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IRRIGATION MANAGEMENT NETWORK

THE DOMINANCE OF THE INTERNAL RATE OF RETURN AS A PLANNING CRITERION AND THE TREATMENT OF O&M COSTS IN FEASIBILITY STUDIES

Mary Tiffen

ODI/IIMI Irrigation Management Network Paper 87/1b April 1987

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ISSN: 0951 189X

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Mary Tiffen is a Research Officer at the Overseas Development Institute and in charge of the Irrigation Management Network. She undertook this study for the Overseas Development Administration, U.K. She is grateful for the co-operation of the World Bank and other Agencies for making material available. The conclusions, however, are her own and should not be attributed to any of the organisations involved. The paper was first given at the Joint FAO/USAID Expert Consultation on Water Charges, at FAO, Rome, in September 1986.

THE DOMINANCE OF THE INTERNAL RATE OF RETURN AS A PLANNING CRITERION AND THE TREATMENT OF O&M COSTS IN FEASIBILITY STUDIES

Mary Tiffen

1. INTRODUCTION

In 1986 I completed a study for the Overseas Development Administration. It reviewed the socio-economic and institutional problems reported in 50 recent evaluations of irrigation projects in developing countries, funded by various agencies. The objective was to make recommendations for improving the study of these matters during the preparation and planning phases. In five cases the original feasibility or appraisal documents were also examined. Staff of consultancy firms and of the FAO Investment Centre were consulted on the difficulties in taking proper account of socio-economic and institutional factors in scheme design, in these and other cases. During the study the current importance attached to a high Economic Internal Rate of Return (EIRR) as a deciding factor for project funding emerged as in practice a constraint on institutional and technical design, on the phasing of implementation, and on the lack of adequate consideration given to either farmer incomes or to the income and expenditure of the project authority or other operating organisation (Tiffen, 1986). The study is now being prepared for publication and we will notify members when it is ready.

It is not suggested in this study that economic criteria should be ignored, but rather, that there should be a different stress to that created by the EIRR. It is assumed that farmers should normally meet at least O&M costs, and where possible, a proportion of capital costs. If it is not possible for them to achieve a reasonable income after meeting O&M costs, this should be clearly stated in the feasibility study, so that a government can take a reasoned decision on whether it wants to subsidise both capital and O&M costs because of social conditions in the area, and if so, whether the cost of the subsidy can be met from alternative sources of government revenue. It is argued that it is necessary not only to look at benefits to the national economy as a whole, but also to the costs and benefits created for the project beneficiaries and for the project administration.

2. DEFECTS OF THE INTERNAL RATE OF RETURN AS A DECISIVE PLANNING CRITERION

The EIRR is attractive as a summary indicator of a project's worth, giving a single figure which subsumes many factors, which can then be compared with unlike alternatives, and which appears easy to understand in its comparability to the interest received on capital. It is probably for these reasons it has acquired its dominating importance as a test of project acceptability and the suitability of the project's concept and components.

The major drawbacks against over-dependence on the EIRR in the selection of projects are the following:

a. The bias against durability, and the assumption that capital is the scarce factor

Since costs and benefits occurring in the more distant future are discounted highly, little account is taken of project sustainability after the first 10-15 years of the project's life. For example, there may be little difference in the EIRR of a rehabilitation project which is thereafter maintained, and one which is not maintained, and which disappears after 15 years (World Bank Tenth, 1985). Yet for a farmer, and also for the nation, it is important in practice that the scheme is maintained and endures for 50 or more years. Choosing projects on the basis of a high EIRR introduces a bias against those with a high initial capital cost even if they have low maintenance costs, because it assumes initial capital is the scarce factor.

b. Bias against slow start up

The EIRR often causes excessive stress to be placed on rapid implementation to secure early realization of full benefits, and indeed this is stressed in the World Bank guidelines. On the Rahad scheme, the choice between use of pumps and the alternative of a longer gravity canal was based on the greater speed of implementation possible with the former. On the Rahad, charges to farmers do not meet operating costs, including pumping, whereas they do on all the large gravity schemes in Sudan (FAO Investment Centre, 1986).

Correctly used, the EIRR should not bias against projects in which parts of both costs and benefits are delayed, as demonstrated by a discussion in FAO 1986, Annex 2. However, in practice "if two projects, one with a lengthy and the other with a short take-off period, are to have the same internal rate of return then the long-term advantages of the first must be far higher than those of the second" (Bergmann and Boussard, 1976, p. 73). The bias against projects which are implemented in phases also derives from its inconvenience for the financial time horizons of the lending agency.

In real life it may be a distinct advantage to plan for phased implementation since this allows for the build up of experience amongst both farmers and scheme O&M staff, making it more likely that expansion or intensification of the original scheme will be handled efficiently. This was what happened, accidentally, in the case of Muda, Malaysia. The first phase provided field-to-field irrigation for two rice crops per year. A later phase provided for an improved water delivery system for diversified cropping. By the time the second phase was implemented farm incomes were much higher than previously; farmers were more capable of on-farm investment; higher O&M charges could be met if desired (the Government intentionally subsidised paddy farmers), and institutions and personnel were well established and capable of meeting more challenging O&M requirements.

c. Under-emphasis on risk of different outcomes

The comprehensiveness of the sole figure for the EIRR gives a false picture of the very real danger of different outcomes. Theoretically, this is met by sensitivity analysis. However, it is often difficult to predict either the crucial factors which may change or the extent of change. In any case, sensitivity analysis comes at the end of the preparation period, and the results are seldom allowed to cause a fundamental reassessment of the scheme's components.

d. Bias against flexibility

It may happen that some of the solutions which are slightly sub-optimal from the point of view of maximization of the expected benefits, will have a much narrower range of possible outcomes, because of their increased flexibility, and will thus be safer (OECD 1985, pp. 57-59). This is important since one can safely predict that the outcome of an irrigation project will not be as predicted.

e. Ease with which cost-benefit analysis can be manipulated

All practitioners know how manipulation of key variables will increase the EIRR to the desired figure, and the abuse has been commented on in the literature (Carruthers 1985). Because of this manipulation, and genuine difficulties in predicting the outcome, the EIRR is in practice a very unreliable estimate. Fig 1 shows the difference between the EIRR as predicted at appraisal compared with that calculated at project completion, in the 37 cases out of the 50 where both figures were available. Table 1 shows the calculation made some years after completion, in the three cases where it was available. The completion figure is based on real costs, but on an estimate of the trend of future benefits. The latter may not materialise if maintenance is not carried out, or if farmers lose interest because of insufficient incentive.

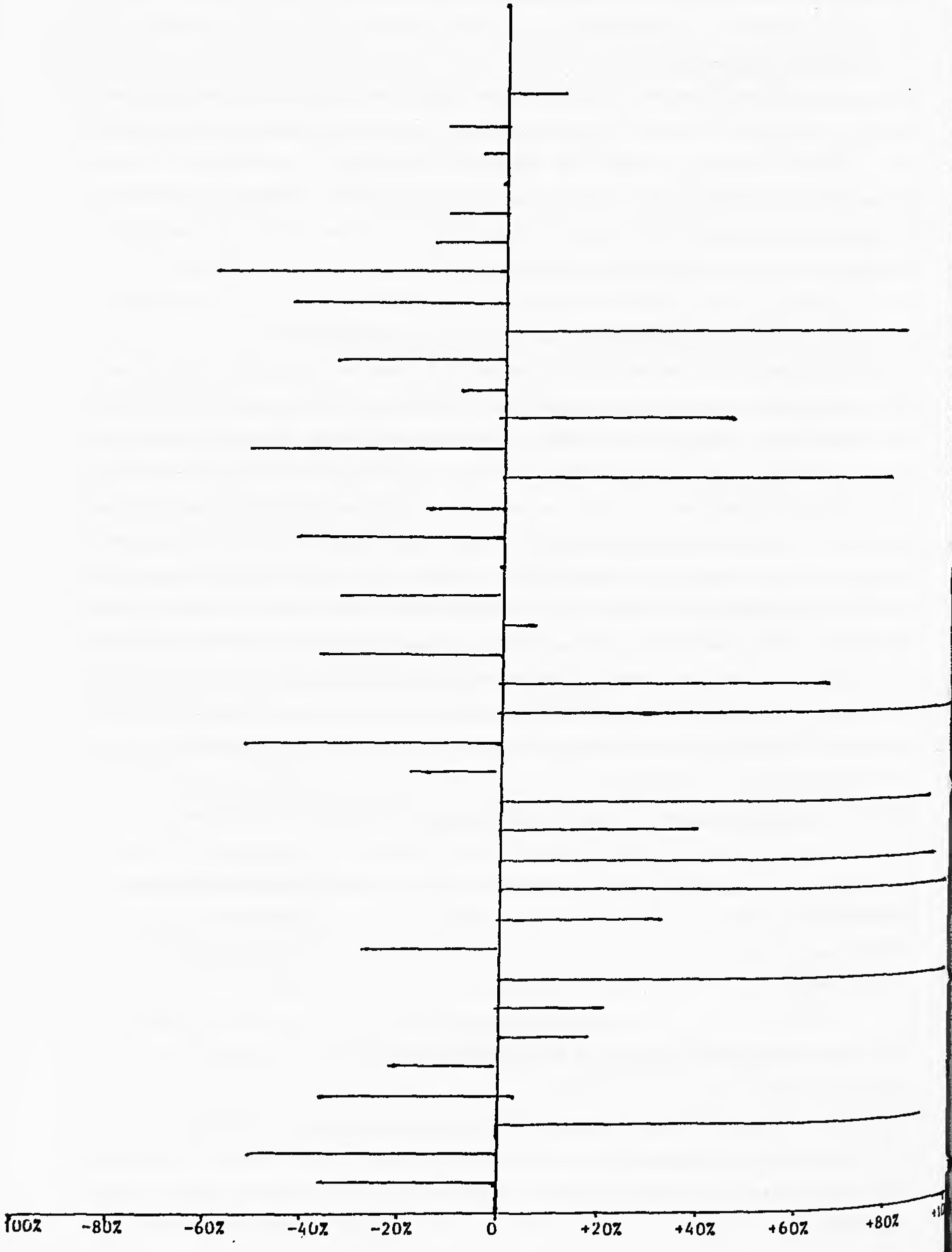
Table 1: Economic Internal Rate of Return at Three Points of Time

Scheme	Appraisal	Completion	Later Impact Evaluation
Gambia Agric Devt	30	22	negative
Lake Alaotra	11	22	negative
Mexico Third	11	21	17

3. FACTORS INFLUENCING PROJECT SUSTAINABILITY

The poor outcome of many agricultural projects, particularly irrigation ones, has been a source of concern for sometime, and the World Bank, in its Tenth Annual Review of the results of its project audits, has suggested that during design there should be much greater concern for

Figure 1: IRR estimated at PPAR as a percentage of IRR estimated at Appraisal



sustainability (World Bank Tenth, 1985). There has also been concern with the increased burden of recurrent costs on government budgets, and a number of writers have noted the need to give this issue greater attention during design appraisal (Carruthers 1985, Heller and Aghevli 1985). It has been suggested that one method of doing this would be to attach a higher shadow price to expenditures which make demands on limited government revenue when calculating the EIRR (Finney, 1984). While this method might have some attraction to governments which fund irrigation O&M costs out of general rather than specific revenue, there would still be the difficulty of deciding the correct shadow price (Heller and Aghevli 1985) and it would still be open to manipulation. It therefore seems doubtful if this suggestion is sufficiently radical. The EIRR has only been used as the dominating criterion for the choice of projects since the early 1970s. If it is an unreliable indicator of the outcome of projects, do we need to consider alternatives or complements to it, and can we decide if there are more important economic issues likely to affect a project's success?

The analysis of the socio-economic and institutional problems reported in 50 recent irrigation projects is shown in Table 2. While this shows the frequency of certain problems, it does not indicate their importance for the success or failure of the scheme. In general, it was found that problems in Group 1 were most likely to jeopardise a good outcome since they resulted in a lack of interest by the intended beneficiaries. The most important defects were found to be related to the prices and availability of inputs and outputs, which together affected the income a farmer could achieve from the scheme as compared with alternative activities that might be open to him. Thus, one conclusion of the study was that farm incomes were of central importance in deciding whether the constructed facilities would be fully exploited. In Group 3 it will be seen that cost recovery (I) was mentioned as a problem in a third of the cases. Problems connected with the provision of resources for O&M were reported under J and were frequently an underlying factor in the difficulties in securing that farmer organisations carried out the tasks expected of them, (H), which often included some maintenance activities.

There is an obvious linkage between farm incomes and farmer payments for O&M, particularly in low income countries where there is a danger that if

Table 2 <u>Percentage of evaluations noting particular problems, by region</u>

Group	Local Economics				Socio-Political				Institutional/Planning					Implementation		Unpredictable
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Asia	23	40	20	23	23	30	10	70	33	40	54	27	30	17	13	17
N Africa and Middle East	17	33	17	17	67	0	0	17	50	33	50	83	17	33	0	17
Sub Saharan Africa	48	83	17	50	58	33	50	25	33	50	33	58	33	16	8	33
Latin America	0	100	40	0	40	0	40	0	20	0	80	0	40	0	0	0
Total	25	49	21	26	38	26	23	43	34	38	49	34	30	17	9	19

<u>Key on pages 11 and 12</u>

Key to Table 2

Socio-economic and institutional problem areas in irrigation schemes.

Group 1: The Local Economy and Farm Level Economics

A. Existing, non-project activities of intended beneficiaries

B. Agricultural marketing factors (prices and price policy; risk in purchasing inputs or main staple food; crop patterns at variance with market requirements; availability or quality of inputs including repair services and credit; poor communications infrastructure).

C. Natural resource use and conflicts (ground-water management conflicts; water-use outside project area; conflicting hydro electric power requirements; conflict with livestock owners over land use)

D. Labour (peak labour shortages, appropriate farm size, employment effects)

Group 2: Social and Political Factors

E. Land tenure, consolidation, compensation, resettlement.

F. Equity issues (income, power and wealth distribution and conflicts; disadvantages for women)

G. Conflicts between state and farmer aims and other political constraints (excepting price policy issues considered in B)

H. Farmer organisations, conflicts between farmers affecting institutional arrangements, conflicts between farmers and farmer groups and other local institutions (eg local governments etc)

Group 3: Institutions, organisation and management, resources for operation and maintenance

I. Cost recovery, water charges

J. Allocation of responsibility and provision of resources for maintenance and on farm development; efficiency and equity of water delivery service

K. Project concept and development assumptions; suitable technology, faulty planning mechanisms (eg. inadequate preparatory studies, unrealistic timetable)

L. Staff: incentives, quality, quantity

M. Relationships of main and other national agencies involved in project

Group 4: Implementational problems not deriving from feasibility study

N. Procurement and contract mechanisms

O. Lending agency role and supervision; lending agency and national government conflict; consultancy and government department conflicts.

Group 5: General

P. Unpredictable external events (unexpected inflation, extraordinary drought, civil conflicts, etc) farmers pay the full costs of irrigation, they may be left with unacceptably low incomes (Carruthers and Clark 1981, Sagardoy et al, 1982). In this case, the risk is that any structures built will not be fully utilised. However, in such countries, it is also likely that general government revenues are low. The challenge, therefore, is to design appropriate structures for an area that will yield adequate incomes to farmers, including the payments they make for running costs. Whether they should also pay a proportion of the capital cost is an issue the government should decide in advance of the feasibility study, as this will affect the design.

4. TREATMENT OF RECURRENT COSTS AND FARM INCOMES IN FEASIBILITY STUDY GUIDELINES

When one examines the guidelines for the preparation of irrigation feasibility studies issued by various agencies one is struck by the different importance given to financial viability at farm and project level by those drawn up mainly on the basis of developed country experience and those drawn up for use mainly in developing countries receiving loans from aid agencies.

This is not to say that the World Bank has been unconcerned with farmer payments for water. On the contrary, particularly in the 1960s and early 1970s, the Bank was most insistent as a condition of loan that there should be a water charge to recover costs. However, this was more because such changes were felt to be indicative of good economic management and national ability to repay the loan, than because of specific concern with revenues for maintenance. The Bank was not necessarily concerned to see that water payments went to the project authority, or were ear-marked in any way.

The Bank-approved Guidelines for Irrigation and Drainage Projects were first published in 1970 and reissued in substantially revised form in 1983 (FAO Investment Centre 1983). Revised guidelines for Agricultural Investment Projects were published in 1985 (FAO Investment Centre 1985). Both recommended substantially the same 10 or 11 chapters, in slightly different order. In the Irrigation one, a description of the Project

Area precedes the central chapters V. Project Design Considerations and VI. The Project. However, it is not shown how consideration of the local economy and institutions should influence design, and no mention is made of O&M costs as a design factor, although they are required to be estimated in the chapter on The Project. The main design consideration amplified in the guidelines is concerned with water supply and technical factors. In Chapter IX, Markets, Prices and Financial Results, one main concern is to show that the extra production can be marketed. It is also required to be demonstrated that the project gives attractive incomes to the farmers, although low objectives are set for this - the projected net cash income should not be lower in any year than it was before the project. It is noted that "incremental cash income may be less than the incremental value of production" and that this should be taken into account in estimating repayment capacity, and in the design of the project. This is not amplified. An examination of the government's cost recovery policy is required, and "Note should be made of the extent to which recoveries meet operating and maintenance costs".

It is noticeable that Chapter X, Benefits and Environmental Impact, contains some implied criticism of the Internal Rate of Return, because it may not include all social benefits of the project. This is not a valid criticism since all social benefits will depend on increased agricultural production and sustained O&M, so they must be regarded as secondary objectives. The EIRR is not faulted for leading to under-valuation of the importance of financial viability at farm and project level, or because it is difficult to estimate accurately in the real world of changing conditions. It is clear that the EIRR is still regarded as the main justification of the project, and that much of the earlier financial analyses are required simply to provide data for its calculation.

The Guidelines for the Preparation of Agricultural Investment Projects are in several respects better than the Irrigation ones. Under Design Considerations, it lists more items that need justification, including appropriate scale, the range of components, choice of technology and farming systems, appropriate time frame and phasing, etc. The chapter on consideration of the Project area is given 8 pages instead of the 2 in the irrigation document, and shows greater realisation of the need to see the project matches the locality in more than technical respects. The calculation of the cost of maintaining services at levels necessary to achieve project objectives is required, and it is noted "it may be desirable to comment on the government's capacity to meet the implied financial commitments". In the following chapter on Organisation and Management it is noted that "In some cases it may be necessary to consider reductions in project scope to conform with institutional capacities", indicating one way in which institutional considerations might affect project design. In the chapter on Markets, Prices and Financial Results, it is stated that it has first to be shown that the project will be sufficiently attractive financially to encourage the participation of the farmers, and secondly, that it is acceptable from the wider economic point of view. However, the same rather low objectives for farm incomes are set as in the Irrigation document. It does require careful attention to the impact on the Government budget. The final chapter on Benefits and Justification again concentrates on the EIRR.

In summary one could say of both these Guidelines that they deal with farm incomes and O&M costs, but do not give them central importance as factors to influence design. The revisions show some doubt about the EIRR, but retain it as the main test of project acceptability. Of the two, the Agricultural Project Guidelines go further in showing how local economic and institutional considerations might affect the scope and components of the project. However, both begin with the necessity to maximise benefits and minimise costs. As the recurrent cost element in costs will be discounted heavily in the EIRR calculation, recurrent costs are not shown as necessarily affecting decisions on the project's size, scope and components.

The emphasis on maximising production for national benefit and the lack of centrality for farming incomes and project O&M costs stands in marked contrast to older guidelines developed in the United States and Europe. The USBR manual of 1951 defines irrigable land as that which can:

> meet all production expenses, including irrigation operation and maintenance costs, and provide a reasonable return on the farm investment;

provide a reasonable repayment contribution toward the cost of project facilities;

provide a satisfactory standard of living for the farm family.

This summary is taken from Guidelines: Land Evaluation for Irrigated Agriculture (FAO Soils Bulletin 55, 1985) which basically endorses the USBR approach, and which suggests that at the reconnaissance study stage, one looks at potential yields, but that at the final stage of eliminating unsuitable marginal lands, the Net Incremental Irrigation Benefit be calculated, taking into account:

i. farm investment and operating costs, and returns ordinarily accruing from the agricultural use of land

ii. all project investment, operating and maintenance costs.

The Guide to the Economic Evaluation of Irrigation Projects (Bergmann and Boussard, 1976) was published in 1976 after testing in 14 irrigated areas, mainly in southern Europe. However, it was intended to be useful everywhere. The 5 chapter headings in the illustrative feasibility study indicate the greater importance given to farm profitability and O&M costs than in the World Bank model. The central chapter C, The Targets, covers the technical description of the project, the agricultural development envisaged with irrigation and the operating and maintenance costs. Chapter D is entirely devoted to profitability at farm level. The final chapter, E, looks at profitability from the standpoint of the national economy. The authors state it is essential to deal with private profitability before making the profitability calculation from the national standpoint. They suggest farmers will look for 2 or 3 times their present cash income if they are to be induced to make the necessary complementary investments and to utilise fully the water provided. In their discussions on national economic benefit, the main authors, Bergmann and Boussard, favour the use of the internal rate of return while noting it is difficult for long-term agricultural projects to show a higher rate than 16 - 17%. They include the calculation of the financial viability of the operating organisation where this is an independent legal entity, as it often is in Europe.

5. IMPLICATIONS FOR PROJECT DESIGN

Irrigation must offer farmers a substantial improvement over alternative and perhaps less demanding types of work. It also requires a constant flow of resources for operation and maintenance, without which schemes will decay. The financial outcome at farm level and the resource flows at project level must therefore be the two primary tests for project sustainability. This suggests a return to an older method of preparing irrigation projects, followed for example by the investors in the original Gezira scheme. Even in the case of the old government schemes in India in the nineteenth century there was generally a concern to see that the costs could be met out of expected increases in government land revenue.

There are many ways in which a greater concern from farm incomes and for resources for O&M would influence design. It might affect, for example, the size of the service area and the length of the main canal. It could affect the choice of technology according to local availability and skills for repair. On the institutional side it might indicate a greater role for farmer groups in maintenance, which normally has to be compensated for by giving them also a greater role in design choices and agricultural management at least at the tertiary level, and taking into account as far as possible existing tenure boundaries and social and administrative boundaries in designing block layout. It could affect the phasing of development, with provision for simple structures initially that could be up-graded as funds accumulated. It could indicate in certain circumstances that heavier and stronger gates are provided initially, rather than cheaper ones that need more frequent repair or replacement. It might indicate the advisability of accepting a higher than normal risk that the optimum water supply was unavailable for the second or third crop.

It is not suggested that the EIRR be totally abandoned. There are two ways of using financial and economic criteria: to try to optimise, and to see whether a test is passed. Currently, most projects have tried to optimise the EIRR, and them test at farm income level. It is suggested it would be better to optimise at farm income level (in practice, it is difficult to prevent farmers from doing this) and to test, firstly by seeing there will be adequate resources for the amount of O&M that will be necessary to sustain the project and secondly, that the EIRR is 8% or better. Given the uncertainties attached to the calculation of EIRR anything less than 8% should be ruled out as within the margin of error that could include a negative outcome and a waste of national resources; given the same margin error it is not important if the EIRR is 16% or 24%.

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Note. I am grateful to Michael Snell of Sir Malcolm McDonald and Partners, for points he made on the use of the IRR as a test rather than for optimisation, and for the discussions we had on the implications for design of certain socio-economic and institutional factors. As mentioned in the first paragraph, many other people also contributed to shaping my thoughts during this study. In addition to presenting the paper at FAO in September 1986, it was the subject of lunch-time meetings and discussion at the Overseas Development Institute in January 1987 and at the USAID office in New Delhi, India, in February 1987. There was a considerable measure of agreement on the danger of over great dependence on the EIRR, and the necessity for planners to take decisions in a multi-criterion framework.

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IRRIGATION SERVICE FEES IN ASIA

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ODI/IIMI Irrigation Management Network Paper 87/1c April 1987

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ISSN: 0951 189X

IRRIGATION SERVICE FEES IN ASIA

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IRRIGATION SERVICE FEES IN ASIA

Leslie E. Small

In 1985 IIMI conducted a Regional Study on Irrigation Service Fees with support from a Technical Assistance Grant from the Asian Development Bank (ADB). The primary objectives of the study were (1) to develop a conceptual *framework for evaluating* irrigation financing policies and (2) to review the procedures and rationale for irrigation financing mechanisms in five Asian countries: Indonesia, Korea, Nepal, the Philippines and Thailand. The study also included a literature review of conditions in other parts of the region. Emphasis was placed on examining mechanisms for financing recurrent expenses of operation and maintenance (O&M), and their relationship to the quality of irrigation performance. *The study was discussed at a Regional* Seminar in Manila, in July 1986.

1. GENERAL CONCLUSIONS

A. Irrigation services can be financed by a wide variety of mechanisms: water pricing, based on demand-determined consumption; *irrigation service fees assessed with* reference to irrigated area; general taxes levied without specific reference to irrigation services; implicit taxation through control over prices of inputs and regulation of the market sector; and supplemental income to an irrigation agency through other revenue generating activities.

B. Mobilizing resources through irrigation *service fees* and other mechanisms involving direct or indirect payments by water users or other beneficiaries is not an end in itself, but is only important

<u>first</u>, in so far as it results in improved irrigation performance through:

(a) more efficient O&M of irrigation facilities (by improving O&M funding; by improving the accountability of irrigation managers to water users; and by encouraging greater cooperation and involvement of water users in O&M); and

(b) more efficient use of water by farmers; and

<u>second</u>, in so much as it promotes other objectives of government by:

(a) leading to better investment decisions;

(b) easing the government's fiscal burden; and

(c) resulting in a more equitable distribution of income;

The effects of alternative resource mobilization mechanisms in relation to various government objectives are summarized in Table 1.

C. The effects of irrigation service fees on irrigation performance and on investment decisions depends on the institutional framework of the irrigation agency. In particular, it depends on whether the agency has a significant degree of financial autonomy or is financially dependent on the central government (see Table 1). The key elements of financial autonomy are (a) that the irrigation agency must rely on user charges for a significant portion of the resources used for O&M, and (b) that the agency have expenditure control over the use of the funds generated from these charges.

D. Financial autonomy is the more appropriate institutional framework to obtain improvements in irrigation performance. The fact that the autonomous agency must be able to collect direct payments for irrigation services is likely to lead to greater involvement of farmers in decisions regarding actual expenditures on O&M, including staffing levels. Furthermore, if farmers are expected to repay some capital costs, then there is a rationale for increasing their involvement in decision-making processes during planning and construction as well as in regular operation and maintenance.

Table 1. Summary of Potential Consequences of Irrigation Financing Mechanisms in Relation to Financing Objectives

Financing Objectives	Institutional Context and Financing Mechanisms						
	Financial Autonomy: Funds controlled by irrigation agency			Financial Dependence: Funds controlled by non-irrigation agency; irrigation agency financially dependent on government budget allocation			
	Irrigation Service Fees	Water Prices	Secondary Income	Irrigation Service Fees	Water Prices	Taxes	Implicit Taxation
1. Improve Irrigation Performance							
a. More efficient operation of irrigation facilities							
- Improve funding of O&M	yes	yes	yes	no	no	no	no
- Improve managerial and financial accountability	yes	yes	no	no	no	no	no
- Improve involvement of water users	yes	yes	no	no	no	no	no
b. More efficient utilisation of water	no	yes	no	no	yes	no	no
2. Improve Irrigation Investment Decisions	?	?	no	no	no	no	no
3. Improve Fiscal Position of Government	yes	yes	?	yes	yes	yes	yes
4. More equitable income distribution	?	?	?	?	?	?	?

E. Irrigation agencies with a significant degree of financial autonomy are often able to reduce the amount of direct payment required from farmers through institutional arrangements whereby the agencies earn secondary income from sources other than charges on water users. Types of secondary income include interest on deposits, rental of assets owned by the irrigation agency, sale of water for non-agricultural purposes, and the sale of fishing rights in reservoirs.

F. The impact of irrigation service fees and other resource mobilization measures on the government's fiscal burden and on the equity of income distribution depends on, and is generally dwarfed by, the effects of other agricultural sector policies (such as fertilizer subsidies, rice price controls and trade restrictions) designed to promote broad social objectives such as regional development, employment creation, rural-urban income parity and food self-sufficiency.

G. Pricing water deliveries to individual farmers is likely to be prohibitively expensive in most gravity systems serving large numbers of small farms. The cost is not merely in terms of measurement of flows, itself a difficult task, but in the administration, reporting, billing and collection procedures. Pricing is only likely to be effective if groups of farmers, say at the tertiary level, can be served with a single bill.

H. In the absence of a water-pricing mechanism, the argument that user charges for water will increase the efficiency of water use by the farmers loses most of its validity. Even if water pricing were possible, its benefit in terms of increased water use efficiency by farmers would be much less than is sometimes suggested. Much of the current "wastage" of water can be attributed to poor supply control rather than excessive demand in the absence of water prices. But effective supply control is a prerequisite for a system of water pricing. It is likely that once this prerequisite exists, the amount of "wastage" will be greatly reduced, thus lowering the potential efficiency gains from any subsequent attempt to introduce water pricing.

I. Indirect benefits of irrigation are often quite large, and in some cases may even exceed the direct benefits. Although it is rare to find cases where indirect beneficiaries are directly assessed, they may be subject to indirect taxes that go to the central government.

2. *COMPARATIVE EXPERIENCES IN ASIA*

2.1 Pricing Policies

Within the five countries studied there are wide variations in policies and approaches towards mobilizing resources to finance irrigation services. Financial autonomy is found in Korea with decentralized Farmland Improvement Associations ([1]), and in the Philippines with a centralized National Irrigation Administration. Decentralized financial autonomy is also found in the tertiary portions of systems in Indonesia, while financial dependence prevails at the main system level. The national irrigation agencies in Nepal and Thailand are also financially dependent on funds allocated by the central government.

In Korea, Nepal and the Philippines, and at the tertiary level in Indonesia, resources are mobilized from the water users through irrigation service fees. Fees are also being imposed in a few areas in Thailand that have undergone land consolidation. In all cases, these fees are assessed at a flat rate per hectare of irrigated land, but with some adjustments possible according to season and crop type. Because of the decentralized nature of the irrigation associations in Korea and at the tertiary levels in Indonesia, the rate per hectare in these countries can vary both within and among associations. By contrast, the centralized approach to the assessment of fees used in Nepal and the Philippines results in much greater uniformity of fees in these countries.

