431	13.0	431	15.2
Subtotal	1900	57.1	1900	66.9
Local mobilized resources				
Communal labor	1077	32.4	592	20.8
Construction materials	82	2.4	82	2.9
Construction implements	267	8.1	267	9.4
Subtotal	1426	42.9	941	33.1
Total	3326	100.0	2841	100.0

[a] The wage rate for communal labor is computed on the basis of the wage rate for construction workers ($1.07/day) in case A and for farm workers ($0.59/day) in case B.

puts consists of the cost of nitrogen fertilizer (50 kg N/ha at $0.56/kg), plus 0.2 times the cost of nitrogen for chemicals, plus $12.00 for seeds; the yield is 1.76 t/ha, priced at $0.14/kg; sweet potato yield is 50 sacks/ha, priced at $2.67/sack, assuming no production inputs. Labor inputs were assumed to be equal for rice and sweet potatoes. The annual flow of benefits from the rehabilitation project was then estimated by multiplying the increase in irrigated area in the dry season by the increase in farm income per hectare under irrigation.

The following assumptions concern the costs of the irrigation system: the gestation period for rehabilitation is 1 year, the period of usable life is 10 years, the discount rate is 12%/year, and the O&M cost in communal labor is 466 man-days/year (Table 4).

The *B-C* ratios and *IRR* were calculated with the assumptions used in cases A and B, and with an imputed value of zero for communal labor in case C (Table 5). Even with the most conservative and unlikely estimate, for which the opportunity cost of communal labor equals the wage rate of professional construction workers, the *B-C* ratio is above 2, and the *IRR* is 54%.

Since most of the work on the project was done during the slack season, the actual opportunity cost of labor in the village can be expected to be lower than the market wage rate for hired farm workers. Therefore, the real payoff from investment in the project is probably between that shown for cases B and C. Such rates of return are attractive.

From the standpoint of the village community, a more relevant criterion would be the demand for contributed labor. This was estimated as the return per man-day of village labor contributed to the project (Table 6). The total return to communal labor was calculated by subtracting from total benefits both capital costs for items and O&M costs. To show the average daily return to labor, the total return was divided by the number of man-days mobilized for the communal work.

The results show that the rate of return to communal labor for capital construction is high, ranging from $8 to $11, or more than 10 times the prevailing farm wage rate.

Table 4. Annual communal labor mobilized for operating and maintaining the Cavite Communal Irrigation System. Castillejos, Zambales province, Philippines, 1974-75

Task	Man-days (no.)
Main canals	
Water scheduling	18
Cutting grass	169
Desilting	123
Subtotal	310
Farm ditches	
Cutting grass	116
Desilting	40
Subtotal	156
Total	466

Conditions of Communal Labor Mobilization

The high rate of return to labor contributed by the whole community does not necessarily imply incentive to participate. The individual participates in the work if he expects the project to generate substantial benetits for him. Therefore, the effective mobilization of communal labor depends on the distribution of benefits among members of the community.

We have already seen that participating farmers with land inside the system contributed more labor than the landless (Table I). To further examine the possible distributional impact of community participation in the project, we compared the amounts of labor contributed by different groups of farmers within the system, classified according to socioeconomic characteristics (Table 7).

The first characteristic is size of cropped area operated within the command area. The hypothesis was that a farmer's expected benefit from the rehabilitation project would be positively related to the size of his holding. The second characteristic, land tenure, was hypothesized as another important determinant of benefit because increases in farm output and productivity often benefit owner-operators and leasehold tenants more than share tenants. The farm-size and land-tenure classes were cross-classified according to farmers residing within and outside Nagbayan.

Table 5. Benefits and costs associated with rehabilitating the Cavite Communal Irrigation System. Castillejos, Zambales, Philippines, 1974-75.

	Case A [a]	Case B [a]	Case C [a]
Capital cost (CC) ($)	3,326	2,841	1,899
Operation and maintenance cost:			
Annual flow ($)	497	262	0
Capitalized value (O&M) ($)	2,810	1,546	0
Benefits:			
Annual flow ($)	2,321	2,321	2,321
Capitalized value (B) ($)	13,111	13,111	13,111
Benefit: cost ratio = $\frac{B}{CC + O\&M}$	2.1	3.0	6.9
Internal rate of return (%)	54	72	122

[a] The wage rate for communal labor is computed on the basis of the wage rate for construction workers ($1.07/day) in case A, for farm workers ($0.59/day) in case B, and as zero in case C.

Table 6. Estimates of the average rate of return to communal labor used in rehabilitating the Cavite Communal Irrigation System. Castillejos, Zambales province, Philippines, 1974-75.

	Case A [a]	Case B [a]	Case C [a]
Capitalized value of benefit ($)	13,111	13,111	13,111
Capital cost excluding the imputed value of communal labor ($)	2,248	2,248	2,248
Capitalized value of operation and maintenance (O&M) cost ($)	2,810	1,546	0
Total return to communal labor [b] ($)	8,053	9,317	10,863
Communal labor mobilized (man-days)	1010	1010	1010
Av. return to communal labor [c] ($/man-day)	8	9	11

[a] For cases A, B, and C the imputed cost of O&M labor is assumed as $1.07, $0.59, and $0 per day, respectively.
[b] Total return to communal labor = capitalized value of benefit - (capital cost + capitalized value of O&M cost).
[c] Average return to communal labor = total return ÷ number of man-days mobilized.

The third hypothesis was that village residents would respond more positively to requests of their leaders because of better communication and stronger social compulsion.

In general, the first and third hypotheses were confirmed. Slightly more labor was contributed by farmers with larger holdings and by village residents (Table 7). Contrary to expectations, however, share tenants contributed the highest average labor and owner-operators the lowest. These unexpected findings can probably be explained in terms of the village social structure. Nagbayan is essentially a share-tenant village. The majority of the population, including the captain and council members, are share tenants. The common identity and the interests shared by the villagers and their leaders seem to provide them with special motivation to participate actively in the group project. In contrast, owner-operators belong to a different social class. Most live outside the village and have nonfarm sources of income; their farm operations are based primarily on hired labor. It is not surprising that they are less willing to become involved in a community work program.

The quality of leadership was, of course,

Table 7. Distribution by socioeconomic characteristics of labor contributed by farmers for rehabilitating the Cavite Communal Irrigation System. Castillejos, Zambales province, Philippines, 1974-75.

Socioeconomic characteristic	Farmers (no.)			Av. labor contribution (man-days)		
	Nagbayan residents	Non-residents	Total	Nagbayan residents	Non-residents	Weighted av.
Farm size (ha)						
Less than 1.0	11	8	19	10.1	5.5	8.1
1.0 to 1.9	10	36	46	13.2	7.2	8.5
2.0 to 2.9	9	10	19	11.7	8.1	9.8
3.0 and above	11	5	16	15.5	8.2	13.2
Land tenure status						
Owner-operator	0	20	20	0.0	3.9	3.9
Part owner-operator	2	2	4	7.0	15.0	11.0
Leasehold tenant	5	9	14	10.9	5.5	7.4
Share tenant	30	27	57	13.8	9.6	11.8
Seasonal tenant	4	1	5	9.3	8.0	9.0

critical for the effective organization of the community work program. The leaders in Nagbayan, especially the village captain, not only perceived the potential profitability of the project but were highly resourceful in pursuing political routes to acquire assistance from government agencies. They utilized outside assistance as a lever to persuade community members to participate in the project.

Furthermore, the leaders did not merely plan and coordinate the work of other community members in the project but also contributed their own manual labor. The village captain himself contributed 63 days of work. The average labor contribution of village leaders was 36% higher than that of village residents. The presence and participation of the leaders in the work undoubtedly raised the morale of the other community members.

Distribution of Benefits

The high productivity of local labor in the rehabilitation of the Cavite System implies a strong incentive for the community to carry out the project. However, the high return to the community as a whole does not guarantee that the returns to individuals and classes within the village are sufficient to ensure their participation in future work. Shares of gross value added per farm were therefore estimated before and after the rehabilitation to show the changes in income associated with the project.

The distribution of benefits among different groups was calculated by determining net agricultural income per farm and apportioning that income among landowners, farm operators, and hired laborers according to the transfer payments found for a subsample of 30 respondents from the original survey. The analysis compares the changes in the shares before and after the rehabilitation project.

Landowners as a group increased their shares by 133%, farm operators by 142%, and hired laborers by 180% (Table 8). The benefits from the rehabilitation are widely distributed, with all three groups receiving substantial increases in income. Hired laborers had the largest relative gains, reflecting the fact that benefits in the form of increased employment opportunities spilled over from large farmers to landless laborers and small farmers. The seven participants with no land inside the systems contributed significant amounts of labor with the expectation of more dry-season employment (Table 1), providing evidence that such an expectation may have also been an incentive to farmers with small holdings to participate in the project. In fact, the village leaders used increased employment as a rationale to persuade the poorer members of the community to cooperate.

Unlike the two other groups, landowners received their benetits without having contrib-

Table 8. Output per farm[a], input costs, and gross value added for different rural groups before and after rehabilitation of the Cavite Communal Irrigation System, Castollejos. Zambales province, Philippines, 1972 and 1974

Factor	1972 (US$)	1974 (US$)	Change from 1972 to 1974 (%)
Output[b] per farm	100	257	157
Payment for current inputs per farm	11	38	245
Gross value added per farm	89	219	146
Distribution of added gross value among			
Landowners	43	100	133
Farm operators	26	63	142
Hired labor	20	56	180

[a] Mean of 30 sample farms [b] Valued at a constant price of US$0.12/kg rough rice

uted significantly to the project. It is quite likely that Philippine landowners, confronted recently by a land reform program, have little incentive to invest in further land improvement. But if this is the case, they should be obliged to forgo their gains from projects such as the rehabilitation of the Cavite System in favor of those who contributed their resources.

Summary and Conclusions

In the rehabilitation of the Cavite Communal Irrigation System, the mobilization of local resources, primarily labor, was facilitated by government assistance, with local resources constituting about 50 to 75% of the government subsidy.

The project proved highly profitable in terms of social benefit and cost criteria. Estimated *B-C* ratios ranged from 2.6 to 6.9 and *IRRs* ranged from 54 to 122%. The estimated daily return to the communal labor used in the project was over 10 times the prevailing farm wage rate, suggesting the attractiveness of communal rehabilitation projects.

The labor contribution of individual community members was extensive and relatively uniform among different farm-size and land-tenure classes, although farmers with large holdings contributed more. Participation was extensive because of capable local leaders with whom most villagers had a close social link. It was uniform because the increased employment opportunities resulting from the rehabilitation benefited landless laborers and small farmers more than they did landowners.

The impact of the communal rehabilitation project might be quite different in communities with diverse physical and economic environments, social structures, and local leaders. A stronger basis for designing effective policies to mobilize local resources for irrigation development could be provided if the study were repeated in a variety of socioeconomic environments. Studying the success and failures of completed projects may also yield valuable information.

The pricing of irrigation water: a case study of the Philippines' Upper Pampanga River project

R. N. TAGARINO and R. D. TORRES

THE RESERVOIR-SUPPLIED UPPER PAMPANGA RIVER PROJECT in Central Luzon, Philippines, was completed in 1975. It has a command area of about 83,000 ha. A preliminary study showed the project to be economically viable, but the 1974–75 surplus income from rice production was found inadequate to fully cover farm production costs, family expenses, and current irrigation fees.

Hundreds of millions of dollars are currently being invested in irrigation infrastructure in many Southeast Asian countries, but there is little information to guide the people who finance, design, or manage these projects. The most definitive data are often found in feasibility studies undertaken before a project is begun, or in subsequent progress reports and reviews. Very few thorough economic studies are available to decision-makers concerned with the economic performance of irrigation systems or with ways of financing investment in irrigation.

In 1974-75 a preliminary study was undertaken to provide insights into the formulation of future policies on irrigation charges in the Philippines' Upper Pampanga River Project (UPRP). Surveys of farmers within and outside the project area were undertaken to estimate costs and benefits associated with the project, and to assess farmers' capacity to pay the costs.

R.N. Tagarino, Researcher. and *R.D. Torres,* Associate Professor, Center for Policy and Development Studies and Department of Agricultural Economics, Institute of Agricultural Development and Administration, University of the Philippines at Los Baños, Laguna, Philippines.

The Upper Pampanga River Project

The UPRP in Central Luzon covers an area of about 83,000 ha, 40,000 ha of which had previously been partially irrigated from diversion sources for many years. Initially conceived in 1962, the UPRP went into full operation under the National Irrigation Administration (NIA) in 1975 as the Philippines' most important multipurpose water development project. It utilizes the irregular flows of the Pampanga River and its tributaries for irrigation, hydroelectric power generation, flood control, domestic and industrial water supply, recreation, and fish conservation.

The UPRP is also the Philippines' first reservoir-storage project. It is intended pri-

marily for dry-season irrigation, with 94% of the command area currently double-cropped. Supplemental irrigation and reduced flood damage during the wet season are also made possible by reservoir storage. The present average wet-season irrigation efficiency of 30% (Kampen, 1970) can probably be doubled through rotational irrigation and other improved management practices being introduced in the UPRP area.

Costs of UPRP Irrigation

Irrigation costs consist of construction charges and day-to-day operations and maintenance (O&M) expenditures. The total capital investment in the UPRP is about US$105.5 million (NIA, ECI-EDCOP, 1975).[1] About 40% of the investment was financed by the International Bank for Reconstruction and Development, and 60% by the Philippine government. Almost half of the total construction cost was for dam and reservoir construction (Table 1).

Table 1. Estimated total capital investment by category. Upper Pampanga River Project, Philippines, 1975.[a]

Item	Sources of funds (million US$)		
	Local	Foreign[b]	Total
Civil works			
Dam and reservoir	26.8	23 0	49.8
Irrigation Infrastructure	18.6	6.5	25 1
Government procurement	0.1	3.2	33
Engineering supervision and administration	13.9	0.2	14.1
Consulting services	0.7	1.8	2.5
Contingencies	3.1	1.1	4.2
Interest charges during construction	0.0	6.5	6.5
Total	63.2	42 3	105.5

[a] Source: National Irrigation Administration and Engineering Consultants Incorporated-Engineering Development Corporation of the Philippines (1975). [b] Foreign funds consisted of $34 million direct loan plus $8.1 million indirect funding from the International Bank for Reconstruction and Development.

Table 2. Allocation of reservoir storage capacity. Upper Pampanga River Project, Philippines, 1975.[a]

Intended use	Volume (million m³)	Share (%)
Irrigation	1,667	79.5
Flood control	330	15.8
Power	86	4.2
Municipal water supply	10	0.5
Total	2,093[b]	100.0

[a] Source: National Irrigation Administration and Engineering Consultants Incorporated-Engineering Development Corporation of the Philippines (1975). [b] Excludes assigned storage capacities of 130 million m^3 for sediment, 95 million m^3 for inactive storage, and 688 million m^3 for surcharge.

Total capital investment was apportioned among the project's primary purposes — irrigation, flood control, power, and water supply — in proportion to their use of the reservoir (Table 2). No investment was assigned to fish conservation or recreation. Almost 80% of the resevoir storage capacity is intended for irrigation; thus, 80% of the total joint project costs plus specific cost items amounting to about $86.8 million, or $1,037/ha are charged to irrigation (Table 3). Assuming a 50-year repayment period corresponding to the expected economic life of the system, and the average interest rate of 7% paid by NIA for its domestic and foreign loans, the equivalent annual financial cost for construction is $75/ha. The corresponding economic cost is $7l/ha.

The average O&M cost in the UPRP in 1974 was $19/ha. Thus, the total annual financial cost of construction and O&M is $94/ha, and the annual economic cost is $90/ha. The current annual irrigation fee is $45/ha,[2] or 48% of the financial cost. During

[1] All cost and price data in this paper have been converted to US dollars at ₱6.6 = US$1.

[2] The annual UPRP fee for two crops is equal to the value of 300 kg of rough rice, priced at $0.15/kg.

Table 3. Allocation of capital Investment by category. Upper Pampanga River Project, Philippines, 1975.[a]

item	Allocation of investment (million US$)				
	Irrigation	Flood control	Power	Municipal water supply	Total
Civil works					
Dam and reservoir	37.4	7.0	5.2	0.2	49.8
Irrigation and infrastructure	25.1	0.0	0.0	0.0	25.1
Government procurement	2.6	0.6	0.1	0.0	3.3
Engineering supervision and administration	11.2	2.2	0.6	0.1	14.1
Consulting services	2.0	0.4	0.1	0.0	2.5
Contingencies	3.3	0.7	0.2	0.0	4.2
Interest charges during construction	5.2	1.1	0.2	0.0	6.5
Total	86.8	12.0	6.4	0.3	105.5

[a]Based on percentage of Intended use of the reservoir. For detailed computational procedures see Tagarino (1976).

the last 5 years, only about 37% of the assessed charges in the systems now comprising the UPRP were collected; this repayment rate is slightly lower than that for other NIA systems (Table 4), and is based on a period when the level of charges was much lower than it is now.

Costs and Benefits of Irrigated Rice Production

An important criterion in fixing the level of irrigation fees is the farmers' capacity to pay. This capacity is based on farmers' benefits from irrigation and their family living expenditures.

Benefits from irrigation were estimated through a 1974-75 stratified random sample survey[3] of 123 irrigated and 121 rainfed farms representing with-project and without-project farms. Because the UPRP went into full operation only in 1975, the results are preliminary.

The average size of farm is 2.6 ha. The with-project farms grew a mean of 1.7 crops/year, a substantially higher cropping intensity than the 1.0 for without-project farms, and used about twice as much hired labor (Table 5). The vast majority of farmers were leaseholders. [4]

Annual rice production costs for with-project farms were about double those for without-project farms (Table 6). More than 50% of the total costs were noncash, representing imputed values for in-kind wage payments to hired labor and farm-owned inputs, e.g., operator and family labor, land, seed, machinery, and equipment. Of cash expenses, those for hired labor were highest, followed by those for fertilizer.

Benefit and cost analyses were based on a set of assumptions involving three alternative levels of yield, production costs, cropping intensities, and prices. These levels are 1) those reported in the 1974-75 survey, 2) those reported by farmers as typical for the 5 years before the survey, hereafter termed "normal," and 3) those reflecting NIA targets, hereafter termed "future potential."

[3]The farms were stratified by land class.

[4]The finding that 7% of with-project and 15% of without-project farmers were share-tenants suggests that the Philippine land transfer program was not fully implemented in 1974-75.

Table 4. Proportion of assessed irrigation fees actually collected, National Irrigation Administration, Philippines, 1970-75.[a]

Fiscal year	Collection rate (%)	
	UPRP systems[b]	All NIA systems
1970-71	34.2	34.6
1971-72	30.7	50.1
1972-73	40.7	42.3
1973-74	52.0	35.6
1974-75	2.3	8.3
Av.	37.1	39.3

[a] Source: National Irrigation Administration (1975).
[b] Systems absorbed into Upper Pampanga River Project upon its completion.

Table 5. Resources of with-project and without-project farms. Upper Pampanga River Project, Philippines, 1974-75.