In addition to mobilizing resources directly from the water users, the financially autonomous irrigation agencies in Indonesia, Korea and the

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[1] See ODI Network Paper 12d: K.S Park, Institutional aspects of operation and maintenance in Korea, November 1985.

Philippines also rely on secondary income as an important source of funding for irrigation services. In Korea the irrigation associations derive an average of 25% of their income from secondary revenue. In the Philippines secondary income is as much as 60% of actual O&M expenses; however, much of this is tied to the construction activities of the irrigation agency. The financially dependent irrigation agencies in Indonesia, Nepal and Thailand have no significant secondary income.

Other mechanisms to mobilize resources are also found in Indonesia, Nepal and Thailand. Taxation, in the form of a land tax, is used in both Indonesia and Nepal. Thailand relies on indirect taxation, primarily through the depressed price of rice resulting from its structure of rice export levies.

If irrigation service is satisfactory, then the benefits derived by farmers are more than adequate to cover O&M costs in all of the five countries, but they cannot cover more than a small portion of the capital investment (Table 2). In Korea there is a specifically defined portion of the fee set aside for capital recovery, even though total fees assessed and collected may not cover the full cost of O&M. In the other countries no separation of the fee is made.

2.2 Fee Collection

Korea obtains the highest rate of fee collection, over 98%, in part because great importance is attached by agency staff to meeting the 100% target. Considerable efforts are made in administering the fee collection process. In the Philippines, where the National Irrigation Administration has switched from a financially dependent to financial autonomous body only in the past few years, increased importance is now also being attached to fee administration and collection. Reflecting this change, collection rates have increased somewhat from past years, and are now about 60% of the amounts assessed. In contrast, Nepal collects only an estimated 20% of fees due. This reflects the lack of importance of fee collection to the irrigation agency, which is dependent on the central government for its entire budget.

Table 2. *Estimated Benefit Recovery Ratios*
Under Alternative Financing Policies (percent)[1]

Country	Policy			
	Actual	Actual Modified to Set Irrigation Service Fees Equal to O&M Costs	Actual Modified to Set Irrigation Service Fees Equal to O&M plus Full Recovery of Capital Costs	
			Moderate Capital Cost	High Capital Cost
Indonesia				
low estimate[2]	8	10	56	114
high estimate[2]	21	27	154	313
Korea[3]				
low estimate[2]	26 (54)	27 (58)	141 (297)	203 (429)
high estimate[2]	33 (70)	36 (75)	183 (387)	264 (557)
Nepal	5	10	74	122
Philippines	10	7	43	98
Thailand[4]	9 (30)	31 (53)	155 (176)	279 (300)

[1] A benefit recovery ratio is the ratio of all increases in direct and indirect farmer payments for irrigation services to the incremental net farm income resulting from irrigation.

[2] Low and high estimates result from alternative estimates of the net benefits of irrigation.

[3] Figures in parentheses represent the estimated benefit recovery ratios that would prevail if domestic prices of paddy were allowed to drop to a level consistent with 1983 world prices (estimated to be 239 won/kg paddy), while all other prices and input amounts remained constant.

[4] Figures in parentheses represent the values that would apply if the implicit tax on the farmgate price of paddy were 22 percent, as estimated for the late 1970's in World Bank, "Thailand: Case Study of Agricultural Input and Output Pricing", Staff Working Paper No.385, 1980, p.50.

In Korea and Nepal irrigation fees are assessed in cash, although in Korea the maximum amounts which can be charged are established in terms of paddy. In the Philippines the fees are assessed in terms of paddy but can be paid in cash based on the official price. In Indonesia water user associations have both cash and in-kind contributions. The primary advantage of a crop-based assessment is that there is a built-in adjustment for inflation: if crop prices rise, or are increased by central government, the agency is able to increase its revenues without facing the political pressures associated with requesting an increase in fees.

The relationship between actual O&M costs and the rate set for irrigation service fees varies greatly among the five countries (Table 3). Only in the Philippines is the rate set higher than actual O&M costs; however, because collections are only about 60% the revenues actually collected are considerably less than total O&M costs

2.3 Cost Reduction

Although there is a tendency for agencies to try to raise fees if income falls below expenditure, there are also some efforts made in all countries to reduce costs. These may be dictated by central government, as is the case in Indonesia, Nepal and Thailand, because requests for annual appropriations are not fully met during budget allocations. In the Philippines the irrigation agency both prepares budgets and funds them. With lower than desired fee collection rates, secondary income has become a crucial source of financing O&M. Still, funds are limited, and efforts have been made to cut costs by reducing staffing levels. In Korea the decentralized water user associations generally earn adequate revenue to support O&M; however, the resulting levels of irrigation fees are quite high, and the associations' expenditure budgets are subject to strict government control.

3. DISCUSSIONS AT THE REGIONAL SEMINAR ON IRRIGATION SERVICE FEES

A Regional Seminar on Irrigation Service Fees, jointly sponsored by the Asian Development Bank (ADB) and IIMI, was held in Manila from 21-25 July 1986. Participants included 25 representatives from 13 of the Developing

Table 3. Estimates of Average Operation and Maintenance Costs, and of Revenues Collected by Irrigation organisations in Five Asian Countries

	Indonesia	Korea	Nepal	Philippines	Thailand
1. O&M Costs ($/ha)	22	211	10	14	27
2. Irrigation Service Fees Assessed					
a) Amount per ha ($)	[5]	196	6	17	0
b) % of O&M Costs	[5]	93	60	121	0
3. Approximate % of Fees which are collected	[5]	98	20	62	-
4. Revenues Collected from Irrigation Service Fees					
a) *Amount per ha* ($)	15	192	1	10	0
b) % of O&M Costs	68	91	10	75	0
5. Revenues from Secondary Income ($ per ha)	[5]	59	0	36[6]	0
6. Total Revenues					
a) Amount ($ per ha)	15	251	1	46[6]	0
b) % of O&M Costs	68	119	10	329	0

[5] *Information not available.*

[6] Includes $28 of interest and management fees derived from and mostly utilised for construction activities.

Member Countries (DMCs) of the ADB, one observer each from the World Bank, the FAO and the United States Agency for International Development, three researchers from IIMI and 10 Bank staff. The primary purpose of the Seminar was to examine how national policies for internally generating funds for irrigation operation and maintenance (O&M) could help the DMCs achieve more cost-effective O&M of irrigation systems. The seminar discussions were organized around key findings of the IIMI study on Irrigation Service Fees described above. Country papers were presented from each of the DMCs.

As has been shown, a key conclusion of the IIMI report was that the potential effects on irrigation performance of a system of irrigation service fees depended on whether the irrigation agency possessed a significant degree of financial autonomy, or whether it was financially dependent on the government. The Country Papers presented at the Seminar indicated that agencies operating with partial financial autonomy exist in Fiji (for drainage projects), the Republic of Korea, the People's Republic of China, ([2]) the Philippines and Vietnam. Elements of financial autonomy are found in Water Users' Organizations at the tertiary level in Indonesia, in agencies responsible for lift irrigation in Karnataka in India, and in some irrigation projects in Sri Lanka. On the other hand, irrigation agencies operating within the context of financial dependence are found in Bangladesh, Fiji, Indonesia, Malaysia, Nepal, Pakistan, Sri Lanka and Thailand. In general, participants from countries where financial dependence prevails felt that administrative considerations would preclude any move toward financial autonomy. Some participants from these countries also expressed reservations about the desirability of financial autonomy. They were concerned that financially autonomous agencies, responding to user pressures to limit O&M costs, might fail to properly maintain the infrastructure of the main irrigation system.

The IIMI study concluded that in situations where the irrigation systems were functioning satisfactorily, farmers could pay for the full O&M costs from their incremental income. Although the Seminar participants were in

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[2] See ODI-IIMI Irrigation Management Network Paper 86/3b: Xu Guohua, The Irrigation Water Charge in China, November 1986.

favour of recovering O&M costs from the farmer, they emphasized the need to monitor the magnitude of the benefits received by the farmers. Some participants felt that it was unlikely that the benefits would be great enough to permit the farmers to cover the full cost of O&M in the near future, and that some additional funds from the government budget would be necessary.

The IIMI study suggested that one approach to increasing the accountability of irrigation managers to water users would be to decentralize the administration of irrigation projects. One specific approach suggested is that of the bulk sale or "wholesaling" of water to decentralized Water Users Organisations (WUOs) which would then be responsible for the subsequent distribution and "retailing" of the water to individual farmers. Information from the Country Papers and from the Seminar discussions indicates that WUOs of various types exist in many of the DMCs, although their specific responsibilities and authority vary greatly. Arrangements for the bulk sale of water exist in the People's Republic of China and in Vietnam.

All but two of the countries represented at the Seminar use some form of irrigation service fees to mobilize resources for operation and maintenance of irrigation systems directly from the farmers who benefit from the projects. In nearly all cases the fee is an area-based charge, although there is considerable variation among the countries with respect to the details of how the fees are computed. Assessment and collection procedures also differ among countries.There are very few cases of fees based on water pricing. Thus the fees are generally used to recover the costs of irrigation services from farmers, but not as a means of allocating water.

Note: Previous Network papers on this subject were:

10f Introduction to Discussion on Water Rates
11e M Tiffen (ed). Cost Recovery and Water Tariffs: A discussion
86/1c I Carruthers. Irrigation Pricing and Management
86/2b M Svendsen. Meeting Irrigation System Recurrent Cost Obligations

These are still available at ODI.

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IRRIGATION MANAGEMENT NETWORK

COMPUTERISED CONTROL OF IRRIGATION WATER DISTRIBUTION

Jean Verdier

ODI/IIMI Irrigation Management Network Paper 87/1d April 1987

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ISSN: 0951 189X

COMPUTERISED CONTROL OF IRRIGATION WATER DISTRIBUTION

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He will be joining the staff of the International Irrigation Management Institute (IIMI) as their Resident Scientist in Morocco, later this year.

COMPUTERISED CONTROL OF IRRIGATION WATER DISTRIBUTION

Jean Verdier

The ever-increasing power of micro-computers and the reduction in their cost may considerably change the approach to the design and management of hydraulic structures which convey and distribute irrigation water. Existing computer technology can bring the security and flexibility of computerised control to small schemes. Used on a wider scale, computers could increase the adaptability of agricultural production systems to market needs through a better control of one input: water. Moreover, computerised systems often incur lower investment costs than standard methods of regulation.

Balanced against these benefits is the need for more complex and longer design studies, a need which is all the more acute as the methodologies to determine optimal control procedures are as yet rudimentary.

This paper demonstrates the utility of mathematical modelling for the design and the verification of control algorithms. It analyses the possibilities of second order linear models, summarises some results obtained with these models on a river in South-Western France, and describes the process used to compare various management policies for a Mexican canal.

1. *INTRODUCTION*

Along the Mediterranean coast, systems to regulate water levels have been employed since antiquity in conveyance canals and in rivers with insufficient low flows. These systems usually consist of simple weirs providing upstream control. The weirs are basically intended to mitigate the adverse effects of rapid fluctuations in water demands or inflows.

It is worth noting that in Roman times people clearly realised the importance of regulation systems in the management of water delivery. Indeed, even with the limited means available at that time, attempts had been made to improve the situation by rethinking the general design of structures. In some cities of the Roman Empire, a system of automatic priority was followed if there was water shortage. Intakes in buffer-tanks within the aqueduct system were sited according to their importance: the public standpipes required to meet the most essential needs of the population were supplied by intakes located in the lower parts of the tanks whilst the pools of rich patricians' villas were supplied from an intake in the upper part of the tanks only when water was plentiful. Such sophisticated hydraulic structures were uncommon, but demonstrate that ancient hydraulic engineers realised that through technical innovation they could respond better to the needs of their fellow citizens.

Watercourse regulation techniques were not further improved until the 20^{th} century when two major innovations were developed: downstream regulation and, more recently, the use of process control computers. The first technique, which is commonly used in many countries today, introduced the closed-loop (or feedback) concept in the design of irrigation networks to offset automatically the effects of unexpected disturbances. The second technique, which is not as well-known, provided irrigators with the flexibility and adaptability of computerised regulation systems and relaxed the limitations imposed on management by the original design structure.

The purpose of this paper is to review the possibilities offered by the development of computerised control in the conveyance and distribution of irrigation water. Some potential problems encountered in implementing these techniques are also considered together with possible solutions. The paper considers only the daily management of water distribution and does not discuss policies related to seasonal or inter-year water management.

2. GENERAL CONSIDERATIONS ON HYDROMECHANICAL REGULATION

The benefits derived from computerised control of irrigation water can only be assessed through a comparison with more conventional regulation methods such as upstream and downstream control. Consideration of the objectives of farmers and managers is particularly important.

2.1 Objectives for the management of irrigation control structures

The objective of the management of irrigation canals is apparently simple, to supply farmers with the water needed for crop production. However the means to achieve this will depend on the particular environment and season. Questions that need to be asked are:

- will the distribution be on demand or by rotation ?
- will the system be able to cope with exceptional demands such as failure, leakage, illegal abstraction, and if so, to what extent? If not, who will suffer the consequences?
- is it advisable to try and save water by, for instance, collecting rainfall runoff in the dry season?
- will the system have to cope with spatial or quantitative variations in demand and will the variations be anticipated and allowed for by management before the season (regulated crop rotations, cropping plans) or not (crop selection by farmers in response to changing market conditions) ?
- what guarantees will be given for farmers' water supplies should a failure occur in the regulation system? In the event of a canal breach what security can be given to people living beside the canal?

The flexibility to cope with given situations rests largely upon the cost and type of regulation structures and techniques used within the canal network.

2.2 Upstream regulation

Upstream regulation implies a certain rigidity in water distribution since it maintains a fixed upstream level at the regulator (constant upstream level gates or weirs) whilst unused water supplies in a reach are routed downstream. These structures require an early knowledge of the overall downstream demand in the project area and of the transient behaviour of watercourses: such configurations are characteristic of what control engineers call "open loop regulations". In practice, such a method of regulation requires rotation of water supplies if water resources are to be conserved. If there are operating failures of structures, the downstream users will be the ones to suffer.

2.3 Downstream regulation

Downstream regulation maintains a constant downstream level at the control structures (generally constant downstream level gates). Contrary to upstream regulation, downstream regulation reacts directly to any disturbance and any unexpected demand deviation is automatically sent back upstream. This is due to the fact that, in a plain, the flow in a watercourse is always subcritical (i.e. downstream conditions influence upstream water levels) and that irrigation water can serve as a data transmitter along the canals. In spite of its simplicity, such regulation constitutes a genuine servomechanism in which any control is a function of a deviation between a set value and the measurement of a controlled variable. These data feedbacks between system inputs and outputs, called "closed loops" by control engineers, are a key element in any servo-system.

Downstream regulation has considerably improved the management of irrigation canals because:

- a high level of accuracy is no longer required in managers' forecasts,
- changes in hydraulic regimes are more rapid since the water volumes passing through the reaches are better controlled,
- by correcting the adverse effects of disturbances, such regulation allows water savings,
- though it usually requires rotation of water supplies, flexibility is introduced by absorbing excess water and meeting unexpected small demands.

Despite unquestionable advantages, downstream regulation has several drawbacks, especially when it uses hydromechanical gates:

- since set levels are determined by the positioning of regulation gates, distribution policy is established once and for all when the structure is designed. Evolutions in management policy caused, for instance, by significant changes in crop production, often require costly modifications of the structure's physical characteristics (except for electrically controlled gates),

- downstream control regulators are more expensive and less easy to install than upstream ones,
- since canal banks have to be horizontal, civil engineering works are more important than is the case for upstream regulation. This method of regulation is only suitable for canals with a slight slope.

In addition to these drawbacks, which have financial implications, downstream regulation may prove to be unstable. This is an unavoidable consequence of a closed-loop control. It can result in practice in an oscillation of regulator gates which is dependant on the structure's physical characteristics and totally independent of external influences. In other words, the system becomes completely uncontrollable. Control engineers call this phenomenon "hunting"; it is due to combinations of divergences and control saturations. It characterises systems which are highly sensitive, i.e. which aim at keeping levels within closely set values with excessive accuracy. In order to solve this "stability-accuracy dilemma", it is not only necessary to modify the parameters of the control algorithm, but also to change its nature.

To maintain a stable downstream regulation, it is important that it does not react too quickly to small changes in levels. Since the chance of instability increases with the inertia of the controlled system, conventional downstream methods of regulation are less valuable for large irrigation schemes where water transit time may be several days. Adequately monitored upstream regulation, requiring lower investment, may prove a better alternative for such systems.

3. COMPUTER SCIENCE AS A REAL-TIME MANAGEMENT TOOL

During the last few decades, various hydromechanical or electromechanical regulation devices have been developed to supersede the two categories previously described. Almost all of them are combinations of upstream and downstream regulation developed to mitigate the ill-effects and achieve the benefits of both. For data transfer between sensors and actuators, most engineers use electrical or radio transmissions which are much quicker than hydraulic transmission. Thus the inertia of the system decreases while the accuracy of the regulation increases without prejudicing its stability.

The most sophisticated management controllers use remote controlled actuators, sensors scattered along canals or rivers and a teletransmission system connecting all these devices. With such a system, it becomes easy to gather data collected by sensors in a central unit where they can be processed by a computer to control the actuators.

Regulations can be of any type, especially as the performance of computers has increased whilst prices have dropped. Today microcomputers which are cheaper than cars allow real-time management of sophisticated irrigation systems. Where they are used, these computers have improved scheme management not only in the field of regulation but also in control and adaptability.

The main benefits from computerised control are:

(i) For regulation, the ability to:

- process all the data provided by from sensors and to have a comprehensive control on actuators.
- compute in real time elaborate forecasts of farmers' needs and external supply (e.g., rainfall). The pseudo-inertia thus created makes it possible to reach a better compromise between stability and accuracy, and to deliver water on demand without excessive waste of resources,
- store past operations and compute flow propagations on waterways in order to detect possible disturbances more rapidly and accurately.
- adapt regulation to the specific context, such as the beginning or end of the irrigation season, shortage periods, reach closures, actuator breakdowns, etc. It is also worth noting that the possibility of partial operation increases the safety of the system.

(ii) For monitoring, computers allow advanced processing of data from sensors. They provide almost instantaneous detection of failures, rapid diagnosis of breakdowns and immediate requirements for repair. Assuming that trained technicians can be sent without delay and with suitable equipment, repair time is reduced and overall system performance is increased.

(iii) For management improvements. This is the major benefit of computerised watercourse management. Changing the software is enough to alter them wholly or partially while neither the mechanical, electrical or hydraulic equipment, nor the civil engineering works at structures need be changed. If the new software has been correctly tested on a simulator (see paragraph 4(ii) below), the shift to another regulation takes only a few minutes without stopping water deliveries. Two major consequences for the manager can be singled out:

- it is possible to improve management as irrigation requirements evolve and as understanding of scheme behaviour improves. A simple form of regulation can be implemented at first, and improved when the data collected during the first irrigation season are analysed.
- the management mode can be easily adapted to meet changes in farm patterns because there is better control of the water which is a major agricultural input in sub-humid or sub-arid zones during the growing season.

The flexibility provided by computerised systems is important in the agricultural sector where crop supply cannot always match demand. It is not the purpose of this paper to dwell on the adverse effects of continuing gaps between supply and demand in inflexible agricultural markets. However, we must remember there may be social and financial upheavals due to large fluctuations in prices or to the social cost of permanent support of the prices of surplus goods, or the financing of imported goods when there is a deficit.

To conclude this overview, it is worth adding that, due to the improved performance of computerised regulation, it is now possible to bring down the number of actuators (especially gates) on canals and to reduce safety devices (buffer tanks, weirs, freeboard and horizontal banks, etc). The reduced investment cost of civil engineering works and of mechanical and electrical equipment may offset the costs of computer and teletransmission equipment in new schemes.

With computerised control, it even becomes possible to use natural rivers efficiently for bulk transfer of water over long distances. The use of rivers is attractive as the transfer distances are large whilst the number of regulation or control devices required can be limited.

4. PROBLEMS RAISED BY THE DESIGN OF COMPUTERISED CONTROLS

While computerisation of irrigation canal management offers many advantages, the design and development of the corresponding control algorithms is laborious.

Two main problem areas can be identified:
(i) As far as design is concerned, the aim is to find the optimal control of a system which often has several inputs (actuator controls), many outputs (data supplied by sensors and/or by operators) and which is dependent on constraints such as structural characteristics, decision-makers' wishes or administrative regulations.

The optimisation of canal management cannot be achieved purely from theories of optimal control. Several methods of optimisation are available based on "linear" processes, the evolution of which is governed by linear differential equations with constant coefficients, but flow propagations along watercourses do not fall into this category since they are represented by non-linear partial differential equations known as the Saint-Venant equations:

Continuity equation (1)

$$l \frac{\partial Z}{\partial t} + \frac{\partial Q}{\partial x} = 0$$

Dynamic equation (2)

$$\frac{\partial Q}{\partial t} + \frac{\partial (QV)}{\partial x} + gS \frac{\partial Z}{\partial x} = -gSJ$$

where

t = time x = abscissa Z = free surface elevation
Q = discharge l = surface width g = acceleration of gravity
V = velocity J = energy gradient S = wetted cross-sectional area

To avoid these difficulties, the researchers propose two alternatives:

- developing heuristic procedures which can be sharpened through the experience acquired during the first years of operation; this is the method successfully adopted for the past twenty years by the Société du Canal de Provence for managing large canals in South-Eastern France and *in some other Mediterranean countries*,
- simplifying the mathematical models of flow propagations so as to be able to use the proven theories of optimal control for linear processes. This procedure was adopted by the Compagnie d'Aménagement des Coteaux de Gascogne to automatise the recharge of the Arrats river in South-Western France. For this, the CARAMBA method developed by ONERA-CERT has been used.

(ii) In both the above cases, and particularly in the second, there is no question of directly implementing rough algorithms for computers managing irrigation schemes in real time. Indeed it is not easy to determine if necessary simplifying hypotheses will not result in biased solutions or if the algorithm will react properly in extreme situations (failures combined with disturbances, sudden change in demand, harmonic prompting of canal waters). It would also be presumptuous to consider a large computer program free from error before thorough testing.

In order to avoid any disruption of the canal system due to a design fault *in the control* algorithms it is necessary to test them on a simulator before their implementation on site. Given the widespread use of computer science, these simulators will necessarily be mathematical models handled by digital computers. However, such models are difficult to develop since Saint Venant's equations cannot be integrated. Furthermore, specific difficulties entailed by the description of structures (diversions, movable gates, etc.) and some hydraulic peculiarities (hydraulic jumps, loops, changes from open flow to pipe flow, etc.) need to be taken into account.

To summarise, the development of computerised management of irrigation water distribution is currently hindered by an inadequate theoretical approach to the design and development of optimal, or at least pseudo-optimal, control algorithms. Long and costly studies are required which can exceed one man-year even when the projects are relatively simple. Progress in this area would contribute a great deal to the improvement of irrigation management through reducing the cost of policy elaboration while making these new approaches easier to understand and use by the decision-makers and managers of irrigation schemes.

5. SIMPLIFIED MODELS OF IRRIGATION WATER DISTRIBUTION

5.1 Main lines of research

This paper does not tackle the modelling of actuators such as gates since the problem is dealt with elsewhere (paper by B.de Leon Mojarro presented to the 14th European Regional Conference of ICID, May 1986).

The high cost of standard mathematical models results from the numerical solution of Saint Venant's equations using the methods of finite differences, generally with an implicit scheme. Such methods require an accurate description of the geometry and roughness of watercourses. This is easy to carry out with new systems but long and detailed ground surveys are needed in natural rivers and old canals.

Generally, managers investigate hydraulic data (such as discharge and depth of flow) only at selected points (near regulating gates or significant intakes) along the conveyance and distribution structures. To meet the needs of the end users, "transfer function" type models between a limited number of points are sufficient. This approach has the advantage of requiring ground surveys only at the points selected for the model.

Since it is necessary to consider varying periods of time and locations which are not only at the head and tail ends of canals, the selected transfer functions must be closed for the spatial and temporal concatenations. Such constraints which are part and parcel of system analysis may appear trivial but prevent the use of a great number of methods used in flood propagation (models of Kulandaiswamy and Muskingum for instance).

For more than a decade, CEMAGREF has used a thirty-five years old model developed by Shoitiro HAYAMI. Hayami noticed that, in "normal operation", the energy supplied to water by gravity is "nearly always" entirely dissipated through friction on the canal bed. The energy necessary to set the water in motion can be regarded as negligible in comparison with previous values ; thus the term of inertia, $\frac{\partial (QV)}{\partial x}$, can be suppressed from the Saint Venant's dynamic equation (2). With the help of a few other hypotheses on the regularity of watercourses, it can easily be proved that the discharge transfer function between two points of analysis, can be described as follows in a Laplace's plane: (p representing the Laplace's variable)

$$\exp\left(\frac{c - \sqrt{c^2 + 4\sigma p}}{2\sigma}\right) \ldots\ldots\ldots (3)$$

where c and σ are two parameters to be determined on an experimental basis.

5.2 Second order models

The main advantages of Hayami's model are that it has a theoretical background and is relatively easy to calibrate, though the parameter proves to have a low sensitivity to field data. Unfortunately, the mathematical form of this model is difficult to handle by optimal control experts who are more familiar with linear transfer functions with a possible delay.

This last point led to an examination of the conditions under which linear transfer functions, restricted to the second order, could reliably describe flow propagations on watercourses. Such transfer functions are expressed as follows:

$$\exp(-\tau p)/\left(\frac{p^2}{w^2} + 2\delta\frac{p}{w} + 1\right) \ldots . (4) \ ,$$

where τ is the delay of the system, w is its natural angular frequency and ζ is its damping ratio (usually about 1).

In practice, such transfer functions are not used in this continuous form but rather in a sampled form, since computerised controls are inherently discontinuous. Noting T the sampling interval and Z = exp (-pT), we obtain the general form of transfer functions such as:

$$Z^{-n} \frac{c + dZ^{-1}}{1 - aZ^{-1} + bZ^{-2}} \quad \ldots\ldots\ (5)$$

where n is the integer nearest to ($\frac{\tau}{T}$ + 1) and a, b, c, d are parameters such that:

$b > 0$, $c > 0$ and $c + d = 1 - a + b$.

The calibration of sampled models could be directly carried out but, propagation recordings of experimental releases being continuous, it seems advisable to make the parameter calibrations on a type (4) continuous model first, and then to develop the discrete model through analytical formulae.

5.3 Examples of implementation

Hayami's model was taken as a simulation basis for many rivers and a few irrigation canals in South-Western France. The empirical results were compared with experimental measurements as well as with the results drawn from a computed solution of the Saint Venant's equations. Deviations between the various methods are acceptable as time variations of wetted cross-sectional areas are not excessive. This requirement is generally fulfilled for recharged natural rivers but it is less well fitted for irrigation canals with widely varying water depths. In such a case, it is preferable to use Saint Venant's equations especially if the geometry of the canals is regular.

Second order linear models are apparently only used in the study of control algorithms designed for river recharge. There is a noticeable improvement compared with more conventional methods of management whilst the necessary investment always proves highly profitable. For instance, in the case of the Arrats River recharge, the CARAMBA method (previously mentioned in section 4) made it possible to increase the water conveyance efficiency from approximately 50 % to 75 % (this efficiency is defined as the ratio between the volume of the water supplied to the users and the water delivered to the canal head). In this case, twelve points for analysis were selected along the river, connected by twenty-seven sampled transfer functions of the type governed by equation (5).

Models based on the numerical solution of Saint Venant's equations made it possible to simulate and compare various water management policies in a Mexican canal (cf. the previously mentioned paper written by Mr Benjamin de Leon Mojarro). As was to be expected, it proved difficult to assess the relative value of the numerous objectives set by the various parties involved (see section 2.1 above). Instead of trying to weight these objectives through a conventional multi-criteria approach, it seemed better to simulate very different types of water management practices (including optimised manual water management) and assess their performance according to each criterion selected for a whole set of possible operation scenarios in the project area. The decision-maker could then ask for further simulations of other operation scenarios and apply the most suitable policy. In practice this comes up against the high cost of the simulator calibration as well as that of simulation with exhaustive models. Studies are under way to investigate whether it is possible to simplify the simulators by replacing Saint Venant's equations by transfer functions of type (3) or (4). The first results are encouraging because this approach simplifies the development of the model and it reduces computation time which is a major asset when the goal is to simulate several weeks of real operation.

6. CONCLUSION

Contrary to predictions made some years ago, the remarkable expansion of opportunities offered by microcomputers has not significantly altered the methods of distribution and management of irrigation water deliveries. Quite surprisingly, development of control algorithms has not kept abreast of the progress made in computer hardware, such that at this moment only large-scale irrigation schemes are provided with computerised management.

This paper has presented the attractive results of some research and development to which the author contributed. Research teams elsewhere are working on similar issues, such as the development of mathematical models suitable for small irrigation schemes, or the adaptation of approaches, such as "system analysis", to the specific characteristics of light computerised equipment or even on the development of heuristic management processes, which are easy to calibrate experimentally.

However, before data processing becomes a widespread real-time management tool of irrigation water conveyance vectors, many difficulties have to be overcome amongst which psychological biases are not the least important.

Editor's Note Martin Burton, Institute of Irrigation Studies, University of Southampton, UK, whose assistance with the English editing is gratefully acknowledged, recommends the following papers for those who would like further reading on this subject:

Hamilton D.L. and J.J. de Vries, "Microcomputer Simulation of Canal Operation". ASCE Journal of Irrigation & Drainage, Vol 112, Nr. 3, Aug 1986.

Zimbelman, D.D. and D.D. Bedworth, "Computer Control for Irrigation Canal Systems". ASCE Journal of Irrigation & Drainage, Vol 112, Nr. 1 March 1983.

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IRRIGATION MANAGEMENT NETWORK

GROUNDWATER MANAGEMENT: EQUITY, FEASIBILITY AND EFFICIENCY

Camilla Toulmin and Mary Tiffen

ODI/IIMI Irrigation Management Network Paper 87/1e April 1987

Papers in this set

87/1a Newsletter
87/1b The Dominance of the Rate of Return as a Planning Criterion and the Treatment of O&M Costs in Feasibility Studies by Mary Tiffen
87/1c Irrigation Service Fees in Asia by Leslie Small
87/1d Computerised Control of Irrigation Water Distribution by Jean Verdier
87/1e: Groundwater Management: Equity, Feasibility and Efficiency by Camilla Toulmin and Mary Tiffen

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ISSN: 0951 189X

GROUNDWATER MANAGEMENT: EQUITY, FEASIBILITY AND EFFICIENCY

A Discussion Paper

Camilla Toulmin and Mary Tiffen

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GROUNDWATER MANAGEMENT; EQUITY, FEASIBILITY AND EFFICIENCY

Camilla Toulmin and Mary Tiffen

1. INTRODUCTION

This paper is intended to provoke discussion of issues related to groundwater management. It stems from various sources. First we received two papers by Professor Tushaar Shah of the Institute of Rural Management, Anand, India, which followed on from his previous work, which members may remember (Paper 11d, "Transforming groundwater markets into powerful instruments of small farmer development", November 1985). We summarised some of Shah's arguments relating to the externalities caused by well interference and a permanent decline in the watertable and circulated them to a few members of the Network with a specific interest in groundwater development. The responses revealed the difficulties in managing groundwater in situations where it is scarce, with conflicts between equity, efficiency and feasibility. We would particularly welcome more comment from members in countries where groundwater is a scarce resource, on feasible methods of rationing it.

The second source was a stimulating Workshop held in February 1987 at the Water Resources Development Training Centre, University of Roorkee, India, with the title Common Property Resources with special reference to Access of Small and Marginal Farmers to Groundwater. Most of the participants were Indian researchers who reported on the studies they had made on the operation of groundwater markets in different localities, (with assistance from the Ford Foundation). The Workshop was extremely useful in pooling existing information on groundwater markets in India. It also began to define the different types of groundwater situation, and areas for further research. Shah, Niranjan Pant and Chambers subsequently visited Eastern UP, including the Deoria District where Pant had worked earlier on groundwater development, and this resulted in further reflections written up by Chambers.

It is useful to distinguish two levels of management: management of the aquifer, which is usually a government responsibility and which may involve various monitoring and regulatory activities; and management of the water extraction mechanism, (WEM), which may belong to an individual, a group, or a local or central government organisation.

2. ROLE AND IMPORTANCE OF GROUNDWATER

With so much money and research work carried out on developing and improving the management of large-scale irrigation schemes, there is a tendency to forget the very great role played by groundwater exploitation for irrigating crops. In the case of India, about one-third of all irrigated land depends on groundwater and Dhawan estimates that groundwater productivity is double that of surface water. He accounts for this difference by the fact that well water is under the farmer's control (subject to the availability of water for purchase and power for pumping) and can thus be applied at the appropriate time and in the right quantity (Dhawan, 1987). The gains are particularly great in the case of private tubewells, since public tubewells are not at the command of the farmer. This was shown in a study in Pakistan, (Table 1).

Kolawalli, in his presentation at Roorkee, was concerned to find out why farmers were prepared to pay more for well water than canal water. He found in the area he observed that farmers used well water to give themselves virtually an on-demand system instead of relying only on the scheduled supplies from canals. This enabled them to eliminate risk of crop stress, augment the canal supply to stretch the beginning or end of a cropping season, or to increase intensity from two to three crops a year. The value of well water at certain seasons in terms of adding to production or preventing loss justified its higher cost.

The fact that much groundwater in India and Pakistan is used in conjunction with canal water or tank water raises many issues concerning the proper management of canals in large gravity systems and of field

Table 1: Average Yields per Hectare for Four Water Supply Situations in Pakistan (1978)*

Water Supply Situations	Average Yield per hectare (kg)			
	Wheat		Paddy Rice	
	No. farms	kg/ha	No. farms	kg/ha
1. No control (no tubewell)	170	1681	75	1308
2. Fair control (public tubewell supplies)	33	1868	13	1775
3. Good control (purchase from private tubewell)	133	1962	35	1962
4. Very good control (tubewell owners)	42	2242	9	2148
TOTAL:	378		132	

*From Lowdermilk, M. K., A.C. Early and D.M. Freeman. Farm Irrigation Constraints and Farmers' Responses: Comprehensive Field Survey in Pakistan. Water Management Research Project Technical Report 48. Fort Collins, Colorado State University, Sept. 1978.

channels in tank commands. In the latter, as a team from Anna University observed, farmers need the flexibility to manage channels using alternative water supplies from the several wells in the command when water is short in the tank. More importantly, in water-logged areas of large gravity systems it may be advisable to deliver less water from canals, (perhaps extending the area served by canals) and to encourage the use of groundwater to improve drainage. (IIMI Pakistan may develop a research programme in this area). There are so many issues to be raised concerning conjunctive use of canal and well water that this deserves a separate paper. We would welcome contributions on this topic, but will not treat it further here.

S. P. Sangal, Deputy General Manager of the National Bank for Agricultural and Rural Development, reported at the Roorkee Workshop that it is now estimated that 39.4 million hectare/metres are available for groundwater development in India, of which only about one quarter is so far utilised. He also said the available resource might be revised upwards substantially. These figures indicate the important potential contribution of groundwater to Indian production. However, in some countries in the Middle East and in parts of India, farming is drawing down aquifers faster than they can be recharged, which will lead eventually to a decline in the area utilised. In still other areas, agricultural productivity is threatened by rising water tables.

3. VARIATIONS IN GROUNDWATER AVAILABILITY, ACCESSIBILITY AND QUALITY

Groundwater resources vary greatly in terms of their accessibility and ease of recharge. The first depends both on the structure of rocks and aquifers and the cost and availability of different water-drawing technologies in relation to local incomes and opportunities. The second also depends on the physical characteristics of the water table and on its relation to other bodies of water from which it could be recharged, such as from rivers or canals and from surface irrigation. Quality may be affected where there is danger of saline intrusion.

Differing combinations of access and rechargeability provide a variety of situations in which different groundwater policies are appropriate. For example, concern will be much greater regarding the mining of an aquifer for which recharge is very limited where the means of groundwater extraction are readily available than where high costs of exploitation greatly limit actual offtake. In this latter case, the long-term consequences of groundwater mining may outweigh the adverse distributional impact of having groundwater available only to those able to mobilise the high investment cost needed. By contrast, where groundwater is in plentiful supply and particularly where its extraction would improve farm productivity due to water-logging, policy can be oriented towards maximising access to this resource and spreading the benefits of its use amongst the rural population. Shah 86 classified 4 main situations, shown in Table 2. Workshop participants began to work on a more elaborate matrix on appropriate policies and technologies for the poor to gain from groundwater.

The depth at which the groundwater lies is a crucial parameter, since it affects the expense of tapping it, the type of pump required, and the discharge rate. With deep wells it becomes necessary to make economies of scale by extending the command area as far as possible and intensifying cropping, so that the capital equipment is used for as many months as possible. Further investment is required for channels, underground pipes, etc. In these circumstances, more farmers are served, and management becomes a more complex affair than with a single hand pump or small mechanised unit serving one owner or a small group. In some cases, there is no choice: there is only one available aquifer and the

Table 2: Policy options for groundwater management*

Policy options	Water-logged area	Good ground-water area	Poor ground-water area	Risk of saline intrusion area
Likely impact of sustained withdrawal	++	+	-	--
Power pricing				
a) flat component	nil	high	high	high
b) pro rata component	nil	low	low	high
Power supply regulations	very liberal	liberal	limited	very stringent
Siting regulations	very liberal	liberal	stringent	very stringent
Capital cost subsidy (+)/ tax (-) on wems	++	+ to resource poor	-	--
Surface water irrigation	Strongly discourage	discourage	strongly support	strongly support

* Table presented by Shah at Common Property Resource Workshop on Groundwater, WRDTC, University of Roorkee, February 1987.

depth and its consequences must be accepted. However, in other cases, as in parts of Bangladesh, there may be a choice between deep and shallow tubewells. There are social, economic and technical pros and cons to be considered in choosing between deep and shallow wells (DTWs and STWs) when both are technically feasible. Because of this, it is important that research into these issues is carried out on an interdisciplinary basis: the Workshop at Roorkee was fruitful because it included both social scientists and engineers. In addition, there may be agronomic considerations; in the case of the first DTWs in Bangladesh, there were unappreciated agronomic reasons why the recommended crops and cropping intensities could not be adopted by many farmers, affecting the economics of the wells (P.Smith, personal communication).

4. MEANS TO MAKE GROUNDWATER ACCESSIBLE TO POOR FARMERS

As the title of the Roorkee workshop indicates, groundwater is usually regarded as a common property resource. However, unlike the case of common grazing grounds, it requires investment by a particular individual, group or institution to tap it. Therefore, it is right that the investment should give some return to the investor, who will also expect to cover his running costs, and in the case of an individual or group, make some profit as a reward for management skills and time inputs. Further, the well has to be sited on a particular piece of land, which is often individually owned. If channels or pipes are necessary to distribute the water to parcels of land owned by different persons, individuals may have to be compensated for loss of land or disturbance. Thus, there is a complex of private and common property rights involved.

There is generally an interest to see that the rural poor are able to get access to groundwater, and that this resource is not exploited and used solely by those who have above-average access to capital and land. Attempts to improve access to the groundwater resource by the rural poor can operate through several mechanisms:

a. helping poor people develop their own water supplies by credit programmes, which may be addressed to individuals or groups. Additional assistance may be provided through programmes to educate them in the technical and financial requirements of managing the group asset.

b. providing publicly-run DTWs which either
   - pump additional water into canal systems, providing water on identical terms to canal water.

   or - sell water direct from the well, at a small profit, at cost or on subsidised terms.

c. Government installation of DTWs or STWs which are subsequently sold or rented to groups of farmers to manage themselves, at cost or subsidised terms.

d. affecting the terms on which groundwater is sold from private wells, by encouraging as many farmers as possible to invest in wells (thus increasing competition) and by manipulating the electricity tariff in the case of electric pumps so that a flat rate makes it attractive to sell water at cheap prices (see Shah 1985).

A number of government agencies and NGOs have been active in pursuit of a. above while writers like Shah have argued that major improvements in rural welfare can be attained by means of d.

In Pakistan, Bangladesh and also in India, the State through the Department of Irrigation, or special parastatals or District Councils, has intervened to provide DTW's capable of irrigating large areas at costs lower than would be possible with many small STW's. In many cases running costs have been higher than expected, costs have proved difficult to recover from farmers, and because of inefficiency, shortage of spare parts or interruptions in the supply of fuel, farmers have not received water in a timely and reliable fashion.

5. POLICY AND PRACTICE ON GROUP OWNERSHIP OF WELLS

a. Formal groups (co-operatives)

In view of the current movement of opinion in favour of privatisation, it is particularly important to understand how privately-controlled wells operate in considering the options for a transfer of state wells into other hands. Where such transfers have taken place, as in Bangladesh, it has often been stipulated that the recipient farmers should be organised into a formal cooperative. However, it has often not been tested whether formal cooperatives work either more efficiently or more equitably than the more informal management systems found in the private sphere. First results from a research project based at Bangladesh Agricultural University indicate that there are no significant differences in levels of productivity and efficiency between wells operated under different systems of management (Mandal & Palmer-Jones 1987). Comparative research in other areas would be useful.

b. Informal groups

Within informal groups, we can distinguish between those initiated by outside organisations and those developed by farmers themselves.

Several programmes have been set up to help marginal farmers and the landless cope with financial constraints and to develop their own water supplies both for their own use and for sale of water to other farmers, such as that run by the Grameen Bank and Proshika of Bangladesh. These are discussed by Wood (1984), Mandal & Palmer-Jones (1987) and Nagabrahman & Vengamaraju (1987). There are also cases where small farmers have been able to gain access to groundwater supplies by cooperating with others to raise the funds needed to dig a well. These informal coops then operate like a water company, the well supplying water not only to the joint investors but also to neighbouring farmers. Successful water coops are usually formed by close relatives and neighbours, and those of similar caste and social class (Nagabrahman & Vengamaraju 1987, Shankar 1987). Shah's material from the water-scarce village of Anklav in Gujarat provides examples of complex water supply companies with up to 150 customers (Shah & Vengamaraju, 1986).

A feature of the groups studied in India was the wide range of patterns in regard to ownership of the WEM and payment for the water. Because farmers had several plots, not all of which were within the command area, they might well be sharers in one well, or sellers of water from their own individual well, and at the same time, buyers from another.

One of the interesting things to emerge from the Palmer-Jones and Mandal paper was that in many cases in Bangladesh the groups managing and selling the water had become smaller over the years, in some cases reducing to one person or two or three relatives. This did not necessarily mean that the command area had shrunk, as the sellers supplied other farmers. The Workshop members became conscious that there could be high transaction costs to farmers in belonging to a cooperative or group owning a well, if this meant they had to take an active part in management decisions, solving problems and quarrels, etc. In some cases farmers actively prefer to specialise in farming, and to buy water from a professional manager. Provided there are many wells in the area, with overlapping command areas, so that the seller does not have monopoly power, prices for water tend to stabilise round a common and reasonable average. Chambers, after his further explorations in UP after the Roorkee Workshop, enquires "Is it really worthwhile trying to form groups, given the equity of the market with saturation?" This leads him on to a second policy question: "How can saturation (with pumps) be achieved rapidly in unsaturated areas?" This last question leads us back to questions of credit and subsidisation.

Saturation and competition also bring us back to the STW versus DTW argument. A monopoly situation is much more likely to arise where a government-operated DTW sells water at a cheaper price than is possible from privately-operated STWs with smaller commands. Chambers recently visited an area of Eastern UP where World Bank tubewells with large commands were being installed in an area where there were many group and private wells. It is worth noting that the Bank wells received a dedicated power supply for 22 hours a day, whereas other pump owners got electricity for 6 - 8 hours. Of the 4 visited, only one was in commission, and it had put out of business several private and group wells. In view of the record of state wells elsewhere, the fear expressed by one farmer seems reasonable:

> All the group and private wells will fail because of the World Bank well, and then it will itself fail.

(Chambers 1987)

On the other hand, if the Bank tubewells are efficiently operated, then farmers will benefit from cheaper water. We need more investigations into how things work in practice. Swaminathan was not too hopeful about the performance of 96 Panchayat (Rural Council) wells installed in 1969 in Coimbatore. When he looked at these recently many were not functioning at all because they had no energy. Others were suffering from disputes about who would be served, problems over rights of way for channels, pressures against using a DTW that might affect the operators of STWs, etc. (Swaminathan 1987)

The solution is not necessarily, or not only, to sell DTWs into private ownership. In Bangladesh farmer groups generally preferred STWs to DTWs where they had a choice, because they could be managed by smaller and therefore more cohesive groups. The difficulties farmers sometimes experienced in managing large command areas with numerous farmers led to various special programmes such as the Irrigation Management Training Programme in Bangladesh to give farmers management training, and to organise them into more cohesive sub-units, by dividing the command into blocks. This claims to have succeeded in doubling the command area of assisted DTW's (Baset 1986), but some investigators have doubted the durability of the effect, and questioned if intensive training can be replicable on a large scale.

6. FORMS OF PAYMENT FOR WATER AND ENERGY

We need to distinguish between economic efficiency (maximising returns to the scarce resource) and other types of efficiency such as water efficiency (preventing waste, maximising returns to water) and energy efficiency (maximising returns per unit of power). The three forms of efficiency may coincide, but do not always do so. In Network Paper 86/2b Svendsen argued that farmers should face a water charge more closely related to actual consumption and to the costs of supply if greater water-use efficiency is to be achieved and if the financial viability of irrigation projects is to be assured (1986). In the case of groundwater, water may be paid for on the basis of quantity supplied, by an hourly pumping charge or by the farmer himself providing the diesel fuel required for pumping, or by a metered electricity supply. In other cases it is paid for by an area charge, sometimes differing for different crops. This variety provides an opportunity for research work to test the efficiency of water use under different charging systems.

The use of electricity prices for promoting rural equity has consequences for levels of economic activity and welfare within both the irrigation and other sectors. Shah argues that groundwater markets exhibit a strong responsiveness to intervention and that policies should be designed to work through these markets (1986). For areas where groundwater is relatively abundant, he favours flat-rate power tariffs to lower water prices and expand groundwater sales. This should benefit poorer sections of the community, since they can then afford to use more irrigation water on their own land and there will be increased demand for labour due to the adoption by all farmers of more water-intensive crops.

The main disadvantage to use of a flat-rate power tariff is that it will encourage inefficient use of power and water supplies, with adverse distributional consequences for other actual and potential users of electricity and water in agriculture and elsewhere. This is important in areas where groundwater is short in relation to demand. From his work in Tamil Nadu, Copestake estimates that a farmer with a 3hp electric pump, run for 400 hrs/year, pays only one quarter of the charge that would be levied on an electricity user outside the agricultural sector, giving an implied subsidy more than 3 times the actual rate paid by the pump owner of Rs. 225 (1986). As a result, demand for power far exceeds supply, leading to the rationing of power by, for example, limiting the number of new connections available. Alternatively, there may be frequent power cuts, leading to uncertainty and loss of output (Chawla et al. 1987, Shankar 1987). Outside the farming sector, enterprises are discouraged which themselves use electricity, such as rural industries that could provide valuable employment to the local economy.

With a flat-rate power tariff, pump owners have no incentive to avoid wastage of power and water, since each additional unit is of negligible cost to them. Most studies of tubewell development find high levels of wastage due to low levels of pumping efficiency, attributable either to negligence or to deliberate tampering with the pump; for example, by partially closing the valves and thus reducing greatly the water pumped per unit of electricity (Copestake 1986). Charging for power on a high pro rata basis, such as happens in Anklav, a water-scarce village in Gujarat with a very deep water table, can generate high levels of water-use efficiency; here, for example, many pump owners have invested in canal linings and the installation of pipelines to conserve water. (Shah and Raju, 1986).

The use of pro rata power tariffs does not always guarantee efficient use of power. Copestake's own material shows diesel pumps to be operated at efficiency levels equal to or even lower than those for electric pumps, a surprising finding given that diesel pumps have a non-negligible marginal cost.

Low pumping efficiency has been attributed to a variety of causes: reducing the pump's flow means the farmer does not have to maintain such close supervision of the irrigation operation and thus saves him time, and pump owners may also not be clearly aware of how far efficiency falls (and costs rise) as a result of certain practices. Widespread pump inefficiency would suggest that power costs are relatively unimportant in determining water prices. If this is so, then policies aimed at affecting groundwater markets that act through power prices should not have much effect. Alternatively, perhaps a certain level of inefficiency must be assumed as a given and about which little can easily be done.

Pro rata power tariffs are likely to be a necessary condition for greater water and power efficiency, but what are the other conditions sufficient to achieve this? Would the spread of smaller scale pumps prevent wasteful practices, such as closing the valves as described above? Do programmes of technical advice have a significant impact on levels of efficiency? Is the reason why farmers use pumps of greater horsepower than necessary because they believe them to be more durable and reliable? Is it because the smaller pumps and their spares are not yet so readily available? If the latter is the case, the situation may be changing in India. S. P. Sangal in his report to the Roorkee Workshop said 3 hp units are now more available and .75 and 1.75 hp pump sets are coming on to the market and farmers are using them with their domestic electricity supply.

It has also to be realised farmers are not always concerned to get the cheapest water or energy. They may put a premium on reliability or convenience. In some areas Chambers and Pant noted a gradual switch from electric pump sets to diesel, preferred as more reliable and moveable from tube to tube. (Chambers 1987)

Pump owners may themselves charge farmers using their water in a variety of ways. In the Indian and Bangladesh case studies, examples were cited of flat charges per hectare, a charge per hour of pumping, or a share of the crop being irrigated. It is to be expected that each of these modes of charging will have different effects on the behaviour of both buyer and seller - an area of investigation in which Palmer-Jones is particularly interested, and on which he invites correspondence.

The consequence for efficient use of resources of sharecropping contracts for land use has been under study for some years, the general conclusion being that sharecropping represents a second-best solution given the prevailing constraints, such as risks to crop production, and absence of insurance markets and risk aversion amongst both tenants and landowners. Information is much more limited on sharecropping where water rather than land is the resource being shared, although it has long been common in the Middle East and North Africa. Shah's study of groundwater markets in India describes a contractual form for Anklav, where the water-seller provides water and half of the fertiliser, the water-buyer proves labour, land and the other half of the fertiliser and the final crop is shared on terms varying from 33% - 60% (1986). Mandal and Palmer-Jones found typical shares for water supplies were 20% to 30%.

There is mixed evidence on the actual efficiency of resource use under water sharecropping systems. From Palmer-Jones' work in Bangladesh, cropshare systems seem to exhibit significantly lower crop yields and smaller command areas than where a fixed charge per unit area is charged on water delivery (1987). One reason for this may be that the water-buyer has reduced incentive to purchase complementary inputs, such as fertiliser and pesticide, since the cost of these is borne by him whereas the benefit from their use is partially appropriated by the water-seller. Secondly, the effective charge per unit area under the cropshare payment system may be substantially higher than under other charging systems, making water far more costly in the former case and thus reducing demand for this input. However, the water provider shares the risk of a poor crop. Wood's survey of group-managed wells under the Proshika landless credit programme in Bangladesh provides a contrasting case in which wells performed relatively better where a cropshare system was in operation (1983). However, in the cases described, the agreement between water-seller and -buyer usually specified a given package of cultivation practices to be followed by the water-buyer, thus reducing the disincentive to use other inputs noted above.

As far as rural equity is concerned, Palmer-Jones concludes that the spread of sharecropping "is likely to be adding considerably to rural inequality" the advantage of cropsharing to the water-seller being to allow "appropriation of income streams by WEM owners at the expense of productivity of the unit" (1987, p.34).

Little comparative material on sharecropping where water is the only input shared is as yet available from elsewhere; it would be interesting to get network members to pool their experiences on the existence of such contracts in other contexts, their operation and effects on equity and efficiency of resource use. In particular, it would be useful to focus on questions such as the following:

- what seems to be the incidence of sharecropping with water and with what particular factors is it associated?

- is the inefficiency associated with sharecropping found by Palmer-Jones also found elsewhere? Is it common for water-sellers to prescribe a particular input package to the buyer, as noted by Wood?

- are there not significant benefits to be derived by the water-buyer from sharecropping with water by, for example, creating an incentive for the well-owner to maintain reliable supplies of water, as the assurance of his getting paid depends on continued irrigation of the share plots?

- is the high implicit charge per unit area under sharecropping a function of the well-owner's monopoly power or a function of the cost of bearing the risk of failure of essential supplies (fuel, spare parts, etc.)? Palmer-Jones notes some downward pressure on the size of crop share, in some areas from 33% to 20-25%. This could be caused either by reduced perception of risk, or increase in the number of competing water suppliers.

7. WELL-SITING CONTROLS, GROUNDWATER REPLENISHMENT AND EQUITY

In many areas, attempts to control groundwater extraction rates have been made by limiting the number of new wells that can be dug in a particular zone, by imposing minimum spacing requirements between new and existing wells, by restricting the number of new electrical connections, by refusing credit to those in certain zones, or by licensing well digging.

Sound arguments usually underlie the imposition of these controls, such as to prevent interference between wells and to limit over-use of an aquifer; but they also have distributional implications for incomes. For example, in some countries spacing norms apply only to modern wells, so that while a new WEM cannot be established next to another modern WEM, there is no bar to it being dug next to traditional shallow wells which will suffer substantially from reduced draft. (In some Moslem countries, all wells traditionally have their own protected area). Similarly, "spacing regulations create and strengthen the monopoly power of existing owners of WEMs" (Shah, p.11) protecting them from competition from other suppliers of water and keeping water prices higher than would otherwise be the case. To the extent that spacing controls are only enforceable through institutional credit channels, they also will mainly affect only the resource-poor farmer.

As it is difficult to limit extraction rates some writers have proposed that more attention be paid to replenishing groundwater supplies. Various techniques have been developed to promote artificial recharge and greater natural recharge of aquifers by limiting runoff, terracing and reafforestation of slopes (Vohra, 1986, 1987). Such policies have obvious attractions, but there are considerable difficulties due to overall cost of implementation and to the inequitable allocation of costs and benefits between different populations. Typically, the costs of promoting greater natural recharge are borne by one group of people, as for example where those in the hills making up a catchment area are involved in reafforestation, while the benefits are reaped by those downstream who get improved water levels in local aquifers, lesser siltation of dams, etc. Do network members know of cases where large-scale watershed management has been successful in significantly improving rates of recharge? What system has been developed to compensate those investing effort in improving recharge? Is this explicitly related to the level of benefits reaped by those downstream or more generally provided from government funds?

8. POLICY AND GROUNDWATER DEVELOPMENT: EQUITY, FEASIBILITY AND SPILL-OVER EFFECTS.

A variety of policy choices are available to control levels of groundwater use according to groundwater conditions and administrative capacity. Some of these choices are presented by Shah (1986), from which Table 2 is taken, for a range of situations. We would be interested to receive from network members comparative material on the operation of these different policies from a variety of contexts, in particular in relation to their consequences for equity, their feasibility and their spill-over effects.

Equity: In India, rural equity and the improvement of the position of small and marginal farmers have been identified by policy makers and researchers as important policy targets. Irrigation development has been seen as particularly relevant in promoting greater welfare amongst the poor, due to its being a "livelihood intensive" sector, providing incomes and employment not only to farmers directly involved in irrigated agriculture but also to those in a wide range of associated activities (Chambers, 1986). The government has a massive credit programme, and the National Bank for Agricultural Development lends to small and marginal farmers in zones where it is judged there is undeveloped groundwater potential. For this purpose almost all States now have Groundwater Boards which categorise blocks as dark (no institutional credit), grey or white.

How far equity should take precedence over issues of productivity is still subject to dispute; Carruthers maintains a sceptical position on the extent to which "poverty planning" is likely to succeed (1984). Chambers however takes the view that while it may be difficult to incorporate equity considerations into planning tools in practice, nevertheless a shift is required in the way by which policies and projects are assessed so that explicit account is taken of the effects on poor people. In choosing alternatives, Chambers considers that increased production in itself should be given less weight than the provision of secure and viable incomes to vulnerable groups (1986).

Do network members have clear examples of cases in which equity objectives have been explicitly incorporated into project selection procedures? Are there identifiable productivity losses associated with the emphasis on equity in such examples?

Feasibility: Discussion of the means to attain a certain goal needs to consider the feasibility and cost of alternative policy measures. Thus, for example, an ideal policy for controlling groundwater use, in theory, might involve the licensing of all forms of extraction so that levels of exploitation can be controlled. This solution may not be feasible in practice because of the difficulty in establishing a system for such licensing and the very high costs in administration and manpower required to make such a system truly effective. Similarly, some pricing policies may involve very high collection costs that outweigh their potential benefits from more efficient resource use. For example, if electric power is to be charged on a pro rata basis, this involves the use of metering and the employment of meter readers at considerable cost to the electricity supply company and with risk of corruption. It is unclear whether any country has devised an effective means to control groundwater extraction rates in practice. Control through the supply of institutional finance is only partially effective where farmers can raise their own resources to pay for the investment. Could network members contribute their own experience with alternative groundwater extraction controls, their relative costs and efficacity?

Spill-overs: Alternative policy measures also need to be considered in relation to the wider economy and an assessment made of their probable spill-over effects. In the case of groundwater exploitation using modern WEMs, an important issue relates to the level and structure of power costs in the agricultural sector as against power costs to other parts of the economy. In many parts of India, electric power to the farm sector is subsidised with a number of consequences for other potential users of power, some of which were considered earlier. Policies to subsidise agriculture have also led to over-extraction from aquifers in many parts of the world; as Peterson notes, "the great social diseconomies" resulting from large-scale aquifer mining in the US "are imbedded in the farm pricing and agricultural subsidies of the US Government" (pers. comm., 1987).

A complex web of policies exists in many countries, each policy aimed at a particular goal but with substantial side-effects; thus, for example, there may be, on the one hand, siting restrictions to control over-use of groundwater while, on the other, farm price support and cheap farm power encourage high levels of groundwater use. Are such conflicting situations inevitable or could a more rational system of policies towards irrigated farming be derived?

9. CONCLUSION

We hope we have said enough here to stimulate further research and discussion. We will hope to have articles on specific issues or case studies in future issues. If many comments are received, we can put together another discussion paper. In the meantime, Network members interested in the work going on in India can write direct to the coordinators of the groups there:

Dr Tushaar Shah, Institute of Rural Management, PO Box 60, Anand 388 001, Gujerat, India

Dr A S Chawla, Professor and Head, WRDTC, University of Roorkee, Roorkee 247667, India

Please note, however, that some of the papers given at the workshop are still in draft form and final versions may not yet be available.

Those interested in the effects of water contracts, may also like to correspond with Dr. Richard Palmer-Jones. He is at the Institute for Agricultural Economics, Dartington House, Little Clarendon Street, Oxford OX1 2HP, United Kingdom.

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IRRIGATION MANAGEMENT NETWORK

NEWSLETTER

ODI/IIMI Irrigation Management Network 87/2a August 1987

Agricultural Administration Unit, Overseas Development Institute, London

The Overseas Development Institute (ODI) is an independent, non-profit making research institute. Within it, the Agricultural Administration Unit (AAU) was established in 1975 with support from the British Aid programme. Its mandate is to widen the state of knowledge and flow of information concerning the administration of agriculture in developing countries. It does this through a programme of policy-oriented research and dissemination. Research findings and the results of practical experience are exchanged through four Networks on Agricultural Administration, Irrigation Management, Pastoral Development and Social Forestry. Membership is currently free of charge to professional people active in the appropriate area, but members are asked to provide their own publications in exchange, if possible. This creates the library which is central to information exchange.

The International Irrigation Management Institute, Kandy

The International Management Institute (IIMI) is an autonomous, non-profit making international organization chartered in Sri Lanka in 1984 to conduct research, provide opportunities for professional development, and communicate information about irrigation management. Through collaboration, IIMI seeks ways to strengthen independent national capacity to improve the management and performance of irrigation systems in developing countries. Its multidisciplinary research programme is conducted on systems operated both by farmers and by government agencies in many co-operating countries. As an aspect of its dissemination programme it is joining ODI in the publication of the Irrigation Management Network papers, to enable these to appear more frequently to an enlarged membership. It has also provided equipment to link ODI's irrigation library into an international irrigation management database centred on IIMI.

ISSN: 0951 1881

NEWSLETTER

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87/2c Irrigation Groups in Bangladesh by R W Palmer-Jones and M A S Mandal

87/2d Economics of Farmer Participation by R K Patil

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NEWSLETTER

1. NETWORK PAPERS AND DISCUSSION

1.1 The Current Issue

The current issue contains three papers, on experience in rehabilitation, irrigation groups in Bangladesh, and the economics of farmers' associations. The thread running through them all is the organised participation of groups of farmers, which for shorthand we term water users' associations, or WUAs. Mention is also made of other publications by IIMI on this subject which readers can obtain from IIMI at Kandy.