Resource	With-project farms	Without-project farms
Farm operator		
Age (yr)	46	46
Education (yr)	5	5
Farming experience (yr)		
Total	23	24
On present farm	16	17
Av. family labor (man-days/yr)	234	218
Tenure status (%)		
Owner-operator	11	15
Leaseholder	80	69
Share-tenant	7	15
Others	2	1
Farmland		
Irrigable area (ha)	2.7	2.5
Cropped area (ha)	4.7	2.5
Cropping intensity (crops/yr)	1.7	1.0
Nonland capital Investment ($/farm)		
Tools and equipment	67	51
Farm buildings	56	21
Work animals	201	334
Other livestock	60	55
Farm supplies	10	18
Total	394	479
Labor inputs (man-days/farm)		
Operator	12	7
Family and exchange	7	5
Hired	31	14
Total	50	26

Normal yields for with-project farms were about 20% higher than the 1974-75 yields, and about 80% higher than normal yields on without-project farms, partly because of serious brown planthopper infestation during the 1974-75 crop year. Future potential with-project yields of 7.7 t/ha per year were almost double the 1974-75 recorded yield, and about 50% higher than the normal yield. The yield increase attributable to the project is 3.1 t/ha per year based on 1974-75 data, 2.4 t/ha per year under normal conditions, and 3.9 t/ha per year for future potential conditions (Table 7).

Production costs and cropping intensities were assumed to be the same under normal conditions as in 1974-75. Under future potential conditions, production costs were assumed to be 50% higher for with-project farms and 40% higher for without-project farms, and the with-project cropping intensity was assumed to increase from 1.72 to 1.94 crops/year (Table 7). Finally, the price of rice was assumed to increase from $0.14/kg under the 1974-75 and normal conditions to $0.15/kg under future potential conditions, reflecting a fully implemented government price support.

These data on cropping intensities, yields, rice prices, and production costs were then evaluated to determine the net value of rice production and farmers' repayment capacity for each of the three yield levels (Table 8). Net value of production represents the difference between the gross value (production times price) and total production costs. It reflects farmers' benefits from UPRP, and ranges from $108/ha for normal conditions to more than twice that amount, $221/ha, for future potential conditions. These benefits compare favorably with the annual economic cost ($90/ha) of supplying irrigation water through the UPRP.

Farmers' repayment capacity represents the difference between their farm income (net value of production plus imputed values of unpaid operator and family labor) and their family living expenses. It reflects the surplus from rice production that farm families could use to pay irrigation fees.[5] While the repay-

[5] Fees are not included as production costs in this analysis.

Table 6. Annual costs of rice production for with-project and without-project farms. Upper Pampanga River Project, Philippines, 1974-75.

Production factor	With-project farms US$/ha	With-project farms %	Without-project farms US$/ha	Without-project farms %
Cash				
Hired labor	89	19	37	16
Fertilizer	86	18	30	13
Chemicals	28	6	10	4
Other items	4	1	2	1
Subtotal [a]	207	44	79	34
Noncash				
In-kind wage payments	47	10	20	8
Seeds	20	4	11	5
Land rent	116	25	62	26
Unpaid operator, family labor, and other Items	74	16	62	27
Subtotal	257	55	155	66
Total	464	99	234	100

[a] Excluding irrigation fee.

Table 7. Yield and cropping intensities for three alternative conditions of with-project and without-project farms. Upper Pampanga River Project, Philippines, 1974-75.

Conditions	Yield (t/ha)			Cropping intensity (crop/yr)		
	Wet season	Dry season	Total	Wet season	Dry season	Total
1974-75 condition						
With project	2.1	2.5	4.6	0.94	0.78	1.72
Without project	1.5	0.0	1.5	0.99	0.00	0.99
Increase	0.6	2.5	3.1	−0.05	0.78	0.73
Normal condition [a]						
With project	2.5	2.6	5.1	0.94	0.78	1.72
Without project	2.7	0.0	2.7	0.99	0.00	0 99
Increase	−0.2	2.6	2.4	−0.05	0.78	0.73
Future potential condition [b]						
With project	3.8	3.9	7.7	1.00	0.94	1.94
Without project	3.8	0.0	3.8	1.00	0.00	1.00
Increase	0.0	3.9	3.9	0.00	0.94	0.94

[a] Mean production reported by farmers for 5 years before 1974-75. [b] Targets set by the NIA.

ment capacity of with-project farms (ranging from $159 to $271 /ha for the three conditions) is substantially higher than that of without-project farms, absolute levels of repayment capacity are still low, primarily because family living expenses are relatively high compared with the gross value of rice production and farm income. To illustrate, 1974-75 rice production on with-project farms failed to meet total production costs and family living

Table 8. Annual net value of production and repayment capacity (US$/ha) with three alternative conditions of with-project and without-project farms. Upper Pampanga River Project, Philippines, 1974-75.

Conditions	Grossvalue of production [a]	Total production costs	Family living expenses [b]	Net value of production [c]	Repayment capacity [d]
1974-75 condition					
With project	612	465	331	147	- 141
Without project	216	234	360	- 18	- 345
Increase	396	231		165	204
Normal condition					
With project	726	465	331	261	- 11
Without project	387	234	360	153	- 170
Increase	339	231		108	159
Future potential condition					
With project	1174	704	331	470	198
Without project	576	326	360	250	- 73
Increase	598	377		221	271

[a] Product of the respective annual yields (Table 7) and rice prices ($0.15/kg for future potential condition, $0.14/kg for the two other conditions). [b] Mean annual living expenses ($904) reported per family converted to a per hectare basis. [c] Gross value of production minus total production costs. [d] Net value of production plus imputed value of unpaid operator and family labor in farming, minus family living expenses.

expenses by $141/ha. Only under future potential conditions would farmers be able to meet the current irrigation fee of $45/ha. This suggests why irrigation fees have been so difficult to collect in the UPRP.

Finally, a benefit-cost ratio (B-C) and internal rate of return (IRR) were calculated for the UPRP, assuming a 50-year repayment period and the 7% interest rate on funds borrowed for the project. The B-C ratio is 2.4 and IRR is 20.7, indicating that the UPRP is economically viable. If interest rates are assumed to be 18%, however, the B-C ratio falls to 1.1.

Water Rate Policy

Two aspects of irrigation water rate policy are considered in this section: the level and type of water rates.

Level of irrigation fee

As previously mentioned, the current annual irrigation fee in the UPRP is $45/ha, or about half the annual cost of supplying irrigation through the system. It could thus be argued, and often is, that farmers should be responsible for a larger share of the irrigation costs. From two standpoints, however, this view may not be valid.

The first standpoint concerns the feasibility of farmers' paying more than the existing fee. The study shows that only under production and pricing conditions considerably more favorable than those of 1974-75, i.e., future potential conditions, does the average with-project farmer have enough surplus income from rice production to meet even the current irrigation fee (Table 8). The second standpoint concerns beneficiaries of irrigation other than the farmers who cultivate the irrigated land. Those beneficiaries are principally landowners whose increased agricultural income due to irrigation is capitalized into the value of the land.[6] Other indirect beneficiaries include 1) the industrial sector, especially rice millers and producers of farm inputs whose businesses expand because of irrigation; 2) laborers, who have greater employment opportunities through project construction and more intensive agri-

[6] In the Camiling Irrigation System, a diversion system in Tarlac province, land values increased from $303/ha in 1950-56 before the construction of the system, to $485/ha in 1957-59 after construction (IRRI, 1971).

cultural production, including double-cropping; 3) consumers, who can purchase larger quantities of lower-priced rice because of irrigation; and 4) government, through more stable and increased employment, greater food self-sufficiency, and savings or earnings of foreign exchange resulting from reduced dependence on imported rice, or from increased exports, or both.

Thus, determination of an appropriate level of irrigation fee for cultivators depends partly on quantifying irrigation gains that accrue to other beneficiaries and on the feasibility of capturing at least part of those beneficiaries' gains. Other factors to consider are national policies on wealth and income flows between the agricultural and nonagricultural sectors and the implications of changed fee levels for regional and personal income distribution. A country's administrative and political leadership must consider and decide such issues.

Form of irrigation fee

The irrigation fee is presently charged at a flat rate per hectare for each crop. Alternative approaches are to assess irrigation fees as a proportion of irrigated output or in relation to the volume of irrigation water used. Of the farmers interviewed, slightly more than 40% indicated a preference for a fee related to output, about 20% preferred a fee related to volume of water used, and fewer than 20% preferred an area-based fee (Table 9).

Table 9. Proportion of farmers expressing preference for each of five proposed forms of assessing the irrigation fee, Upper Pampanga River Irrigation Project, Philippines, 1974-75.

Basis of irrigation fee	Farmers expressing preference (%)
Quantity of produce	41
Volume of water used	21
Size of farm irrigated	18
Av. cost of irrigation services	14
No comment	6
Total	100

The advantages of an output-related fee are that the highest producers would pay the most, and seasonal changes in production levels would be accompanied by corresponding changes in the level of fee obligations. Its disadvantages are a more complicated system of assessment and collection of fees, year-to-year variation in expected revenues, and a possible disincentive to high levels of production.

The main reason for assessing fees according to the volume of water used — by rate or duration of irrigation flow or both — is to achieve efficient use of irrigation water. However, shifting to volumetric pricing would involved additional costs of infrastructure, O&M, and fee collection. With current data, we are not in a position to recommend any specific change in the form of irrigation fee assessment.

Summary and Conclusions

This preliminary study of irrigation costs and benefits and of farmers' capacity to pay for irrigation deals with the current UPRP water rate policy, which uses an area-based irrigation fee of $45/ha per year.

The study shows that annual construction and O&M costs of the project are about $94/ha. Farmer benefits from the UPRP range from about $108 to $221/ha, depending on assumed production and pricing conditions. These benefits, together with the B-C and IRR analyses, show the UPRP to be economically viable.

Farmers' capacity to pay for irrigation was measured by the difference between farm income (net value of production plus the imputed value of unpaid operator and family labor) and family living expenses. The study shows that the average farmer's repayment capacity was inadequate to meet the current irrigation fee in 1974-75. Two alternatives to an area-based irrigation fee were briefly explored, but no definite conclusions were reached.

Any change in the level or the form of irrigation fees in the UPRP should depend on

1) possible changes in the production and price environment for the farmers; 2) the extent of project benefits to nonfarm operators such as landowners, agroindustrialists, laborers, consumers, and government; 3) national policies on intersectoral income and wealth transfer; 4) relative priorities in national policy among the competing objectives of more efficient use of scarce water, greater revenue generation, and more egalitarian distribution of regional and personal income; and 5) the implications of possible changes in irrigation fee policies for each of those national policies.

Further research on the first, second, and fifth items would better inform policy makers as they consider the inherently complex issues that underlie financial policies in the UPRP.

References Cited

International Rice Research Institute. 1971. Annual report for 1970. Los Baños, Laguna, Philippines.

Kampen, J. 1970. Water losses and water-balance studies in lowland rice irrigation. Ph.D. thesis, Cornell University. 416 p. (unpubl.)

National Irrigation Administration (NIA). 1975. Irrigation fee collection efficiency reports of the National Irrigation Systems operated and maintained by the NIA. FY 1970-71 to FY 1974-75. Diliman, Quezon City.

National Irrigation Administration and Engineering Consultants Incorporated-Engineering Development Corporation of the Philippines (NIA, ECI-EDCOP). 1975. Progress report of the UPRP for the period ending December 31, 1974. Report No. 21, prepared and submitted to the International Bank of Reconstruction and Development (IBRD). Exhibit No. 1-5. Diliman, Quezon City.

Tagarino, R.N. 1976. The net value of irrigation water in Upper Pampanga River Project, Central Luzon, Philippines. M.S. thesis, University of the Philippines at Los Baños, Laguna. (unpubl.)

Preliminary analysis of selected gravity irrigation systems in the Philippines

R. R. HUELGAS and R. D. TORRES

THE ECONOMIC PERFORMANCE IN 1974 of seven diversion irrigation systems ranging in size from 2,400 to 9,000 ha is compared with their performance as initially projected. Construction costs are generally about 15% higher than originally projected, operation and maintenance costs are about 55% higher, and farm-income benefits from irrigation are about double. The greater farm-income benefits stem from the much higher rice prices in 1974 than those that were projected. Area irrigated and yields were both substantially below projected levels.

This study compares the performance in 1974 of seven gravity irrigation systems operated by the National Irrigation Administration (NIA) with the performance that had been projected in their feasibility studies. The analysis is preliminary because the construction of six of the seven systems[1] was completed only in 1973, just 1 year before the study was made. Furthermore, rice prices were unusually high in 1974, causing an upward bias in estimated incomes for that year.

The irrigation systems selected for study range in size from 2,400 to 8,860 ha (Table 1). The Banga, Marbel, and M'lang Systems are in Cotabato province, the Baco System is in Oriental Mindoro, the Barit in Camarines Sur, the Bito in Leyte, and the Nayom in Zambales.

R. R. Huelgas, Instructor, and *R. D. Torres*, Associate Professor, Institute of Agricultural Development and Administration, University of the Philippines at Los Baños, Laguna, Philippines.

[1] The Barit System was completed in 1971.

Before the NIA infrastructure was built, most of the systems were partly served during the wet season by supplemental communal or pump irrigation dependent on small creek sources. The dominant crop for all systems was rice, with maize also rather important in the Cotabato project areas.

Both secondary and primary data were used in the study. Data on irrigation costs, potential service areas, actually irrigated areas, and other relevant information for each system were obtained from feasibility studies and various NIA annual reports. Data for 1974 conditions were collected through field surveys with randomly selected farmers in each system, and through interviews with irrigation superintendents and staff.

Areas Served by Irrigation

Of the 27,690-ha potential service area in the seven systems, only 18,950 ha or 68% was irrigated during the 1974 wet season (Table 1).

Table 1. Cropped areas of seven selected irrigation systems, National irrigation Administration, Philippines, 1974.

Irrigation system	Potential service area (thousand ha)	Area irrigated in 1974 (thousand ha)			Portion of potential service area irrigated in the 1974 wet season (%)	Cropping intensity [a] with respect to	
		Wet season	Dry season	Total		Potential service area	1974 wet-season area
Baco	8.86	7.05	1.05	8.10	79.6	0.91	1.15
Barit	4.00	2.50	1.00	3.50	62.5	0.88	1.40
Bito	3.50	0.98	0.78	1.76	28.0	0.50	1.80
Banga	3.36	2.66	2.66	5.32	79.2	1.58	2.00
M'lang	2.85	1.56	1.56	3.12	54.7	1.10	2.00
Marbel	2.72	1.80	1.80	3.60	66.2	1.32	2.00
Nayom	2.40	2.40	1.33	3.73	100.0	1.55	1.55
Total	27.69	18.95	10.18	29.13	68.4	1.05	1.54

[a] Ratio of the total areas irrigated during both seasons in 1974 to the potential service area, or to the 1974 wet-season area, for each system.

The percentage ranged from a low 28% for the Bito System, where water shortages were severe, to 100% for the Nayom System.

The sum of the 1974 wet- and dry-season areas was related to the potential service area and to the 1974 wet-season area for each system. The mean cropping intensity based on the wet-season area was 1.54, reflecting the extent of double-cropping in the area under irrigation. But since the potential service area was not fully developed, the actual cropping intensity is only 1.05 (Table 1).

Costs of Irrigation

Irrigation costs are of two types: 1) one-time construction expenditures for diversion works, distribution channels, water-control structures, access roads, and buildings; and 2) recurring operations and maintenance (O&M) expenditures for personnel, equipment, and supplies.

Construction

The total cost of constructing the seven systems [2] was US$4,121,000 (Table 2), or $149/ha of potential service area. [3] This is about 15% more than the feasibility studies had projected. Recorded costs exceeded projected costs because the construction included some work, such as drainage facilities in the Baco and Bito Systems, that had not been anticipated. A contributing reason is the inflation rate of about I7%/year between 1969 and 1973 (Encarnacion, 1976).

Operations and maintenance

Reported O&M costs [4] in 1974 were $157,900 for the seven systems, or $5.70/ha of potential service area (Table 2). These costs were about 55% higher than projected. The extent to which this reflects greater-than-projected O&M needs, less efficient performance of O&M than projected, or unexpected cost-price inflation, or all three, is not known. The expenditure is quite consistent, however, with levels of O&M recommended by NIA, which are $4.70/ha for systems with 1,000 to 20,000 ha and $7.00/ha for systems with less than 1,000 ha. [5]

Benefits of Irrigation

The benefits of irrigation were analyzed in terms of the net incomes per hectare projected

[2] Civil works accounted for almost 80% of total construction costs; other expenses were for preconstruction surveys, project facilities, and equipment.

[3] All cost and price data in this paper have been converted to US dollars at P7.5 = US$1.

[4] Personnel accounted for 75% of projected (67% of 1974) O&M expenditures.

[5] NIA communications with the authors.

Table 2. Projected and recorded costs (US$) of seven selected irrigation systems, National Irrigation Administration, Philippines, 1974.

Irrigation system	Total construction costs				Annual operations and maintenance costs			
	Projected (thousand $)	Recorded (thousand $)	Difference [a] Thousand $	Difference [a] %	Projected (thousand $)	1974 Recorded (thousand $)	Difference [a] Thousand $	Difference [a] %
Baco	758	1,097	+ 339	+ 45	30.7	56.8	+ 26.1	+ 85
Barit	394	310	- 84	- 21	15.3	19.6	+ 4.3	+ 28
Bito	199	297	+ 98	+ 49	13.1	10.6	- 2.5	+ 19
Banga	430	500	+ 70	+ 16	8.7	18.4	+ 9.7	+ 111
M'lang	1,056	970	- 86	- 8	13.4	20.0	+ 6.6	+ 49
Marbel	347	562	+ 215	+ 62	12.9	21.4	+ 8.5	+ 66
Nayom	408	385	- 23	- 6	7.7	11.1	+ 3.4	+ 44
Total	3,592	4,121	+ 529	+ 15	101.8	157.9	+ 56.1	+ 55

[a] Recorded costs less projected costs

Table 3. Projected and recorded 1974 net farm incomes, seven selected irrigation systems, National Irrigation Administration, Philippines, 1974.

Irrigation system	Projected (US$/ha per year)	Recorded (US$/ha per year)	Ratio[a]
Baco	79	165	2.1
Barit	104	160	1.5
Bito	67	138	2.1
Banga	44	151	3.4
M'lang	62	195	3.1
Marbel	81	110	1.4
Nayom	40	48	1.2
Av.[b]	72	147	2.0

[a] Ratios of recorded to projected incomes. [b] Averages are weighted by the potential service areas of each system.

in the feasibility studies vs. those realized in 1974 in the areas actually irrigated. Thus, the analysis does not consider possible benefits from the 32% of the projected service area that did not receive irrigation in 1974.

The average 1974 net farm income was $147/ha per year, or approximately twice the level that had been projected (Table 3). It was high because rice prices in 1974 ($0.09 to $0.12/kg) were almost three times higher than projected. Yields in 1974 were lower by half in some cases, and production expenses were from 1.5 to 2.5 times higher, than projected. However, both were more than offset by the unusually high rice prices.

Summary and Conclusion

The study aimed to analyze the difference between the projected economic performance of seven NIA irrigation systems as reflected in their feasibility studies, and the performance of the systems in 1974 as found through field surveys and supporting data.

Only two-thirds of the total potential service area in the systems was irrigated in the 1974 wet season. The average cropping intensity relative to the potential service area was 1.05; cropping intensity based on the area irrigated in the 1974 wet season was 1.54.

The total costs of irrigation exceeded the

projected costs by about 15% for construction, and by about 55% for O&M. The net income of farmers in the irrigated area was also higher in 1974 — about twice the projected level. The higher income reflected higher-than-expected rice prices, however, and not larger-than-expected production under irrigation.

The results of the study are preliminary. A more complete understanding of the economic performance of the irrigation systems will have to await the time when the systems reach full maturity and when studies may be conducted for more than 1 year so that atypical prices do not unduly distort the results. More detailed attention should also be given to separating physical from monetary factors in explaining contrasts between projected and actual performance, and to determining underlying causes for variation in the performance of different systems. There will then be a basis for confirming or revising the findings for the seven systems in this study.

Reference Cited

Encarmacion, J., Jr. 1976. Philippine economic problems in perspective. Institute of Economic Development and Research, U.P. Diliman, Q C. 350 p.

Economic analysis of irrigation development in deltaic regions of Asia: the case of Central Thailand

NGO QUOC TRUNG

THIS PAPER IS A HISTORICAL ANALYSIS of the development of irrigation infrastructure in the Chao Phya River Basin in Central Thailand. This land-locked delta encompasses 650,000 ha of irrigable area; almost all is planted to rice in the wet season. The study categorizes the irrigation development into three successive and interdependent phases: the first involves the construction of the Chainat diversion dam and the primary water distribution network; the second, the construction of the Bhumiphol and Sirikit dams and reservoirs to provide dry-season irrigation; and the third, localized on-farm consolidation and development. The analysis shows greater rates of economic return with each succeeding phase.

The major rice-producing regions of Asia are in countries of two contrasting types: insular or peninsular such as parts of Indonesia, Japan, Korea, Malaysia, the Philippines, and Taiwan; and continental such as in Burma, Thailand, and Vietnam. In the insular countries, watersheds tend to be relatively small and physically separated, and precipitation patterns are more even throughout the year. The continental countries, on the other hand, tend to have large, flat deltaic plains and more pronounced monsoon and dry seeasons.

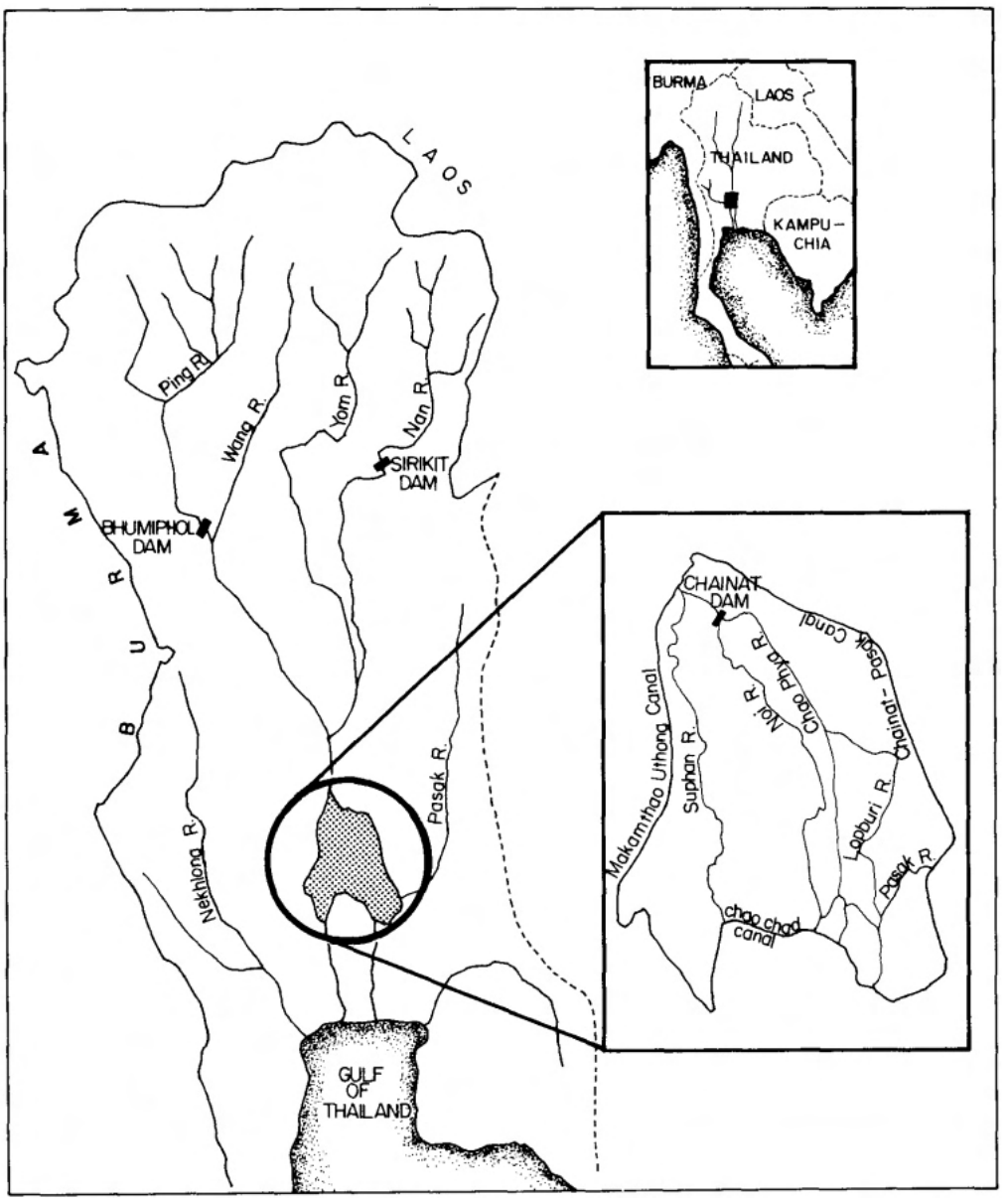
Those contrasting physical environments necessitate the use of different strategies to develop land and water resources. Insular and peninsular countries may develop their resources through relatively small, piecemeal projects, in which double-cropping does not necessarily require reservoir storage.[1] The land and water resources of continental countries, on the other hand, can usually be developed only through large-scale, basinwide approaches. involving protection from floods and salt water intrusion, as well as reservoir storage for dry-season irrigation. Developing the continental countries thus requires more capital.

This paper is a case study[2] of the Chao Phya Irrigation Project in Central Thailand (Fig. 1).

Ngo Quoc Trung, Assistant Professor of Economics, Institute of Agricultural Development and Administration, University of the Philippines at Los Baños, Laguna, Philippines.

[1] See Hayami et al. (1975) for more details on the Japanese experience. Kikuchi 11975) provides more information on Taiwan, Korea, and the Philippines.

[2] This study was part of the IRRI Agricultural Economics Department project *Agricultural growth against a land resource constraint* organized by Dr. Y. Hayami.



1. The Northern Chao Phya area and its location in the Chao Phya River basin, Thailand.

The Chao Phya river basin covers approximately 16.2 million ha, or about 31% of Thailand's total land area. The case study, however, is limited (except where noted) to the northern Chao Phya Project area of about 650,000 ha where most of the postwar irrigation investments have been concentrated.

The Chao Phya delta is a vast flat plain with large areas that are regularly flooded in the rainy season. Rainfall is generally less than adequate for rice production. The average annual rainfall in Central Thailand is between 100 and 150 cm (Beban, 1968), but traditional rice varieties of long growth duration require roughly 170 cm per

season. An equally critical problem is the highly uneven distribution of rainfall during the year. For example, the average discharge from the Chao Phya River in the wet season is about 4,000 m^3/second, but in the dry season it is only 50 m^3/second. During the wet season, flooding problems from heavy rainfall are exacerbated by the delta's shallow slope and the poor drainage of its heavy clay soils. Without major infrastructural development, dry-season cropping would be limited to small areas along the rivers.

Development of Water Control

Although rice has always been an important crop in Thailand, only sporadic efforts to develop the country's land and water resources for rice production were made until the 1950's. This section highlights the development of major post-1950 water control infrastructure in the project area:

1. *The Chainat Dam (1951-57) and major canals and laterals (1952-64).* Initial construction in 1951 of the Chainat diversion dam and the network of major canals from the apex of the delta (Fig. 1) launched the Royal Irrigation Department's (RID) major infrastructure program in the project area. The network was intended primarily to disperse floods and thus stabilize wet-season agricultural production (Small, 1972).

2. *The ditches and dikes project (1962-69).* A low-cost attempt to improve farm-level water distribution provided for ditches spaced at about 400-m intervals, assuming that farmers would complete the distribution network down to their farms. In practice, however, relatively little on-farm development was done.

3. *The drainage canals (1965 to present).* The drainage canal program aimed at moving surplus water through short drainage canals to natural waterways. Program achievements have been somewhat limited, however, partly because the topography is so flat that some drains are lower than the natural waterways and thus cannot discharge their water.

4. *The Bhumiphol Dam (1958-64).* The Bhumiphol Dam is a reservoir-storage dam on the Ping River, north of the delta (Fig. 1). It is intended primarily for hydroelectric power generation, but it also facilitates dry-season irrigation, navigation, and salinity and flood control. The dam was completed in 1964, but drought in succeeding years delayed its effective utilization.

5. *The Sirikit Dam (1965-73).* The Sirikit Dam is a reservoir-storage dam on the Nan River, another tributary of the Chao Phya, northeast of the Bhumiphol Dam (Fig. 1). Its primary purpose is dry-season irrigation. The Sirikit and Bhumiphol Dams are designed to release roughly 4,500 million m^3 of water during the dry season, an amount which should be sufficient to irrigate approximately 40% of the project area.

6. *Land consolidation (1969 to* present). The term land consolidation covers a program to introduce farm-level irrigation and drainage facilities, farm roads, land leveling and boundary realignment (Ananda, this volume). By 1976, about 9,275 ha had been consolidated.

For purposes of this study, the aforementioned infrastructural developments are grouped into three phases. Phase I represents the initial primary development for stabilizing wet-season agricultural production. It includes construction of the Chainat Dam, major canals and laterals, ditches and dikes, and drainage canals. Phase II comprises the two reservoir-storage dams that increased the dry-season irrigation. Phase III includes the most recent program for improving water control at the farm level. Although the characteristics of each phase are conceptually distinct, the phases are in fact interdependent, with each succeeding one becoming feasible only after the completion of the previous ones.

Economic Analysis

Only direct economic benefits and costs are analyzed in this study. The three phases were evaluated separately and in combination through benefit-cost (B-C) ratio and internal rate of return (IRR) analyses. A discount rate of 12% was assumed in the B-C computations. The economic life of infrastructure was assumed to be 50 years. Real, accounting prices were assigned to all the projects' inputs and outputs. That required, among other things, adjusting farm-gate

rice prices to correct for the price premium export tax, [3] adjusting domestic fertilizer prices to correct for the import quota on fertilizer, and imputing shadow wage rates for family and hired labor. [4] All Phase I costs are expressed in terms of either 1961 and 1970 prices; Phase II and II costs are in terms of 1970 prices.

Phase I

The yearly costs of Phase I, including construction and operation and maintenance (O&M) costs, range from US$1.2 to $11.6 million[5] (Table 1). The relative importance of O&M costs increases as the Phase I program matures; those costs stabilize at $4 million/year beginning in 1971.

Agricultural production benefits in the wet season arise from the added water control that enables farmers to shift from broadcasting to more productive transplanting culture, and from less flood and drought damages resulting in complete loss. Independent of these effects are further yield increases partly associated with more intensive cultural management. Some of these increases are attributable to improved water management and are included as benefits; others, such as those resulting from greater use of fertilizers and chemicals, are not included. [6]

Data on sources of increased production as well as the associated increase in production costs (primarily for labor in transplanting, harvesting, hauling, and threshing), and the resulting increase in the net value of rice production, are adapted from Small (1972) and Kaida (1971) (Table 2). The benefits, computed from 1962 when the Chainat Dam and most of the major canals and laterals were completed, are assumed to stabilize in 1971. They range from $10 to $12 million/year.

The B-C ratio for Phase I is 0.59 and the IRR is 6.4%. The rates of return are relatively low because the changes have largely been within the context of traditional agriculture, when the Chao Phya Irrigation project had not yet permitted full double-cropping or effective water control at the farm level.

Phase II

The costs of Phase II construction — more than $10 million annually — are considerably higher than those of Phase I (Table 3). Because the Phase II dams serve multiple purposes, only 37% of their total joint costs, corresponding to the same proportion of expected benefits, was allocated to agriculture.

Benefits of dry-season irrigation, unlike those in Phase I which are restricted to the northern region, are also found in other project areas further downstream in the southern region. The benefits in the two regions differ, although they both became significant around 1970. In the northern region, double-cropping expanded rapidly upon completion of Phase II construction (Table 4). The dry-season area there is assumed to stabilize at 122,200 ha by 1985. In the southern region, [7] additional dry-season water allowed a shift from the traditional varieties usually grown in the wet season, to early maturing improved varieties grown in the dry season. For the south, therefore, the dry-season benefits — which are slightly larger than for the north — arise from the projected yield advantage of improved varieties planted on 340,000 ha by 1985. All benefits for both regions were assumed to stabilize by 1985.

Although some upland crops such as sugarcane, mung bean , and soybean are grown with dry-season irrigation, their value is low relative to that of irrigated rice in the dry season. Therefore, the agricultural benefit associated with expanded dry-season cropping was evaluated mainly in terms of rice production. Estimates of increased rice production were based on two levels of nitrogen application, 21 and 40 kg of

[3] The imputed farm-gate rice price was assumed to be 54% of the export milled rice price, or US$68.50/t (Usher, 1967).

[4] For background information on these computations, see Wattananukit (1975).

[5] All cost and price data in this paper have been converted to US dollars at Baht 20 = US$1.

[6] This greater use of inputs follows national trends and cannot be attributed to the project itself.

[7] Similar changes took place in the southern edge of the northern region, where wet-season floodwaters tend to collect.

Table 1. Annual costs (million US$ at 1970 prices) of construction, operation, and maintenance associated with Phase I development. [a] Chao Phya Irrigation Project. Thailand,

Year	Construction (million US$)			Operation and maintenance (million US$)	Total (million US$)	
	Chainat Dam, canals and laterals	Ditches and dikes	Drainage system		Value in 1970 prices	Value in 1961 prices
1950	1.2				1.2	1.6
1951	1.4				1.4	1.6
1952	11.6				11.6	13.3
1953	8.7				8.7	10.7
1954	5.2				5.2	6.7
1955	9.6				9.6	10.3
1956	3.9				3.9	4.1
1957	4.3				4.3	4.5
1958	4.9				4.9	4.8
1959	3.0				3.0	3.1
1960	4.4				4.4	4.7
1961	5.0	0.1			5.1	5.1
1962	5.4	0.5			5.9	5.5
1963	3.5	0.4			3.5	3.9
1964	2.3	0.5		1.2	4.0	4.2
1965		2.0	0.4	1.3	3.7	3.8
1966		1.2	1.0	1.5	3.7	3.3
1967		0.4	1.2	2.0	3.6	3.0
1968			1.2	2.8	4.0	3.5
1969		0.1	1.1	3.6	4.8	4.0
1970			1.2	3.5	4.7	4.0
1971			1.0	4.0	5.0	4.3
:	:	:	:	:	:	:
:	:	:	:	:	:	:
1987			1.0	4.0	5.0	4.3

[a] Source: unpublished data, Statistics Section, Royal Irrigation Department. Thailand

elemental N/ha.[8] Production was evaluated with the following response functions (FAO, 1973), in which Y = yield (kg/ha) and *N* = level of elemental nitrogen (kg N/ha):

Traditional varieties, transplanted:

Both seasons: $Y = 2080 + 15.57\ N - 0.19\ N^2$

High yielding varieties, transplanted:

Wet season: $Y = 2079 + 20.65\ N - 0.076\ N^2$

Dry season: $Y = 2319 + 29.37\ N - 0.095\ N^2$

[8] The low level of application approximates current use by farmers in the project area (Duncan, 1975: Greene. 1970; Suwanpinolkul, 1975). The high level represents a middle-level recommended rate (IRRI. 1975). Chao Phya soils are not generally deficient in phosphate or potassium (Thitipoca and Walcott, 1975).

The B-C ratio for Phase II using the low fertilizer rate (21 kg N/ha) is 1.27, assuming a 50-year usable life of the project. The corresponding IRR is 13.8%. At the higher fertilizer rate (40 kg N/ha), the measures would be 2.12 and 16.6%, respectively. Note that the much higher returns to the second phase of development would not have been possible without the Phase I primary network of canals.

Phase III

Two levels of land consolidation intensity were assumed (Table 5). The cost for partial development is about 60% of the full-intensity cost of $332/ha in 1970 prices (adapted from Thailand RID, 1973 and 1975; Palayasoot, 1976), primarily because less land is leveled in partial development.

Table 2. Annual Increase[a] in rice production and in production costs associated with Phase I development.[b] Chao Phya Irrigation Project, Thailand.

Year	Increases in rice production (1000t) attributable to				Increased production costs[c] (million US$)	Increased net value of rice production[c] (million US$)
	Shift from broadcasting to trans-planting	Reduction in flood and drought damage	Associated yield increases	Total		
1962	3.1	35.8	133.3	172.2	0.8	11.0
1963	5.7	36.5	131.0	173.2	0.9	11.0
1964	9.0	36.4	128.9	174.3	0.9	11.0
1965	12.3	35.9	126.9	175.1	1.2	10.8
1966	15.6	35.3	120.7	171.6	1.3	10.5
1967	19.7	34.9	117.7	172.3	1.5	10.3
1968	21.2	34.8	116.2	172 2	1.6	10.2
1969	23 3	35.2	113.6	172.1	1.8	10.0
1970	25.0	36.1	133.3	194.4	1.9	11.4
1971	26.4	37.4	134.1	197.9	2.0	11.6
:	:	:	:		:	.
1987	26.4	37.4	134.1	197.9	2.0	11.6

[a] With reference to mean valuesfor 1955-61. [b]Adapted from Kaida (1971) and Small (1972). [c] In 1961 prices, with rice valued at US$68.50/t.

Table 3. Annual costs of dam construction during Phase II development and their allocation to irrigation.[a] Chao Phya Irrigation Project, Thailand.

Year	Annual construction costs (million US$)		Total (million US$)		Allocation to Irrigation (million US$)
	Bhumiphol Dam	Sirikit Dam	Valued at actual prices	Valued at 1970 prices	
1956	1.3	0	1.3	1.5	0.6
1957	1.0	0	1.0	1.2	0.4
1958	3.8	0	3.8	4.4	1.6
1959	14.4	0	14.4	17.8	6.6
1960	18.3	0	18.3	21.0	7.5
1961	19.2	0	19.2	22.4	8.3
1962	26.3	0	26.3	28.9	10.7
1963	20.9	0.3	21.2	24.7	9.1
1964	10.2	1.0	11.2	14.1	5.2
1965	1.0	2.0	3.0	3.5	1.3
1966	0.2	2.4	2.6	2.8	1.0
1967	0.3	3.6	3.9	3.8	1.4
1968	0.1	19.5	19.6	20.1	7.4
1969	0	19.0	19.0	18.9	7.0
1970	0	15.5	15.5	15.5	5.7
1971	0	14.6	14.6	14.6	5.4
1972	0	7.8	7.8	5.9	2.2
1973	0	0.7	0.7	0.4	0.2

[a] Source: unpublished data, Statistics Section, Royal Irrigation Department, Thailand.