We need to be clear about why we want farmers' associations, and why farmers may find them useful. By we, I mean the readers of this Newsletter, who are generally not farmers, but planners, managers, teachers, researchers, etc. The possible functions of a WUA with which we are concerned in this issue are:

1. To convey in an organised way farmers' views on the general purpose of a rehabilitation, and the detailed design of the tertiary system

2. To carry out the water distribution function within a small system, or part of a larger system

3. To carry out maintenance of a non technical nature within the same area

4. To collect fees, either to meet its own costs only, or to meet its own costs plus the charges of the authority supplying water to the group

There is an important difference between the first function and the last three. The first requires the farmers to give a limited amount of time (two or three meetings) on an exercise that may only occur once in every twenty years (assuming major rehabilitation should not be necessary more frequently). As a result of this limited input they will get the very great benefit of a system that meets their needs more exactly than would otherwise be the case. It is not surprising that some farmers in Zimbabwe (who had experienced a rehabilitation that did not meet their needs) put this forward as the first and most important function of a WUA. It has also very important benefits for the government and for the Irrigation Department, as is shown in the paper by D Hammond Murray-Rust and P S Rao, *Learning from Rehabilitation Projects: The Case of the Tank Irrigation Modernization Project (TIMP) of Sri Lanka (87/2b).* It can lead to a more economic rehabilitation strategy and/or greater production per unit of investment.

The other functions require work, money, organization and worry, whether carried out by an Agency, or by farmers. It is not surprising, as R K Patil states in *Economics of Farmer Participation in Irrigation Management (87/2d)*, that Irrigation Departments can see the advantage of getting farmers to undertake them, at least in the lower levels of the system, while farmers are unconvinced, unless they see that they can give themselves a better or cheaper service, and that the costs they incur are both worthwhile in terms of improved service, and feasible, given the income they can make from irrigated crops. Patil suggests some policy changes on irrigation water charging systems will be necessary before WUAs can function; the one very successful example, the Mohini Co-operative in Gujerat State, has a cropping pattern biassed towards sugar, and it is this crop that generates the income that meets the Society's staff costs.

I had the opportunity of discussing Mohini also with Shri V B Patel, Secretary, Command Area Development, Gujerat State, when he visited London recently. Mohini was the model they had at the back of their mind for the development of the huge Narmada-Sarovar Project, with the help of the World Bank. This has been designed with the objective of wholesaling water to WUAs. However, the preparation work for Mohini took time, and only a few of the other 50 or so Co-operatives so far developed are as successful. V B Patel thinks several model types of WUA or water wholesaling institutions are needed, according to different circumstances, such as levels of education and social cohesion amongst farmers. R K Patil would suggest it is also important to look at their crops and their corporate and individual finances. Gujerat has already adopted some of the policy changes Patil suggests are necessary. Co-operatives are charged 25% less for their water than individuals. They also get a management subsidy for 3 months.

R K Patil also discusses the time and costs of activating WUAs. V B Patel finds his department can at the moment only mobilise 8 to 10 units, covering at most 10,000 ha, per year. However, the plan for Narmada-Sarovar is to develop 50,000 ha of newly irrigable land per year. They are therefore now developing a 3-tiered model. The entire project is conceived of as a large co-operative of 200,000 ha, containing 200 small base units and an intermediate tier of 10 units of 20,000 ha. The latter will be able to afford more professional staff. Nevertheless, a clearly awesome task lies ahead. The project is ambitious and difficult. It is following the lines of recent discussions in this Network and elsewhere by going for an autonomous agency whose operation and maintenance costs are financed by farmer contributions. As a first stage, the Gujerat and Maharashtra Irrigation Departments have now taken over from the Revenue Department the collection of irrigation water dues from farmers. Currently, the money then goes to central treasury from whom, in due course, they receive their budget. One hopes in a second stage they will get the reward of an autonomous budget, which will also mean that the farmers will increasingly demand a service from the people to whom they pay dues.

The headaches and rewards of managing small irrigation systems are amply illustrated in the description by R W Palmer-Jones and M A S Mandal of *Irrigation Groups in Bangladesh, (87/2c)*. Like Tushaar Shah *(ODI Irrigation Management Paper 11d*, May 1985) they find the payment system is an important variable. In this case, share-cropping systems seem less productive and equitable than systems where farmers pay a flat-rate, though both types of payments are responsive to competition and other economic pressures. They illustrate the complicated dynamics of these small WUAs, and the way both managers and farmers change their strategies in response to changes in price and in the availability of inputs. The response is often lagged; farmers act on what they expect prices to be or to become, and change policy when a new trend seems clearly to have established itself. The paper also illustrates how farmers retreat from irrigated to rainfed crops when prices of inputs become too high. It is also informative on how farmers like to organise themselves. It is sometimes forgotten that many farmers prefer to concentrate on their farming activities and to leave water supply to others - either a small group of farmers, a single manager, or, in some cases in Bangladesh, a specialised group of landless people. The formal co-operative frequently does not function as planned, and training does not seem to help much. This illustrates the difficulty of government intervention in farmer-managed systems. The working methods of the informal groups suit the farmers, but may not be in accordance with outside assessments of equity, proper accounting practices, efficient water distribution based on a planned cropping pattern (rather than the actual, and changing one) etc.

The performance of the schemes in Bangladesh has been assessed principally by area commanded, yield per ha, and gross output. The largest variation was in command area per tubewell. However Palmer-Jones and Mandal found that there is as yet no satisfactory method of determining optimal tubewell capacity and measuring performance against this. They point out that there may be two Deep Tubewells both with a command area of 16 ha; in the one case the potential command area is also 16 ha while in the second it is 24 ha. They are working on a model to define the economic optimum capacity of a multi-user irrigation scheme. Palmer-Jones is preparing a research project on the technical, ecological, agronomic, economic, social and institutional determinants of capacity utilization of minor irrigation, particularly tubewells, open wells and tanks. The project will develop the multi-disciplinary approach described in 87/2c. He would like to hear from individuals or institutions working in areas where these types of irrigation are practised, who are interested in collaborating in a possible joint project. The studies could form part of PhD programmes. Funding will be sought when suitable countries and sites have been identified and some agreement on methodology and time scale worked out. e hopes the work might begin in the autumn of 1988. It is possible that there are already research projects or datasets on capacity utilization of wells and tanks, which could be the basis for further work or more extensive analysis. If anyone is interested, or can provide information, please write to Palmer-Jones at the address given in 87/2d.

1.2 Other Discussions of Farmers' Associations

Hervé Plusquellec of the World Bank was prompted by the *IIMI Case Study No 1* by Dr Bautista, describing *Irrigation Associations in the Philippines*[1] to send information on WUAs in Mexico. In the 220,000 ha Rio Yaqui project the Water Users' Groups were organised when the system was implemented (about 1910). They are responsible for the operation and maintenance of the minors, with commands ranging from 70 to 7500 ha. They have both elected officers and paid employees, the latter comprising one water master, assisted by a ditch rider for about every 2500 ha. The Mayo Irrigation District of 96,000 ha is now in the process of transferring responsibility for O and M of the minors to 16 WUAs, on the model of the Rio Yaqui. The transfer process includes election of the WUA, joint inspection with the WUA of the infrastructure and its subsequent rehabilitation by the District. In future the WUA will pay volumetric water charges in advance. They will collect these from the farmers, and part will be paid over to the District for the operation and maintenance costs of the main system.

It is interesting to see that in this instance the WUAs were formed prior to the rehabilitation (as Murray-Rust and Rao advocate on the basis of Sri Lankan experience). The rehabilitation is used to give a benefit to the farmers and to induce them to accept the costs of organising their own O and M, as Patil might see it. As part of the deal, an autonomous financial system is introduced. This step was not quite completed in Sri Lanka, where the intention was that farmers' payments should be used for maintenance of their own systems, but where the level of payment has now fallen back after a good start, because farmers did not see any results. In this case, neither the WUAs nor the officers managing a particular scheme or section of a scheme could control the amount of funds available for maintenance.

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[1]Available from IIMI, Sri Lanka, <u>not</u> ODI

Sri Lanka has experimented with two main methods of promoting WUAs. The best known is the use of Institutional Organisers in the rehabilitation of the Gal Oya system. However, in the development of huge new irrigated areas in the Mahawelhi system, the low level staff of the Irrigation Department and the Agricultural Department have been brought together under a Block Manager, and training programmes have been organised for them and for two farmer representatives elected by "turn-out" groups (turn-outs being off-takes from the distributaries serving 18-20 farmers). The turn-out groups were made responsible for water distribution and maintenance of field channels and drains. There is no immediate intention of developing WUAs above the level of the "turn out". Government policy in Sri Lanka has always depended on a certain degree of farmer consultation and participation, and this historical record and the legal forms which derived from it are discussed in another of the interesting papers in a recent IIMI publication, *Participatory Management in Sri Lanka's Irrigation Schemes.* The authors are mainly policy planners, implementors and researchers from Sri Lanka, intimately involved in the programmes they describe and because of this practical experience the papers are particularly useful. Issues that come to mind after reading it are whether it is desirable to have farmers' organisations above the turn-out, i.e at the distributary level, and if so, whether major differences in organisation are required because of the difference in scale and area covered. Patil's paper suggests the answer is yes: at the distributary level the farmers' organisation will require funds and staff and the capacity to monitor both.

IIMI collaborated with the Administrative Staff College of India at Hyderabad to organize a Policy Workshop on *Peoples' Participation in Irrigation Management,* partially funded by a grant from the Ford Foundation, from June 28 to July 21, 1987. The participants included 18 senior officials from 9 States and the Centre. Besides K K Singh, the organizer and convener, and P S Rao, S M Miranda, and Doug Merrey from IIMI, there were a number of Indian and non-Indian specialists to present papers and participate in the discussions.

The objective of the Workshop was to introduce the lessons learned from various experiments with peoples' participation in irrigation management to policy level people, and develop a set of recommendations on this topic. The Workshop opened with a passionate plea from Shri M A Chitale, Chairman, Central Water Commission, for bureaucratic reform and for greater efforts to promote responsible farmer participation. This set the tone for the rest of the Workshop. Commissioned papers were presented and discussed on participatory experiences both outside India (Sri Lanka, Philippines, and Taiwan) and in India. Indian participants reported on significant State programmes of experimenting with different modes and various degrees of participation ranging from minimal involvement to turning over substantial authority and responsibility to farmers' organizations (examples include Gujerat, Kerala, Rajasthan, Andhra Pradesh). They all accepted the concept that "participatory management" must include the concept of empowerment of people, and accountability of the bureaucracy to people and be accompanied by legal provision. There was considerable interest in the Philippines' experience with Community Organizers, and Sri Lanka's experience with Institutional Organizers on the Gal Oya Project.

At the end of the workshop, the participants agreed upon a list of recommendations which included the following:

1. Consultation with farmer organizations (FOs) is desirable in the matter of allocation of water, more specifically, under conditions of water scarcity. Appropriate mechanisms need to be devised to involve FOs in deciding the canal operation plans, water delivery times and dates. The administration dealing with water deliveries should be accountable to FOs, once the water allocation plan is decided. The control of water from headworks to the farm should be with one department or agency.

2. The approach of organizing farmers needs to be bottom up i.e., to start with the lowest unit of the farmers' participation and then leading to farmer representation in higher tiers.

3. The functioning of the FO must start with farmers taking over responsibility for operation of the system and water control with freedom to decide their own cropping pattern and calendar, subject to agroclimatic and technical considerations. They should eventually take over responsibility for collection of water charges and finally the maintenance of the system serving the FOs.

Interestingly, IIMI Research Paper No 4, *Irrigation Management in Pakistan: Four Papers* by Douglas J Merrey and James M Wolf, includes papers by Merrey which illustrate the difficulty faced by farmers in a village in organising improvement works, owing in part to the social structure and to cultural factors which discouraged co-operation. He also reports on a survey of ten reconstructed water courses which identified 6 sociological characteristics associated with good maintenance of the improvements. These were: most farmers had land in the 2.5 to 10 ha range; relatively equal distribution of power and influence; concentration of power and influence at the tail or the tail and middle of the water course; general progressiveness; social cohesion; a small number of farmers per water-course.

Unfortunately, it is generally impossible to legislate for these conditions. It is therefore necessary to accept that in many areas co-operation will be difficult. The aim of legislation should be to create conditions which give farmers a powerful incentive to overcome the social obstacles to the formation of WUAs. Personally, I tend to believe that financial responsibility and the power to control the quality of work done, either because they can hire and fire their own employees, or because they do it for themselves, provide a framework in which farmers will either co-operate, or alternatively, will at least accept that certain leaders, managers or owners of facilities will carry out the necessary functions, for reward. These conditions were present in the 3 successful examples of WUAs carrying out O and M functions mentioned in this issue: Mohini in Gujerat; the Bangladeshi tubewells; and the Rio Yaqui farmers in Mexico.

These conditions were also met in the Magat River Irrigation Project in the Philippines. IIMI Case Study No 1, by Honorio Bautista, has a particular interest because the ordinary agricultural extension workers of the Agricultural Department were able successfully to organise Irrigation Associations over the 40,000 ha scheme in about 5 years, in a framework which gave financial incentives to the farmers to take over maintenance, and at the same time, reduced the Irrigation Department's costs. The training programme for staff and farmers, the careful attention given to financial regulations, and the way many problems have been overcome are well described.

It will certainly be useful to collect more examples of farmers' associations which successfully sustain operation and maintenance, either on a small independent system as in a tubewell, or on part of a larger system as in Mexico and to identify the legal and institutional conditions under which they work (taking legal to include custom as well as formal law). If any one is interested in providing brief data, I will start assembling it and pass on information to IIMI.

It is also useful to listen to farmers. Dr S P Jain, WALMI, Okhla, New Delhi-10025 sent a report of a Workshop on farmers' participation, which was attended by 100 farmers (selected to be representative of different social groups and locations within a command) and 80 Irrigation Department officers and University staff. It was notable that the farmers were enthusiastic to put across their point of view. The main suggestions that arose from the Workshop were unanimous; there was no marked difference between officials and farmers. It was agreed the water course committees anticipated by an Act of 1976 existed on paper only, and in any case there were no detailed regulations giving them powers. On the other hand, 1873 and 1947 Acts gave clear roles to the Village Councils and the Irrigation Department in this sphere. It was therefore suggested that farmers' participation should be through the Village Councils. It was also recommended that the Irrigation authorities have clear responsibility for planning design and construction of the water course system, since they had the right technical background and too many authorities were at present involved. It was agreed it was not necessary to line the whole length of water courses; it was only necessary at certain locations. Reclamation of water-logged and saline areas, and construction and maintenance of water courses could be done by community self help work, and this could save money which the government might otherwise demand from farmers. Warabandi should also be carried out by Irrigation Department staff in the interest of the weaker sections of the community. Feeling was in favour of spreading canal water to as large an area as possible, but using it in conjunction with tubewells. It was also suggested that water rates be increased to encourage economical use. The schedule should be on the basis of 75% dependable supplies, so that agricultural plans could be made in advance. Farmers needed more information. With the present involvement of Command Area Development Authorities, the Irrigation Department, Agriculture, Extension and Credit and other concerned departments, farmers did not even know what water rates applied to different crops and to tubewell and canal water, nor their rights and responsibilities within the irrigation system.

There are arguments for and against using administrative authorities like Village Councils as opposed to specialised bodies of water users served by a single water course or other water source. It can be counter-productive if the Village Council is dominated by interest groups other than those of irrigating farmers. The Workshop in New Delhi seems to have been much influenced by the need to have clear legal powers, and to have felt these were already appropriately given to the Village Council. Certainly, whether water courses are regulated and maintained by a WUA or a Village, it is essential that the body concerned has a clear legal jurisdiction and powers of enforcement.

At present, the primary focus of IIMI's Farmer Managed Irrigation Systems Program (FMIS) is the development of new approaches for assisting the farmer-managed irrigation sector, and basic appraisal techniques to enable managers and planners to reach informed conclusions about intervention options. A second, emerging focus of the FMIS program is the turnover of agency-managed systems to farmer responsibility. Research is currently being conducted in Nepal and Sri Lanka; activities in Pakistan, Indonesia, Morocco, West Africa, and Bangladesh (in approximately that order) are in the planning stage. In addition, the FMIS Network provides a link with more than a dozen other countries in Asia and Africa.

IIMI's scientists in Nepal are involved in two major research activities: 1) an inventory of FMIS in the Indrawati Valley, in collaboration with WECS (supported by the Ford Foundation); and 2) a study of several large FMIS in the Tarai region of Nepal. IIMI Research Paper No 5, *Institutions for Irrigation Management in Farmer-Managed Systems: Examples from the Hills of Nepal*, by E D Martin and R Yoder describes one type of management structure that has evolved, based on a share system similar to that found in the origins of the joint stock company. In Sri Lanka, a series of short-term studies will refine FMIS evaluation methodologies and identify successful assistance strategies. An initial study of several FMIS in Badulla District is being undertaken in collaboration with the Regional Development Division of the Ministry of Plan Implementation. In Pakistan, plans are underway to collaborate in a study with the Aga Khan Rural Support Programme, a private organization which has been assisting FMIS in the northern areas of the country.

For more information about the FMIS Program, please contact Dr Robert Yoder, IIMI, PO Box 3975, Kathmandu, NEPAL; or Dr David Groenfeldt, IIMI, Digana Village via Kandy, SRI LANKA, or ask ODI for a copy of the Paper describing it (86/3c).

Please write to IIMI at Digana Village, Kandy, Sri Lanka for all IIMI publications. At ODI we have only the ODI-IIMI Network Papers.

1.3 Groundwater discussion

In regard to paper 87/1e on Groundwater, Robert Chambers pointed out that although Dhawan's figures show higher productivity per irrigated hectare, the productivity per m^3 of groundwater is probably even greater in comparison with canals, as those who lift it tend to be more sparing in their use of it. However, we have not to forget that energy is also scarce in some countries; Mr. M Badruddin, Director General, International Waterlogging and Salinity Research Institution, Lahore, pointed out, in a contribution to a discussion of research priorities instigated by Hydraulics Research, Wallingford, that operation of wells in energy short situations calls for load management, which leads to the need to develop better irrigation management and high pumping efficiencies.

Plusquellec produced an example of successful reduction of the rate of groundwater mining in Mexico, quoting from a report by R. Cummings, *Improving the Management of Water Resources in Mexico's Irrigation Agricultural Sector*, World Resources Institute, January 1987. The authorities in one region instituted a plan in 1975 requiring systematic reduction in users' applications and pumping of groundwater, with heavy fines imposed on water use in excess of assigned quotas (the fine was equal in amount to the estimated gross value of the water). The 1975-80 period was marked by radical changes in crop patterns and substantial investment in canal linings. The quantity by which groundwater pumping exceeded recharge during the 1970-72 period was about 850 million cubic meters per year, in contrast to the 427 million cubic meter/year rate achieved in 1983.

The saving was not as great as intended, but was nevertheless impressive. This is another example of the way farmers will respond to economic signals, but in this case it also required the ability to operate a quota system strictly and honestly. Without quotas, the only other way to ration water would have been to charge such a high price that many farmers would have been driven out of farming, rather than required to change cropping patterns.

Bhanwar Dan Bithu of the Indira Gandhi Nahar Project writes that their studies in the arid desert region have shown management of watersheds by preservation of desert shrubs and perennial grasses not only significantly increases shallow ground water recharge but also increased land productivity. He quotes measurements by G S Bhati which show what happens when this type of land management ceases. In one village, between 1964 when the watershed had desert shrubs and perennial grass, and 1984, when it did not, the water table fell from c. 10.67-12.2 meters to 15.24 meters, while yields of desert millet fell from to 5 to 2 quintals per ha. In this case the blame was laid on overgrazing. Unfortunately, it is not enough to know the impact of denudation of the watershed; we need to consider what means there are of inducing people to feed their animals from another source, or to seek an alternative form of livelihood.

The world's groundwater literature is being placed in a bibliographic data base for computers by the National Groundwater Information Center, University of Oklahoma, United States.

2. IIMI ACTIVITIES

The Board of Governors of IIMI have appointed Dr Roberto Lenton to succeed Dr Thomas Wickham as head of IIMI. Under Dr Wickham's direction, IIMI grew to an organisation with 20 professional staff in 6 countries. The early development of IIMI is well described in its Annual Report, 1984-85, available from IIMI. Dr Lenton hopes now to meet the challenge of clarifying objectives and finding and disseminating better ways in which irrigation systems in developing countries can be managed. Dr Lenton will already be well known to many members as he was the Ford

Foundation water management specialist in India 1977-83, and later, in New York, was responsible for their international programmes in land and water management. He was an early supporter of the concept of an international institution focussing on irrigation management and was responsible for the Foundation's activities as Implementing Agency for the establishment of IIMI. Dr Lenton, who is from Argentina, is a civil engineer with a Ph.D in Water Resources Systems from the Massachusetts Institute of Technology.

IIMI is now seeking a Regional Representative to initiate its West African regional programme. The post will be based in Ouagadougou, Burkina Faso. It is for an initial one year start up period, but may be extended within the framework of the long term programme implementation. The person (male or female) appointed will be responsible for negotiating collaboration with national institutions and contributing to the formulation of the long term research, professional development and information exchange programmes of IIMI. Excellent oral and written communication skills in French and English are amongst the requirements. Further details are available from IIMI at Kandy or from the secretary of the Irrigation Management Network at ODI. Letters of interest, with cvs and the names of 3 referees should be sent to the Director General, International Recruitment, IIMI, Digana Village via Kandy, Sri Lanka, by 15 October 1987.

IIMI hosted, and co-sponsored for the third time with EDI of the World Bank and for the first time with the Asian Development Bank, a Regional Course on *Planning and Management of Irrigation Schemes* at Digana for twenty-five senior irrigation and planning officials from twelve Asian and five African countries. The course is basically designed to enhance the participants' understanding of sound policies for supply, use and disposal of water as a major input to agricultural production; the choice of technologies appropriate to developing countries; and the institutional framework in which irrigation schemes help to improve agricultural production. Suggestions by participants have changed each succeeding course. For example, the topic on environmental effects on large scale irrigated agricultural projects including attention to water borne diseases, and modern irrigation technologies were added in this year's course because they were suggested last year. This year's participants recommended for next year's course the inclusion of topics such as land consolidation, theory and techniques of management and micro-computer use and practices. A casual show of hands revealed that two thirds of the participants already have micro-computers in their agencies and that the rest are expecting to have them soon. The sessions on individual country reports facilitate application of concepts learned to particular country problems. As a result of a survey conducted for Sri Lanka, IIMI published a report entitled *Training for Irrigation Management in Sri Lanka: an Appraisal of Current Activities and Suggestions for their Enhancement*, which will probably be valuable to other countries engaged in a similar re-assessment of their needs and their facilities.

Within IIMI's System Management programme, one activity concerns *Irrigation Performance Monitoring and Evaluation.* An Institute Post-Doctoral Fellow has developed a methodology for measuring the field level water adequacy and equity of water distribution for lowland rice irrigation systems. Perforated tubes, which act as observation wells, are installed in representative parts of the command area to measure the daily fluctuations of the perched water table in paddy fields. Indices for measuring the frequency, duration and intensity of water stress have been developed and shown to correlate well with yield data from Indonesia and the Philippines. Further details are available from Poh-Kok Ng, at IIMI.

The Communication and Publication Office at IIMI has also brought out their Mailing List as at May 1987, which is a useful directory of people interested in irrigation management, by country and institution.

3. NEWS FROM NETWORKERS

Tom Franks and Tim Harding, of the Project Planning Centre, University of Bradford, UK, have completed research on the commissioning of a paddy irrigation project in Sri Lanka. The data showed that in the first season of operation, water use on the area cultivated within the main canal command area was about twice its forecast value at full development. Even in season 3, it was still about one third more than the forecast value. At the field level, water use was also higher than expected in the early seasons, but the rate of improvement was higher than for the total area commanded by the main canal. The researchers suggest a target phasing for bringing land under irrigation during commissioning, to promote equity and efficiency. The research was carried out in collaboration with the Irrigation Department of Sri Lanka, with funding from the UK Overseas Development Administration. Details on the full report are available from Tom Franks.

The Settlement Study Centre, P.O.B 2355, Rehovat 76120, Israel, has created an International Rural Projects Database, comprising much non-conventional/fugitive literature.

The IFPRI Report, 1986 summarises collaborative research with the International Rice Research Institute, IIMI and the University of the Philippines at Los Baños. This suggests that the construction of new systems generally has higher returns than the rehabilitation of old systems, in addition to benefitting mainly rainfed farmers. The study also found that although communal (farmer-operated) systems and small-scale government operated systems often had lower rice yield levels and cropping intensities than larger-scale systems, the lower investment costs for small systems resulted in higher economic returns to investment.

The Water Resource and Environment Institute, Faculty of Engineering, Khon Kaen University, Thailand, has officially ended its small scale irrigation system project, and embarked on follow up projects. It has also established the Thailand Research on Irrigation Management Network (TRIMNET), which held its first Board meeting in May 1987. This brought together representatives from government agencies, universities (Chieng Mai and Kasetsart as well as Khon Kaen) and several international organisations. The meeting began with presentations on current research on farmer participation at the three universities. This was followed by discussion on how research could be made relevant to action, which is reported in the TRIMNET Newsletter of July 1987. It was decided to have further national and regional meetings.

Experience in Britain has shown that the lunch-time meetings associated with the ODI-IIMI Irrigation Management Network, as well as meetings sponsored by the British National Committee of the International Committee on Irrigation and Drainage have been very useful in bringing together researchers and practitioners, and people from different disciplines, in an informal but fruitful way. If any one wants to follow the Thai example in setting up a national network, we shall be glad to help by sending an up-to-date list of national members of the ODI-IIMI Network. We are also quite happy for articles and items in the ODI-IIMI Newsletter and Papers to be used in national newsletters, with acknowledgement.

The Club du Sahel and CILSS have set up a steering committee to co-ordinate studies by national teams of small-scale irrigated agriculture in Niger, Burkina Faso, Senegal and the Gambia. ILRI is also participating. The first two countries' studies are nearly completed and then the last two will be undertaken.

4. RECENT PUBLICATIONS

IFAD have published a new guide to the *Monitoring and Evaluation of Irrigation Projects* (Rome, 1987) based on a workshop held in Manila in November 1985. It sets out procedures for monitoring and evaluation at four different stages: planning, design and construction; operations, maintenance and water management; crop production; and economic, social and environmental impact. The guide clearly presents useful indicators to monitor at each stage. It would be better if it had emphasised that M&E is only one tool of management; another particularly needed during the planning and construction phase is critical path planning so that the most essential things are monitored and brought to management attention in good time. This is particularly essential when resettlement is involved. It also perhaps confuses crop production monitoring with impact evaluation of income effects. It includes issues which may be important for an extension service to monitor, but which are not necessarily important for the managers of water distribution and this distinction deserves high-lighting. In M&E as in everything else it is important to be cost effective, and in some cases land sat imagery of a large area would provide better data more quickly on cropping intensity than farm surveys. Farm surveys tend to be slow and labour intensive; while they may be essential in finding out why crop production is not satisfactory, they should not necessarily be routine when things are going well. Likewise, impact evaluations should perhaps be done only on a sample of projects rather than all. Despite these criticisms, the handbook is very useful. It is available from: M&E Publications, IFAD, Via del Serafico 107, 00142 Rome, Italy.

M&E, as the IFAD publication emphasises, should be a routine part of management. When it is a question of more detailed investigations to decide on the requirements for rehabilitation or restructuring management, the most useful checklist of questions is still perhaps that of Anthony Bottrall. This is available from ODI in A. Bottrall: *Managing Large Irrigation Systems: a Problem of Political Economy,* AAU Occasional Paper No 5, 1985.

The Asian Development Bank has recently produced a manual on the *Economic Analysis of the Environmental Impacts of Development Projects,* Economic Staff Paper no. 31, prepared by J A Dixon et al from the East-West Center, Hawaii. The authors argue that environmental degradation must be properly taken into account in planning development. If this is not done, the goals of development are themselves put at stake, since income, output and welfare gains will not be sustainable. The environmental impact of projects has been neglected in the past in part due to difficulties in assessing and quantifying the likely effects. This book describes a variety of economic valuation techniques and a series of case-studies to demonstrate how these techniques may be used to assess environmental impact in practice. However, the authors warn that certain effects are not amenable to economic quantification and that special care must be taken with projects that engender such effects, as with, for example, the irreversible destruction of a unique natural environment. They also note that use of any discount rate in project appraisal techniques automatically reduces the significance attributed to long term environmental damage associated with a project. However, there seems as yet no consistent way of taking long term environmental sustainability into account within the confines of project appraisal techniques.

In the June 1987 issue of *Development Policy Review,* Jon Moris argues for a far more careful look at the assumptions and costs underlying the adoption of irrigation as the answer to Africa's food production problems. He discusses many of the problems that have faced irrigation in a number of African countries and concludes that the physical, economic and managerial environment frequently diverge significantly from that assumed in official plans. He notes that "because irrigated farming seems modern and technologically sophisticated, and because most multinational agencies have been willing to fund such projects, it retains its appeal to many African policy-makers..... They have failed to see that, because of its high costs, it cannot be used to grow food crops, while at the same time the bureaucratic controls required for cost recovery make it still more expensive." *This issue of the Review also contains* other articles on African agriculture which may be of interest to network members. We are enclosing details of the *Development Policy Review,* which is published quarterly by ODI, with an order form for subscribers.

Annex IV, *Irrigation and Water Control* is one volume of FAO 1986, African Agriculture in the next 25 years, available from FAO, Rome. It is a further summary and updating of *FAO's recent work on African* irrigation, which makes useful distinctions between the different regions of Africa: North Africa, the Sudano-Sahel region, etc. It concludes that the review of project experience shows that the constraints to the *exploitation* of irrigation potential are mainly institutional, economic and social, rather than physical. It favours small rather than large developments, designed so as to be manageable by local irrigators. However, in addition it suggests priority should be *given to* rehabilitating existing projects, since governments cannot afford to waste previous investments. In a few cases this may be doubted; there are some large schemes in Africa that have had successive rehabilitations without success. It is also *suggested* that the economic rate of return needs to be supplemented by a systematic review of all other important effects before deciding to go ahead wwith an irrigation project. This could, however, be interpreted by governments as an invitation *to* put *forward non-economic* justifications for projects which will need continued subsidies from overstretched budget; it must be emphasised that the non-economic benefits quoted, such as food security, will only come if the project is economically attractive to *farmers,* and if the government can generate the revenues and the resources of skilled manpower to operate and maintain it. Nevertheless, the *Annex* deserves serious study by policy-makers and designers.

The July *Bulletin* from the Overseas Development Unit of Hydraulics Research shows how the design of structures and management *of water* scheduling can be used to minimise the *incidence of* schistosomiasis (bilharzia) in irrigation schemes. Based on a seminar held in Zimbabwe at the end of 1986, the *Bulletin* contains an article by Peter Bolton on how measures have been incorporated into the design of a small holder scheme in southern Zimbabwe to minimise disease transmission, while a second article by Stephen Chandiwana and Paul Taylor describes research into the incidence of the disease before and after irrigation starts. Both contributions emphasize the need to combine the careful design and operation of structures with public health measures, such as location of villages and provision of a safe water supply and sanitation. Too often in the past, disease control measures are only considered once an irrigation project has already been implemented rather than being brought in at the initial design stage. The April 1987 issue contains a useful summary of the highlights of the conference in Kandy in February on *Irrigation Design for Management* by Charles Abernethy, with suggestions for research based round Performance, Control, Information, Interfaces,Participation, Motivation, Decisions, and Institutions. This is an interesting list for engineer to produce! The ODU Bulletin is published quarterly and is available free of charge from Hydraulics Research Limited, Wallingford, Oxfordshire, OX10 8BA, UK.

Members of the network interested in irrigation-related diseases will be pleased to see published the papers from the workshop on *Irrigation and Vector-borne Disease Transmission* held at IIMI in 1985 and organised by IIMI and the Joint WHO/FAO/UNEP panel of experts on environmental management for vector control. The papers concentrate on Sri Lanka but they also have more general applicability elsewhere, given the spread of drug-resistance amongst disease-vectors, the economic cost of chemical control programmes and increasing interest in methods of design and operation to reduce the incidence of malaria and other diseases.

A new journal, *Agricultural Economics,* appeared in December 1986. In the first issue there is an article by R. L. Bowen and R. A. Young on *Appraising Alternatives for Allocating and Cost Recovery for Irrigation Water in Egypt.* The writers examine different methods for charging for irrigation water set against a background of growing water scarcity at the national level. Volumetric charges are compared with a flat fee per land area with additional quotas when water is particularly short, in terms of their relative effects on resource use efficiency, income distribution and cost recovery. Taking account of both direct and indirect costs associated with each method of charging, the authors conclude that the flat fee with quotas best achieves the social and economic objectives.

Water Resources Management is a new journal published for ECOWARM, the European Committee for Water Resources Management, and aims to cover: water resources assessment, development, conservation and control; planning and design of water resource systems; and operation, maintenance and administration of water resource systems. Special emphasis is to be placed on policies and strategies related to water resources, planning methodologies, and decision rules and operating procedures of water resource systems. Overall, the journal's approach is fairly theoretical if the first issue is anything to go by. This contains a useful article by George Mergos on the inclusion of uncertainty into the evaluation of irrigation projects. Using data from irrigated farming in Crete, he argues that farmers' dislike of risky new technologies and crops may significantly slow their rate of adoption and lead to lower project returns. He uses a quadratic programming model to demonstrate that if account is taken of risks to water availability and to crop prices, there will be lower rates of water use, lesser adoption of high value crops and lower farm incomes than where farmers are indifferent to risk. Details of the journal can be obtained by writing to Kluwer Academic Publishers' Group, PO Box 989, 3300 AZ Dordrecht, Holland.

Uncertainty about the performance of new technologies is also dealt with by Dan Rymon and Gideon Fishelson, of the Agricultural Research Organisation, Tel Aviv University, Israel in a paper on the *Economic Analysis of Cotton Irrigation Technologies.* They examine a range of different sprinkler and drip technologies and seek to account for the slow take up of new, more technically and economically efficient techniques in terms of existing sunk capital and of farmers' familiarity with known equipment.

5. FORTHCOMING CONFERENCES AND WORKSHOPS

The European Committee on Water Resources Management and the Irrigation Department of Southampton University are jointly organising an

International Symposium on *Water Management for Food Production* to be held at Southampton from 11-15 April, 1988. Information about the symposium can be obtained from either : The Secretariat of ECOWARM, PO Box 60082, 153 10 Agia Paraskevi, Athens, Greece or from Dr Z J Svehlik, The Institute of Irrigation Studies, Civil Engineering Department, The University, Southampton SO9 5NH, UK.

The Hubei Association for Science and Technology, the Wuhan University of Hydraulic and Electrical Engineering and the Institute of Irrigation Studies, University of Southampton, are organising a conference on *Irrigation System Evaluation and Water Management*, 12 - 16 September 1988 at Wuhan, Hubei, People's Republic of China. Details from Professor Xu Zhifang, Wuhan University of Hydraulic and Electrical Engineering, Wuhan, China.

The Irrigation Research Academy, 35/4, 38-A Cross Road, 8th Block, Jayanagar, Bangalore 560 082, Karnataka, India, announces Interactive Workshops on *Systems Techniques in Irrigation Management*, 6-11 June 1988 and 5-10 December 1988 in Bangalore and 25-28 August 1988 in Manali, Himal Pradesh.

Dr Walter Coward of Cornell University, Warren Hall, Ithaca, NY 14853-7801 will be chairing a session on the *Sociology of Irrigation* at the 7th World Congress of Rural Sociology, to be held at Bologna, Italy, June 26-July 1 1988. Interested persons should provide an abstract of their proposed paper, of approximately 150 words, to Dr Coward and also to K P Wilkinson, Department of Agricultural Economics and Rural Sociology, The Pennsylvania State University, University Park, PA 16902, USA.

The International Commission of Agricultural Engineering, the Nigerian Society of Agricultural Engineers and the National Centre for Agricultural Mechanization will be holding a Symposium in Ilorin, Nigeria, on 5 - 10 September 1988 on the theme: *Rural Technology for Agricultural Growth in Developing Countries.* Sub-theme 2 is *Technology for Small-scale Irrigation Systems,* in which is included management issues. Abstracts not exceeding 250 words should be submitted by the end of December 1987 to Prof E U Nwa, Chairman, CIGR Symposium, Department of Agricultural Engineering, University of Ilorin, PMB 1515, Ilorin, Nigeria. Languages are English and French.

ILRI and CTA (Technical Centre for Agricultural and Rural Co-operation) are organising a workshop in Harare in April 1988 for both anglophone and francophone participants. Themes will include the relationship between rainfed and irrigated agriculture in African farming systems; sharing tasks between farmers and the irrigation authority; and how to incorporate farmers' needs into planning guidelines. Details from Pieter N G van Steekelenburg, ILRI, Staring Building, PO Box 45, 6700 Wageningen, The Netherlands.

6. LUNCHTIME MEETINGS

On June 3rd, Professor Salassier Bernardo spoke on *A New Philosophy for Irrigation in Brazil,* within the context of Brazil's relatively small irrigated sector and the current poor levels of operation and maintenance. Professor Bernardo is at the Department of Agricultural Engineering, Federal University of Vicosa, Minas Gerais, Brazil.

On June 24th, Dr Richard Palmer-Jones (Institute of Agricultural Economics, Oxford) and Dr M A S Mandal (Department of Agricultural Economics, Bangladesh Agricultural University) presented a talk, *Irrigation Water Management in Bangladesh: the Market Takes Over – Imperfectly?,* which considered some of the issues published here as paper 87/2c.

On July 10th, Dr Ian Carruthers (Wye College, London University) and Dr Leslie Small (Rutgers University, USA) began a group discussion of *Financing Irrigation Investments* by presenting preliminary findings from their research programme aimed at identifying operational guidelines to ensure the financial security of irrigation agencies.

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31 August 1987

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IRRIGATION MANAGEMENT NETWORK

LEARNING FROM REHABILITATION PROJECTS: THE CASE OF THE TANK IRRIGATION MODERNIZATION PROJECT (TIMP) OF SRI LANKA

D. Hammond Murray-Rust and P.S. Rao

ODI/IIMI Irrigation Management Network 87/2b August 1987

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87/2b: Learning from Rehabilitation Projects: The Case of the Tank Irrigation Modernisation Project (TIMP) of Sri Lanka by D. Hammond Murray-Rust and P.S. Rao

87/2c: Irrigation Groups in Bangladesh by R.W. Palmer-Jones and M.A.S. Mandal

87/2d: Economics of Farmer Participation in Irrigation Management by R.K. Patil

Please send comments on this paper either to the author or to

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Comments received by the Editor may be used in future Newsletters or Papers.

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ISSN: 0951 189X

LEARNING FROM REHABILITATION PROJECTS: THE CASE OF THE TANK IRRIGATION MODERNIZATION PROJECT (TIMP) OF SRI LANKA

D. Hammond Murray-Rust and P. S. Rao

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LEARNING FROM REHABILITATION PROJECTS: THE CASE OF THE TANK IRRIGATION MODERNIZATION PROJECT (TIMP) OF SRI LANKA

D. Hammond Murray-Rust and P. S. Rao

1. BACKGROUND TO THE PROJECT

The Tank Irrigation Modernization Project (TIMP) was the first major rehabilitation project in Sri Lanka. Between 1950 to 1970 new projects led to a large expansion of the irrigated area. By 1970 suitable sites were scarce and attention began to be paid to improving the performance of existing systems. TIMP involved five reservoir (tank) systems in the northern part of the Dry Zone of Sri Lanka which were in particular need of rehabilitation.

This case study focusses on two of the five tanks involved in TIMP: Mahawilachchiya and Mahakanadarawa. Mahawilachchiya Tank was the first to be rehabilitated during the project; activities at Mahakanadarawa started at a later stage and benefitted from lessons learnt at Mahawilachchiya. Both systems were badly degraded even though they were only 20 years old. The conveyance system was inefficient, operations erratic, and communications between officials and farmers poor. Although both systems were designed for double cropping, only one crop could be assured with partial cultivation in the dry season. Yields were low.

Table 1. Basic Data on the Five Tanks of TIMP

Tank	Irrigable Area (ha)	Tank Capacity (mcm)	Catchment Area (sq kms)
Mahawilachchiya	1053	40.08	362
Mahakanadarawa	2429	41.94	324
Padaviya	5061	104.84	529
Pavatkulam	1781	33.30	296
Vavunikulam	2429	43.17	226

Source: Abeysekera (1984)

2. PROJECT OBJECTIVES

TIMP had a number of substantial objectives aimed at water conservation in both wet and dry seasons:

- increasing cropping intensity through crop diversification in the dry season;
- early land preparation for wet season rice, based on mechanization and dry seeding, to use early rainfall and conserve tank water for the following dry season;
- use of short duration rice varieties in the wet season;
- improved equity of water distribution through introduction of a strict rotational delivery schedules;
- redesign of the conveyance system, lining distributary and field channels, introduction of water measurement capability within the system, and construction of cross-regulators in main channels.

These objectives were developed without the benefit of site specific pre-rehabilitation feasibility studies. They represented contemporary thinking about overall solutions to problems of irrigated agriculture in the Dry Zone.

The first four project objectives were an attempt to reproduce some experiments previously carried out by the Agriculture Department at a small tank at Walagambahuwa. The results were not available at the time when TIMP was planned. The logic was that if cropping intensities were low because of severely limiting water supplies at the beginning of the dry season, then water conservation during the wet season was essential.

There was excessive staggering of land preparation for wet season rice and delayed transplanting in all TIMP systems. Farmers preferred to wait for irrigation releases rather than prepare land using rainfall, delaying the dry season crop. TIMP water saving strategies were to provide sufficient farm power to prepare land with October rainfall, dry seed rather than transplant, rely largely on rainfall for rice production, use short season (90-105 day) rice varieties, and aim to harvest by February. This would permit a prompt start to the dry season non-rice crop.

Irrigation innovations were both structural and operational. Structural improvements included the lining of all field and distributary channels, installation of cross-regulators in the main channels and installation of measuring devices at main and distributary channel level. The design of these improvements represented the first large-scale adoption of the 1-cusec channel[1] approach of the Irrigation Department, which had been first adopted in Wahalkada Tank in 1973 where very sandy soils exist and lining was needed. This led to the Irrigation Department favoring lining even though TIMP tanks do not have many sandy soils. No conveyance loss data were available.

The 1-cusec channel concept requires that field channel command areas are similar in size. Before rehabilitation, field channels had served anything from 10 acres (4 ha) to as much as 100 acres (40 ha) because the design had been based on topography using natural drainage channels as the limits of field channel command areas. During redesign the larger command areas were split into two, and in some cases three, independent command areas, each served by its own field channel. Existing large field channels were filled in, and replaced with two or three parallel channels each with a separate gate at the offtake from the distributary channel.

[1] 28.3 litres per second

Operational rules were altered to fit in with the new design. Prior to rehabilitation continuous issues were made to all parts of the system, with rotations imposed in times of scarcity by closing the sluice at the main reservoir. TIMP planners assumed that water requirements were 3 inches (75 mm) per week, so that 12 hour per day operation of the 1-cusec channel would provide enough water for 28 acres (11.3 ha) during one week. Only one farmer at a time would take water, so pipe outlets to each farm were replaced to accommodate the increased flow.

Organizational innovations included the creation of Tank Committees designed to meet monthly, bring together all relevant government officers and selected farmer leaders (*vel vidanes*) to discuss irrigation and agricultural issues, plan for seasonal dates and activities, and resolve disputes.

3. PROJECT IMPLEMENTATION

Work commenced on TIMP in late 1976 with the construction of buildings, but field rehabilitation did not commence until late 1977, and most equipment did not start arriving until early 1978. Mahawilachchiya was the first of the five tanks to be tackled, the other four due to be phased in by 1980. The project was actually completed in early 1984, approximately two years behind the original timetable (Table 2).

Rehabilitation work was undertaken by the Irrigation Department. They were responsible for all aspects of design and construction, as well as subsequent operation and maintenance. The Department of Agriculture had a parallel program for the agricultural component of the program. Areas were designated for trial projects involving both agencies in all of the five tanks.

The cost of the TIMP project was about US$ 30.0 million. The World Bank (IDA) loaned US$ 5.0 million and the United Kingdom granted U$ 6.0 million. The two together financed about 48% of the total project cost net of taxes and duties.

Table 2. Construction Schedule for TIMP

Tank	Planned	Actual	Delay (months)
Mahawilachchiya	3/77-9/77	1/78-12/82	63
Mahakanadarawa	3/77-9/78	6/78-12/82	51
Padaviya	3/79-9/80	6/79-12/82	27
Pavatkulam	3/79-9/80	6/80-12/82	27
Vavunikulam	3/78-9/78	6/79-12/83	63

US$ 300,000 were provided for Technical Assistance, including provision of a water management specialist to improve the layout and design of the irrigation system, to develop operating schedules for supply system, and to train local technical personnel and farmer leaders/contact farmers on rotational irrigation. A socio-economic impact study of the project was conducted by the Agrarian Research and Training Institute.

Mahawilachchiya was treated as a pilot project for the remainder of the five tanks. It proved that the complete reconstruction and lining of all distributary and field channels throughout an entire irrigation system was more expensive and time consuming than had been anticipated. Mahawilachchiya had been planned for completion in one entire dry season. Work was not completed until 1983. It is estimated that about Rs. 22 million plus US$ 0.46 million were spent on Mahawilachchiya to rehabilitate 1000 ha. This was 29% of the rupee allocation and 12% of the dollar allowance for only 8% of the total project area. The whole TIMP programme could not have been completed within the budget, nor on time, if progress was similar to that in Mahawilachchiya.

The response to the slow rate of progress in Mahawilachchiya was to limit lining in the other four tanks to those areas where soils were particularly sandy or where parallel field channels were required to sub-divide large field channel command areas. This pragmatic approach speeded up construction activities.

There were also significant changes in the design of water delivery schedules. The flow of 1 cusec to 30 acres (12 ha) for 12 hours per day barely meets the estimated requirement of 75 mm/week, and on lighter textured soils is inadequate. Lengthening the time of irrigation was inevitable, and the system continued to operate 24 hours a day. This was essential for the land preparation period where the combined requirements for puddling, maintenance of standing water, seepage, percolation and evaporation greatly exceed 75 mm/week. Despite mechanization, farmers preferred to wait for irrigation releases for land preparation, as there were still uncertainties about the steady onset of the rains. Water demand therefore exceeded channel capacities.

The arrival of the water management consultant in 1980 assisted in the preparation of revised operational schedules. Each channel had a schedule drawn up which calculated the number of hours per week needed to deliver 75 mm. This schedule was posted on boards in the field that indicated the exact time of irrigation for that field channel. Because the discharge was to be kept constant, many field channel gates were scheduled to be closed during the night, something that proved difficult to implement or enforce. In reality the schedule was largely ignored and farmers continued to take water when they could.

4. ASSESSMENT OF PROJECT IMPACT

Assessment of project impact has been made difficult for two reasons: the lack of detailed monitoring, and high variability in water conditions during and after the project. There neither was, nor could be, a guarantee that water supply would be adequate during the rainy season, particularly during the early part of that season. Similarly, availability of water for the whole command during the dry season could not be ensured. Although water measurement devices were installed at the head of every channel no records were kept of gauge readings since their main purpose was the initial calibration and it was thereafter assumed that the flow was approximately 1 cusec. By 1986 virtually all measuring devices were broken or missing. The only way to assess water consumption is at system level.

Similarly, there are only limited agricultural data, and these are only detailed for Mahawilachchiya. Given the fluctuation in water supplies in the reservoir, it is hard to determine to what extent agricultural benefits derive from rehabilitation rather from increases in water supply. Table 3 shows the data available on cropping intensity.

Mahawilachchiya and Mahakanadarawa show starkly contrasting water supply situations. At Mahawilachchiya, originally chosen because of severe water shortages in both wet and dry seasons, the water supply has improved independently of the project. Development of the Right Bank of Mahaweli "H" Block, started in 1983, has resulted in drainage increases into Modaragam River which feeds Mahawilachchiya Tank. In 1983 water was in short supply. However, during the 1983/84 wet season, there was so much rainfall that only one season was possible in that year, since farmers found it too wet to prepare the land and broadcast the second crop. Drainage into the tank now normally permits two rice crops per year throughout the system.

The water situation in Mahakanadarawa has worsened. Since 1980, independently of TIMP, many village tanks within the catchment have been rehabilitated, and this appears to have reduced inflow into the reservoir (Kariyawasam, 1983). By 1986 water was only sufficient to irrigate 800 ha in a late wet season crop out of the total command area of 2429 ha. No dry season crop was possible during 1986.

Table 3. Cropping Intensities in the Project Area

(a) Wet Season	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86
Mahawilachchiya	96	93	93	93	100+	100	100	100
Mahakanadarawa	67	58	58	0	0+	100	63	32
Padaviya	100	84	80	79	61+	*	*	*
Pavatkulam	60	68	74	20	8+	*	*	*
Vavunikulam	70	80	66	77	73	*+	*	*
(b) Dry Season	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**
Mahawilachchiya	0	50	42	36	0	0	100	100
Mahakanadarawa	0	0	0	0	0	0	0	0
Padaviya	*	*	1	2	37	*	*	*
Pavatkulam	0	0	0	0	0	*	*	*
Vavunikulam	7	24	*	27	33	*	*	*

Note: * data not available + First season after rehabilitation

Sources: 1978-83: Abeysekera (1984); 1984-86: Authors' interviews

5. ANALYSIS OF EXPERIENCE

TIMP has contributed significantly to the understanding of the requirements of rehabilitation projects in Sri Lanka: good aspects have been adopted subsequently, poorer aspects modified and not merely repeated elsewhere in the hope they will happen to be successful next time around. Many lessons learned have been incorporated into planning and implementation of two major rehabilitation projects in Sri Lanka: the World Bank supported MIRP, and the USAID supported Irrigation Systems Management Project in several different schemes in north central districts.

5.1 Agricultural Innovations

a. Dry Tillage, Dry Seeding and Short Duration Varieties:

This package requires mechanization, timely water supplies, and varieties that ripen in 3 to 3 1/2 months. Tractors were made available, but water conditions were never such that farmers were induced to change from traditional practices. Water is now plentiful at Mahawilachchiya; so farmers have been able to get two rice crops, even with staggered planting. At Mahakanadarawa water supply is too unreliable for farmers to risk land preparation before the reservoir has partially filled. Dry sowing is now rare.

The package depends on the relationship between rainfall and filling of the tank. Prior to the project, water was not released until the tank had started to fill rapidly. If the Irrigation Department tried to get an earlier start, then farmers refused to plough. Farmers remain reluctant to risk dry seeding prior to what may be "false rains". The Department of Agriculture has changed its opinion on the package: their experiments at Walagambahuwa Tank were successful under closely monitored conditions but were difficult to sustain. Policy in the country is now to ensure a good wet season paddy crop, use irrigation water for both land preparation and crop growth, and plant the more robust and yield-stable 4 to 4 1/2 month varieties which are less susceptible to fluctuations in water supply. Policy has changed partly because the development of the Mahawelhi areas means there is no longer the same pressure to intensify rice production elsewhere. The new policy seems more in line with farmers' preferences in this area, where farmers are concerned to safeguard their main food crop.

The project enabled many farmers to obtain either 4-wheel or 2-wheel tractors. However, the concerns of Ranatunga et al. (1981) that water, not farm power, was the constraint to land preparation appear to be fully justified.

b. Crop Diversification

Uncertainty over water and lack of marketing arrangements were major constraints to adoption of non-rice crops (Table 4). The Irrigation

Department had had no experience with system operation requirements to support non-rice crops and there were complaints that excess deliveries resulted in overirrigation. Water management was difficult since it had to be adapted to two markedly different soils: the upper soils were highly suited to non-rice crops, but the valley bottoms were better suited to rice due to poor internal drainage and high water tables. Tail end farmers cannot fully control their water supply. Actually, preference and practice is for constant flows at low levels rather than rotation between channels.

Table 4. Expected Benefits and Actual Performance at Mahawilachchiya

	Area (ha)			Yield (t/ha)		
	Before (1978)	With Project	Actual (1985)	Before (1978)	With Project	Actual (1985)
(a) Wet Season						
Rice	770	990	1050	1.85	2.35	(3.50)
Cereals	none	60	none	none	2.00	none
Cropped Area	770	1050	1050			
Crop Intensity	0.73	1.00	1.00			
(b) Dry Season						
Rice	80	365	1050	1.75	3.50	(3.50)
Cereals	none	120	none	none	2.70	none
Pulses	20	40	none	0.85	1.60	none
Cropped Area	100	730	1050			
Crop Intensity	0.10	0.69	1.00			
(c) Annual						
Cropped Area	870	1780	2100			
Crop Intensity	0.83	1.69	2.00			

Note: figures in parentheses are estimates

Sources: TIMP Appraisal Report (1976); authors' interviews

It is ironic that while TIMP was intended to support widespread crop diversification, some other systems originally designed for rice are now highly diversified in the dry season. The Mahaweli Authority has offered high support prices non-rice crops in "H" Block. In the TIMP areas pricing and marketing were never developed to support project objectives, and crop diversification is only found in parts of the three more northerly tanks where soils are too sandy for rice production.

5.2 Irrigation Innovations

The package of irrigation innovations reflected the belief at the beginning of the project that the majority of irrigation water management problems were at farm or field channel level, and that wastage of water had to be discouraged at that level if the full benefits were to be obtained from limited water supplies. The irrigation innovations were based on the belief that farmers would switch from one season of 4 months rice to dry ploughing and dry seeding of 3 month rice in the wet season, and non-rice crops in the dry season. When these agricultural innovations were not adopted, the new design created several difficulties.

a. Field Channel Redesign and Reconstruction

The strategy adopted at Mahawilachchiya in the first phase of TIMP was to completely redesign and reconstruct field channels. The new rectangular-sectioned channels have proved unsatisfactory because water demand for land preparation for wet sowing of rice is greater than the capacity of the channels. The result is that staggering of land preparation remains a serious problem, not because of draft power limitations (although these may also still be present for some farmers) but because of competition for water. The new channels were expensive to construct, and took longer to complete than anticipated.

The concept of the 1-cusec channel has remained with the Irrigation Department since TIMP, but it has been substantially modified. There are more simple control structures in MIRP (which, provided farmers are allowed to operate them, increase flexibility without increasing staffing needs). Channels have traditional trapezoidal cross-sections and a bigger freeboard to accommodate peak demand. Twice the normal flow can be sent down when necessary. These modifications have largely eliminated the need for parallel field channels, and lining is limited to areas where soils are particularly sandy.

b. Rotational Scheduling

The original design limited irrigation deliveries to 12 hours per day, so that no farmers would have to irrigate at night. Operational plans were never developed by design staff and, at first, O&M staff were never trained to implement the rotation. It proved impossible to operate the system in daylight hours only. The flow of 1 cusec to 30 acres for 12 hours per day barely met the estimated requirement of 75mm/week, and on lighter textured soils was inadequate. In 1980, when the water management specialist arrived, training was started and schedules revised. Although the revised schedule was based on a continuation of the 75 mm/week water delivery requirement, with slight modifications for changes in evapotranspiration, field channel discharges were if necessary adjusted downwards from a 1-cusec norm and time lengthened to accommodate the actual size of each field channel command and to ensure gates only had to be opened and closed during daylight.

In MIRP the scheduling process has undergone modifications that result in a more manageable plan. Design discharges are more variable, some modifications have been made to allow for soil differences, and gate openings and closing are all in daytime. During land preparation the schedule is not implemented so that as many farmers as possible can prepare land at the same time.

c. Farmer Rotations and Pipe Outlets

The design of TIMP proposed that water be distributed to two farmers at any time on a field channel, starting at the tail end. This system has not been widely adopted, farmers generally preferring to adopt a wide variety of sharing techniques that reflect local conditions and the relative cooperativeness of neighboring farmers. It would also seem that farmers here prefer, and find less labour-demanding, a continuous trickle for a longer time than larger slugs at infrequent intervals.

d. Main Channel Cross-Regulation

The installation of cross-regulators has been a major benefit to water elevation control in the main channels of the systems. When discharges have to be reduced, it is possible to maintain heads or, if necessary, use them to demarcate the extent of the area permitted for irrigation in times of considerable water shortage. Cross-regulation is being provided in several other systems at the present time.

e. Water Measurement Activities

TIMP was the first effort in the country to provide full measurement capacity at all levels in the system. Parshall flumes were installed downstream of tanks, and weirs and gauges installed below all distributary and field channel turnout. At present, gauges are missing, weir boxes broken, and no measurements are recorded except for issues into main channels from the tank. Lack of measurement means that precise water delivery is not possible, and the fine tuning indicated in the schedule cannot be implemented. It is not possible to verify the assumption that demand is more or less uniform at 75 mm/week.

f. Reliability and Equity of Water Distribution

The lack of a detailed monitoring program makes it impossible evaluate changes in reliability and equity of water distribution. The overall water situation in Mahawilachchiya has improved dramatically since Abeysekera (1984) conducted his post-project evaluation, and our observations and interviews in 1986 indicate a much greater degree of satisfaction than reported by him.

Abeysekera (1986) reported that farmers in tail end areas appear to have benefitted from the introduction of parallel, lined field channels that specifically serve lower portions of what were once larger command areas. The redesign may have increased problems for some farmers who were in the middle of a field channel command area and who are now at the tail end of a shorter field channel. During normal irrigation, between transplanting and harvesting, the channels appear to have adequate capacity.

The situation in Mahakanadarawa is more complex because not all channel sections were reconstructed or lined, and overall water supply remains poor. A different approach has therefore been adopted to try to improve equity, which utilizes the traditional principle of *bethma* which is used in other irrigation schemes when water is in short supply. *Bethma*, which has its origins in village tanks, involves dividing the command area into two or three zones. In good years all zones receive water, but in bad years collective decisions are made to restrict irrigation to one or two zones. Head zone farmers are obliged to let others farm part of their land at no charge.

In the 1986 dry season in Mahakanadarawa water was judged to be sufficient for only one third of the command area (800 ha out of 2429 ha). Each head end farmer was allowed to cultivate one third of his 1.2 ha holding, and two tail end farmers allocated temporary rights to the other 0.8 ha. This appears to be equitable, but in practice there are severe problems for tail end farmers. Their homes are up to 15 km from their allocated land that it is difficult to move animals, care for crops and manage water. Head end farmers can often cultivate all their land. However, various arrangements may be made with tail end farmers, such as sharing arrangements, or the head ender might buy the cultivation right back.[2]

g. Water and Land Allocation

The rotational irrigation schedule included in the project objectives calls for irrigation rates of 75 mm per week, plus approximately 200 mm for land preparation. Allowing for the project efficiency design of 72%, the total seasonal requirement is 1320 mm. In Mahakanadarawa the irrigable area for the 1985/86 wet season was determined using the long-standing Irrigation Department estimate of 6 acre-feet/acre (1830 mm). In this respect traditional water allocation principles described in detail elsewhere (Murray-

[2] Contrast this with the innovative *bethma* in Mahaweli "H" block where land reallocation is within the confines of a single distributary channel serving about 100 ha. The distance problem does not arise, farmers are generally known to each other and there is very little leasing back of land by head end farmers.

Rust and Moore, 1983) appear not to have changed despite the intentions of the project to conserve water and extend the dry season irrigated area.

In Mahawilachchiya the abundance of water means that there is no reason to restrict the cultivated area: the tank capacity of 40.08 mcm permits the whole area of 1053 ha to be irrigated with a seasonal supply of 3800 mm.

5.3 Institutional Innovations

a. Irrigation Department Organization

TIMP was conceived in Colombo and all initial designs were undertaken using the facilities available at the Irrigation Department Headquarters. However, designs had to fit local conditions and needed adjustments in the field to the existing functioning irrigation system. The Project Director soon found that slow design work was impeding the rate of progress of the project, and that equipment use and construction were being delayed.

The transfer of design activities from Colombo to a town nearer to the project is the first case of major devolution of design within Sri Lanka, and has been copied in the MIRP and Gal Oya Projects.

b. Farmer Representation and Tank Committees

The establishment of Tank Committees under TIMP was the first effort in Sri Lanka to involve farmers formally in the management of major irrigation systems. The first step was to create a Tank Committee, since the pre-seasonal meeting held in every irrigation system to discuss the cropping timetable, etc, was not an effective institution for regular management. It involved all farmers and as many as 50 government officials. In practice it was a rally for rubber-stamping government proposals. The new Tank Committees were intended to be more democratic and to meet more frequently. However, the farmers were "represented" by the *vel vidanes*, who were selected by a government department, and who were potentially outnumbered by government officials.