Table 4. Recorded and expected expansion in area cultivated during the dry season. Chao Phya Irrigation Protect, Thailand.[a] 1970 to 1985

Year	Area (thousand ha) double-cropped in northern region[b]	Area shifted from traditional varieties wet season crop to HYV season crop[c] (thousand ha)	
		Southern edge of northern region	Southern region
1970	5.0	1.8	39.7
1971	8.8	2.7	52.1
1972	10.3	3.3	69.0
1973	25.6	6.1	97.8
1974	50.5	12.4	142.7
1975	73.5	14.2	175.1
1976	90.8	20.8	211.4
1977	100.4	23.3	245.1
1978	105.6	25.3	269.4
1979	108.7	27.3	288.2
1980	110.9	28.4	296.4
1981	113.1	29.5	302.5
1982	115.4	29.7	305.8
1983	117.7	30.2	308.2
1984	120.0	30.2	309.5
1985	122.2	30.4	310.3
⋮	⋮	⋮	⋮
1995	122.2	30.4	310.3

[a]Source: unpublished data. Operation and Maintenance Division, Royal Irrigation Department, Thailand. Negligible dry season cropping prior to 1970, almost all dry season plantings are modern varieties. [b]Excluding southern edge of northern region which is used as a water storage area. [c]No further wet season cropping following this shift

The cropping patterns were assumed to make greater use of improved varieties in full land consolidation than in partial development (Table 6). After 4 years of partial development, for example, 30% of the wet-season rice area and 40% of that in the dry season were assumed to be planted to improved varieties, whereas the corresponding figures for full development were 40% and 50%. The data are based on the 1971-74 experience with pilot land consolidation projects in the Chao Phya area (Duncan, 1975; Thailand RID, 1975).

The economic evaluation of Phase III assumes the development of 5,000, 10,000, 15,000, and 20,000 ha during each of 4 successive years. The figures reflect the projected capacity of Thailand to implement land consolidation. The fertilizer response relationships discussedearlier were again used, assuming current levels of nitrogen application.

The B-C ratios based on these assumptions for partial and full land consolidation development alternatives in Phase III are 1.33 and 1.56, respectively (Table 7). The corresponding IRR are 16.2% and 18.4%. The findings suggest that on-farm development in the Chao Phya project after the completion of Phases I and II is highly profitable. Furthermore, the investments — unlike those in Phases I and II — can be planned and undertaken in individual parts of the delta.

For consistency in computing benefits and costs, the above analyses of both Phases II and III used constant 1970 prices. Because costs and prices increased substantially since that year, however, the Phase III analysis was computed again using the 1975 investment cost of $626/ha for full development (compared with $332/ha) and the 1975 rice price of $127/t (compared with $68.50/t). These changes reduced the above-mentioned economic returns by about 5% of their values.

Overall project

The foregoing economic analysis has been applied to each phase of development independently of preceding phases. Such an analytical framework is valid if the purpose is to make investment decisions on succeeding phases after prior phases are completed. In that case, the costs that require consideration at each point of decision-making are only the costs of further development. For purposes of an investment analysis for phased expenditures, the costs of prior phases are thus treated as sunk costs to Thailand, and therefore not included in the analysis.

It is clear, however, that achievement of the benefits of each succeeding phase is dependent on the infrastructure provided in the preceding phases. In other words, Phase II could not have been undertaken effectively had Phase I not been carried out, and Phase III could not have been undertaken effectively if Phases I and II were

Table 5. Costs of partial and full land consolidation development (Phase Ill).[a] Chao Phya Irrigation Project, Thailand.

Task	Costs (US$/ha in 1970 prices)	
	Partial land consolidation	Full land consolidation
Surveying and issuing of title deeds	16	16
Designand preparation	11	11
Implementation		
Survey and staking out	15	15
Land clearing	12	12
Land leveling	25	103
Roads and ditches	22	47
Excavation of ditches	13	21
Structures	16	29
Rehabilitation	47	47
Administration, supervision and service	13	19
Annual operation and maintenance	8	9
Extension	3	3
Total	201	332

[a] Source: adapted from Thailand, Royal Irrigation Department (1973, 1975), and Palayasoot (1 976).

Table 6. Annual change in assumed area (% of total) for different types of rice culture with partial and full land consolidation.[a] Phase Ill development, Chao Phya Irrigation Project, Thailand.

Years after implementation	Annual change in assumed area (% of total)						
	Wet season					Dry season transplanted improved varieties	
	Broadcast partial and full	Transplanted traditional varieties		Transplanted improved varieties			
		Partial	Full	Partial	Full	Partial	Full
0	30	55	55	15	15	25	25
1	27	51	51	22	22	31	29
2	21	52	49	27	30	36	35
3	12	58	53	30	35	40	45
4	12	58	48	30	40	40	50

[a] Source: Thailand Royal Irrigation Department (1975) and Duncan (1975).

Table 7. Benefit-cost ratio (B-C) and corresponding internal rates of return (IRR) for investment in Phases I, II, and III development.[a] Chao Phya Irrigation Project, Thailand.

Phase of development	B-C	IRR
Phase I (at 1961 prices)	0.59	6.4
Phase II (at 1970 prices)	1.27	13.2
Phase III (at 1970 prices)		
Partial development	1.33	18.4
Full development	1.56	16.2
Phases I and II combined (at 1970 prices)	0.63	8.7
Phases I, II, and III combined[b] (at 1970 prices)	0.72	10.1

[a] All computations assume feertilizer use at the rate of 21 kg N/ha. [b] Phase III development was assumed in these calculations to consist of 30% full land consolidation and 70% partial development (Komate, 1976), and to eventually cover 60% of the northern region.

missing.[9] A framework for analyzing the relative profitability of the three phases should thus consider cumulative costs and benefits.

The analysis using separate phases was therefore supplemented by first combining Phases I and II, and then all three phases. The combined Phases I and II yielded a B-C ratio of 0.63 and an IRR of 8.7% (Table 7). [10] These phases played the crucial role of transforming the delta so that local development could be undertaken to assure water control at the farm level, a prerequisite to the introduction of modem agricultural technology.

All three phases combined produced an IRR of 10.1% assuming use of the actual level of fertilizer application. If the higher rate of nitrogen application (40 kg N/ha) is assumed, the IRR would be close to the 12% rate of discount which approximates the return to capital throughout the Thai economy. That is a respectable performance when one considers the complex processes in developing a large delta over a span of almost four decades.

[9] Confirming this view, the analysis shows that without Phase II, the IRR to Phase III is only 4.5%.

[10] Without the various delays in planning and construction, the project would have yielded a higher rate of return.

Conclusion

This case study illustrates the massive quantity of resources required to develop large deltaic river basins in a continental country such as Thailand. It also suggests that although the payoff from initial investments in land and water resource development may be inadequate to justify the investments being undertaken, making subsequent investments in infrastructure can help realize the latent potential from the earlier investments.

References Cited

Ananda, Karunyakon. 1978. Planning and implementing land consolidation in Thailand. Paper presented at the IRRI, ADC, SEARCA research seminar on irrigation systems in Southeast Asia. Los Baños, Laguna, Philippines. 19 p.

Behrman, J.R. 1968. Supply response in underdeveloped agriculture: a case study of four major annual crops in Thailand, 1937-63. North Holland Publishing Company, Amsterdam. 446 p.

Duncan, S. 1975. The social and economic impact of the Channasut Project. Outline of a talk given in July 1975.

Food and Agriculture Organization (FAO). 1973. Soil fertility research. Thailand: use of fertilizer on rice. FAO Tech. Rep. No. 2. 131 p.

Greene, B.A. 1970. Rate of adoption of new farm practices in the Central Plains, Thailand. Cornell University Occasional paper No. 41.

Hayami, Y., and associates. 1975. A century of agricultural growth in Japan: its relevance to Asian development. Tokyo University Press. 248 p.

International Rice Research Institute (IRRI). 1975. Constraints to high yields on Asian rice farms: an interim report. Los Baños, Philippines. 234 p.

Kaida, Yoshihiro. 1971. An analysis of the effect of environmental factors on paddy rice yields. Tonan Ajia Kenkyu (The Southeast Asian studies), Vol. IX, No. 2.

Kikuchi, Masao. 1975. Irrigation and rice technology in agricultural development: a comparative study of Taiwan, Korea, and the Philippines. Ph.D. dissertation, University of Hokkaido.

Komate, Somchart. 1976. Labor problems of double-cropping at Channasut Land Consolidation Project. M.S . thesis, Thammasat University, Bangkok. 97 p.

Palayasoot, Paitoon. 1976. On-farm development works in Thailand. Paper presented at the national seminar on water management and control at the farm level. Rangoon, Burma. p. 78-101,

Small, L.E. 1972. An economic evaluation of water control in the Northern region of the Greater Chao Phya Project of Thailand. Ph.D. dissertation, Cornell University, Ithaca, N.Y. 394 p.

Suwanpinokul, Supan. 1975. Socio-economic constraints on rice yield in parts of Suphanburi Province, Thailand. M.A. thesis, University of the Philippines, Diliman, Quezon City, Philippines. 174 p.

Thailand Royal Irrigation Department (RID). 1973. Land consolidation project in the Central Plain of Thailand (ILACO).

Thailand Royal Irrigation Department (RID). 1975. Chao

Phya Irrigated Agriculture Development. Chao Phya feasibility study. Stage II (ILACO).

Thitipoca, H., and J.J. Walcott. 1975. Recent results from the soil fertility program. *In* Proceedings on the Thai Australian Chao Phya research project, Chainat: 1968-75, Canberra. The Australian Development Assistance Bureau.

Usher, D. 1967. The Thai rice trade. *In* T.H. Silcook. Thailand: social and economic studies in development. Australian University Press, Canberra.

Wattananukit, Atchana. 1975. Comparative advantage of rice production in Thailand: a domestic resource cost study. M.S. thesis, Thammasat University, Bangkok. 158 p.

ORGANIZATION OF IRRIGATION ACTIVITIES AND BEHAVIOR OF IRRIGATORS

The organization of farm-level irrigation in Indonesia

R. HUTAPEA, PRAJARTA DIRJASANYATA, and N. G. S. NORDHOLT

FOUR SYSTEMS OF FARM-LEVEL IRRIGATION management in Indonesia are the Balinese irrigator group *subak,* the village ditch tender *.ulu-ulu desa,* the canal ditch tender *ulu-ulu pembagian,* and the more recent Central Javanese water management group *dharma tirta.* A review of the historical development of these water management systems and recent case studies of each system suggest five factors that influence the effectiveness of farm-level irrigation services: 1) the congruence of the boundaries of irrigation groups, irrigation command areas, and village jurisdictions; 2) coordinated organizational responsibility for irrigation; 3) the nature of village values and leadership and the extent of economic and social disparity within villages; 4) the perception by irrigators of who owns their water supplies; and 5) uniformity in the structure of irrigation organizations and the speed at which they are introduced.

This paper discusses four models of farm-level irrigation management in Indonesia. The models are based on 1) the irrigator group *subak* in Badung and Negara Regencies; 2) the village ditch-tender model *ulu-ulu desa* in Grobogan and Demak Regencies; 3) the canal ditch-tender model *ulu-ulu pembagian* in Brebes Regency[1]; and 4) the water management group *dharma tirta* in Brebes[1] and Sragen Regencies. All the regencies are in Central Java, except Badung and Negara, which are in Bali, the place of origin of the *subak.*

We preface the paper with a brief historical sketch of rural development in Indonesia, with particular emphasis on irrigation[2]. Van Akkeren (1970) indicates that traditional values in Javanese society are reflected in irrigation organizations that Wittfogel (1957) described as Asian "hydraulic civilizations." Javanese pioneers cleared forests and built irrigation systems to more effectively use water for rice production. Villages with a strong community spirit usually contributed voluntary labor for those activities.

In Java's early history, village communities were reasonably small and self-sufficient. Few

R. Hutapea, Research Project Officer; *P. Dirjasanyata,* Research Assistant; *N.C.S. Nordholt,* Technical Advisor, Research Institute of Social Sciences, Satya Wacana University, Salatiga, Central Java, Indonesia.

[1] In the Brebes Regency study area, water management was by a canal ditch-tender system until 1974 and by a *dharma tirta* system afterwards.

[2] For a detailed historical background, see Research Institute of Social Sciences (1975).

farmers were attached to landlords and central government was required only for public works and security. But village life gradually changed with Dutch rule, particularly with the implementation of the Compulsory Cultivation System *Cultural Stelsel* from 1830 to 1860, and the Political Ethic Program *Eriesche Politiek* in the early 1900's.

The Compulsory Cultivation System imposed constraints on farmers' choices of crop selections, labor contributions, and irrigation water use. It caused some loss of local autonomy and helped create privileged village leadership and landless labor classes.

The Political Ethic Program brought greater economic opportunities to rural Indonesia through the construction of irrigation systems. But village autonomy was weakened because a common water source often served more than one village. Another factor contributing to diminished authority of village heads, *lurah,* was their remoteness from the people, which increased as the village rapidly expanded (the population of the average Central Java village increased from 800 to more than 2,500 from 1900 to 1970). The guerrilla war of independence and subsequent political turmoil further disrupted village life. The introduction of high yielding rice varieties, with their more exacting requirements and cultural practices, eroded the concept of shared poverty and encouraged the development of more individualistic and profit-oriented motives (Collier et al., 1974; Geertz, 1963; Sayogyo, 1973). Water thus began to be regarded less as a public good for general use and more as a scarce resource with economic and political significance.

Systems of Farm-Level Water Management

The four models of farm-level water management in Indonesia are examined within the social context of changing values, individual freedom, and village autonomy.

Balinese irrigator group, *subak*

The *subak* is the traditional organization for controlling the supply and use of irrigation water in Bali.[3] *Subak* is derived from the word *seuwak,* meaning a portion of the same current. A subak is made up of rice fanners that obtain water from a common source. *Subak* borders do not usually correspond to administrative borders of individual villages (Birkelbach, 1973).

A *subak* is a democratic institution based on consultation and agreement. Although landowners formally make up a *subak,* the tillers are responsible for executing its communal labor activities. *Subak* chairmen, known as *pekaseh* or *kelihan,* are elected on the basis of merit. A chairman often owns rice fields but, unlike those in Central Java, his fields are usually no larger than average. The chairman acts as a mediator between his *subak* and other government agencies. Above him is the subdistrict coordinator, the *sedahan;* above the *sedahan* is the regency coordinator, the *sedahan agung.* Both are appointed by the regency head and have civil service status.

Comparing the chairman of a *subak* with a *lurah* or an *ulu-ulu* (whose responsibilities are described in the next section) is rather difficult. A *lurah* is a village head, and an *ulu-ulu* is his assistant for irrigation affairs. Although both have strong influence over irrigation matters, they are not chairmen of a formal organization such as the subak. Furthermore, unlike the *lurah,* the *ulu-ulu* does not usually farm an area larger than that of the ordinary farmers.

In the early stages of Balinese irrigation, each *subak* developed, operated, and maintained its own infrastructure. Recently the Balinese Department of Public Works assumed those responsibilities. Each regency irrigation coordinator, however, still has complete responsibility for irrigation operation, as well as for coordinating crop rotations, solving water disputes, and collecting land taxes. In Java, on the other hand, the Provincial Irrigation Services is responsible for operating the main irrigation system; the Provincial Agricultural Services looks after government agricultural functions; and the Pro-

[3] At one time the *subak* was also present in Java, but the Compulsory Cultivation System caused it to disappear (Soetardjo, 1965).

vincial Interior Department manages land revenue collections.

The general regulations governing *subak* complement customary law; they deal with the duties of *subak* members, solution of water disputes, and performance of irrigation ceremonies and rituals. Such ceremonies, based on the Hindu religion, are performed when water is initially distributed, when fertilizer is applied, and just before and after harvest. The regulations aim at providing a smoothly functioning irrigation environment for rice and upland crops.

Each *subak* has its own regulations, shaped by the conditions surrounding its establishment and development. Since most *subak* originated long ago, special skill is required to interpret the legal status of new practices. For example, for harvesting the short-strawed and easily shattering high yielding varieties of rice, sickles are more suitable than the traditional small knives, ani-ani. Because the new varieties were considered "external" (not originating in Bali), the traditional *subak* prohibition of the modern sickle was viewed as invalid and regulations were not changed.

New practices that conflict with existing regulations can be accepted only if all *subak* members approve the required changes in the regulations. For example, the uniform planting schedules recommended for modern rice varieties are inconsistent with most traditional regulations on irrigation scheduling; our field study showed some conflict among farmers in resolving the scheduling dilemma.

Village-unit working groups, *badan usaha unit desa (BUUD),* recently were established to undertake various rice production and marketing activities. In Bali, this organization is now integrated with the *subak,* with *subak* leaders responsible for marketing. A point of particular concern is whether *subak* leaders with substantial experience in water management but none in marketing would be capable of providing *BUUD* leadership. If they were not, the confidence of members in their leadership, even in matters regarding water, may diminish. The strength of the *subak* would thus be threatened.

A second cause for concern is the encroachment on the traditional autonomy of the individual *subak* by the Provincial Irrigation Services, which is responsible for *subak* irrigation construction. The growing involvement of the coordinator is due to greater water demands, which are increasingly difficult to supply and which require more technical expertise and large-scale construction. The government may have to assume a greater role in operating the systems at the expense of traditional *subak* autonomy, because of the large capital investments and the more careful water control needed for high yielding varieties of rice. When that happens, the individual *subak* may consider irrigation water no longer its own property and hence have less incentive to use it carefully.

We conclude our discussion of the *subak* by summarizing the elements that seem critical to highly effective water management:

1. Most *subak* were initially established to provide relatively small and independent water sources for irrigation. The simultaneous development of the sources and the institutions governing their use contributed to the belief of local communities that irrigation water was their own property, and therefore they had rights and responsibilities for its efficient utilization. These circumstances are quite different from those of most large-scale irrigation projects in which the govemment plays the major role in initial water development.

2. Because the boundaries of a *subak* are defined by the areas served by the water source and seldom correspond to village administrative units, the danger of conflict over water between groups from different villages is reduced.

3. The coordination of *subak* irrigation by the regency irrigation head improves the efficiency of government administration and reduces the number of agencies with which farmers must maintain contact.

4. Socioeconomic differences among members of a *subak* are relatively small. Feelings of village solidarity are quite strong, as illustrated in some villages by informal credit policies through which the community essentially guarantees the loan repayments of its members. Because Bali was relatively untouched by colonialism and international market forces, the villagers are somewhat less individualistic and

profit-seeking than those in most parts of Indonesia.

5. Religious and cultural values are the basis of irrigation regulations and practices; they provide important bonds for unity. Although some commentators on Balinese irrigation have suggested that the values are peculiarly Hindu, our comparative case studies of a Muslim and a Hindu *subak* showed no significant differences in the quality of water management attributable to either religion.

Village ditch tender, *ulu-ulu desa*

The most common type of farm-level water management in Java is the traditional village ditch-tender system. Village ditch tenders are usually appointed by their *lurah,* with the consent of the subdistrict government superior *camat,* and are therefore part of the local government, *pamong desa.* They are responsible for regulating the flow of irrigation water, organizing communal labor to maintain terminal irrigation facilities, and communicating with their superiors and government officials, especially the *lurah* and irrigation officers.

The responsibility of a village ditch tender is determined by the administrative boundaries of his village and not by the area commanded by a water channel, as in the case of *subak.* A village may have one or more ditch tenders, depending on its size. Eight of the 13 villages studied had only one ditch tender each. The area covered by a ditch tender in the study villages varied from 150 to 250 ha.

In Central Java, the local officials' compensation is the right to produce from village-owned rice land, *bengkok.* [4] The average size of a ditch tender's *bengkok* in the study area is about 1 ha, similar to that of the average farmer's, but much less than the 5-ha *bengkok* often reserved for the lurah. About 18% of the farm land in the villages was used for the *bengkok;* the *lurah* and his relatives had rights to 75% of it. Since more than half of the local officials were relatives of the lurah, there appeared to be substantial nepotism in the appointment of local officials (who also enjoyed better-than-average irrigation services).

Eighteen village ditch tenders were interviewed. They averaged 43 years of age, had 4 years of formal education, and had served as ditch tenders for about 12 years. Several had attended in-service training courses in farm water management. All were farmers, but 20% held other positions in the local government, and 24% pursued other nonfarm occupations such as trading, fishing, and driving horse carts.

Evidence from the villages studied indicates that the village ditch-tender system is not wholly satisfactory. Nepotism in the appointment of ditch tenders and other local officials seems to be widespread. By exercising their influence on water allocation decisions, the rural elite use irrigation to strengthen their advantage. These circumstances are due not only to the power of the *lurah* but also to the limited formal education and technical training of ditch tenders. Farmers acknowledged that the ditch tenders find holding more than one job economically necessary, and that breakdowns in water distribution often result from inadequate water supplies rather than from ditch tenders' ineptness. Therefore, the extent to which the modest operating performance of this water management system can be attributed to the village ditch tender is not clear.

Canal ditch tender, *ulu-ulu pembagian*

The canal ditch-tender system of water management was introduced in Central Java in 1918 and was strengthened in 1927. It was based on experiments conducted in the Pemali-Comal area by J.C. Numans (Polderman et al., 1936) and combined features of two regulations: *Pateguan* and *Pekalen* (van Witzenberg, 1936). To gain the farmers' active participation in irrigation, *Pateguan* gave them some freedom to regulate water; *Pekalen* gave some external government controls to help ensure efficient water use.

The rationale for this legislation appears to have been that although the government had become heavily involved in financing irrigation infrastructure in the form of tertiary channels, village leaders were still able to get better-than-

[4] Systems of payment differ in other provinces. In East Java, for example, village ditch tenders are paid directly by farmers, rather than through proceeds from the *bengkok.*

average irrigation services. Therefore, the time was ripe to introduce another form of water management that would be more sophisticated and technically efficient, and that would also overcome some of the shortcomings of the village ditch-tender system. The emerging canal ditch-tender system had the following distinguishing features:

1. The administrative jurisdiction of canal ditch tenders correspond to irrigation command areas, as in the case of *subak,* not to the village administrative areas.
2. Ditch tenders were elected by and directly responsible to the farmers and landowners served by the irrigation channels, not to their *lurah.*
3. Ditch tenders were expected to take technical instruction in improved water management from the *pengamat* (irrigation overseers), officials in the Irrigation Services.
4. Responsibility for operations and maintenance (O&M) was explicitly divided: the government is responsible for the primary and secondary irrigation systems, and the canal ditch tenders take charge of the tertiaries.
5. Irrigation officials or district heads could dismiss ditch tenders for incompetence or partiality.
6. Members of each block paid canal ditch tenders in cash, not through produce from the village *bengkok.* Payment was based on the area irrigated. The change was intended to reduce conflicts of interest in water allocation. Initially, farmers paid ditch tenders directly, but because the income of ditch tenders suffered severely when crops failed, the system was changed to a "ditch-tender fund," which paid out a regular sum monthly. A pension fund was also created.

The canal ditch-tender system continued until World War II, when irrigation infrastructure fell into disrepair. During this period, the role of the Provincial Irrigation Services was also reduced and the canal ditch-tender system was abandoned,[5] except in the Pemali-Comal System. Our 1975 study in this area showed the original canal ditch-tender system to be still more or less intact; the area of responsibility for individual ditch tenders is from 100 to 600 ha,[6] and annual payments to each ditch tender are about 100 kg of rough rice/ha (US$l5/year)[7].

Central Javanese irrigator group, *dharma tirta*

The *dharma tirta* system of water management was informally introduced in parts of Central Java in 1968, and officially introduced throughout the province in 1971.[8] Legislative statutes provide certain common guidelines for *dharma tirta* groups, but discretion concerning some details of organization and responsibilities is left to individual irrigator groups.

The *dharma tirta* concept presupposes strong but democratic village government with the village council *rembung desa* as the highest local authority. The concept is based on certain *subak* principles as well as on customary law. Critical to its operation are voluntary cooperation, mutual help, and agreement.

The introduction of *dharma tirta* usually involves the further development of physical infrastructure as well as organizational change. The infrastructure includes both tertiary and quaternary canal systems, the latter serving areas of 10 to 30 ha each. Simple diversion structures are usually built and land is leveled.

Ditch tenders are responsible for individual canals and provide a vital link with the village leadership. *Dharma tirta* leaders are usually farmers elected by their constituent farmer members. They are responsible for O&M, as

[5] Ambiguities in authority between traditional village-oriented local government and new irrigation-oriented leadership may also have contributed to the abandonment of the system.

[6] The Federal Directorate of Water Resources Development encourages the introduction of Pilot Tertiary Plots that use features from both the village and canal ditch-tender systems. Irrigation blocks of approximately 50 to 100 ha are subdivided into 10- to 20-ha subblocks. Plot and canal ditch tenders are directly responsible for O&M, but they are subject to advisory boards of village ditch tenders, which are under the supervision of village heads.

[7] All cost and price data in this paper have been converted to US dollars at Rp415 = US$l.

[8] Although the provincial regulation calls for the establishment of *dharma tirta* throughout the province by 1975, when the study was undertaken the system had been established only in some villages of Brebes, Karanganyar, Pekalongan, and Sragen Regencies.

well as regulation enforcement and fee collection. Funds for maintaining the primary and secondary irrigation system are assessed through the land development tax, *Iuran Pembangunan Daerah* (IPEDA); special fees and voluntary labor from farmers are required for terminal-level O&M.

Two *dharma tirta* cases were examined. One was in Sragen, the first *dharma tirta* introduced in the province; the other was in Brebes Regency, introduced in 1974. These cases are not necessarily representative, and the shortness of their existence at the time of study precludes definite conclusions.

Sragen dharma tirta. The idea for the *dharma tirta* in Sragen originated with the local community in 1968. The village's earlier special Irrigation Regulation, *Peraturan Air Sukawati,* had governed water distribution quite well, but there was a desire to modernize the village by intensifying terminal irrigation facilities. Farmers were required to contribute cooperative labor, gotong *royong,* for constructing quaternary channels, and to pay for locally made concrete division boxes called Thomson weirs, which cost about $5 each. Land leveling, which also involved the farmers' close cooperation and cost about $180/ha, proceeded at a slower pace, but was nevertheless satisfactorily completed.

Water distribution in Sragen is excellent — rice can be grown throughout the village during the dry season with no water conflicts. This is noteworthy since the "technical" irrigation data showed that available water could supply only 38% of the requirement. Farmers prefer dry-season irrigation that would permit everyone to grow rice, even if water shortages reduce average yields. Recognizing that strict water rotation can save water, farmers cooperate with one another and with ditch tenders toward this end.

Strict water rotation requires not only strong village solidarity, but also enlightened village leadership, skillful irrigation O&M, and coordination among government departments. Factors that contributed to favorable water management in Sragen were

1. Little disparity in the size of landholdings among farmers and the leaders,
2. A command area that coincided with the village administrative boundaries [9],
3. The use of water purely for irrigation,
4. Topography that permits efficient water distribution throughout the command area, and
5. A tradition of selecting ditch tenders on the basis of merit rather than personal relationships.

The villagers' common view that irrigation water is their property stems from the villages being served by a more or less independent water source and from farmers' participation in planning for fuller exploitation of the water.

Brebes dharma tirta. The history of the *dharma tirta* in Brebes' Regency is quite different. The village had long been accustomed to a canal ditch-tender system, when in 1971, a farmers' group was successfully organized to provide input supplies, village broadcasts, and labor for fishpond construction and irrigation canal rehabilitation. In 1972 the irrigation infrastructure was repaired so that ample water was made available to the village with the help of *Proyek Irigasi IDA* (PROSIDA), the implementing agency for Indonesian irrigation projects financed by the World Bank and International Development Association (IDA).

But the irrigation system did not function well. Sugarcane estates and onion producers with external financing paid for favorable irrigation service at the expense of the village's economically weaker rice farmers. Therefore, the Regency was requested in 1973 to establish an irrigation organization in the village. In February 1974, PROSIDA constructed a quaternary canal and sluice system in the village without prior consultation with farmers and with no compensation to those on whose land the canals were built. [10] The Regency then instructed the village to establish a *dharma tirta* in March 1974.

Our field study in late 1975 showed rather unsatisfactory irrigation performance in Brebes.

[9] Beause there is only one source of water supply in Sragen village, the nominal village ditch-tender system is actually the same as the canal ditch-tender system.

[10] We do not know if this work was in response to the 1973 request to the Regency.

The quaternary system was not being used, partly because the sluices had been inappropriately located. New regulations on water use were neither followed nor understood, and conflict over water continued among sugarcane, onion, and rice producers.

Although our study was conducted only 18 months after the formal establishment of the *dharma tirta* and we lack data on certain critical features of the village, we believe that the most fundamental problem in water management may have been the existing power structure within the village and the consequent inequitable allocation of water among competing groups, rather than inadequate terminal infrastructure or outdated water allocation procedures. Use of the existing and apparently effective farmers' organization in the village may have been preferable to creating a new institution.

But after the decision to create a new institution and to develop a few infrastructures, the haste with which action was taken appears to have been counter-productive. Errors in construction and failure to elicit farmer participation in the new institution probably could have been reduced if time had been taken to secure local feedback while plans for the various changes were being contemplated or carried out. We do not believe that the village's conflicts over water could be overcome without skillful and time-consuming efforts to help various factions understand the power-related inequities in the village and the need to work together in solving such problems.

Conclusions

The following factors are important in organizing farm-level irrigation services:

1. The boundaries of an irrigator group's area of responsibility, the irrigation command area, and village jurisdiction should coincide as nearly as possible. Command areas are often laid out quite differently from village boundaries because of topographical considerations, and the question of which is the more suitable basis for establishing irrigator groups then arises. Where boundaries of irrigator groups and command areas coincide, systems are easier to manage and conflicts are less likely. But care should be taken to prevent the new institution created for the command area from eroding the authority of existing organizations or their strengths when it could build upon them.

2. From the standpoint of irrigation performance, coordination of all development activities within an irrigation project by a single institution has clear advantages. Administration would be more efficient because the opportunities for one agency to blame another for any shortfalls or difficulties would be eliminated. On the other hand, creating a project authority with responsibilities that overlap with those of existing state or provincial departments might remove an important component of those existing agencies' activities and erode their staffs morale. Also, the authority might not be able to recruit specialized personnel.

3. Our case studies illustrate that the quality of local leadership, the nature of local values, and the extent of economic and social disparity within a village are important determinants of successful irrigation and village organization. The central issue may be the danger of conflicts of interest among village leaders who seek to improve their personal welfare to the disadvantage of the community. The practices of appointing rather than electing local officials and of compensating them from the harvest of village-owned land tend to increase these conflicts of interest. The chances of conflict are greater in communities where individualism and commercialization prevail over the traditional Javanese values of neighborliness, mutual help, interpersonal trust, and community problem solving. Local organizations are generally less effective in communities with wide economic and social disparities.

4. Water may be perceived as a property over which individuals, villages, or government may exercise rights. Local irrigator organizations are usually strongest where water is viewed as village property. Conducive to such perception are independent water sources that serve individual villages, and local irrigator groups that play important roles in water use. But viable local irrigator groups are less likely to be established where government plays a dominant role in

developing water resources, or where individuals or groups exploit the economic power of irrigation for their own ends.

5. The nature of new irrigation institutions and the speed at which they are introduced are important incentives to local initiative in irrigation.

One aspect of the issue is whether uniformly structured irrigator groups should be introduced on a large scale from the top. The administrative simplicity of such an approach to institutional change is obvious. The irrigation needs and opportunities of different villages are often so different, however, that the advisability of such an approach is highly questionable. Furthermore, because power factions within a village often underlie poor water management, crash programs to change the institutions are almost certain to fail. If real progress toward the more equitable and productive use of a community's irrigation resources is to be made, a more deliberate program of institutional development, with detailed attention to those variables that most significantly influence local institutional change, may be essential.

References Cited

Akkeren, van Ph. 1970. Sri and Christ. Butterworth Press, London.

Birkelbach, Jr., A.W. 1973. The Subak Association, Indonesia. 16:153-169.

Collier, W.L., Soentoro, Gunawan Wiradi, and Makali. 1974. Agricultural technology and institutional change in Java. Stanford Food Res. Inst. Stud. 12(2):169-194.

Geertz, C. 1963. Agricultural involution: the processes of ecological change in Indonesia. University of California Press, Berkeley. 176 p.

Poldennan, L.J. et al. 1936. Waterbeheeren Waterschappen, in De Inginieur in Nederlandsch Indie, III/2.

Research Institute of Social Sciences. 1975. Water management at the farm level: an Indonesian case study. Paper presented by the Research Institute of Social Sciences at Satya Wacana University in Salatiga, Indonesia, for an IDRC workshop on technical and social progress in rural development, 16-19 December 1975, Penang, Malaysia.

Sayogyo. 1973. Modernization without development in rural Java. A working paper presented for the study of structural change of agriculture to the FAO, UN.

Soetardjo, K. 1965. *Desa* (Village). Sumur Press, Bandung.

Wittfogel, K. 1957. Oriental despotism: a comparative study of total power. Yale University Press, New Haven.

Witzenberg, J.H. van. 1936. Waterbeheeren Waterschappen, in De Inginieur in Nederlandsch Indie, III/2.

Conflict between rice and sugarcane farmers over irrigation water: a case study in Thailand

KANAENGNID TANTIGATE

THE ECONOMIC IMPACT OF CONFLICTS between rice and sugarcane farmers over water distribution in the Mae Klong Irrigation Project in Thailand's Central Plain is examined. The study concerns the recently completed Kampaeng Saen Subproject, a part of the overall Mae Klong Project Stage I development encompassing 173,000 ha. Conflicts over water were found along tertiaries in which both rice and sugarcane were planted. These conflicts tended to discourage rice farmers from adopting more productive practices such as transplanting and cultivating a dry-season rice crop. These conflicts also adversely affected sugarcane production. Elimination of the conflicts could be expected to increase the incomes of rice farmers during the dry season, and to increase total production of rice and sugarcane and real revenue from rice during both seasons.

Irrigation is essential to agricultural production. Through good water management, farmers can increase their crop yields, cultivate unused land, and practice multiple cropping. The reduction of risks associated with a stable water supply should also encourage farmers to adopt modern technology. To achieve such benefits, numerous irrigation projects have been implemented in Thailand.

The distribution of water is a source of conflict in many irrigation schemes. To suit their needs, farmers upstream can manipulate the flow of water to the disadvantage of farmers downstream. The problem is likely to be aggravated if different types of crops are cultivated in various parts of a project area. In the Mae Klong project, for example, sugarcane farmers in the upper reaches are believed to block the flow of water through their fields; such blockage results in reduced rice yields downstream. Sugarcane cultivators may want to prevent water from flowing through their lands because of past crop damage during the wet season. Finding no use for the irrigation facilities, rice farmers may abandon the ditches and dikes and permit the channels to silt up. Therefore, high maintenance costs will be incurred to keep large tracts of the irrigation network from being seriously damaged.

This *study*[1] investigates the impact of water conflicts on crop yields and incomes. The

Kanaengnid Tantigate, Faculty of Economics, Chulalongkorn University Bangkok, Thailand.

[1] This paper draws from Kanaengnid Tantigate (1975).

study area is the Kampaeng Saen subproject, one of the first completed parts of the Mae Klong Irrigation Project. The area is well suited for study of conflict because the areas devoted to sugarcane and rice are almost equal.

Background

The Mae Klong River Bash,[2] one of three major drainage basins in Thailand, covers an area of 400,000 ha[3] in the Central Plain. The Greater Mae Klong Project was started in 1964 under the Royal Irrigation Department (RID) to irrigate the arable land in the basin and to harness the river for storage, flood control, transportation, and hydroenergy generation.

Stage I of the project covers 173,000 ha in parts of seven provinces: Kanchanaburi, Petchaburi, Ratchaburi, Suphan Buri, Nakorn Pathom, Samut Songkram, and Samut Sakorn. This stage gives supplementary irrigation to rice in the wet season and protects the project area from flooding. Because there is no provision for water storage, the only irrigation possible during the dry season is from the normal river flow. Stage II will extend additional canals to another 230,000 ha. The construction of the Ban Chao Nen Dam at this stage will allow double-cropping and the generation of hydroelectric power. Subsequent stages of the project are aimed at extending the irrigable area and constructing more dams for hydroelectric power.

Kampaeng Saen subproject is in Stage I of the project. Its irrigation system, completed 3 years ago, is fed by the Vajiralongkorn Dam. Due to inadequate storage capacity, however, water shortage occasionally occurs during the dry season.

Scope, Objectives, and Methodology

In evaluating the impact of the water conflict on crop yields, an effort was made to determine if mixed-ditch and homogeneous-ditch areas differ in productivity and, if they do, to measure the differences attributable to water conflict. The study was initiated to obtain possible suggestions on how to raise productivity in mixed-ditch areas for future irrigation planning and water management.

To evaluate the impact of water conflicts on yield, ditches with or without conflicts were compared for productivity. To remove possible disturbing effects of external variables, the ditch areas were selected from the same ecological and institutional environment.

Narrowing the study area to the Kampaeng Saen subproject removed institutional differences. On the basis of test results reported by the RID Agronomy Station in Kampaeng Saen, 4 out of 23 zones were initially selected. Each zone had the same elevation (7 m above sea level). Subsequent field tests indicated that only three zones had the same soil type (clay loam) and about the same salinity (0.14 to 0.30%); only those zones were used in the study.