TIMP used the *vel vidane* to undertake several water management tasks, including implementation of the rotational schedule, representation of farmers at the Tank Committee, and liaison with government officers. *Vel vidanes* were not universally popular, their appointment sometimes being for political favour, and, with about 12 field channels each, they had too large an area to manage effectively. A second improvement, therefore, was to establish a more hierarchical arrangement, where all farmers holding title to an allotment elected a field channel representative who would be responsible for arranging water distribution, and be the contact person for dealing with the Irrigation Department officers. He was also the representative to the Tract Committee which in turn elected a representative to the Tank Committee. Because these changes came about during the project, farmers had had no mechanism to participate in aspects of design or construction. The Tank Committee was still very large, and biassed in favour of government officers, and still proved ineffective for management of the Tanks.

The model, however, has been modified and is now being adopted nationwide within the Project Manager system. This is being implemented by the Irrigation Management Division created in 1984. The main differences from the TIMP Tank Committees are that farmers and government officers are equally represented, that the tasks are more clearly specified, and that they have some degree of authority. In MIRP formation of farmer organizations has preceded design and construction work, and there are examples from Nachaduwa of incorporation of farmers' suggestions into design and location of structures.

The greatest difference between Tank Committees and the Project Manager Systems lies in the pre-seasonal decision-making process. Before and during TIMP, there were few discussions before the meeting: government officers came to the meetings with plans that were then "approved" by farmers without significant change. Under the Project Manager System, the proposals made to the seasonal meeting have been discussed in monthly meetings by officers and farmer representatives, brought back to, and discussed with, other farmers, and modifications made before being presented to the seasonal meeting for approval. Preliminary indications suggest this system is more effective than the Tank Committee, although the Tank Committees did represent an important stage in the evolution of a more democratic process for irrigation management in Sri Lanka.

6. CONCLUSIONS

TIMP was the first major rehabilitation project in Sri Lanka. Despite numerous criticisms, and particularly over the appropriateness of the agricultural innovations, a number of important lessons have been learned. Within Sri Lanka there is now much more emphasis on the operational and institutional side of projects, and less on the physical reconstruction. There is a greater effort to incorporate operational criteria into designs, and train engineers in operational innovations. However, in some respects, TIMP was an expensive way to learn that greater attention had to be paid to management, operation and maintenance. There are also some signs that progress in this area still needs to be made.

There has been little or no increase in maintenance budgets, despite efforts to allocate irrigation service fees for maintenance in the systems where the money was collected. After one successful year, fee collection rates have dropped to low levels because maintenance works were not undertaken.

The same is true for operation, where there have been cuts in the field staffing of the Irrigation Department due to financial difficulties. At Mahakanadarawa the number of Irrigators, responsible for operating gates within the system, has been reduced from 16 to 8, and there are now only 3 Work Supervisors instead of 4 to cope with maintenance. The Irrigators work for 12 hours per shift, so the four on duty at any time have to cover all 50 offtakes from the main channel and 200 field channel gates. This is clearly an impossible task, and it is therefore not surprising that it is difficult to regulate discharges, and sustain the measurement programme. This is an example of the way the operational system may constrain design choices: for good design, the operational mode has to be selected first.[3]

There can be little doubt that overall the project has had benefits, and that some of these have been sustained for the past three years. However, there is no reason to feel complaisant: the project stressed redesign and

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[3] *It is probably worth also pointing to the desirability of incorporating as much flexibility as possible to meet unanticipated changes in water supply, government policies, price and marketing changes, etc. In this example, trapezoidal cross-sections are more flexible than rectangular ones. Ed., Mary Tiffen.*

construction at the expense of maintenance, operation and monitoring, and there is every likelihood that rehabilitation will be necessary within the next 15-20 years.

The experience of TIMP stresses the need to have good information concerning past operation of an existing project before rehabilitation. For this consultation with the users is helpful. The least successful aspects of the project were largely associated with imposition of assumptions on the designers rather than spending time assessing the real constraints to improved performance. Physical solutions, notably lining and mechanization, proved not to be effective and did not result in improved system management.

ACKNOWLEDGEMENTS

We would like to thank the following for their assistance in providing data and sharing their experiences in TIMP: Mr. N. Kumarasamy, Senior Deputy Director, Irrigation Department; Mr. J. Alwis, Director, Irrigation Management Division; Mr. W.P. Jinadasa, Deputy Director of Irrigation, Anuradhapura; Mr. Jinadasa, Irrigation Engineer, Mahawilachchiya; Mr. S. Wijesooriya, Irrigation Engineer, and Mr. Gunetilleke, Senior Technical Assistant, Mahakanadarawa; Mr. Y. K. Choo, World Bank Water Management Consultant, Anuradhapura; Mr. Godaliyadde, formerly Irrigation Engineer, Mahakanadarawa; Dr. W.A.T. Abeysekera, ARTI; Mr. N. Grant, formerly ODA volunteer for TIMP.

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IRRIGATION MANAGEMENT NETWORK

IRRIGATION GROUPS IN BANGLADESH

R.W. Palmer-Jones and M.A.S. Mandal

ODI/IIMI Irrigation Management Network 87/2c August 1987

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87/2b: Learning from Rehabilitation Projects: The Case of the Tank Irrigation Modernisation Project (TIMP) of Sri Lanka by D. Hammond Murray-Rust and P.S. Rao
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ISSN: 0951 189X

IRRIGATION GROUPS IN BANGLADESH

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IRRIGATION GROUPS IN BANGLADESH

R. W. Palmer-Jones and M. A. S. Mandal

1. INTRODUCTION

In view of the interest in farmers' associations as managers either of their own systems or of tertiary units, we need to know what institutional factors affect their performance. This paper reports on a study of groups managing tubewells in Bangladesh. The authors would like to propose similar studies in other countries to test their conclusions and invite interested persons to correspond. The paper outlines groundwater development in Bangladesh and its complicated economic and institutional background in section 1. Section 2 describes the research teams involved in this study and its main conclusions. Section 3 illustrates the factors influencing performance through two case studies. Section 4 looks at access and competition more generally, and Section 5 summarises the hypotheses arising which it is thought deserve further work and testing.

1.1 Groundwater Irrigation Development in Bangladesh

The adoption of mechanically powered irrigation - Low Lift Pumps (LLPs) and Deep Tubewells (DTWs) has been promoted since the 1960s. With the exception of one project area, pumps were hired out by the Bangladesh Agricultural Development Corporation (BADC) to farmers' groups organised either within the official cooperative programme (the KSS system), or as less formal groups. Average farm size was recorded in 1976-7 as 1.4 ha in 9 separate plots so farmers have to coordinate to obtain a reasonable command area. Although LLPs were included in the sample, this paper reports only on DTWs and STWs, since LLPs were found to be so affected by situational factors, that it was not possible to separate out institutional determinants.

After 1970 DTW development was organised within the Integrated Rural Development Programme (IRDP), now formally organised by the Bangladesh Rural Development Board (BRDB). However, from about 1974 Shallow Tubewells (STW), were distributed largely outside the KSS programmes of the BRDB.

1.2 Economic and policy background

Table 1 shows the growth in numbers of irrigation units in Bangladesh. Installation of DTWs grew by 1000 to 500 per year since the mid 1970s. The numbers of STW sold per year increased steadily during the 1970s and rose dramatically between 1980-1 and 1982-3; since then the absolute numbers and growth rate of STW sold has declined sharply.

Privatisation, initiated in 1979, involved the selling off of existing LLPs and DTWs, and an acceleration in the sales of STW, both from BADC with credit from BRDB, and through private dealers with credit provided by commercial banks. Payment on "commercial" terms was supposed to lead to improved capacity utilisation. Almost all LLPs and a number of DTWs have been sold, nominally to either KSS or other informal groups, although recently the policy has reverted to selling to KSS groups only.

Table 1. Growth of Groundwater and Power Pump Irrigation Units in Bangladesh.

Year	LLP	DTW	STW	
	Rental per year	Private Cumulative Sales	Cumulative Operating	Cumulative Sales
1962-3	2024			
1967-8	6558		102	
1972-3	32924		1237	938
1977-8	36730		7453	14714
1978-9	35895		9329	19973
1979-80	37381		9795	24458
1980-1	31688	2206	10131	42009
1981-2	28117	9594	11491	68474
1982-3	17619	21973	13794	107619
1983-4	9308	34307	15519	138156
1984-5	8337	42324	16901	160786
1985-6	0	49837	18044	

The main economic influences on the demand for tubewells (with appropriate allowance for risks) are their real capital and operating costs, the costs and returns to boro[1] rice, and the opportunity costs of alternative crops - especially aus and jute. While the *nominal prices* of STWs, which are almost universally sold with credit, have increased rapidly, the real cost to buyers depends on the level of credit repayments, which have fallen well behind. It has been reported that the overall recovery rate of institutional credit to agriculture in the early 1980s averaged around 40% but had *fallen to 27% in 1986 (WB, 1987). Likewise rental payments* for irrigation equipment are often not made, and non repayment of credit applies to operating as well as capital costs. In the imperfect factor,

[1] The following terminology is used in Bangladesh:
Boro: Main dry season rice crop
Rabi: Dry season (November-March)
Amon: Late summer rice crop, either broadcast in March/April or transplanted in July/August (according to expectations on flood depth and timing)
Aus: Early rice crop, planted April May, harvested July August

product, and credit markets of rural Bangladesh the seasonal expectations of prices of crops and of agricultural inputs which affect cultivation and irrigation investment decisions defy simple definition, but Tables A1 and A2 in the Annex set out the best available data on price and quantity series for some of the main variables.

Tubewell demand is affected by shifts in the cropping pattern to make more or less use of the rains. The main demand for tubewells has been to irrigate the boro rice crop that in recent years has been planted in January or February and harvested in May or June. Formerly it was planted earlier, but this tended to result in lower yields, and higher pumping costs compared to later plantings; the later the planting the more likely that the period of peak water demand was to coincide with early rains in April and May. However this increased the likelihood of early flood damage. Later planting has meant that it was usually impossible to grow aus, mixed aus/amon, or jute on boro land. Earlier plantings also prevented growing rabi crops; later plantings allow a short season rabi crop such as mustard or potatoes in some cases.

The downturn in demand for tubewells has been ascribed to the policies of privatisation and the removal of subsidies pursued since 1980, and the failure of rice prices to rise to offset these cost increases (e.g Bangladesh Development Studies, Vol XIII, (3 and 4) 1985); others argue that, following a period of rapid growth of sales in the early 1980s the downturn is due to the technical and institutional factors causing poor capacity utilisation of irrigation equipment.

Taking a naive view of the trends it seems that there was a sharp rise in irrigation at a time when prices of inputs, particularly equipment, fertilizers and diesel, were rising sharply relative to the price of rice, due to privatisation and the withdrawal of subsidies. The price of the competing jute and rabi crops fell in the early 1980s when boro acreage was rising. The downturn in STW sales has occurred while these input to rice price ratios have not risen further; the exception is that the availability of credit declined and its effective cost rose from around 1984.

It might seem, therefore, that a large part of the trends can be explained in terms of unsatisfied potential demand in the early 1980s. This period has been followed by a process of rationalisation from 1983/4 as the most favourable sites had been used up, the unfavourable trends in price incentives that had followed "privatisation" were not reversed, and credit became less freely available (for quite similar views see Osmani, 1985, Hossain, 1985). It is also possible that agronomic problems arising from the increase in cropping intensity were limiting response to fertilizer and HYVs (Hossain and Salim, 1986). Thus there may well have been a reassessment of the profitability of boro cultivation on existing and potential areas, especially following the widespread floods in May and June 1984. However a number of sources, particularly the National Water Master Plan Organisation (1985), and Gill, (1983) have suggested that there is still considerable unexploited potential for further expansion of tubewell irrigation, and believe the downturn is due to failure to achieve the potential private financial benefits from irrigation, because the failures of group irrigation management has inhibited full capacity realisation.

1.3 Forms of Tubewell Management

During the 1970s several experimental programmes have aimed at improving the widely perceived poor performance of KSS and informal tubewell groups. These programmes included the Deep Tubewell Irrigation and Credit Project (DTICP) run by CARE in conjunction with the Bangladesh Krishi Bank and BADC, and the Irrigation Management Programme (IMP) of BRDB for the KSS system. Both these programmes aimed to provide a package of improvements, including improvements to the pump and motor installation and the canal layout; block rotational water distribution; timely supplies of irrigation, agricultural inputs, and credit; and new agricultural technology (seeds, pesticides, fertilizers). Both programmes have claimed considerable success in raising the command areas and increasing yields (GOB 1980, 1981; GOB and WB, 1982, CARE, 1984); IMP remains the main official vehicle to improve capacity utilization of DTW (WB, 1987). Another set of irrigation management projects involved the organization of groups of landless people to buy or rent irrigation equipment with equity objectives and the aim of generating employment; the Non Governmental Organisations (NGOs) PROSHIKA and BRAC had such programmes, starting in the late 1970s, and BRDB also started a landless irrigation project (Ahmed, 1986). The Grameen Bank has also financed the purchase of irrigation equipment by a number of landless groups (Mortuza, 1986). Here too increased command areas and high yields have been claimed (Wood, 1984, p.69), together with improved equity outcomes. The CARE DTICP project has been replaced by the LOTUS project which makes the same technical and managerial package available to Landless Owned Tubewell Users through groups assisted by local NGOs.

1.4 Resume

In summary then there are now three modern minor irrigation technologies - Low Lift Pumps, Deep TubeWells, and Shallow TubeWells; these can be owned or rented from BADC, and are managed either by KSS groups, informal pump groups relating directly to BADC, private owners who may be either individuals or groups, or landless groups. KSS groups may own or rent their equipment. Schemes which are nominally managed by groups may in fact be managed by a small number or even one individual. The landless groups may be organised by an NGO, such as PROSHIKA, or BRAC, or by the Grameen Bank. DTWs may be managed under special schemes such as the CARE-BKB-BADC project, or the IMP project of BRDB.

2. THE BANGLADESH AGRICULTURAL UNIVERSITY (BAU) RESEARCH ON MINOR IRRIGATION MANAGEMENT

An earlier project by a group of researchers at BAU showed that, contrary to previous ideas, water management was not a constraint on irrigation productivity until a large command area had been arranged (Biswas and Mandal, 1982). On many schemes there was ample water and no need to arrange its more efficient use until the agreement of a larger number of cultivators to irrigate a larger area had been obtained. Since there were a number of institutions and programmes attempting to promote greater capacity utilisation, a logical next step was to investigate their success in achieving greater command areas and whether they then encountered water management problems. In 1985 the BAU team, with further funding from the Ford Foundation, comprising a core team consisting of an irrigation engineer, S. Dutta, and agricultural economist, M.A.S. Mandal, led by Professor M.R. Biswas, with consultancy inputs from R.W.Palmer-Jones, and "reinforcements" from agricultural engineering, agronomy, soil science, agricultural economics and irrigation engineering, and the assistance of the

Ford Foundation programme officer, A. Bottrall, developed a joint approach to the comparative study of irrigation management institutions. The basic objective of the research was to compare and account for the performance in terms of efficiency and equity of different irrigation management institutions, and to identify their individual constraints to further achievements.

The main hypothesis was that, once the technical and ecological factors affecting performance had been accounted for, command area and yield would vary by management institution; the reasons for this would be found in the structure of incentives provided by each institution (see Palmer-Jones, 1985, Mandal and Dutta, 1985). The first stage of the research required a large sample to enable statistical testing. This survey was conducted in 1985; it was followed in 1986 by detailed case studies of four tubewells, and a more rapid follow-up survey of some of the installations surveyed in 1985 was also made.

It turned out that the sample contained 19 combinations of district, management institution and irrigation technology. A minimum sample size of 5 of each DTW institution and 10 STW institution was desirable to enable testing. Resource constraints and the need for intensive supervision of data production meant that many technical and other variables could not be collected from such a large sample by the usual methods of surveying all schemes and making a large random sample of cultivators on each. Thus a number of methodological innovations were required to measure certain key variables; for example rapid procedures were required from irrigation engineers to measure pump discharge, water losses, depth to water table, and irrigation costs. The agronomists had if possible to arrive at measures of soil types, topography, and cropping practices; the agricultural economist had to measure crop inputs, outputs and relevant prices. More detailed descriptions of the methods have been given elsewhere. Further developments in cost effective field research techniques are required.

2.1 Location of the Study

The research was conducted in two locations. The Ghatail-Kalihati area is in the new floodplain of the old Brahmaputra with flat topography, fertile loam soil, high water table and high density of population, which have encouraged very rapid expansion of DTWs and STWs well above the national average. The second area, Gazipur, has a combination of flat, undulating, and broken topography with loam to sandy clay loam soils and lower population density. There are non-farm employment opportunities because of proximity to the industrial cities of Joydebpur and Dhaka. Because of the very low water table only DTWs have been developed in this area, with some LLPs around open water surfaces.

2.2 Some Results from the Survey

Initially we were interested in finding out if there were any systematic differences in performance among the different management institutions and with what factors any such differences were associated. The experimental and privatisation programmes were all concerned to improve performance. The experimental programmes (IMP and CARE) had claimed to have achieved considerably better performance through packages of irrigation management and extension services, and that these gave rise to improved pump, canal system and agronomic performance. The privatisation programme was supposed to affect incentives to increased command areas and/or yields (GOB and WB, 1982). The KSS cooperative of cultivators in the command continues to be supposed to be the logical organisation to manage irrigation (see Coward and Ahmed, 1979), although in reality even KSS pumps tend to become the de facto property of the person or small group who engineered the necessary initial relationship with Government officials.

2.2.1 Dropouts from Experimental Programmes

Both the experimental programmes (CARE and IMP) had high drop-out rates, which undermines claims of improved performance based only on those pumps which remained within the programmes. CARE has apparently adopted the view that though, with intensive management inputs, it can achieve improvements in productivity, but it cannot replicate its programme widely. It has consequently developed the LOTUS programme which provides technical, agronomic, and mechanical services to NGOs which have landless irrigation programmes (CARE,n.d.).This survey found that CARE assisted projects had no higher productivity than other institutions but CARE report they selected DTWs that were initially well below average) The number of staff required and intensity of supervision, the high drop-out rate help explain the lack of lasting impact on productivity from IMP and DTICP in the two districts studied.

2.2.2 Non payment of Bank Loans and Pump Rental

Another feature that came to light was the widespread non-repayment of bank loan installments other than the initial deposit, and the arrears in rental payments to BADC (see also Gill, 1983). In Ghatail-Kalihati only 7 out of 143 DTW were up to date. In some cases rental payments to BADC and DTWs were many years in arrears. Managers' and agencies' accounts of payments made differed (Mandal, 1985, 1986a).

2.2.3 Differences between Areas and Technologies

In general comparisons of physical productivity are made between schemes sharing the same technology and District because we want to highlight institutional differences rather than those due to technology or the ecological and economic environment. However the differences in command area and yield on DTWs in the two Districts are surprising in that though in Gazipur DTWs had significantly lower discharge, command areas were significantly higher than DTWs in Ghatail-Kalihati. Thus for a given technology lower discharge does not necessarily mean a smaller command area or total output. This is not of course to argue that low discharges do not contribute to the poor average performance of pumps in terms of area irrigated, rather it shows that the variations in physical productivity of a given technology in a given region are not caused by variations in pump discharge. To some extent discharge (and engine speed) is chosen to fit the command area which is determined by other factors. The performance of these schemes was assessed principally in terms of physical productivity - area commanded, yield per unit area, and gross output - the product of yield and command area (Table 2). We attempted to explain physical productivity in terms of the physical parameters of pump performance. Table A3 in the Annex reports performance in technical dimensions. It will be

Table 2. Performance of Minor Irrigation Management Institutions in Bangladesh.

District	Institution	Technology	Command area ha.	Groups*	Yield kg/ha	Output '000kgs.	Groups*
Ghatail-	BRDB-IMP	DTW	26.95	A	5143	138.57	A
Kalihati	BADC-S	"	23.37	A B	5120	119.72	A B
	GB	"	22.30	A B	4850	104.82	A B
	BADC-R	"	16.48	B C	5518	91.24	B C
	BRDB-KSS	"	13.30	C	5151	66.17	C
	Mean		19.44		5195	99.52	
	cv		33		13	32	
PR > F#			.02		.78	.02	
Ghatail-	GB	STW	5.26	A	5789	30.79	A
Kalihati	BKB	"	4.98	A B	5409	27.46	A B
	BADC-S	"	4.93	A	5636	27.88	A
	BRDB-KSS	"	3.13	B	4961	16.37	B
	Mean		4.63		5462	25.91	
	cv		40		18	48	
PR > F			.07		.35	.09	
Gazipur	BADC-S	DTW	27.73		4256	122.56	
	BRDB-IMP	"	24.90		4880	123.56	
	CARE	"	23.60		4983	121.83	
	BADC-R	"	21.40		4845	105.84	
	BRDB-KSS	"	18.16		4331	82.69	
	Mean		22.49		4659	108.28	
	cv		37		20	50	
PR > F			.49		.69	.73	

Notes: * Sets of groups that are not significantly different at .05 (SNK test) have the same letter. # PR > F gives the probability of the computed F value; it indicates the probability that the members of groups were drawn at random from the same population - i.e a low value indicates significant differences.

seen that variations in the area commanded[2] were far more significant in determining variations in output than variations in yields. A longer discussion of the physical determinants of productivity appears in BAU 1985 and 1986.

2.2.4 Management Institutions and Performance

Table 2 gives the same letter, A, B or C to institutions without statistically significant differences in performance. Differences in yield between institutions were not statistically significant. However, in Ghatail-Kalihati command areas of DTW schemes managed under IMP, by Grameen Bank groups, and BADC private DTW were significantly higher than those managed by KSS and those rented from BADC. STW schemes managed by the Grameen Bank groups and those purchased from BADC or BKB did better than those managed by KSS groups in terms of command area and output, although the probability level here is only 10%. The poor performance of KSS groups occurs for both owned and rented pumps. In Gazipur DTWs managed under IMP and CARE did not have statistically significantly greater command areas or estimated gross output (command area multiplied by average yield) than other institutions.

The command area is not surprisingly associated with the hours of operation, and the total fuel consumed; both these variables reflect the fact that to a large extent variations in discharge can be compensated by varying the number of hours of pumping. At some point periods of peak demand for water - probably for land preparation or in April when the weather is much hotter - will mean that a greater command area can only be achieved by providing less, or less timely, water per unit land. The command area is not obviously related to the cost of supplying water as measured by the fuel per unit water (this is supported by the lack of association between discharge or depth to the water table and command area).

[2] The command area was recorded both by asking the manager; by asking the manager for the area of each participating farmer, and by asking the other interviewed farmers. The results were remarkably consistent.

2.2.5 Payment Systems and Productivity

In contrast to the relative failure of physical factors and management institutions to explain much of the variation in performance among pumps at least one economic variable was found to be quite strongly associated with performance. Table 3 shows the effect of the payment system for water on performance. In Ghatail-Kalihati there are two systems; on all STW and 72% of the DTW water payment was by 25% of the gross output; on the remaining DTWs payment was a fixed charge per unit area corresponding more or less to the average cost of water supply. In Gazipur there were two systems; one corresponded to the fixed charge system paid in Ghatail, covering both overheads and operating costs, with the manager responsible for the supply of fuel and the organisation of water distribution. The other involved a fixed charge for the use of the pump; actual pumping was on demand and the farmer was responsible for supplying or paying for the fuel actually used. This system, called farmer's fuel, may appear to equate (private) marginal costs and benefits, but has problems in lack of coordination over a water rota and the high transaction costs involved in purchasing diesel individually in rural markets, with a high probability that some fuel will be adulterated, and lead to high engine maintenance costs.

The command area and total output of DTWs in Ghatail-Kalihati was strongly associated with the payment system; schemes with share payment had on average 25% smaller command area than on fixed cost schemes, and 30% less total output. There was also an association between the payment system on DTWs in Gazipur and command area, and to a lesser, and not statistically significant extent, with yield. The command area was 28% lower on schemes where farmers were responsible for their fuel, and output 37% lower. All STWs employed share payment systems for water.

The effective charge for water per unit area under a share system will vary according to yield. In the year of this study the share system resulted in a much higher charge than other systems (despite delivering a smaller volume was nearly Tk. 5500 per ha. on DTWs and about Tk.6000 per ha. on STWs, while on fixed cost systems in Ghatail-Kalihati were little over Tk.2000; in of water). The average water charge per hectare on share payment schemes Gazipur District the water charges when the manager was responsible for

Table 3: Command Area, Output, and Manager's Returns from Water Selling, by Technology, District and Water Contract

Technology	Payment System			
District Variable	Fixed cash	Fixed cash + farmer's fuel	Share of crop	Probab. Diff > F
DTW				
Ghatail-Kalihati				
Command area (ha)	23.66	-	17.81	0.08
Yield (kg/ha)	5392	-	5119	.60
Total Output ('000 kg)	126	-	89	0.015
Water Charges (Tk/ha)				
Received by managers	2051	-	5410	
Paid by cultivators1	2051	-	5445	
Water costs to mngt. (Tk/ha)2	1644	-	2166	
Return to "management"3				
per ha. (tk/ha)	407	-	3244	.000
Total (Tk)	9608	-	59284	
Gazipur				
Command area (ha)	25.33	18.24	-	.03
Yield (kg/ha)	4900	4298	-	.26
Total Output ('000 kg)	127	80	-	.02
Water Charges (Tk/ha)				
Received by managers	2525	1205	-	
Paid by cultivators1	2572	2603	-	
Water cost to mngt (TK/ha)2	1956	593		
Return to "management"3				
per ha. (tk/ha)	569	612		
Total (Tk)	15986	11316		
STW				
Ghatail-Kalihati Command area (ha)		-	-	4.63
Yield (kg/ha)	-	-	5462	
Total Output ('000 kg)	-	-	26	
Water Charges (Tk/ha)				
Received by managers	-	-	5813	
Paid by cultivators1	-	-	5819	
Water cost to mngt. (Tk/ha)2	-	-	2705	
Return to "management"3				
per ha. (tk/ha) -	-	3108		
Total (Tk) -	-	-	15885	

Note: US $1.00 = (approx)Tk 30.00

Footnotes: 1. Water cost to farmers exceeds that to managers because it includes payments to linemen/water distributors, and fuel in the case of Gazipur "farmer's fuel" DTW.

2. Total O&M paid by managers excluding rental charges and credit installment payments (which were generally not made).

3. Net of O&M costs.

Source: Field Survey by BAU group, 1985-6 the fuel were about Tk.2500, and where the farmer was responsible for fuel water charges were just over Tk.1200 per ha.; the actual cost to the farmer in this case was just over Tk.2600. These differences were not due to differences in the cost of supplying water; the net incomes to pump owners was far greater when the share payment system was used. On most schemes the manager paid the labourers responsible for the distribution of water; occasionally farmers had to pay this in addition to other payments. A measure of the return to "owners" of the irrigation equipment under the different systems is the pay-back period of the (subsidised) capital cost; for share payment systems it was just over two years, while for the other system it ranged from 10 to 20 years. Given that in many cases loan repayments and rentals are not being made, and where the water charges are received by an individual or small group, it is evident that very large net revenues are accumulating to some water owners employing the share payment system. Since these people are already larger landowners, as shown by the average holding size of managers, the share payment system is likely to be adding considerably to rural inequality.

Although the survey did not collect information on the quantities of farm inputs used, the distributional implications of the share-payment system can be illustrated by using approximate figures for farm costs. Table 4 shows the estimated average costs and returns per hectare to irrigated boro rice production by district and tenure. Wage rates were higher in Gazipur, and yields were lower. Share cropping results in lower output levels, especially for labour and chemical fertilizers and lower yields (BAU 1985). The figures indicate that the returns to share-croppers will be unable to cover their labour costs; share-croppers must therefore be prepared to work for less than the going wage rate, perhaps partly in order gain access to share-tenancies in other seasons, and perhaps, to ensure against the risks of the wage labour market.

The returns to those who extract the water payment varies with the payment system and the number of "owners"[3] amongst whom the returns to water management must be distributed; where the payment is either by a

[3]Managers are not always the owners of residual income from tubewells, there are often sharers who may or may not include all those in the nominal irrigation group. The number of effective co-sharers is not easy to discover

Table 4. Estimated Cost and Returns to BORO Rice Cultivation (1984/5) By Water Contract and Land Tenure in Ghatail-Kalihati (Tk/ha).

Water Contract Type:	Fixed		Share			
	DTW		DTW		STW	
Land Tenure:	own	share	own	share	own	share
ITEM						
Labour						
Family	2200	1840	2200	1840	2200	1840
hired	3000	2660	3000	2660	3000	2660
Tillage						
Family	889	889	889	889	889	889
Hired	593	593	593	593	593	593
Seedlings	1607	1607	1607	1607	1607	1607
Fertilizer	2162	2267	1994	1509	2329	2242
Water	2051	1936	5781	2468	6068	2705
Total						
Incl fam l+tl	12502	11791	16064	11566	16687	12535
Excl fam l+tl	9413	9062	12976	8837	13597	9806
Gross Output	25304	11781	23545	9871	24466	11122
Net Return						
Incl fam l+tl	12801	-11	7482	-1694	7780	-1413
Excl fam l+tl	15891	2718	10571	1035	10869	1316

Footnotes: 1. l+t = labour and tillage costs supplied by family owned resources.

fixed cost, or by fixed cost and farmers' fuel the returns to managers over the cost of supplying water appears to be negligable. However, they benefit from larger than average areas within the command area, and managers obtained significantly higher yields than other farmers. This is presumably the result of allocating more and more timely water to their own plots, and having lower risks on water supply they may well apply more other inputs. (However, incomes, as opposed to output/ha, are for various reasons difficult to compute).

The returns to owners of water who charge by share payments are very large. Where these returns are distributed within a group, as in the case of Grameen Bank and some others, the effect on individuals' incomes from water selling are not so large per person[4]; but if a single individual or small group controls the water supply the effect on income can be enormous. The variablility of incomes from water selling is high and does not necessarily correspond with the presumed distribution of risk by payment system. Thus it is often assumed that share payment distributes water supply cost risks to the water seller and cultivation risks to the buyer, while fixed cost systems share water supply cost risks; however where fixed charges are paid in installments and may be incompletely realised the distribution of risks may be more even between the two systems. There is some evidence that on schemes where there has been crop damage fixed payment schemes realise higher water payments than share payment schemes, and the reverse where yields are good. Just as there has been some tendency for shares paid for water to fall, the level of fixed payments has risen following privatisation.

The share payment system for water entails a redistribution of income towards those who control water. In Gazipur where the wage rates and irrigation costs are higher this diversion would have to come at the expense of either landowners or labour; there is not a great enough surplus to pay the established shares for water and land in Gazipur. This suggests a reason why the share payment system for water has not yet become established in Gazipur. Nevertheless the lack of substantial profits to water owners has not prevented a greater capacity utilisation in this district where cultivators are able to cooperate; what requires explanation is why it is that on some schemes cooperation exists, as manifest in high command areas and associated with fixed cost payment systems.