Three types of ditches were identilied: homogeneous-rice ditches, homogeneous-sugarcane ditches, and mixed sugarcane and rice ditches. The first two ditch types were arbitrarily divided at their midpoints into upstream and downstream areas. Since mixed ditches commonly had sugarcane in the upstream areas and rice in the downstream areas, six categories were identified:

Rice
Rice upstream, *Ru*
Rice downstream, *Rd*
Rice in the mixed areas, *Rm*

Sugarcane
Sugarcane upstream, *Su*
Sugarcane downstream, *Sd*
Sugarcane in the mixed areas, *Sm*

A total of 16 ditches were selected, or 5 samples for each ditch type. Ditches excluded from the study were 1) mixed sugarcane and rice ditches whose farmers did not request water for the entire season; 2) ditches that were inappropriately located, i.e., with sections sloping up-

[2] For background information on the Mae Klong Project, see Royal Irrigation Department (1962, 1967, and 1974).

[3] Land area data in this paper have been converted to hectares: 1 ha = 6.25 rai.

land; and 3) some mixed sugarcane and rice ditches with unequal areas planted to sugarcane and rice.

Four rice farmers were randomly chosen from each ditch, two from upstream and two from downstream. For each ditch type a total of 10 farmers were sampled.[4] Because sugarcane crops of varying ages have different yield performances and input requirements, a comprehensive study would have required a comparative analysis among age groups. For this study, however, sampling was restricted only to third-year crops.

The data were collected primarily through field interviews in two periods, the first in November, 1974, and the second in February, 1975, after the harvest season.

Analytical Procedures

Productivity differences were analyzed in terms of costs and net returns, and measured in US dollars per hectare for each ditch.[5] The assumed farm-gate prices were $110/t for rice and $14.20/t for sugarcane. Only variable costs, including cash and noncash components, were studied. Cash costs are out-of-pocket expenses during production; noncash costs involve inputs owned or produced by the farmers. Seed was valued at its market price; animal power, in terms of its current rental or hired rate; and family labor at the local wage rate in 1974-75. Because of the high level of commercialization in the area, costs were not difficult to measure. Yield, cost, and income averages for each group were weighted by area harvested.

Returns should therefore be interpreted as returns above specified variable costs, not above total costs. Fixed costs, such as charges for land, were excluded because they did not vary among groups. This accounting procedure may overstate costs as viewed by the partly subsistence rice farmer, who may not explicitly consider the value of his family labor or the cost of power from his own animals.

The costs and returns for upstream, downstream, and mixed-ditch fields of each crop were compared (*Ru* vs. *Rd* vs. *Rm*, and *Su* vs. *Sd* vs. *Sm*). The analyses involved comparisons of sample means.[6]

Results

Pattern of water distribution in the study area

The RID distributes irrigation water during both wet and dry seasons. About half of the project area is irrigated in the dry season, mainly for rice. No direct charge is levied for water, but the farmers are expected to clean the ditches. In practice, however, the ditches are usually neglected unless there is a specific need for water in a certain area.

The official procedure for a farmer to get water is to submit to the RID zone man an application form approved by his village headman. When water shortages occur, the zone man assigns priorities. But in practice, half of the farmers sampled secured water from the canal themselves ("water stealing") and the other half only orally informed the zone man or headman of their water needs.

For official applications, the lag between the time permission is sought and the time water is received is 4 days for upstream, 3 days for downstream, and 6 days for mixed-ditch rice areas. Zone men and farmers along mixed ditches believe that long time lags arise because someone blocks the water. All sugarcane groups report a time lag of 3 days.

All farmers were asked, "Do you have enough irrigation water from the ditch this season?" Answers were categorized as follows: 1) adequate, 2) inadequate but not serious, and 3) seriously inadequate. Since farmers were not asked about critical periods during crop seasons, their answers reflect judgments of general water

[4] The *Sd* group is an exception; it involved only six farms.

[5] All cost and price data in this paper have been converted to US dollars at 20 Baht = US$1.

[6] To test whether or not the sample means came from the same population, a two-sample statistical test involving the F-test and the student t-test was used. Comparisons were made between upstream and downstream producers, downstream and mixed producers, and upstream and mixed producers. If the F-test showed variances to be homogeneous, a simple t-test was used. If the F-ratio indicated differences in variances, the Cochran method for comparison of means was used.

adequacy throughout the year. "Adequate" may be interpreted as "I had all the water I needed and lack of water was not a constraint on my rice yield." "Inadequate but not serious" may be interpreted as "My rice yields were lower than they should have been because I didn't have enough water." "Seriously inadequate" means "My rice yields were considerably reduced through lack of water. "

Thirty-seven percent of the rice farmers reported that they had enough water, 47% could have used more than they received, and 17% termed the supply "seriously inadequate." About 40%, indicated that their crops were damaged because they did not have assured and timely supplies of water.

Sugarcane farmers did not have such difficulties. In fact, 58% of them, being accustomed to rainfed production, had no use for irrigation facilities. One reason they failed to use water was that the system did not deliver sufficient quantity during the dry season when it was needed.

Faulty drainage and poor irrigation planning caused floods in parts of the project. In the lower reaches of one ditch, about 6.4 ha that had been farmed in the wet season was flooded all year because of inadequate drainage. Furthermore, some ditches follow undulating topography instead of having a uniform gradient. Irrigation with such ditches causes the flooding of low areas. The RID is currently trying to finish the drainage system and hopes to reduce the flood problem.

Sources and impact of the water conflict

Two factors were responsible for the water problem. The primary one, which is the major focus of this study, is the distribution of crops and the conflicting needs for water that result from such distribution. Upstream sugarcane growers often block the flow of water to protect their fields, thereby denying water to the rice farmers downstream. The second factor is that poachers open the water gates to catch fish in some ditches, causing floods downstream.

Water conflict has a negative impact on both rice and sugarcane. Water problems were more serious for the crops planted along mixed ditches than for those planted along homogeneous ditches (Table 1). One factor that underlies the conflict in mixed ditches is that rainfed sugarcane requires little irrigation water; in fact, too much water causes crop damage. Irrigation water flowing through sugarcane fields to rice farms downstream produces both seepage and flooding problems. Seepage is usually relatively mild, but it damages the young cane and reduces the sucrose content of cane that is ready for harvest. Flooding is serious, but relatively rare. Flooding damages the sugarcane more than does seepage, but floods occur only when the ditch is choked with weeds and alluvium. For example, in 1973 the RID was compelled to reline a ditch

Table 1. Reported water problems, Kampaeng Saen subproject. Thailand, 1975.

Ditch type	Ditches (total no.)	Ditch problems (no.)			Ditches with reported problems (no.)
		Seepage	Flooding	Water shortage	
Homogeneous Sugarcane	8	3	0	0	3
Homogeneous Rice	5	0	0	2	2
Mixed [a]					
Sugarcane	6	5	4	0	9 [b]
Rice		0	0	4	4
Aggregate	19 [b]	8	4	6	n.a [c]

[a] Upstream portions planted to sugarcane; downstream portions to rice. [b] The number of ditches with water problem: is higher than the total number because three ditches had both seepage and flooding problems. [c] Not applicable.

because a flood damaged an entire sugarcane farm. Water passing through sugarcane fields into the rice plots poses another problem; it soaks the soil making it impossible for trucks to collect the cane. Farmers are reluctant to hire porters as they are expensive. Rice depends heavily on water, and its irrigation period lasts almost the entire season. Yield losses from water shortage were faced by four farmers in the mixed-ditch areas. Finally, rats breed in fields that have been dry for a long time, but they disappear when the land is continually wet.

There is a general water shortage in the Kampaeng Saen subproject, not only in mixed-ditch areas but also in some homogeneous-rice ditches, especially during the dry season. This problem should be solved when the Ban Chao Nen Dam is completed and wet season water can be stored.

Yields, costs, and returns for rice

Yields, costs, and returns under prevailing farm-gate prices were computed for the three groups of rice farmers (Table 2). Rice yields were generally poor because of rampant disease and recurring floods. Yields varied widely within each rice group, especially among downstream farms. Nevertheless, the yields and costs of producing rice in the homogeneous ditches, both upstream and downstream, were significantly higher than those in the mixed ditches. However, the differences in returns among the three rice groups were not significant.

Farmers do not use fertilizer, herbicides, or high-yielding varieties because these inputs were reported as unavailable or were unfamiliar to the sample rice farmers. Water availability, method of planting, and mechanization apparently account for yield differences among ditch types (Table 3).

Water availability and method of planting were analyzed through a two-variable analysis of variance methodology (Table 4). Water was classified as adequate, inadequate but not serious, or seriously inadequate. Planting was either by the broadcast method or by transplanting. The planting method explained yield difference more fully than did water conflicts (F-ratio = 217.5). The F-ratio of the water conflict was relatively low (28.2) but significant at the 5% level. The sample size was probably too small, however, for the findings to be conclusive.

Nevertheless, farmers' statements concerning their methods of planting merit reporting. Before the irrigation project was completed, all the rice farmers in the sample areas had broad-

Table 2. Mean yields, costs, and returns for rice from upstream, downstream, and mixed-ditch areas at 1975 market prices.[a] Kampaeng Saen subproject, Thailand, 1975.

Rice location	Yield (t/ha)	Cost (US$/ha)	Return above variable costs (US$/ha)
Upstream	2.3	144	118
Downstream	2.1	128	113
Mixed area	1.6	73	114

[a] Means are not significantly different at the 5% level.

Table 3. Characteristics of upstream, downstream, and mixed-ditch rice farms. Kampaeng Saen subproject, Thailand, 1975.

Rice location	Av. farm size (ha)	Farms trans-planting (no.)	Labor input (man-day/ha)	Farms reporting inadequate water (no.)	Farms using tractors (no.)	Farms owning water pumps (no.)
Upstream	0.9	10	14.4	0	1	1
Downstream	1.2	10	8.1	2	2	4
Mixed area	1.5	1	1.3	3	0	0

Table 4. Mean yields on farms planted by different techniques and with different levels of water adequacy. Kampaeng Saen subproject, Thailand, 1975.

Planting technique	Yield (t/ha) when water supply was			
	Adequate	Inadequate but not serious	Seriously nadequate	Av.
Broadcast	1.8	1.6	1.4	1.6
Transplant	2.3	2.1	2.0	2.1
Av.	2.1	1.9	1.7	1.9

homogeneous ditches transplanted, while this was the case for only one of the mixed ditches. The farmers said that transplanting required conflict in the mixed ditches discouraged it. Almost all farmers in the mixed ditches said that they would continue to broadcast their seeds even if they knew that transplanting is theoretically more productive.

Comparison of returns for rice using shadow prices

The analysis of returns in the previous section was based on the prices farmers actually received. The returns using the farm-gate price did not reflect the real economic dimensions of the water problem, however, since the price of rice in Thailand was distorted by various taxes. The analysis was therefore extended to use the shadow price of rice — the price that farmers would have received if the rice premium, export tax, and the preserve ratio[7] had not been assessed.

Following Tipaporn's method (1975), the shadow price was computed by adding the farm-gate price and an appropriate fraction of the total rice tax, which was based on the retail price of 5% white rice. It was adjusted for the percentage of the retail price that the farmers received (80%, according to TipapoRN) and the amount of paddy (1.5 t) required to produce 1 t of milled rice. Thus, the shadow price = farm-gate price + $\frac{0.8}{1.5} \times$ total rice tax.

In 1975, the average f.o.b. price of 5% white rice was $34/t. The rice premium was $65/t and the export tax was $31/t. The exporters were subject to a preserve ratio of 50% and received an average price of $137/t for rice sold to the government. The estimated total rice tax on the farmers' rice, then, was $134/t. Since the farm-gate price in the study area is equivalent to $113/t, the shadow price is thus $184/t.

On the basis of the shadow price, no significant differences were found in returns between upstream and downstream rice in the homogeneous ditches nor in returns between downstream rice and mixed-ditch rice (Table 5). However, the returns for upstream rice in homogeneous ditches were significantly higher than those for mixed-ditch rice. This finding is different from that of the earlier analysis using the farm-gate price of rice, which showed no difference in returns between upstream and mixed-ditch rice.

The comparisons using both farm-gate and shadow prices were based on returns per cropping season. If the comparisons had been made on an annual basis, the differences in productivity would have been larger, for dry-season rice could only be grown in the homogeneous-ditch areas, and not in mixed-ditch areas.

Comparison of yields, costs, and returns for sugarcane

The yield of sugarcane in the study area was 36 t/ha. It was rather modest because the crop was in its third year and also because fertilizer application had declined as a result of a sharp increase in prices.

No significant difference was found in average yields, costs, and returns between upstream and downstream sugarcane in the homogeneous-ditch areas (Table 6). But yields, costs, and returns were significantly higher for the upstream and downstream groups than for mixed-ditch areas.

[7] The portion of exported tonnage that had to be sold by the exporter to the government at a price below the f.o.b. price. The preserve ratio was suspended in 1976.

Table 5. Mean yields, costs, and returns for rice from upstream, downstream, and mixed-ditch areas, using shadow prices.[a] Kampaeng Saen subproject, Thailand, 1975.

Rice location	Yield (t/ha)	cost (US$/ha)	Return (US$/ha)
Upstream	2.3 a	144 a	282 a
Downstream	2.1 a	128 a	264 a
Mixed area	1.6 b	73 b	231 b

[a] Means in the same column followed by the same letter are not significantly different at the 5% level.

Table 6. Mean yields, costs, and returns for sugarcane from upstream, downstream, and mixed-ditch areas.[a] Kampaeng Saen, subproject, Thailand, 1975.

Sugarcane location	Farms (no.)	Yield (t/ha)	Cost (US$/ha)	Return above variable costs (US$/ha)
Upstream	10	41.3 a	184 a	413 a
Downstream	6	36.9 a	149 a	380 a
Mixed area	10	29.4 b	99 b	326 b

[a] Means in the same column followed by the same letter are not significantly different at the 5% level.

The amount and type of inputs used, and the extent of water problems were associated with differences in productivity. Since almost all farmers grew the same sugarcane variety, Q83, the variation in yield did not result from the strain.

The weighted average sugarcane yield in homogeneous ditches was about 10.6 t/ha higher than that in mixed-ditch areas (Table 7). Yield seemed to be rather strongly correlated with labor input. The weighted average yield of farmers who spent more than 37 man-days/ha, no matter how much fertilizer was applied, was about 37.5 t/ha, or about 25% more than that of farmers who used less than 37 man-days/ha. The application of more than 188 kg /ha of fertilizer did not generally result in higher yields.

Farmers in mixed-ditch areas used about 25% less fertilizer than those on the homogeneous ditches. It is not clear whether that reflects a historical pattern or a greater responsiveness of the farmers in mixed-ditch areas to the recent increase in fertilizer prices.

The seasonal flood during 1975 damaged sugarcane along the mixed ditches more than that along the homogeneous ditches. Damage on the mixed ditches was higher because they were at lower elevation, and therefore their sugarcane was submerged longer. Applied fertilizer may also have been washed away.

Table 7. Mean sugarcane yields of farms where different input levels and ditch types were used. Kampaeng Saen subproject, Thailand, 1975.

Ditch type	Yield (t/ha) at input levels of				
	Less than 188 kg fertilizer/ha		More than 188 kg fertilizer/ha)		Weighted av.
	Less than 37 man-days/ha	More than 37 man-days/ha	Less than 37 man-days/ha	More than 37 man-days/ha	
Homogeneous	34.4	39.4	31.3	41.3	40.0
Mixed	28.8	30.0	31.3	31.3	29.4
Weighted av.	29.4	36.9	31.3	40.0	36.3

Summary and Conclusions

Not all the results and implications of the Kampaeng Saen subproject study can be generalized because certain circumstances were possibly unique to the study area. The sugarcane farmers there have long been accustomed to rainfed cultivation. The RID has also had difficulty delivering timely and assured supplies of water during the dry season. Another possible local phenomenon is the annual flooding from the Mae Klong River, which postpones sugarcane harvesting. The high commercialization of sugarcane farms and the subsistence nature of rice production in the study area also may not be typical of other sugarcane-rice areas.

Within this context, the main findings from the study have been summarized and implications drawn. There are three main findings:

1. Water conflicts have discouraged rice farmers along the mixed ditches from transplanting and cultivating a second crop in the dry season.

2. Although rice yields were significantly lower on mixed than on homogeneous ditches during the wet season, farmers' returns did not differ significantly. But if shadow prices — which correct tax-induced price distortions — rather than farm-gate prices are used to calculate returns, mixed ditches generate significantly lower rice returns than do homogeneous ditches. Reducing water conflicts during the wet season could therefore be expected to help achieve macro-objectives of higher rice production and more real revenue, but would not have much effect on the economic welfare of individual rice farmers. Eliminating water conflicts in the dry season, however, would undoubtedly improve farmer's incomes because a second rice crop could be grown.

3. Water conflicts in sugarcane production lead to lower yields and returns. Thus, a resolution of the water problem could be expected to increase sugarcane productivity within the mixed-ditch areas.

What are the alternate ways by which the problems of water conflict between rice and sugarcane farmers might be resolved?

One basic strategy would involve converting mixed sugarcane-rice ditches into homogeneous ditches having a single crop. Such a target might be realized naturally over time with no outside intervention. It should be remembered that the current situation in the Kampaeng Saen subproject is transitional, with only 3 years of farmer experience in adjusting to the new environment of irrigation and drainage. With additional knowledge and experience, farmers could conceivably determine what particular ditch areas are best suited to one crop or the other, and thus solve the problem.

If such a strategy is impossible or if it would involve an undesirably long time, the government could intervene, perhaps by providing knowledge and incentives that would encourage all farmers along mixed ditches to raise the same crop. To accomplish this, additional information is needed on the relative suitability of particular mixed ditches and their farmers for raising either crop. The RID is organizing farmers to more effectively deal with these problems.

Alternatively, steps could be taken to improve the drainage and irrigation infrastructure and the distribution of irrigation water so that sugarcane and rice could be grown together. Such an approach might involve 1) lining affected canals, 2) increasing the density of canals in different areas, 3) coordinating the timing of irrigation flows and planting dates so that irrigation water would not flow through sugarcane fields during early growth stages when the cane is unusually susceptible to excess water, or during harvest when water seepage adversely affects the transportation of cane, and 4) exploring possibilities for more effective local group action to resolve conflicts among farmers.

Determining the technical, economic, social, and administrative implications of each alternative would help provide information useful in dealing with this complex problem.

References Cited

Royal Irrigation Department (RID). 1962. The feasibility report on the Greater Mae Klong Multi-purpose

Project, Thailand. First stage development for irrigation and flood protection, Ministry of National Development.

Royal Irrigation Department. 1967. The feasibility report on the greater Mae Klong Multi-purpose Project, Thailand. Second stage development for irrigation, flood control and hydro-power, Ministry of National Development.

Royal Irrigation Department. 1974. Greater Mae Klong Irrigation Project, Vol. II, Annexes. Amheim, The Netherlands: Ilaco.

Tantigate, K. 1975. The conflict between rice and sugarcane farmers over irrigation water in the Mae Klong Irrigation Project (A case study in Kampaeng Saen subproject). M.A. thesis, Faculty of Economics, Thammasat University, Bangkok. (unpubl.)

Tipaporn, L. 1975. Economic comparison of broadcasting and transplanting dry-season rice (case study of Amphoe Bang Nam Prieo, Cha Choeng Sao). M.A. thesis, Faculty of Economics. Thammasat University, Bangkok. (unpubl.)

Local irrigators' groups: assesment of their operations and maintenance functions

S. DUNCAN

THE PAPER GIVES PRELIMINARY FINDINGS from a study of efforts to achieve greater farmer participation in the operations and maintenance of a 1,840-ha pilot area in the Channasut Land Consolidation Project in Thailand's North central Plain Irrigation System. Factors that underlie the reluctance of farmers to participate in operations and maintenance are identified and possible approaches of government to provide farmers with greater incentive to participate are suggested. The condition that seems most essential for full farmer participation is the adequate and timely delivery of water in the main irrigation system.

This paper presents the findings of a research project undertaken to analyze factors affecting farmers' willingness and ability to operate and maintain on-farm irrigation systems, and explores organizational aspects of local irrigators' groups. It is based on a study of rice farmers in the Channasut Land Consolidation Project[1] in Thailand's central river delta, but the findings may also be valid for other settings.

Since 1969, land consolidation has been undertaken by the Royal Irrigation Department (RID) in Thailand (Fig. 1) on about 5,100 ha[2] in the first stage of a program intended to cover 524,000 ha by 1983 (RID, undated). Land consolidation represents the most advanced stage in the progressive intensification of water resources development in Thailand. It aims to permit farmers to control irrigation and drainage flows to and from their individual plots.

S. Duncan, Fellow, the Food Institute, East-West Center, 1,777 East West Road, Honolulu, Hawaii, 96822, USA.

The land consolidation program involves four major steps:

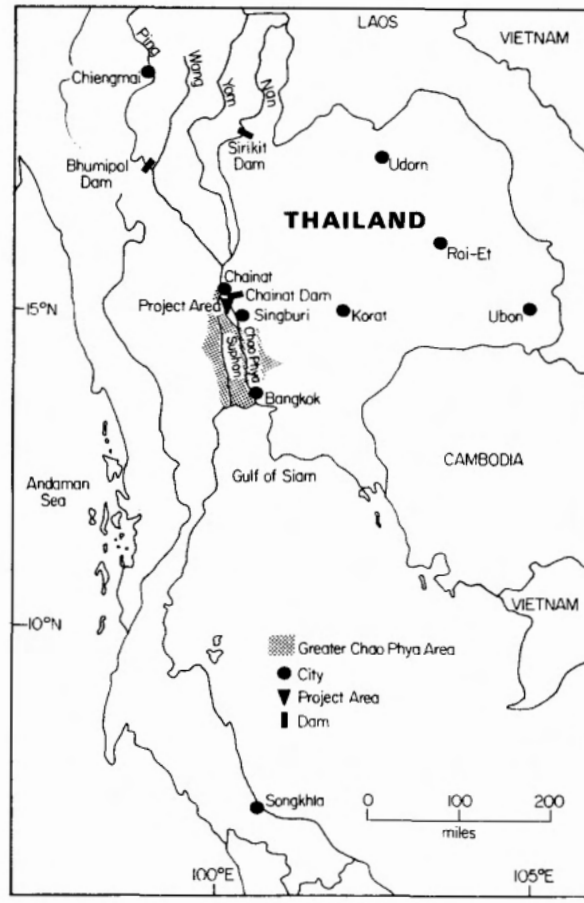
1. Constructing minor irrigation systems to supply water to individual plots;
2. Constructing minor drainage systems to remove excess water from individual plots;
3. Constructing farm roads along irrigation canals to improve access to farmers' fields; and
4. Clearing and leveling land to improve water control.

The Channasut Land Consolidation Project

The pilot Channasut Land Consolidation Project (Fig. 2) was implemented on about 160

[1] Channasut is the name given to the first land consolidation project, the larger irrigation district administered by RID, and is a market town on the Noi River where the headworks of the system are located. Channasut used in this paper has the first meaning, unless otherwise indicated.

[2] Land area data in this paper have ken converted to hectares: 1 ha = 6.25 rai.



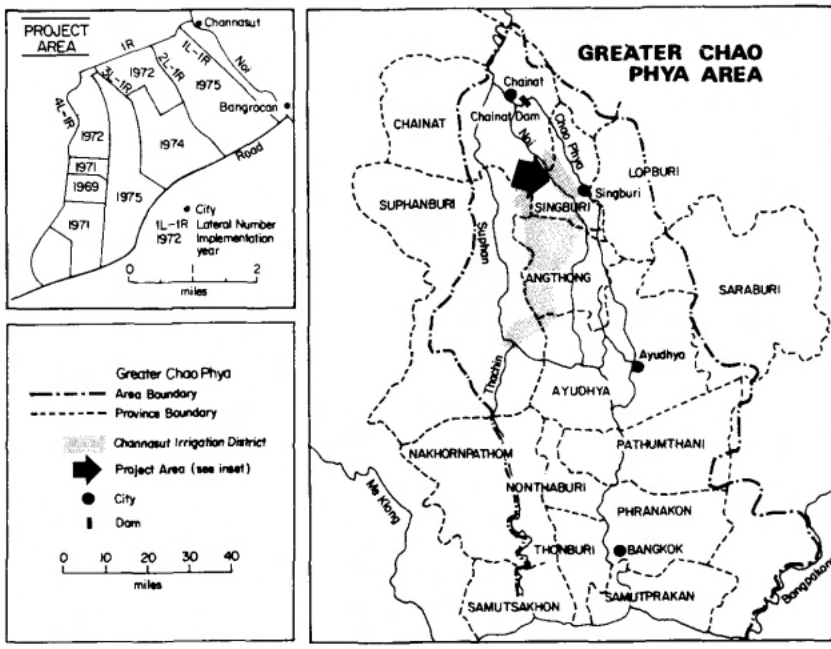
1. The Kingdom of Thailand, showing the greater Chao Phya area.

ha in 1969, on 530 ha in 1971, and on another 500 ha in 1972. An extension area to the pilot project, constructed in 1972, brought the total pilot project area to 1,840 ha. The research covered in this study was confined to that area, although additional land has since been consolidated.[3]

The field work for the research was undertaken in Singburi province from September 1974 to August 1975 under the joint sponsorship of the RID and the Food Institute, East-West Center, Honolulu, Hawaii. It was divided into three stages. In the first stage, during the 1974-75 wet season, a questionnaire was served to about 12% random sample of 74 households. The sample yielded data on land ownership, farm size, household composition, tenancy, and irrigation. In the second stage, during the 1975 dry season, farming and farmer behavior along two ditches in the pilot area were intensively studied. In the final stage, at the end of the 1975 dry season, an expanded version of the original questionnaire was administered to the 74 sample households.

The following descriptive data are intended to provide a perspective on the project within which the study's main preliminary findings can be viewed. Of the farmers interviewed, 63% had

[3] By the end of the 1975 dry season, over 4,300 ha was covered.



2. Location of the Channasut Land Consolidation Project, Thailand.

completed 3 years of farming under land consolidation; 29%, 4 years; and 9%, 6 years. Farm holdings ranged from 0.5 to 19 ha and averaged 5.1 ha. The extent of tenancy in the study area was lower than that in other areas in the Central Plain. Only 11% of the household heads were pure tenants, 20% were owner-tenants, and 69% were pure owner-operators.

Water Users' Associations

The Thai Government has emphasized cooperative group action in agricultural development by creating 17 village associations through which farmers might pursue development goals (Ingersoll, 1969). The associations are grouped into credit cooperatives, land cooperatives, crop production associations, and irrigation associations.

One form of irrigation association is the Water Users' Association (WUA). The WUA was introduced by RID in 1967 in Northeast Thailand and in 1968 in Central Thailand. They were initially established as multipurpose organizations to supply credit, fertilizer, and other farm inputs, as well as to mobilize the manpower and funds for irrigation operations and maintenance (O&M). Operating funds to cover WUA staff and O&M were to be raised through a one-time membership fee of US$0.49[4] per farmer, plus annual assessments of 10% of "the increase in crop production" (NEDECO/ILACO, 1970).

The Thai Government formed WUA mainly to preclude future increases in its O&M budgets for handling the expanded RID terminal infrastructure created by land consolidation. It was believed that farmers who derive substantial benefit from irrigation ought to at least partly pay for it. In practice, however, the early performance of WUA was weak. Membership was voluntary, mechanisms for assessing and collecting water charges were not developed, and the power of members to formulate policy was negligible.

[4] All cost and price data in this paper have been converted to US dollars at 20 baht = US$1.

Common irrigator

In the government's view, the key person in a WUA is the common irrigator. This position was first established in 1962 within the framework of the Common Irrigators' Organization; it followed the model of "head irrigators" found in North Thailand's indigenous irrigation systems. The duties of the common irrigator were to supervise the distribution of water among farmers and the cleaning of irrigation and drainage ditches, and to act as an intermediary between the farmers and RID. A common irrigator was generally responsible for an area ranging from 160 to 190 ha. Although he was to be selected by farmers, in practice, project engineers sometimes intervened in the selection because they believed that ". . . the farmer(s) do not always select competent men" (NEDECO/ILACO, 1970).

Although common irrigators were originally to be paid from farmers' contributions, a transitional period during which they would be paid by RID was begun in the Northeast and Central Plain in 1967. This change of policy was prompted by a growing awareness of the farmers' negative view of the common irrigators. In particular, many farmers viewed a common irrigator's major function as one of saying "no." He must ensure that water is not misappropriated and farmers do not evade their maintenance and repayment responsibilities. He must also mediate in any disagreements among farmers. In short, when a farmer thought of a common irrigator, he thought of regulations and compliance with them, not of positive assistance.

Therefore, it became necessary for the RID to continue subsidizing the salary of the common irrigator. A 1970 report summarizes the rationale for this decision:

> "Most of the Project Engineers are in favor of the present system in which common irrigators are paid by RID, since it takes them very much time to establish a water users' association, for each new association must be officially approved by the Ministry of the Interior, which may take up to one year. Moreover, they fear that this new type of association will not be able to work satisfactorily because of lack of funds" (NEDECO/ILACO, 1970).

Chaek*[5] *(service unit) organization

The organizational difficulties with the originally designed WUA led in 1970 to a shift in emphasis to smaller scale, single-purpose O&M *chaek* (service unit) organizations. The common irrigators continue to be responsible for irrigation operations and the chaek leaders, for maintenance. It is envisioned that when the *chaek* become effective, they will be incorporated as units into WUA (MAC, 1974).

During a series of meetings between RID officials and farmers in late September 1974, *chaek* were formed in each of the 26 service units in the Channasut pilot and extension areas. Guidelines for establishing the chaek are:

> "The members of the *chaek* will choose a man they all trust as leader. He will be more independent of RID than the common irrigator and will therefore have more influence with farmers . . . Emphasis must be put on his technical ability. There will also be a secretary-treasurer. Together, they will form the *chaek* committee and will be responsible for the money collected from the farmers" (MAC, 1974).

As the field work in this study ended only 11 months after initial steps were taken to establish the *chaek* organizations, it was too early to assess the results of the efforts of the new organization. It appeared, however, that the initial success in securing funds from farmers to pay the *chaek* leaders was no greater than that in securing funds for the WUA.

Operations and Maintenance

Operations and maintenance are separate activities that differ both in tasks and timing. Maintenance, except in emergencies, is done only twice a year, after the completion of each crop cycle. In contrast, operations take place from day to day throughout the cropping season.

---

[5] A *chaek* is defined as the area served by one inlet structure from a lateral. It varies in size from 80 to 160 ha and serves from 16 to 40 farm households.

Maintenance

The main maintenance activity in the Channasut Project is ditch cleaning. At the end of the wet season in December or January, all weeds and undergrowth are cleared and silt is excavated. Maintenance after the dry season in May or June involves only weeding. Infrequently, feeder roads are repaired and drainage ditches are excavated.

In the first 2 years of the project, considerable effort was made to organize communal maintenance activities. It was reported that:

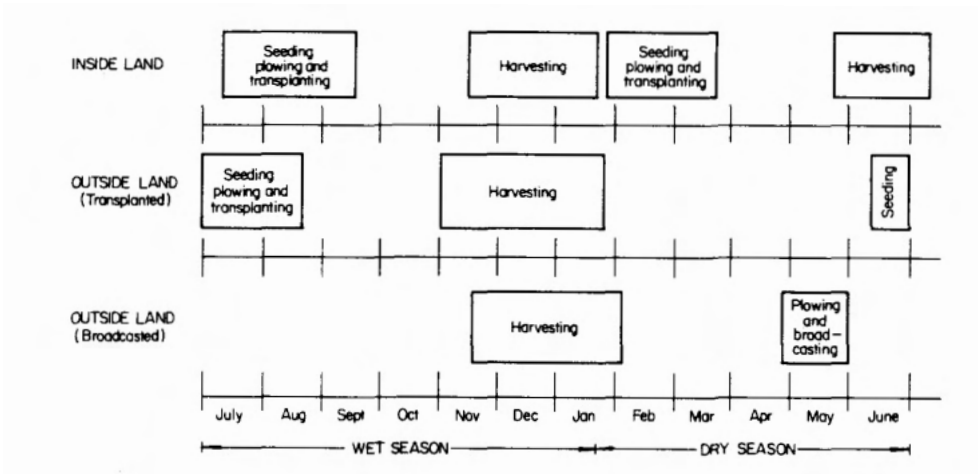
> ". . . so far, the silt deposits have been removed by communal labor of the farmers . . . The cooperation of the local administration proved to be indispensable to organize this communal labor. In farmers' meetings, the *Nai Amphur* and the *Phuyaiban* (local officials) emphasized the importance of maintenance work. Later, the *Nai Amphur* notified the farmers on which day, at which hour, and where they had to be present to start the maintenance activities" (NEDECO/ILACO, 1970).

As the project expanded, however, the active involvement of the local administration in organizing communal maintenance became infeasible. The common practice now is for farmers to individually clean and weed the sections of the ditches adjacent to their plots. However, the results do not always meet RID standards, and sometimes the work is left unfinished.

Many farmers do not perceive the value of ditch cleaning because they have not personally experienced reduced water flows in ditches that suffer from accumulated vegetation and silt. Other farmers may not regularly participate in group maintenance because of competing demands on their time by activities outside the project area. For example, about half the Channasut farmers own land outside the project area, and the scheduling of cultural operations on that land is dependent on rainfall (Fig. 3). The photoperiod sensitivity of most rainfed varieties puts an additional constraint on the allocation of a farmer's time. The lack of participation in scheduled communal maintenance may be explained as much by these economic and environmental factors as by farmers' lack of initiative or public spirit.

Operations

Operations consist of opening, closing, and regulating ditch intakes; regulating check and drop structures; and distributing water according to schedules. In the Channasut scheme, the planned allocation of water is continuous to the ditch intake, but rotation within the service unit adheres to a fixed delivery schedule with an



3. Cropping calendar for two crops of rice. Channasut Project Area, Thailand, 1974–75.

interval of 7 days. The common irrigator operates the constant head orifices and other structures along the ditch to maintain the proper head and flow, but farmers are responsible for opening and closing the inlet pipes that connect delivery canals to their land.

Water distribution is based on a formula that takes into account the area to be cultivated and the irrigation water required per hectare. The irrigation requirement depends on the crop's water requirement, the delivery system's efficiency, and the desired interval between waterings. On the average, a 2.5-ha farm receives water for about 16 hours per week.

In practice, irrigation schedules in the project are rather haphazardly followed. Farmers often open their inlets on the wrong day or fail to shut them off at the scheduled time; check structures may be closed out of turn, reducing downstream flows; and temporary dams are frequently erected along ditches. Neither the common irrigators nor their superiors, the zone men, seem to provide effective supervision.

Despite this lack of direction and farmers' disregard of scheduling, difficulties do not seem to arise when water supplies are plentiful.[6] During periods of water shortage, however, self-regulation breaks down and conflicts develop. Farmers tend to store as much water as their fields will hold as insurance against possible later shortages. Generally, those with land at the tail end of ditches experience greater difficulty in obtaining water than those at the head end. Thus, as observed with maintenance, what may be termed as the problem of poor cooperation by farmers may reflect some of the rather fundamental constraints that they face.

We now examine in more detail contrasts between government and farmers in their perceptions of water shortage. Many officials view water shortage as a matter of theft by users, claiming that if stealing could be prevented, shortages would disappear. From the farmers' viewpoint, however, the reverse may be true — shortages may cause them to steal, particularly in areas with uneven terrain. Rather than leave an elevated piece of land unirrigated, a farmer may extend his allocation beyond the scheduled time to allow water to build up to the point where the elevated area can be irrigated. Localized areas with excessive seepage and percolation also result in fields becoming dry within 4 or 5 days of irrigation, thus encouraging attempts to get water out of turn. Many farmers prefer a constant flow of water through their fields, rather than the warmer stagnant water, which is frequently believed to hinder crop growth. Furthermore, farmers may allow water levels to build up to control weed growth, thus eliminating the need for costly herbicides or the arduous task of hand weeding. In each instance, the choice is clearly between using more water, which is often called ' theft," and suffering possible crop damage or financial loss. Only after removing these causes can water authorities realistically expect the ready participation of farmers in *chaek* or WUA or their adoption of recommended practices of water management.

Village Organization

The discussion so far has centered on the technical and environmental factors that influence farmers' irrigation behavior. Social and organizational variables are also important in explaining the rationality of farming decisions and should be examined in the Thai social setting.

Examples of irrigation organization in the North (Frutchey, 1969; Moerman, 1968) and of village unity (Moerman, 1967) may come as a surprise to those who view the results of the government's efforts to initiate cooperative action as confirmation of the unstructured or individualistic character of Thai society. Those studies provide numerous examples of Thai villagers repairing roads, constructing schools and temples, and collecting funds for various local projects, thereby demonstrating an indigenous organizational capability.

Two *chaek* observed in the project during the 1975 dry season provide a useful illustrative comparison. In one, a laterite road project was successfully completed; in the other, it was not.

[6] Citing the work of G. Wickham and others in the Philippines, Castillo (1975) notes that "Apparently, where a water problem exists, there is a reason to participate or cooperate. Where water supply is adequate, water is taken for granted and is not perceived as a problem."

In the successful *chaek,* a wealthy retired farmer took organizational initiative. After a series of informal meetings with his fellow-villagers, plans for the laterite project, including the rate of assessment against village households, were developed. The project went forward smoothly, aided by occasional informal appeals of friends and kinsmen toward others who initially were hesitant to cooperate.

The other laterite project never got off the ground, partly because a large landowner who farmed 16% of the land commanded by the ditch of the *chaek* refused to support the project. Unlike the first *chaek* whose farmers came from only one village, this one involved farmers from several villages. The lack of social ties among its members and the greater physical remoteness of its members undoubtedly worked against the success of the proposed community project.

These cases illustrate the key role in development — sometimes positive and sometimes negative — of prominent village people. The cases also suggest the importance of learning about and responding to existing social structures in attempts to introduce institutional reform.

Conclusions

We have seen something of the experience of the Royal Irrigation Department in assigning to farmers greater responsibility for on-farm O&M through local irrigators' groups — first, Water Users' Associations, and later, the *chaek.* We have also seen some of the social, environmental, and technical factors that affect farmers' willingness to perform O&M and to function within formal local groups.

The study has shown only a modest response of farmers in participating in the new irrigators' groups and in following recommended irrigation schedules and practices. While part of the modest response may reflect unfavorable social attitudes, other factors are clearly involved as well. Perhaps the principal factor is undependable water delivery in main irrigation systems. Without added attention to main-system O&M, expecting greater participation of farmers in on-farm O&M will not be realistic.