Finally it is worth noting that the performance of Grameen Bank tubewells, as shown in Table 2, was achieved despite universally charging on a share payment basis. The range tests show that for DTW in Ghatail the Grameen Bank groups had significantly (at p>5%) greater command areas and outputs

[4]Although it should be noted that a significant process of concentration of ownership of shares has been occurring with Grameen Bank groups (Mandal, 1986b)

than the BRD-KSS. This was despite being less able to provide seasonal agricultural production credit to the farmers within their command areas than other groups. The Grameen Bank STW groups also performed well, having significantly larger command areas and total outputs than all other groups except those sold through BADC.

3. GROUP MANAGEMENT OF IRRIGATION

Although there was a period when DTW were sold to individuals the norm in Bangladesh has been to make them available through groups of the cultivators in the command area, whether these are formal KSS groups or informal groups. The official rationale for this policy have been partly based on the assumption that irrigation is best managed by the water users as a group, and partly on the desire to avoid "water-lordism" that it was suggested individual ownership might cause. The following case study of a KSS DTW groups shows how at least one KSS group was constituted and functions.

3.1 Water Users Cooperatives - the "G" KSS DTW.

The "G" KSS was formed in 1979 on the initiative of its present Chairman and Manager, with the intention of obtaining a DTW with a BRDB loan. In 1981 eighteen of the members approached BADC to purchase a DTW. Their map showed a potential command area of 72.36 acres with 25 cultivators. The DTW, whose purchase price was Tk 50,000, was installed in December 1981 and commissioned in December 1982. A down payment of Tk 10,000 was paid by 16 people, only 11 of whom were KSS members. BRDB sanctioned a loan of Tk 40,000 against the 16 people in the DTW group to be repaid over 5 years; apparently only Tk 10,000 has been repaid by the end of June 1986. It was reported that an incentive of Tk 5,200 had to be paid to officials to obtain the installation. The DTW had a second hand diesel engine for the first two years, but in 1985 the tubewell was electrified following payment of Tk 32,000, for the connection alone, to a contractor; at the same time the contractor made 6 domestic connections for Tk 1,500 each, and two STW for Tk 15,000 each, to the same line. The diesel engine was sold for Tk 14,000 and an electric motor and accessories purchased for about Tk 20,000. No meter was connected to the line. The local Power Development Board presented one bill for Tk 14,800 despite frequent power cuts, based on average consumption. The tubewell owners ultimately succeeded in getting the bill reduced to Tk 8,000 after a process of bargaining which included at least one deliberate power cut by the PDB and heavy protests and demonstrations outside the PDB office.

The same set of people control both the KSS and the DTW; the 16 DTW owners are members of four clans who are related by marriage, friendship and business connections. The chairman (of both KSS and DTW group) manager, and driver of the DTW control its activities and only their signatures are required for loan transactions. (Most loans received from BRDB are distributed to a minority of the DTW/KSS members, who divert some of the money to their businesses).

There were 85 farmers in the 1986 command area of 12.63 hectares, which was 4 ha less than in 1985. The main cropping pattern for the irrigated land is boro-amon while on non-irrigated land it is aus/jute-transplanted amon. This DTW is clearly underutilised; not only is the marginal cost of water effectively zero, since there is no electricity meter, and because there is no reason to think that maintenance costs would rise greatly with more pumping, but also the pump did not run for considerable periods when electricity was available, and water often went to waste. The potential to expand however is constrained by topography, and encroachment. To the east of the tubewell a depression which would require an expensive raised and lined canal for several hundred feet limits expansion; also the land that could then be irrigated is already irrigated by an STW belonging to a non-KSS member of the village. Discussions suggested a reluctance to compete with this water supplier to avoid the ensuing "chaos" that the conflict with this supplier would entail; this person, although not a close relative of the dominant members of the KSS was a neighbour. To the north there are some potentially irrigable lands, but they belong to members of other villages in that direction, and are irrigated by two STW owned by residents in those villages, which were installed before the KSS DTW. To the west the land rises towards the road, and the soil is more sandy; it is not really commandable by this tubewell.

The main opportunity for expansion of the "G" DTW lies to the south; but to the south and south-east the land is owned and cultivated by members of a different village and irrigated by a STW owned there. As a result of a dispute with the owner of that STW some villagers have indicated that they may move to the "G" KSS DTW next year. To the south west the command area of the DTW was encroached in 1986 by an STW owned by one of the prominent KSS members, who is also owner of the brick field that lies on the edge of the command area. He is a close relative of the KSS Chairman, although the relationship between them was not good; he is, however, described as a close friend of the Manager, who, like this STW owner, is an owner of a brickfield nearby. This STW commands some high land that could not easily be commanded by the DTW, but has also encroached some low lying lands. There appears to be no relationship between this man and the farmers he is supplying, except that they come from the same village; however he is described as a local mediator.

This action may represent the sort of "easy-riding" to which cooperatives are subject; this man as a member of the cooperative has a return from irrigating the encroached lands through the cooperative equal to 1/16th of the net share of output going to the cooperative, whereas as an individual he can obtain the whole share going to water, less his operating and maintenance costs. Since the STW is also used to supply water to his brickfields management costs for the STW are likely to be low. His low lands benefit from spillage waters, and seepage from the KSS DTW. None of the KSS members individually has a strong incentive to defend their command area against this encroachment, not only because they individually only get a share, but also because he is relatively powerful and those who could least afford to loose the income from the encroached area would be least able to oppose him, especially if he comes to an arrangement with the Manager.

Given the low marginal cost of water and the physical and social barriers to expansion in all directions, and the dilution of incentives faced by the KSS members, it is not surprising that their proposed strategy for expanding the command area seems to be lowering the share paid by water users from the present 25% to 20%. Not only would they each benefit individually as farmers within the command area, but also, one can hypothesise, this is their best means of enticing farmers from other social arenas into their sphere without incurring the social friction that a more direct attempt at encroachment would entail.

An interesting contrast with "G" is provided by the "B" DTW which is not far away and lies in the same agro-ecological and administrative region. This DTW is privately owned by the Secretary to the Union Parishad but has a larger command area (17.84 ha), and efficient water supply. Water is also sold to users for 1/4 crop share. This case goes to show that private individuals can achieve better performance than KSS in some circumstances (for more complete details see BAU, 1986).

When considering the relationship between KSS, "water users' groups" and performance on the basis of the evidence presented here it needs to be noted that KSS cannot generally be considered proper cooperatives; the situation at "G" of concentrated ownership of the tubewell within the KSS membership and share payment for water was common. In 3 out of the 6 KSS DTW in Ghatail (including 1 KSS within IMP) there were fewer than five "owners". In none of the KSS groups were all the cultivators members of the KSS, let alone party to the management and control of the DTW. Six of the 8 KSS STW had single effective owners. Five of the 6 KSS in Ghatail charged a share payment for water, including one of the IMP KSS. On the other hand 5 of the 12 non-KSS DTW had group management, and 4 of the 12 non-KSS had fixed payment systems for water (2 of these 4 with fixed payment were "owned" by fewer than 5 people). In Gazipur 6 out of 16 non-KSS DTW had the farmers' fuel system, while 4 out of the 9 KSS had this system, which was associated with lower productivity; thus 4 out of 9 non-KSS/non-CARE DTW, with fewer than 5 "owners", had fixed payment managers' fuel system. These examples show that there is no necessary connection between choice of water contract and form of management; the very small number of cases in each combination of management institution, ownership group size, district and water contract prohibits testing for performance differences by this breakdown, but indicates what might be done with a larger sample.

4. ACCESS AND COMPETITION MORE GENERALLY

A number of the findings both about the dynamics of ownership and of command area negotiations can be amplified from a follow up survey conducted in 1986 of deep and shallow tubewells in Ghatail Upazilla only. These findings can be summarised under the following headings; mobility and mortality of tubewells, command area adjustments, changes in payment systems, changes in cropping patterns, changes in power source from diesel to electric, and mechanical breakdowns particularly of diesel engines.

4.1 Tubewell Mortality

One of the 18 DTWs in Ghatail had broken down and was consequently out of action; two of the three GB DTW had changed ownership. Eight out of 33 STW were in the same site 1986 as they had been in 1985; 4 had been sold because of serious mechanical breakdowns and serious management problems. Three STW were kept idle, one because the command area was covered by the STW owner's DTW, one because the command area had been submerged by sand brought down by the river flooding, and the last because of conflict within the managing group. One STW was shifted to another site because of factional conflict among the command area farmers. Some of the vacated command area was irrigated from other sources.

4.2 Changes in Command Areas

Only 2 out of the continuing 15 DTWs had no change in command area; 5 DTW command areas increased by an average of 1.4 acres, and 8 decreased by 3.5 acres. 14 of the command areas of the 25 STW that remained in operation decreased by an average 1.7 acres, 7 increased by an average of 1.7 acres, and 4 remained unchanged. Thus in both DTW and STW there were significant net decreases in command area of 1.45 acres per DTW and 0.5 acres STW (this excludes those that were out of operation). The reasons for changes in command areas are as follows. 18 out of 34 changes were to non irrigated crops because they were more profitable or because the plot was too expensive to irrigate; the changes out of boro were brought about partly by the rise in the expected price of jute following the high price in 1984, and partly due to the rise in fertilizer prices causing expectation of reduced boro profits. 12 out of 34 changes in command area were shifts between tubewells; the remainder were a combination of the above. The shifts between command areas were brought about by a number of factors including: (1) shift to tubewell with better record of mechanical reliability; (2) to a tubewell closer to the plot than the previous supplier; (3) to a well that started irrigating comparatively early; (4) to a well with lower water charges (e.g. from crop share to fixed cost); (5) to a well whose owner has more control or power over the plot's farmer; (6) to the well whose owner is more trusted, often a kinsman or neighbour.

4.3 Changes in Water Payment System

While a common cause of decline in command area of DTW was by shift of plots to STW the reverse also occurred. Some plots shifted from STW to two DTW; these were also shifts from crop share payment for water to fixed payment. Two of the other DTW changed the payment system from fixed to crop share; the remaining 2 DTW maintained the fixed payment system, which we found to be associated with higher productivity in 1985. In one DTW the crop share system was resisted by strong organization by the command area farmers, and on the other by cooperation and trust among the water users.

In another case a DTW which had been rented from BADC was sold to a small group who changed the payment system from fixed cash to crop-share; however the threat to install two STWs within the command area by some water users persuaded the small group to incorporate more of the users and to revert to the fixed average cost system. The crop-share has tended to decrease from an initial 33% to the presently dominant 25%; a few wells have shifted to 20% but there was one case of a change from 20 to 25% to encourage the supplier to provide a better service.

Another significant change from 1985 was the refusal by farmers to pay linemen, who were responsible for the distribution of water through the canals to the fields; instead the water supplier was responsible for their payment (which had been about 23kg paddy per acre in addition to the crop share).

4.4 Breakdowns of Tubewells

Serious mechanical breakdowns have become a feature of the irrigation supply; 4 out of 15 DTWs had a serious breakdown, and the 25 STWs, which were between 3 and 6 years old in most cases, had repair bills between Tk. 2,000 and 7,000. This plus the low running speed entailed by the use of substandard spares and maintenance procedures constitutes a heavy cost to water suppliers, and the economy.

4.5 Electrical Connections

Because of the low cost of electrical power and the greater reliability of electrical motors compared to diesel electrical connections are keenly sought. Acting as contractor for tubewell owners in obtaining connections has become a business; contractors receive large deposits and sometimes get the free use of the tubewell for a number of years (three in the cases encountered) as payment. Connections to a tubewell often provide the opportunity for domestic and other connections as well, which are often unmetered. Charges vary; the "G" case can be contrasted with a DTW owner who paid a deposit of Tk. 16,500 to a contractor as a down payment for a connection. Once connected the supply of electricity and payment of electricity charges become matters of bargaining and negotiation between the tubewell owners and staff of the Power Development Board and Rural Electricity Board, illustrated by "G".

4.6 Summary

This brief review of developments in 1986 indicates that the groundwater market in Tangail is quite dynamic; water suppliers are seeking more economic sources of power, and more economic use of their equipment by screening plots (and command areas); water users are seeking more satisfactory sources of supply by screening water suppliers. The terms and conditions of sale of water, although predominantly one-quarter crop share, are quite variable and have not stabilised; the quantity and timing of water supplies is left to the water supplier who hires a driver and linemen, and generally does the management himself. A dissatisfied water user can put some pressure on a supplier by organising a protest with other users, and by threatening to install another STW, or change to another water supplier.

Both the water supply and demand curves are shifting as economic conditions change, and as agents become more aware of the costs and returns involved, and more experienced with the technology. The downward movement in command areas, without an obvious increase in irrigation intensity or yields is probably largely due to competition among water suppliers, and to aging of the equipment and the less favourable economics of boro cultivation. Water suppliers are more aware of the need to avoid straining their engines to supply large command areas, and farmers aware that given high water charges, and less favourable input/output price ratios boro has become less attractive especially if water supplies are unreliable. The avenue of increasing command areas by obtaining electrical connections is widely sought, but it is subject to "rent-seeking" since contractors act as intermediaries with the electricity agencies, and as the latter uses its control over power supplies to extract resources from farmers.

5. HYPOTHESES ARISING

It should be emphasised that the work reported here was based on very slender resources, and because of this the conclusions must necessarily be tentative. The aim has been to raise a number of issues and to indicate topics for further research.

Firstly, no satisfactory method of determining optimal tubewell capacity utilisation exists; thus we have made comparisons on the basis of command areas and yields, but the potential command area may be more limited in some areas than others. Yet there are no guidelines as to how to estimate the potential. If two DTW have command areas of 40 acres, one may have a potential of 60 acres, and the other a potential of 40 acres. In this case the first achieves two-thirds while the other has 100% capacity utilisation. Actual capacity utilisation should be compared with the optimum rather than a fixed figure. One of us has developed a model that allows a definition of the economic optimum capacity of a multi-user irrigation scheme where the manager does not control the decisions of the water users (Palmer-Jones 1987); previous economic definitions of optimal irrigation management practices have assumed complete control of cropping and water application regimes by the manager.

Secondly, despite the limitation imposed by the lack of a clear definition of optimal capacity, a number of findings seem important:

- the formal management institution under which a tubewell is managed is not strongly associated with performance, and the experimental programmes based the establishment of water user groups to perform water management have not been outstandingly successful. Following from this, for example, we can see that the optimism of Coward and Ahmed that "local inventiveness and bureaucratic tolerance" would lead to successful irrigation management in KSS groups has proved to be unfounded; a notable example of what they have in mind is the adoption of share payment systems for water, and yet this appears to be associated with lower levels of productivity.

- the payment system for water is strongly associated with performance. Without assuming that this caused the difference, this points to the need to study the economic and institutional factors determining the choice of contractual form (and its *effects). It may well be that there* are "structural", such as the unequal distribution of land and power, as well as technical, ecological and economic factors limiting tubewell capacity utilisation.

- the benefits from conceptualising what is happening in minor irrigation in Bangladesh as an imperfect market, interlinked with other imperfect market and bureaucratic processes. This point of view complements rather than replaces the technical emphasis of most work on irrigation, and, we believe, provides a means to put technical and ecological factors into economic terms; it also enhances and provides the possibility of quantifying the views of the water management sociologists and *anthropologists. Indeed we hope that our work,* which involved innovations in field studies by irrigation engineers as well as economists, will encourage other to employ effective interdisciplinary approaches.

- the apparent downturn in growth of minor irrigation. From our description of the negotiations between water sellers and buyers in Ghatail, the changes in command areas, and the terms and conditions of contracts it is apparent that economic factors play a large part in the determination of command areas and cropping patterns. However there remain considerable apparent inefficiencies, most evident in the wide variation in command areas despite apparently uniform technical and ecological conditions. Thus to some extent both of the points of view about the reasons for the downturn discussed earlier find some support from our evidence. However we cannot go on from this to support without qualification either of the policy prescriptions advanced by these contending parties. We do not have space here to argue these views in any detail, and we have drawn on other work to derive the following conclusions. It seems to us that the reintroduction of input subsidisation and bureaucratic control, whose workings are still manifest in the imperfect factor markets we have discussed, would be unlikely to advance efficiency or equity greatly; nor does it seem likely that the policy of promoting irrigation efficiency through IMP, or similar programs predicated on the need for water users groups, with their high drop out rate, heavy costs, and limited and apparently short lived effects, will significantly improve irrigation productivity. Our own view is that irrigation can also be managed by "entrepreneurs" but there are obvious dangers if resources are concentrated in too few hands. Success of the landless irrigation program or its equivalent however is probably dependent on effective political will. In the absence of political will the task of improving minor irrigation capacity utilisation will be all the more difficult, and will probably include elements of both subsidy and institutional innovation. The general aim however should be to make the water market more efficient and equitable rather than to eliminate it or to let it imperfectly take over the tasks of resource allocation and income distribution.

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STATISTICAL ANNEX

Table A1. Prices of irrigation equipment (current prices)

		DTW		STW
	Procure ment	Rent	Sales1 (new)	Sales2
Year	'000 Tk	Tk/year	'000 Tk	'000 Tk
1975-6	140	1200		(10-12000)
1976-7	160	1200		"
1977-8	160	1200		"
1978-9	180	1200		"
1979-80	220	1200		"
1980-1	260	1200	60	17
1981-2	340	1200	60	20
1982-3	310	1800	70	25 (32)
1983-4	407	3000	85	28 (35)
1984-5		5000	112	(28-35)
1985-6		5000	220	(30-35)
1986-7				

Sources: BADC, and field surveys by authors

Note: Figures from 1983-4 have to be treated with considerable caution as they have been derived from fieldwork rather than official sources in many cases.

1 Sales prices of STW between 1980-1 and 1983/4 are BADC official prices for new Yanmar ts70 engines and standard accessories (pumps, pipe and strainer, excluding installation - see Gill, 1983); those in parentheses are from field survey information and refer in some cases to different models and accessories.

Table A2. Prices of Main Agricultural Inputs and Outputs, Crop Acreages and Fertilizer Use.

	Paddy (farmers) tk/ton1	Offical Fert/paddy price ratio Urea (tk per ton)	TSP	Fertilizer Consumption Urea	TSP '000 tons
1974-5		.90			
1975-6	1955	1.59	1.19	312	110
1976-7	1741	2.00	1.60	353	126
1977-8	2192	1.59	1.27	480	192
1978-9	2542	1.60	1.26	470	177
1979-80	3273	1.60	1.24	531	202
1980-1	2698	1.84	1.80	560	214
1981-2	3440	2.08	1.77	518	208
1982-3	4020	2.15	2.02	619	202
1983-4	4344	1.99	1.87	708	260
1984-5	(4300)	(2.21)	(2.14)	831	346
1985-6	(4690)	(2.28)	(2.21)	647	259
1986-7	(5390)	(1.87)	(1.87)		

Sources: BBS, Statistical Yearbook of Bangladesh, various issues

Note: 1 Ideally seasonal expected prices of paddy should be used.

Table 3 continued.

	aus	amon	Acreages boro m. acres	wheat	jute	Jute price tk/mnd	Diesel fuel tk/lt	Reported ag. wage tk/day
1974-5	7.86	13.47	2.87	.31	1.41			9.05
1975-6	8.45	14.24	2.84	.37	1.28	85	9.05	8.82
1976-7	7.95	14.36	2.11	.40	1.60	115	9.28	8.93
1977-8	7.81	14.26	2.70	.47	1.80	159	11.46	9.44
1978-9	8.00	14.35	2.62	.65	2.05	134	13.79	10.88
1979-80	7.50	14.76	2.84	1.07	1.87	110	22.52	12.46
1980-1	7.68	14.92	2.87	1.46	1.57	111	23.66	13.96
1981-2	7.77	14.85	3.22	1.32	1.41	116	33.67	15.48
1982-3	7.80	14.81	3.54	1.28	1.42	193	33.67	17.05
1983-4	7.76	14.85	3.46	1.30	1.43	203	33.67	19.58
1984-5	7.26	14.11	3.89	1.67	1.49	433	33.67	24.45
1985-6						(207)	33.67	(30)
1986-7							33.67	(30)

Sources: Bangladesh Bureau of Statistics, Statistical Yearbook of Bangladesh, Statistical Pocketbook of Bangaldesh, and Monthly Statistical Bulletin, various issues; figures in parentheses are derived from fieldwork.

Table A3: Technical Characteristics of Tubewells (mean values).

TECHNOLOGY by DISTRICT by INSTITUTION	Dis-charge lps	Operat-ing Hours	Speed Ratio	Estimat-ed head m	Water loss %	Canal density m/ha
Deep Tubewells						
GHATAIL-KALIHATI						
BADC RENTAL	45.76	769.80	.68	12.61	17.57	61.50
BADC SALES	46.83	895.25	.78	12.10	11.45	42.79
KSS IMP	51.14	850.00	.83	13.22	27.35	40.11
KSS	47.69	647.25	.82	12.25	21.10	41.75
GRAMEEN BANK	40.89	1191.3	.61	11.67	14.55	63.00
TOTAL	46.21	849.61	.74	12.33	18.33	50.83
GAZIPUR						
BADC RENTAL	24.90	938.29	.56	15.08	16.13	90.81
BADC SALES	29.32	1041.5	.68	18.41	16.60	50.13
KSS IMP	31.81	1084.7	.58	15.40	7.70	46.63
KSS	26.77	631.83	.55	16.53	14.83	93.97
CARE	31.15	1144.0	.61	16.26	7.27	62.41
TOTAL	28.14	939.96	.59	16.62	13.06	74.08
Shallow Tubewells						
GHATAIL-KALIHATI						
BADC SALES	13.07	906.27	.83	-	26.88	91.21
KSS	10.09	1000.6	.60	-	25.10	110.47
GRAMEEN BANK	11.79	1034.3	.65	-	25.98	64.98
BKB	13.32	993.33	.77	-	26.12	95.62
TOTAL	12.38	975.33	.75	-	26.22	88.97

Source: Field Survey by BAU group, 1985-66

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IRRIGATION MANAGEMENT NETWORK

ECONOMICS OF FARMER PARTICIPATION IN IRRIGATION MANAGEMENT

R.K. Patil

ODI/IIMI Irrigation Management Network 87/2d September 1987

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ISSN: 0951 189X

ECONOMICS OF FARMER PARTICIPATION IN IRRIGATION MANAGEMENT

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ECONOMICS OF FARMER PARTICIPATION IN IRRIGATION MANAGEMENT

R K Patil

1. INTRODUCTION

One of the implicit assumptions for the advocacy of irrigated agriculture is that the water availability is per se beneficial to the farmers, as it increases the productivity of the land and hence the farmers' incomes. So no farmer would abstain from the use of water, if this is available in adequate quantity. On this assumption, benefit-cost studies are done at the macro level to justify major and medium surface irrigation projects.

Of late, it is also suggested that if the management of water allocation and distribution were done by the farmers themselves at the tertiary and quaternary levels of the canal system, the benefits to the farmers would be more than they are at present. To-day, most of our public systems are managed by the bureaucracy right from headworks up to the farm gate. The bureaucracy establishes a clientele relationship with each and every farmer and is responsible for the operation and maintenance of the total system. The experience shows that bureaucratic management at the tertiary level is inefficient and prone to corrupt practices. Inadequate and untrained manpower, indifferent physical system, lack of knowledge of modern irrigation methods on the part of irrigators, are also responsible for the poor management. It is felt that if farmers' associations or societies are formed, these will bring in the needed efficiency. It is on this premise that the Sixth and the Seventh Plan documents endorsed the suggestion for the formation of water users' associations (WUAs). However, past experience shows that none of these assumptions has been validated in the field. Under-utilisation of water remains a fact of life and in spite of many incentives declared by the Union Government, and further aided by the World Bank, progress in forming WUAs has been extremely slow. It is, therefore, necessary to examine the assumptions in greater depth and find out the reasons for the current state of affairs. Such an analysis may help in making the necessary policy changes.

At the outset, it may be stated that full utilisation of project water and related farmer behaviour are affected by a complexity of interactive factors: technical (the state of the physical system including drainage, reliability and stability of water), agronomic (soil conditions, suitability of crops) economic (price relations, marketing and credit facilities) and sociological. In this paper, we shall limit ourselves only to the financial and related aspects with a ceteris paribus assumption in respect of other factors.

We may start by raising two questions: why should a farmer take advantage of water available through public systems on conditions stipulated by the Agency and why should he collaborate with fellow farmers in forming a WUA for managing the distribution system in a small size command area, say of an outlet or a minor (40–300 ha)?

The rational answer to both the questions is almost simplistic. He would behave in the desired manner, if the costs he had to incur in both cases were lower than the benefits he was likely to get, and the surplus was sufficient to induce him to undertake the needed agricultural production and the processes thereto. We have to analyze the implications of this expected rational behaviour in respect of the issues raised.

2. ECONOMICS AND POLITICS OF IRRIGATED AGRICULTURE

Pursuing the above logic, one can say that a farmer in the command area would use irrigation water if the returns which he would get (ie physical production multiplied by the expected prices) exceeded the costs he had to incur (input costs including the water charges). If not, he may prefer rainfed agriculture or other ways of earning his living. This paper will not pursue the question of incomes from irrigated agriculture further, except to emphasise its importance in understanding the farmers' behaviour. We wish instead to focus on the incentives to form WUAs. First, let us review their objectives. It is said "active farmer involvement is cost effective in terms of the mobilisation of local resources, improvement and maintenance activities, reduction of irrigation department staff time, provision of local wisdom for better design and planning of systems, reduction in the destruction of facilities, improved fee and fine collection, resolution of disputes and provision of an organised means of extension and farmer training." (Lowdermilk 1986).

The individual farmer may not be interested in saving the time of the departmental staff, cost recovery, etc. His simple question would be: How do I personally benefit from joining the society? If he or the society saves water, will any benefits accrue to him individually and, if so, in what form? Once the society is formed, there will be some collective costs, which he will have to share. Does he get tangible benefit from the costs so incurred? These questions need to be answered, before societies are formed by direction or by persuasion.

The process of establishing a WUA is complicated by many factors. Some mentioned by Carruthers et al (1985) are:

the roles and expected objectives of the associations are inconsistent with each other or unfocussed;

role expectations are unrealistic, given the resources and authority of the associations;

the responsibilities of the association are too trivial or undesirable to generate farmer commitment;

farmers and officials have inconsistent or conflicting definitions of their respective roles;

groups are too heterogeneous or too large to function;

farmers do not have enough technical knowledge to enable them to make reasonable decisions;

officials are unwilling to share information or authority;

farmer leadership is weak, inexperienced, or faction ridden.

As can be seen from the above list, there is a socio-political angle to WUA formation. Quite apart from weaknesses amongst the farmers, there is a question of power between officials and groups. The 'official' thinking is that groups will take away some of their management headaches, which is the main advantage of group management from their angle. However, groups are only willing to take responsibility provided it helps and benefits them as a group and as individual members. For this to happen, the Irrigation Agency must shed some of its powers and hand them over to groups. Unfortunately bureaucracy does not like surrendering powers, justifying this by a plea that it is the custodian of public interest. This plea has to be examined to see whether, in regard to each power involved, the public interest is really best served by the retention of control by the Irrigation staff, or whether there are other means of safeguarding public interest, and whether the staff are already so perfectly guarding the public interest that WUAs are likely to make the situation substantially worse, etc.

3. SUCCESSFUL AND UNSUCCESSFUL WUAs

Even if we assume the problems posed by the above factors are overcome, some financial and motivational problems would still remain.

a. Minors 5 and 7, Mula command

In Minor 5 of Mula Command, as a prelude to group formation, a rotational water supply (RWS) system was introduced and implemented. This meant costs to the responsible Agency. It was presumed that once the benefits were known, farmers would take over the system, and after RWS proved successful and beneficial, farmers would be asked to form a group. Their answer was: "What for?" They felt the RWS as operated by the Agency was quite satisfactory, and there was no need for them to take it over. It should be noted that Minor 5 is on an easily accessible route. VIPs are taken there to be shown the success of RWS and every care is taken to see the schedules are maintained and enforced. What this experience highlights is that unless something in the existing system causes dissatisfaction to the individual farmers, which could be corrected by forming an association, no WUA will be established. Farmers will not join groups unless the benefits from membership outweigh the costs. In the above example, the costs of improving the water supply were born by the Agency, leaving farmers with no incentive to come together. By contrast, on Minor 7, which is more out of the way, farmers found that about six months after the introduction of RWS, the benefits of which they appreciated, the old problems began to occur again. Therefore, they have become interested in forming a Society and appointing their own waterman to supervise distribution. However, they are first asking for answers to cogent questions about society income, crop area rates, and whether they are free to change the cropping patterns. They have evident concern on financial matters before they proceed further.[1]

Let us, however, assume that by deliberate policy a situation is created which induces farmers to organise for collective action, and that they find it is in their interest to take over the management of a system or part of a system. The next question which requires examination, is the financial viability of the group and the policy changes necessary to ensure this viability. When a WUA is formed, some collective costs will be incurred to meet staff and administrative expenses.[2] These costs must be covered by some income source to ensure the long term sustainability of the group. The usual income of the WUA will be irrigation charges. In the case of a WUA managing a part of a system, such as a minor, the WUA has also to pay the Irrigation Agency managing the whole system water charges. It is therefore obvious that there must be some surplus between what members pay to the society and the irrigation dues that the society has to pay to the government. If the Agency charges the same rates to farmers that have

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[1] For further details, see RK Patil, "Experiences of farmer participation in irrigation management: Mula Command. Ahmednagar, Maharashtra", in Irrigation Design for Management, published by Hydraulics Research Ltd, Wallingford, UK, 1986. For these and other case studies see also Centre for Applied Systems Analysis in Development, 1987, "Farmer Managed Irrigation Systems: Indian experiences", No 2 Rehem Mansion, 44 S B Road, Colaba, Bombay 400039.

[2] *Theoretically, farmers could avoid some cash costs by contributing physical and organisational work themselves on a voluntary basis. However, it will often be found that farmers prefer to specialise on their farming activities and to hire in operational staff, contract out for repairs, etc. In almost all cases, some cash costs for materials, fuel etc cannot be avoided. Therefore it is safest to make the assumption, as R K Patil does, that measures will be necessary to give financial viability to WUAs.* (Ed., Mary Tiffen)

formed groups and to those that have not, there is no reason why the WUA should take *management responsibilities which increase their costs.* So there is a need for a policy to charge groups at lower rates than individual farmers. Unfortunately, in their enthusiasm for group formation, the State Irrigation Departments have neglected to analyse this problem and find a solution.