It therefore appears that the improvement of water management should be an evolutionary process. In the short run, the government will probably have to assume greater responsibility in providing reliable supplies of water and creative leadership and support to local irrigators' groups. As progress toward these ends is achieved, there should emerge a growing capacity for effective farmer participation in O&M[7] and hence, the attainment of an important goal in Thailand's strategy for irrigation development.

References Cited

Castillo, G.T. 1975. All in a grain of rice. Southeast Asian Regional Center for Graduate Study and Research in Agriculture, College, Laguna, Philippines. pp 390-395.

Frutchey, R. 1969. Socio-economic observation study of existing irrigation projects in Thailand. United States Bureau of Reclamation.

Ingersoll, J. 1969. The social feasibility of Pa Mong Irrigation: requirements and realities. United States Bureau of Reclamation.

Ministry of Agriculture and Co-operatives (MAC). 1974. Chao Phya irrigated agriculture development project: rural institutions in the project area. Bangkok, Kingdom of Thailand, Tech. Note No. 16:2-4.

Moerman, M. 1967. A minority and its government: the Thai-Lue of Northern Thailand. Reprint No. 249. Center for Southeast Asia Studies, Institute of International Studies, University of California, Berkeley.

Moerman, M. 1968. Agricultural change and peasant choice in a Thai Village. University of California Press, Berkeley and Los Angeles.

NEDECO/ILACO. 1970. Northern Chao Phya study. International Land Development Consultants, Arnhem, The Netherlands 3:7-9.

Pasternak, B. 1972. The sociology of irrigation: two Taiwanese villages. *In* W.E. Willmott, ed. Economic organization in Chinese society. Stanford University Press, Stanford, California.

Royal Irrigation Department (RID). Undated. Plan for land consolidation 2517-2529 (1974-1986). Bangkok, Kingdom of Thailand. (mimeo.)

[7] Studies elsewhere in Asia document the strategy as generally viable. For example, in his study of two Taiwan communities, Pasternak (1972) noted the flexibility of their populations in reacting to external circumstances. Hankenberg (cited in Castillo, 1975) also refers to the adaptation of agricultural communities to a changing environment.

Stereotypes and facts in irrigation management: prelimenary findings from a case study of a Philippine communal gravity system

R.P DELOS REYES

PRELIMINARY FINDINGS from a study of farmer behavior in a 500-ha communal irrigation system in the Philippines' Camarines Sur province area are reported. Farmers use their irrigation water with considerable care. They have worked out generally satisfactory local arrangements for allocating and distributing scarce supplies of water, and they pay substantial amounts for irrigation even though formal water payments are low.

There is a need to differentiate between what people say and what they do. The two may not be the same, and knowing one may not lead to knowledge of the other. For example, a production technician attached to the Philippines' Masagana 99 rice production program tells you how he helps farmers fill out the farm plans and budgets required for production loans. His words may accurately describe what he should do, but not what he actually does. The technician may generalize about Filipino rice farmers, and be more than willing to share his generalizations. These statements may have value, but the degree to which they portray reality remains questionable until they have been compared with on-site observations of the farmers themselves.

In this paper, I compare several common pronouncements about farmers' water management practices with what I saw while studying a Philippine communal gravity irrigation system. I conclude that, in some respects, each of the statements is a stereotype, an oversimplified and uncritical judgment only partially based on fact.

The Setting

The data to be compared with the selected stereotypes were gathered through unstructured depth interviews, on-site investigations, and 5-month-long participant-observation. The communal irrigation system studied is the Harani-Malinao-Tugmad (HMT) [1] system in Camarines Sur.

The rice fields that receive water from the HMT system are in the municipalities of Tahaw and Sirangan. The command area of the Harani

R. P. de Los Reyes, Graduate student, University of California at Berkeley, US A

[1] Names of people and places in this paper have been disguised.

subsystem includes farms in two villages of Tahaw and one of Sirangan. The Tugmad and Malinao subsystems, on the other hand, irrigate farms only in Sirangan. The total system irrigates about 500 ha for two crops a year.

The Malinao and Tugmad subsystems have existed since the late 1920's, but their temporary dams were rebuilt with concrete only in the late 1950's and early 1960's. Funds for the construction came from the provincial government and the so-called pork-barrel allocations of the then incumbent congressman.

The Harani dam and canal network, on the other hand, was built in stages. Construction, which began in the early 1950's, supplemented the water supply of the smaller Malinao and Tugmad subsystems. Through congressional appropriations, the Harani subsystem was in full operation and connected to the others by the early 1960's.

Stereotypes and Realities

In rural development it is axiomatic that specialists need to teach farmers better ways of doing things. The principle that underlies this process is diffusion of innovations. By this plan, specialists first develop ways to do things better and more efficiently and later teach them to users through extension programs (Coward, 1973). The average farmer, it is said, follows tradition and is not aware of the improved practices that the specialist is prepared to teach him.

One who starts with these assumptions and is only superficially acquainted with the irrigation behavior of rice farmers may easily accept these three uncritical judgments:

1. Farmers do not understand the critical role of water at various stages of the rice-growing process;
2. Farmers who reject the block-by-block rotational scheme of water distribution in favor of the usual continuous flooding are bound by tradition and are not aware of the benefits to be derived from the innovation; and
3. Farmers who do not pay for irrigation water are freeloaders who want something for nothing.

Each of these stereotypes will be considered in the light of observations on the HMT communal system.

Ignorance of the role of water

Results of experimental and on-farm studies (Levine, 1972; Wickham, 1973a,b, 1974;Reyes and Wickham, 1973) indicate that factors to be considered in assessing the role of water in rice farming should include the depth of flooding, the rate of water supply per day, and the stage of crop growth. My interpretation of the data reported in these studies is stated in the following rules of irrigation use for rice farms:

1. For high yields, practice continuous flooding as much as possible;
2. For high yields, allow the daily application of water to at least approximate the rate of evaporation, and so prevent cracks in the rice paddies; and
3. Be sure that the crop has standing water during the reproductive growth stage (from just before panicle initiation until full grain development).

To what extent do farmers of the HMT irrigation system follow these rules? Data gathered on behavior related to water distribution and allocation indicate the basic understanding that once a farmer has access to water, he has a continuous right to irrigation. Thus, a farmer whose land is closest to the headworks has permanent claim to water. Similarly, those farmers who cultivate land in the first parcels of a major canal system, or have fields along major diversion structures, also have permanent claims.

This emphasis on farmers' rights to a continuous water supply reveals that the ideal expressed in the three water-use rules is accepted. Any farmer who can see the possibility of continuous irrigation will make sure that his fields receive water.

Farmers discuss these matters and are well aware of the benefits of irrigation water. They speak of proper water depths of from 1.5 to 5 cm at various growth stages. Farmers also point out that proper water use depends on the soil, time of year, stage of rice growth, farming phase, and water needs of neighboring paddies. Furthermore, farmers invariably emphasize the importance of having water in the paddies from

panicle initiation onward.

Irrigation leaders, who are farmers themselves, are aware of the adverse effects of what the specialists call late stress. As a result, the irrigation association's policy during the dry months, when the HMT system can not irrigate the entire service area, is to give priority to standing crops.

This policy suggests that both the leaders and the ordinary farmers in this communal irrigation system are well informed on water's role in rice growing. Their problem is one of practice, not of theory. They would like to have continuous flooding for all, but must settle for less. Irrigation, like politics, is the art of the possible.

Willingness to adopt the rotational scheme of water use

A common complaint about rice farmers is their reluctance to adopt the block-by-block rotational scheme. It is said that farmers do not appreciate the surpassing benefits of this method or, if they do, are reluctant to change their existing ways of irrigation through continuous flooding.

We might first look at what specialists say about the rotational scheme in general. The method is claimed to be the best way to equalize access to irrigation water among rice farmers. To achieve a high efficiency of water use with the rotational scheme, farmers in a block should start planting in the areas farthest from the canal and proceed to the closer areas, so that "water movement becomes shorter toward the end of a [cropping] season and losses and conflicts which usually arise due to paddy-to-paddy conveyance during the harvesting period can be minimized" (Reyes and Wickham, 1974).

A pilot study of the rotational irrigation scheme has been made in one of the laterals of the Upper Pampanga River Project system. As a result, doubt has been cast on the efficiency that some specialists claim for the method. One report on this pilot study, for instance, states that compared with the continuous method of irrigation, the rotational scheme does not save more water; nor does it significantly increase yields (Wickham et al., 1974).

Wickham and his associates also note that because the farms in the pilot areas were not well oriented to the rotational method, there was a need to construct interior farm ditches, which sometimes caused drainage problems. They also found that allocating given amounts of water to each block at specified periods increased management demands.

From this study, I conclude that the rotational scheme is not necessarily the most efficient and should not be recommended unless the particular service area has been studied. Furthermore, even if rotational irrigation seems technically suitable for a given place, it may require inputs of funds, labor, or management that farmers cannot afford.

To what extent are these conclusions applicable to the HMT system? The answer depends on 1) where the farms are situated relative to the canal network, 2) how farmers get access to water and the stability of the arrangements, and 3) whether the irrigators' association is prepared to shoulder the added management burdens imposed by the rotational scheme.

My observations on farms and canal orientations have yet to cover the entire HMT system, but information on the Harani subsytem has been collected. Most farmers of this subsystem have direct access to irrigation water from the main canal through 44 turnouts along 4 km of the subsystem's main canal. Seventeen of these turnouts directly serve individual farms and, below these, an undetermined number of other farms. The remaining turnouts lead into subcanals or farm ditches that the farmers may have built to maximize their access to irrigation water. In fact, some farmers whose rice lands are farthest from the main canal willingly pay right-of-way fees for farm ditches that serve their farms through lands owned or tilled by others. Hence, even when water has to flow to these distant farms, it flows almost directly and not from paddy to paddy.

A point that is often overlooked is that the physical network of an irrigation system may change through the years even when the service area remains the same. Data are being collected on the changes that have been made in the subcanals, farm ditches, and turnout locations of the HMT system. For example, cases have been

found in which a farm far away from the main canal is now served by a longer farm ditch than before. Such changes often result from dissolution of verbal right-of-way contracts between two or more farmer-irrigators. The reasons most often cited for these social breaks are one party's default of his obligation by failure to pay right-of-way dues, or a disregard of the other party's rights in the water-sharing arrangement, as when the farmer near the canal allows minimum water to flow to a more distant farm.

Farmers also change the location of turnouts and ditches to fit the topography of their farms, that is, a farmer may change the location of his turnout or ditch to give him better access to water.

The current HMT system is thus responsive to changes in both physical and social relationships. Furthermore, its canal-to-paddy arrangement is probably as efficient in minimizing losses and conflicts as is the paddy-to-paddy conveyance of the rotational scheme. It is problematic, therefore, whether one could easily reorient the farms to the rotational scheme, and if doing so would be worth the effort. It is possible that if this step were taken, farmers would no longer have the escape route they currently use when they have a misunderstanding with the farmer whose goodwill gives them access to water.

Management of a rotational scheme would be another problem. Who would manage it? Under the present arrangement, officials of the HMT irrigation association are poorly compensated because the association's income is relatively small. There is little likelihood that the association would be able to hire full-time employees to allocate water to the system's blocks under the rotational scheme. Since January 1976 the association has been able to employ only one full-time worker at US$0.67/day[2]. Is there any realistic hope that is could undertake the more demanding tasks of the rotational arrangement?

If we compare the continuous and rotational methods, we are not necessarily speaking of a black and white difference. The HMT system does not irrigate sections of blocks in fixed succession. Rotation is practiced, however, in the sense that some turnouts serving certain portions of the system are closed at particular times to increase water delivery to other parts of the service area.

Various factors influence the decision to open or close a turnout, or when to allow water from the Harani subsystem to supplement the Malinao and Tugmad subsystems. I have been told and have observed that the existing norms of water allocation and distribution in the HMT system are altered by the following considerations: the water tender's discretion and evaluation of the water needs of particular farms on the basis of the type of soil or stage of rice growth; direct requests of farmers for water; and direct orders from officials of the irrigation association in response to farmers' requests or complaints. The HMT water rotation scheme is further affected by pressure placed by influential persons on the irrigation officials, or imposed by existing or newly developed social relations between farmers and irrigation officials, or between farmers and water tenders.

Thus, much remains to be learned from local expertise and field experience. For example, in late April 1976, during one of our visits to the Harani subsystem's main canal, water flow estimates[3] agreed with the water tender's opinion that the water entering a turnout was more than enough for the estimated 14 ha served by the turnout. When questioned about how he arrived at his assessment, the water tender explained that he knew from experience and had seen the waste water flowing from the area.

While there are occasional problems in the enforcement of the HMT rotational scheme, the irrigation officials and the water tender in fact exercise power in the allocation of water. Many farmers agree with the leaders' decisions, although some may reopen turnouts that had been closed because of delinquency in the payment of irrigation fees or because it was not time for their area to receive water. Briefly,

[2] All cost and price data in this paper have been converted to US dollars at P7.5 = US$1.

[3] Since mid-April 1976, the Irrigation and Water Management Department of IRRI has collaborated in conducting research related to the physical aspects of irrigation management.

then, farmers who do not adopt the block-by-block rottational irrigation scheme may have very good, practical reasons, with which even the experts might agree. Farmers are not necessarily unaware of the merits of the new scheme, nor are they bound to tradition. More likely, they are simply being practical. We should not be in too great a hurry to recommend the rotational scheme. It should not be indiscriminately pushed, at it has been on at least one occasion during a water management seminar conducted by the National Irrigation Administration (NIA) for officials of the HMT irrigation association.

Nonpayment of irrigation fees

The third stereotype concerns rice farmers who do not pay their irrigation fees. Such farmers are labeled as freeloaders who want something for nothing. Alternatively, they are said to place no value on irrigation water. But because they do value water, the question is whether or not they want it for nothing.

To prove that an HMT farmer was trying to get free irrigation service, one would have to show that he did pay his irrigation fee. In addition — and this is essential — one would also have to show that the farmers made no other payments in lieu of that fee. But if a farmer spent personal time equivalent to his fee doing maintenance work on canals, for which the association would otherwise be required to pay from its receipts, that farmer has in effect paid his fee in labor. A general account of the payments (cash, kind and labor) made by the HMT farmers as a group can be given.

It is true that many farmers do not pay irrigation fees. In 1975 (two cropping seasons), only 223 out of about 424 farmers paid their fees, and the total payment received was only about a third of potential collections — $1600 out of $4800.

But many farmers pay a reasonable sum for the water they receive, sometimes in addition to and sometimes instead of the stipulated irrigation fee, which is currently at the rate of 50 kg rough rice/ha for each harvest. The payment may be made in the form of gifts to the water tender, right-of-way payments to other farmers, or labor for maintenance of the canal systems.

Data on farmers' gifts to a water tender are difficult to obtain. Some farmers indicate that before or after they ask for water they sometimes give the water tender gifts of liquor, tuba, chicken or other fingerfood *sumsuman*, which the farmer and the water tender often consume together. Former water tenders do not deny receiving such gifts.

For right-of-way payments, the current rate at the Harani subsystem ranges from 12 to 50 kg rough rice/ha per harvest. So far, only about six farmers have incurred such expenses. In at least one of these cases, the paying farmer represented other farmers who in turn depended on him for water, thus the number of cultivators paying right-of-way fees may be considerably greater than is apparent.

Regarding labor for maintenance, our records show that in the 3-month period from February to April 1976, 344 farmers worked 26 days to upgrade and maintain the canals. Because the names of the farmers who participated in the work groups were not listed, the proportion of these farmers in the total number of HMT farmer-users cannot be ascertained. However, observations at the work sites indicated that about half of the farmers who worked appeared regularly. These 172 farmers thus contributed about $17 (26 days at $0.67/day) in addition to the average irrigation fee of about $9. If they worked but did not pay the fee, they were still contributing $8.25 above what they owed the association for water.

According to these data, some farmers who did not pay their official irrigation dues, or only remitted partial payment, may in reality have paid in other ways for their irrigation water. In short, many farmers in the HMT system do not receive free irrigation water even if they do not pay their irrigation fees.[4]

Concluding Remarks

The information gathered in a study of a communal gravity system in Camarines Sur

[4] Additional data are currently being gathered on this question. Another aspect of fee-paying that deserves further study is the farmers' disenchantment with an organization that they may associate with misuse of funds and with power struggles.

casts reasonable doubt on several popular beliefs about rice farmers. Stereotypes that do not seem to conform to the facts include the farmers' ignorance of rice-water relationships, resistance to rotational schemes, and unwillingness to pay for irrigation water.

Other stereotypes that favor the rice farmer also deserve study. One is the reportedly superior irrigation behavior of farmers in communal systems. Some irrigation officials, impressed by the reported success of communal systems in Ilocos, Mindoro, Rizal, and Camarines Sur provinces, generalize that communal systems are operated and maintained better than the systems administered by the government through the NIA. Some officials would like to transform the existing NIA systems, including the Upper Pampanga River Project, into communal units.

Such judgment is premature. Although considerable information is available on the working of communal systems, it does not all point in one direction. We must learn more about the operation of communal systems and their associations before making pronouncements about the relative worth of existing NIA and communal models.

A final point is that while stressing the importance of understanding the farmers' viewpoints in water management, it is not proposed that farmers be left on their own. Farmers will need assistance in many matters if their irrigation systems are to be efficiently and successfully operated. One objective of this research is to identify forms of assistance that are most urgently needed.

References Cited

Coward. E. W., Jr. 1973. Sociocultural innovation and development change. Philipp. Sociol. Rev. 12 p.

Levine, G. 1972. The water environment and crop production. Pages 378-395 in K.L. Turk, ed. Some issues emerging from recent breakthroughs in food production. Wail-Ballon Press, Inc., Binghamton, N.Y.

Reyes, R.D., and T.H. Wickham. 1973. The effect of moisture stress and nitrogen management at different growth stages on the yield of lowland rice. Paper presented at the Fourth Scientific Meeting of the Crop Science Society of the Philippines, May 21-23, 1973. Cebu, Philippines. (mimeo.)

Reyes, R.D., and T.H. Wickham. 1974. An extensive pilot project on water management. Paper presented at the Saturday seminar, August 3, 1974. International Rice Research Institute, Los Baños, Philippines. (mimeo.)

Wickham, T. 1973a. A low-cost technology for improved irrigation of lowland rice. Paper presented at the Water Management Seminar, July 23-27, 1973, Malaysia. 18 p. (mimeo.)

Wickham, T. 1973b. Some soil-plant-water research findings useful to irrigation design and management. Paper presented at the 1973 FAO Malaysia National Water Management Seminar. (mimeo.)

Wickham, T. 1974. Tropical lowland rice: some findings regarding its water requirements and yield loss due to drought. Paper presented at the National Teaching Seminar on Water Management and Control at the Farm Level, July 1-19, 1974, Jakarta, Indonesia. 20 p. (mimeo.)

Wickham, T., O. Giron, A. Valera, and A. Mejia. 1974. A technical comparison of rotational and continuous irrigation in the Upper Pampanga River Project. Paper presented at the Saturday seminar, August 3, 1974. International Rice Research Institute, Los Baños, Philippines. 23 p. (mimeo.)