Informal discussion with irrigation officials of Maharashtra and Gujerat (where a few efforts at group formation are to be seen) suggests their thinking is that if societies are charged on a volumetric basis and the members on a crop area basis, there would be enough surplus to make the societies viable. This is not always the case, as two contrasting examples show.

b. Experience of the *Mohini Water Distribution Co-Operative Society*, Gujerat

One highly successful society is the Mohini Water Distribution Co-operative Society in Gujerat state. Briefly, the Society was established in 1979 with a membership of 142 farmers in a 428 ha command served by 3 subminors of the Kakrapara irrigation system. Financially it became an instant success, distributing a dividend of 12% from the second year onwards. It is given the highest classification 'A' by the auditors of the Co-operative Department. It has a reserve fund of Rs 16,000, and Rs 160,000 earmarked in different funds. It owns a tractor, which is leased to members for cultivating operations. The Society is responsible for the payment of irrigation charges to the Department and these are fully paid every year. The staff are well paid, by local wage standards. In accordance with the agreement with the Irrigation Department of Gujerat State, the Society is charged on a volumetric basis and the Society charges its own members on a crop area basis. The volumetric rate was fixed at Rs 3 per $100m^3$. The current crop area rates are shown in Table 1. To understand the financial success of the *Mohini Society* it is *necessary* to analyse the volumetric rates per ha of crop (costs to the Society) and the scheduled crop area rates (gross income of the society) as is done in Table 1. It will be seen that surplus is available only from the sugarcane, orchard and cotton crops. Other crops have a deficit. At present prices, the society makes a profit only if the major area is put under sugarcane. If the major area was under

Table 1. Estimates of Water Charges on Volumetric Basis and Comparison with Irrigation Rates on Crop Area Basis (ha)
Mohini Water Distribution Co-operative Society, Gujerat

Seasons	Crops	Water requirement as per modified Penman formula (in mm)	Total water requirement after adding losses @ 17.5% (in mm)	Water requirement in cubic metres per hectare	Value of water needed @ 30 paise per 10 cubic metres (in Rs)	Current Crop Area Rates per ha (in Rs)	Surplus or Deficit (in Rs)
Kharif	Sugarcane	215.8	261.5	2615	78.5	170.0	92.5
Rabi	Sugarcane	417.6	506.2	5062	152.0	290.0	138.0
Hot	Sugarcane	927.4	1124.1	11241	3370.0	370.0	33.0
Kharif	Paddy	557.3	675.5	6755	202.0	110.0	-92.0
Rabi	Vegetables	227.0	336.0	3360	101.0	100.0	-1.0
Hot	Vegetables	600.0	727.0	7270	218.0	140.0	-78.0
Kharif	Others	-	-	-	-	60.0	-
Rabi	Others	277.2	336.0	3360	101.0	100.0	-1.0
Hot	Others	601.2	729.3	7293	219.0	140.0	-79.0
Rabi	Wheat	450.0	545.0	5450	163.0	110.0	-53.0
Rabi	Sorghum	315.0	382.0	3820	115.0	100.0	-15.0
Pre-Kharif	Cotton	11.5	14.0	140	4.0	-	-4.0
Kharif	Cotton	333.0	403.0	4030	121.0	75.0	-46.0
Rabi	Cotton	153.0	185.0	1850	55.0	125.0	70.0
K + R + H	Orchards	770.0	933.3	9333	280.0	570.0	290.0

Table 2. Prescribed and Actual Cropping Patterns in Mohini Command

a) Prescribed (from Modernisation Report, 1978)

		Percentage Area
Kharif		
(Paddy, Sorghum, Pulses, etc)		27
Rabi		
Sorghum	13	
Wheat	10	
Pulses and Vegetables	15	38
Perennials		
Sugarcane		18
Others		8
Two-Seasonals		
Cotton		2
Hot Weather Vegetables		5
		98

b) Actual

Sugarcane	88.5
Paddy	5.0
Vegetables	0.5
Cotton, Fodder, and Wheat	0.5
Others	5.5
	100.0

food grains, the society would make losses. The Mohini Society became a financial success because more than 85% of the area was put under sugarcane, instead of the prescribed 18%.

In most Indian public irrigation systems, there is a prescribed cropping pattern based on the pattern estimated at the time the project was formulated. Though the design pattern should in theory be respected, the actual pattern varies considerably. If the Mohini Co-operative followed its prescribed cropping pattern, shown in Table 2 (a), it would be in deficit. Any group or society who abided by the prescribed pattern would not be viable, since the surplus is too small to cover its administrative and staff costs. The financial success of Mohini is primarily due to the sugarcane biassed crop pattern, followed in practice (Table 2b).

c. The Siddeshwar Water Distribution Society, Maharashtra.

An actual example proves the case. The data is from a Maharashtra Irrigation project where sugarcane is unimportant. The Siddheswar Water Distribution Society was registered early in 1986 to take over the management of Direct Minor 4 in the Bhima Project, Solapur District. The Society took over the management from the rabi season, 1986-87. Tables 3 and 4 present the financial data. Table 3 shows the finances of the society on a volumetric and crop area basis, based on the design crop pattern. The exercise is done for 200 ha assuming a cropping intensity of 1.48, as provided in the Appraisal Report. Under these conditions the Society will make a small surplus of Rs. 2404, which is inadequate to meet their collective costs. Table 4 shows what actually happened. The irrigated area totalled 192 ha, i.e. cropping intensity was less than planned and some suggested crops were not grown. Water charges totalled Rs 20,494, on the volumetric basis. However, the society's income, based on the crop area rates, was only Rs 18,195, resulting in a loss of Rs 2,300. They would also be unable to pay the cess to the local government, which is equivalent to 20% of the Government irrigation charge. This short exercise shows that if the society is to be sustained on a long term basis, some more avenues of income have to be sought. Alternatively, it will be necessary to revise charges upwards, or to change crops. It should not be assumed any of these options will be attractive to the Society, particularly without careful investigation of the income that can be derived from irrigated crops compared with unirrigated crops, taking into account the suggested level of water charges. It will be noted that farmers did not grow the suggested groundnuts, cotton, and chillies. If the economics of a WUA are going to depend on the adoption of new crops, it will be necessary to ensure that market conditions are attractive, and that the necessary inputs and knowledge are available as part of the preparatory work for a WUA.

d. Conclusion

In our enthusiasm to set up WUAs we must not forget the financial viability of the society and also of individual irrigators. Otherwise, all efforts at setting up WUAs will come to nought. A careful analysis of the financial situation of the society as it relates to the crop pattern and the rate structure has to be done before they are set up. A policy decision

Table 3. Budget Exercise of Siddeshwar Water Distribution Society (Net Service Area 200 ha) Based on Design Cropping Pattern

Crop	Design Crop Pattern %	Area Under Crops (ha)	Crop Area Rate (Rs/ha)	Income of the Society (Rs)	Water Requirement ($000m^3$/ha)	Water Charges on Volumetric basis	Surplus/Deficit (Rs)
1	2	3	4	5 (Col 4x3)	6	7 (3x6xRs 23.55)	8 (5-7)
Perennials							
Sugarcane	6.3	12.6	750	9450	28.48	8450	1000
Fruit	0.7	1.4	500	700	28.48	939	-239
Kharif							
Sorghum/Millet	32.0	64.0	50	3200	3.5	5275	-2075
Maize	7.0	14.0	50	700	3.5	1154	-454
Vegetables	2.0	4.0	100	400	3.5	330	70
Pulses (Unirrigated)	10.0	20.0	-	-	-	-	-
Rabi							
Wheat/Maize	15.0	30.0	75	2250	9.0	6358	-4108
Local/Sorghum	40.0	80.0	75	6000	4.0	7536	-1356
Gram	7.0	14.0	75	1050	4.0	1319	-269
Vegetables	2.0	4.0	167	668	5.0	471	197
Chillies	2.0	4.0	333	1332	6.5	612	720
H W Groundnut	15.0	30.0	300	9000	6.5	4592	4408
L S Cotton	9.5	19.0	400	7600	6.5	2908	4692
Total	148.5	297.0	-	42350	-	39944	2406
Net Area	100.0	200					

Table 4. Estimates of Siddeshwar's Financial Situation in the Rabi Season 1986-87.

Crop	ha	crop rate Rs/ha	income of Society	Water delivered (day-cusecs)	Government charges at volumetric rate (Rs)
1	2	3	4	5	6
Sugarcane	16.50	300	4950.0		
Sorghum	149.50	75	11212.5		
Wheat	16.15	75	1211.5	355.68 day-cusecs ($870\ 207 m^3$)	667 per million (Rs 23.55 for $1000 m^3$)
Gram	5.65	75	424.0		
Vegetables	0.40	167	67.0		
Maize	1.10	75	82.5		
Others	3.30	75	247.5		
Total	192.60	-	18195.0	355.68	20 493

Deficit = Rs 2289

might be made to charge higher rates to farmers who are not members of a WUA. There has to be some financial incentive to the members of WUAs. Or, if they have to pay more than other farmers, they should be convinced that there will be tangible benefits from a better water service.[3]

4. COSTS AND METHODS OF ORGANISING GROUPS

Finally we would like to refer to the costs that need to be incurred by voluntary agencies and government agencies when initiating the group formation process. So far we have discussed the economics of individual farmers and society. But some costs have to be incurred when persuading the irrigators of the advantages of farmer participation and preparing them for the organisational effort. Unfortunately, no data are available in this regard. The efforts in Mohini were made by leaders from amongst the irrigators. Many Gujerati farmers are already members of co-operatives running sugar factories, and are therefore familiar with the organisational requirements. In Maharashtra, so far, CADAs have done the preliminary work. But no information is available on the costs incurred. The only firm information relates to the Sri Lanka experiment of Institutional Organisers supported by USAID and assisted by Cornell University.

In a pilot area of over 4000 ha in the Gal Oya project command, the Institutional Organisers' experiment was started in 1981. The cost of the programme, including all training, supervision and salaries was about Rs 150 per ha per season. Direct benefits from increased production came to about Rs 225 per ha per season. The cost of the maintenance phase is estimated at Rs 30 per ha per season. The capital output ratio works out at 1:1.5. These calculations do not include intangible benefits like reduced damage to the physical structure, reduced conflicts over water and yield increases attributable to more reliable water which encourage adoption of new

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[3] *This analysis also shows the importance to farmers of being able to manage the accounts of their society. Readers might like to refer back to ODI Irrigation Management Paper 9c, 1984, where G. Belloncle describes a method by which previously illiterate farmers were taught both literacy and accountancy, based on the management requirements of their systems.* Ed. Mary Tiffen

technology. Uphoff (1986) concludes by saying that such a rate of return on 'software' is several times greater than that accepted now on investments in irrigation hardware.[4]

As noted above, we have no data on the likely costs that are needed for organising farmer groups in the Indian situation. However, in September 1985, the Ministry of Water Resources prepared a scheme for farmer participation to be implemented by voluntary organisations. They estimated an annual expenditure of Rs 230 000 for an area of about 1000 ha. It was expected that the organisational work would taper off and in about 3 to 5 years, societies would be able to function on their own, without any outside assistance. This would mean a capital expenditure of roughly Rs 600 000 for 1000 ha in 3 years. Thus, the annual cost would come to about Rs 200 per ha per year. It is difficult to estimate the pay off from this expenditure in monetary terms. But assuming the project became a success, it would lead to water saving, timely deliveries and a consequently favourable effect on yields and hence on the recovery of irrigation charges. There is a presumption that this sort of outlay should give a capital-output ratio of more than 1:1.5 over three to four years. It is time that we tested this hypothesis on a pilot basis. In any case, the present situation is extremely unsatisfactory and efforts have to be directed towards rectifying the obvious weaknesses.

It is our submission that the pilot programme tested in Sri Lanka needs to be introduced into our projects with suitable modifications to accelerate water utilisation. Though precise calculations of costs and benefits are not possible at this juncture, there is a hope, based on isolated success stories, that the experiment would result in a greater payoff. In our situation, there is a need for planned outside intervention into the irrigators' community, which is demarcated by hydraulic considerations, just strong enough to

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[4] *A fuller account of the Sri Lankan programme is given in International Irrigation Management Institute (IIMI) 1986 "Proceedings of the workshop on participatory management in Sri Lanka's irrigation schemes". In this, Perera gives slightly higher costs for the Institutional Organiser (IO) programme. He also comments on the repeated need for training, due to high turnover by IOs who preferred more permanent employment. There is a conflict between the aim of providing only temporary help to farmers in the initial stages of forming a WUA, and the IO's desire for a permanent career.* (Ed. Mary Tiffen)

catalyse the internal dynamism of the community, but sagacious enough not to dominate it. The type of talents needed for this effort are amply available in rural areas. What is needed, is strong financial support for non-governmental organisations. It must be emphasised that any government intervention is likely to be counter-productive and any pilot experiments have to be conducted by the non-governmental organisations. The experience of the Mula project, though limited, brings out clearly the weaknesses of government supported intervention.[5]

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[5] *Readers may like to debate whether, and under what circumstances, non-governmental organisation (NGO) can be effective in instigating WUAs. Are they more suited to test out a model in a few areas rather than introducing them on a large scale? Is there a danger they would be too paternalistic? Would they want to impose social objectives that might not be shared by the farmers?* (Ed., Mary Tiffen)

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odi-IIMI

IRRIGATION MANAGEMENT NETWORK

NEWSLETTER

ODI/IIMI Irrigation Management Network Paper 87/3a December 1987

Agricultural Administration Unit, Overseas Development Institute, London

The Overseas Development Institute (ODI) is an independent, non-profit making research institute. Within it, the *Agricultural Administration* Unit (AAU) was established in 1975 with support from the British Aid programme. Its mandate is to widen the state of knowledge and flow of information concerning the *administration* of agriculture in developing countries. It does this through a programme of policy-oriented research and dissemination. Research findings and the results of practical experience are exchanged through four Networks on Agricultural Administration, Irrigation Management, Pastoral Development and Social Forestry. Membership is currently free of charge to professional people active in the appropriate area, but members are asked to provide their own publications in exchange, if possible. This creates the library which is central to information exchange.

The International Irrigation Management Institute, Kandy

The International Management Institute (IIMI) is an autonomous, non-profit making international organization chartered in Sri Lanka in 1984 to conduct research, provide opportunities for professional development, and communicate information about irrigation management. Through collaboration, IIMI seeks ways to strengthen independent national capacity to improve the management and performance of irrigation systems in developing countries. Its multidisciplinary research programme is conducted on systems operated both by farmers and by government agencies in many co-operating countries. As an aspect of its dissemination programme it is joining ODI in the publication of the Irrigation Management Network papers, to enable these to appear more frequently to an enlarged membership. It has also provided equipment to link ODI's irrigation library into an international irrigation management database centred on IIMI.

ISSN: 0951 1881

NEWSLETTER

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b) Situational Compatibility - The Example of Warabandi by Walter Huppert

87/3e: Developing Effective Extension Irrigation Programs with Appropriate Technology by Marvin N Shearer

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NEWSLETTER

1. ENCLOSURES

There are one or possibly two important enclosures with this Newsletter. The first is from IIMI, and gives details of posts which it desires to fill. The second, which we will either have enclosed with these papers, or which will follow shortly, is from the British Overseas Development Administration (ODA). ODA has been funding the Irrigation Management Network since 1975, through a succession of three year grants to ODI's Agricultural Administration Unit. The current grant expires in March 1989. ODA regularly reviews our activities before deciding on a continuation of its support, and on this occasion, wishes to get the opinion of members. Please take the trouble to fill in and return this form.

2. NETWORK PAPERS AND DISCUSSION

2.1 The current set of papers

The current set of Network Papers focusses on the methodology of rehabilitation and the need for taking a systems view.

The first paper, 87/3b, *Rehabilitation and participation: The views of the engineers*, by Mary Tiffen, reviews the conclusions of the Thirteenth International Congress on Irrigation and Drainage held at Casablanca, Morocco, in September 1987, concentrating on its sessions on rehabilitation. The need for taking a systems view and for incorporating the aims and objectives not only of the government but also of the farmers came out clearly in the discussion of the papers which were presented there. The systems view was presented in a diagrammatic form by Professor C A Fasso, who was the General Reporter for the sessions on rehabilitation. His diagram, *Rehabilitation and Modernization: Why?* is reproduced in 87/3b. It shows the process of diagnosis as to whether design, construction, operation and maintenance are currently adequate. If the latter two are inadequate, the need is for policy and institutional changes rather than for an alteration in the hardware. The diagram also shows the interaction with the social, economic and physical environment; if there are changes in these the original design presumptions are no longer valid, and a modernization programme may be necessary to bring the system into line with new objectives, new technologies and new elements in the economic life of the surrounding region, or with changed conditions in, for example, the watershed or upstream water use. A clear conclusion of the Congress was that the objectives of the users were normally taken into account in the rehabilitation process in countries such as the USA and France; a similar process of identification of both existing problems and the current needs of users, accompanied by negotiation on the type of rehabilitation required and the distribution of costs between the users, the government and other interested parties was recommended as good practice everywhere.

One interesting paper in the Congress showed considerable agreement between US experts with experience in developing countries and Indian engineers that changes in the operation or maintenance system were often of higher priority and likely to bring greater benefit at less cost than physical reconstruction measures.

The process of diagnosis and the identification of physical or institutional changes that will bring the greatest possible degree of conformity between, on the one hand, the system's environment and the objectives of the parties concerned and on the other hand, the selected organizational mode and the hardware provided, can be greatly assisted by a good checklist. I have already commended the general checklist on the management of irrigation schemes, evolved by my predecessor, Anthony Bottrall, after much consultation with the founder members of this Network and which was tested in India, Pakistan, Indonesia and Taiwan. This is still available from ODI as AAU Occasional Paper No 5. It is also useful to have checklists which concentrate on particular aspects. Paper 87/3c, contains two articles. One by H Frederiksen of the World Bank, *Checklist for Incorporating System Operation and Maintenance in Design*, is intended mainly for designers and appraisers of new schemes, who need to keep in mind how the scheme will be operated and why there will be limitations, inherent in the environment particular to that scheme, as to how it can be operated and therefore, in how it should be designed. However, the checklist will also be useful in the diagnosis of rehabilitation needs. The other, *Planning Implications of Socio-Economic and Institutional Findings*, by myself, and deriving from the study I carried out last year of 50 evaluations of irrigations schemes, shows the linkages between socio-economic and institutional factors and organizational and technical choices. The way these linkages work in particular cases is illustrated in other papers in this set.

Compatibility of technology with objectives and with the local environment is often best tested by laying out a matrix, using either some form of scoring system, or even a simple yes/no, +/- system. The technique is illustrated by W Huppert - *Situational Compatibility, the Example of Warabandi*, which forms the second part of Paper 87/3d. In warabandi systems water is divided amongst farmers by giving them a fixed time for taking water, in proportion to the size of their irrigated holding. Warabandi has both advantages and disadvantages, and it is necessary to take a systems view in deciding if the former outweigh the latter, and if it is the most appropriate method of allocation, given the environment and the objectives. The first paper in 87/3d, by J Berkoff, illustrates how the productivity of a large system in India has been improved by changes in water scheduling, and goes on to consider further developments along these lines which might be introduced to bring water delivery more into line with crop-water requirements than is possible in traditional warabandi systems. This however entails a more complicated operational mode and Huppert's matrix is helpful in identifying when this might be feasible, and what further changes in the system it might require. It is rarely possible to satisfy all objectives; compromises have to be made to achieve a workable system at reasonable cost.

While Paper 87/3b argues that some of the principles and processes used in developed countries are transferable to developing countries, the appropriate technology will often be different, because the environment is different. Svendsen, in a recent paper he wrote for the American Society of Agricultural Engineers, highlighted one important difference between the USA and most developing countries: farm size. Even in the Indian context discussed in Paper 87/3d, the fact that farms in southern India are often smaller than those of Northern India is shown to be important. In Tunisia in Paper 87/3e, *Developing Effective Irrigation Extension Programmes*, M Shearer shows how differences in the marketing environment make sprinkler systems a good choice in one part of the country, but inappropriate in the more isolated region where he was working. He also used a matrix to identify appropriate technologies for small farmer operated systems. Because they were appropriate they were adopted very quickly and enthusiastically by the farmers. Shearer emphasises the importance of selling the idea of the new technology first to the extension worker; only if he is convinced can he convince the farmer. The paper is also useful for its discussion of extension philosophy in relation to water management.

2.2 Discussion on Performance Indicators

I had expected that Paper 86/2d by C L Abernethy, *Performance measurement in canal water management: A discussion*, would stimulate quite a lot of correspondence. This has not been the case, but Rajan K Sampath (Department of Agricultural and Resource Economics, Colorado State University, Fort Collins CO 80523, USA) and David Seckler are amongst those working to develop an indicator that covers not only equity of delivery, but also current performance in relation to design performance. Another contribution to the debate came from Robert C Hunt, Department of Anthropology, Brandeis University, Waltham MA 02254, USA. While he thinks that Analysis of Variance framework is essential for understanding the operation of irrigation systems, he points out that water scarcity should not be considered as a simple relationship between plant need and water supply. There is also a factor he calls crop discipline.

"Which crop to plant and how many of them to plant have a great deal of influence on total moisture need... At any point in the growing season, total moisture need is determined by a combination of variables which include environmental stress, water supply, crops actually growing and the prior decision about how much of which kinds of plants should actually be planted... In some systems (there are) rules for crop discipline, which some irrigators violate. Once the crops are in the ground, it is very difficult to deny them water. At that point, water may become scarce due as much to overplanting as to shortfall of water supply. And this is a management problem. But it is not a water management problem... More precision about the content of irrigation management would be productive. Irrigation management could apply all the way from watershed maintenance to the delivery of water from the furrow to the root zone. The authorities of a system may or may not have responsibility for this vast range. Usually their authority does not reach to the farmer's field..."

2.3 Value added per M^3

The importance of crop choice is something that also concerns Peter McLoughlin, Resource Development Consultant, Comox, British Columbia. He suggests that planners in countries where water is becoming short in relation to demand, should be concerned to establish where the Value Added (VA) of existing or contemplated M^3 of water is highest. This will apply to the choice between using water for hydro-power, industry, forestry or irrigated agriculture. The principle would also apply within irrigated agriculture. "In some cases, exemplified by citrus, new plantations probably will provide lower VA/M^3 than continuing to apply water to existing plantations. This is a matter of the sorts of soil, yields and production costs obtaining in this particular case. Sugar, cotton and rice tend to return least per M^3; maize, vegetables and general field crops and grains somewhat more; and tree crops generally most. Thus,... under shortage conditions, based only on VA/M^3 data, the rice, sugar, cotton should be dropped first, then the field crops and only then tree crops."

This is not the order of priority that has guided irrigation development or contraction in most countries. Peter McLoughlin recognises fully "that the real world is far too complicated to allow the theme of economic maximization of water available to rule the day in decision-making. Small irrigated farmers producing the nation's food supply plus crops for exports remain an ideal in the minds of many, regardless of the greater economic value of scarce water in other uses. Yet... the employment impacts of these other water uses (forestry, thermal power or mining) plus their associated transport, other infrastructure and service needs can have impacts equal to or indeed in excess of those associated with the same volumes of water devoted to irrigated agriculture".

It is sometimes salutary to remind irrigation enthusiasts that water might have greater value to other parts of the economy.

2.4 Economics of Farmer Participation

Commenting on Dr Patil's Paper 87/2d, *Economics of Farmer Participation in Irrigation Management*, Mr Agustin M Ferrer, Agricultural Specialist, IDD, UPRIIS, National Irrigation Administration, Cabanatuan City, Philippines notes that the NIA have provided the necessary financial incentive for farmers to play a greater role in operation and maintenance through the contract made between the NIA and the Farmer Irrigators' Association. Details of this are in the paper he gave at the Symposium organised by IIMI and Hydraulics Research, Wallingford at Kandy in February 1987. He feels that the Irrigation Agency should itself play the major role in organising and training farmer organizations because it will be financially involved both in necessary capital investment for improvements, and in the current expenditure on operation and maintenance. He suggests that the role of an NGO could usefully be to evaluate the process of WUA formation, so that the Agency could learn to improve its techniques. The NIA is holding an International Seminar on Farmer Participation in Irrigation Development March 27 to April 4 1988. Details from The Administrator, National Irrigation Administration, EDSA, Quezon City, Philippines.

Doug Vermillion, working with IIMI at the West Java Irrigation Service, Kertamukti Building, 2nd floor, Room 28, Jl Braga 137, Bandung, Indonesia, writes that the Indonesian Government has initiated a pilot project in West Java and West Sumatra to turn over most systems below 150 ha to users. In a second phase it is envisaged that systems between 150 and 500 ha will also be turned over. The Government of Indonesia has decided to use provincial irrigation staff as water user association organizers to assist this process, since it is felt this will help the agency reorientate itself, and develop its commitment to the change. In the Philippines and Sri Lanka outside university-trained social scientists were originally used in this role and it will be interesting to compare the results of the two approaches in due course. IIMI will be involved by conducting action research and helping develop the turnover project for national application.

Diyawara, Vol 2 No 4, Nov 1987, published by the Agrarian and Training Institute, 114 Wijerama Mawatha, Colombo 7, Sri Lanka, contains articles on Sri Lankan experience and policies with regard to farmer participation in system management.

There are many new publications on farmer participation and farmer management, reviewed later in this Newsletter.

3. IIMI ACTIVITIES

IIMI has recently undertaken its third programme review. It is also engaged in a major strategic planning exercise to determine its priorities over the next few years. The third review shows important progress in its research programme. As it was only completed in December, it arrived in London too late to do justice to it in this set of Papers. We are therefore intending to summarise highlights from its programme in the next issue. The Farmer Managed Irrigation Systems programme now has its own Newsletter, available from Dr David Groenfeldt, IIMI, Digana Village, Kandy, Sri Lanka. The latest Management Brief, No 5, is on *Responsibility in Irrigation System Management: Some Policy Suggestions for Sri Lanka*, by Douglas J Merrey and Senarath Bulankulame. Details of posts currently available at IIMI are enclosed with this Newsletter.

4. NEWS FROM NETWORKERS

The Cornell University Irrigation Studies Group held a workshop on Improving Performance of Irrigation Bureaucracies in Ithaca, New York, USA in May 1987. Other invited participants were irrigation engineers from the Dominican Republic, India, Mexico and Sri Lanka and irrigation scientists from other US and British Universities, and from the World Bank. The participants critiqued a book length report on improving irrigation bureaucracies' performance, looking in turn at the objectives, the context, the management structures and at alternative management strategies. Factors like staff stability and transfer, bureaucratic reorientation, career paths, interdependence between agencies and water users were examined for their influence on performance. We hope to carry news of publication plans in the next issue.

Land and Water No 29 from Land and Water Development Division, FAO, Rome contains details on the FAO map of irrigation and water potential for Africa.

The Water and Land Management Training and Research Institute (WALAMATARI) at Himayatsagar, Hyderabad - 500 030, India, has published the proceedings of a one day seminar held in August 1987 on *Importance of On Farm Development in Irrigation Projects.* One of its most interesting conclusions concerned the importance of reducing deep percolation losses for paddy crops grown in light textured soils. Savings here could greatly extend the area that could be irrigated. The recommended measures included the growing of green manure crops which could be incorporated into the soil, along with extensive puddling operations. This is of interest, because farmers often use large quantities of manure, while in many cases extension recommendations are only for artificial fertilizers. The effect of organic manures in improving soil structure and therefore in some cases slowing down deep percolation, or, in dryer environments, limiting erosion and surface run off may well be better known to practicing farmers than to their advisers.

5. FORTHCOMING CONFERENCES

The fourteenth International Congress of the ICID will be held in Rio de Janeiro, Brazil 29 April - 4 May 1990. The topics for the Congress are:

Question 42: *The influence of irrigation and drainage on the environment with particular emphasis on the quality of surface and ground waters*
Question 43: *The role of irrigation in mitigating the effects of drought*
Special Session: *Socio-economic and technological impacts of mechanized irrigation systems*
Symposium 1990: *Real-time scheduling of water deliveries.*

Requests for further information should be sent to your National Committee or to B C Garg, Secretary, ICID, 48 Nyaya Marg, Chanakyapuri, New Delhi 110021 India. The lead time for papers is quite long and it is advisable to get details in good time.

The Centre Technique de Cooperation Agricole et Rurale (CTA) which is funded by the EEC, is organizing a workshop in conjunction with ILRI in Harare, Zimbabwe in April 1988 on *Irrigated Agriculture in Africa.* The main emphasis will be on the relationship between rainfed and irrigated farming. As the organizers say, farming systems often receive very little attention when irrigation is introduced. Further details are available from B W van Ersel, ILRI, Staringgebouw, 11 Marketweg, 6709 PE Wageningen, The Netherlands.

As part of Wasser Berlin 1989, DVWK will be holding its ninth Irrigation Symposium. The theme is related to the topic discussed in some of the papers in this issue: management in conformity with the local situation. Details can be obtained from Dr Ing W Dinksen, DVWK, Gluckstrasse 2, D-5300 Bonn, West Germany.

Workshops on *Simulation Exercises for Use in Training in Irrigation Management* were held in Morocco in September at the Centre International de l'Irrigation, Institut Agronomique et Veterinarire Hassan II, Rabat, and during the sessions of the ICID Congress in Casablanca. They were organized by Wye College and the Moroccan National Committee of ICID, and sponsored by the British Council. Further information on simulation exercises can be obtained from L E D Smith, Department of Agricultural Economics, Wye College, Ashford, Kent, TN25 5AH, UK.

The report on the Colloquium held at Wallingford on Research Needs in Third world Irrigation in April 1987 is carried in ODU Bulletin No 6, available from Hydraulics Research, Wallingford, OX10 8BA. It contains an article by Mark Svendsen, *Conceptual Frameworks for Analyzing Irrigation Schemes*, which is very relevant for the concern to look as schemes in a whole system framework.

6. RECENT PUBLICATIONS

Better management of the software of irrigation, as opposed to the hardware of high technology is stressed by Phillip Kirpich in a recent article titled *Developing countries: High tech or innovative management?* in the Journal of Professional Issues in Engineering, vol 113(2):150-166. Using case studies from Bangladesh, India, Sudan, Mali and Mexico, he argues that institution-related problems frequently explain failures in project performance. However, while much technology introduced into developing country projects is often over-elaborate, there may be a useful role for specific techniques, such as satellite mapping of resources, or laser levelling of fields. Examples of the changes in management practices which he suggests include the provision of appropriate incentives to bureaucracies so that they fulfill the role expected of them, and the more frequent use of pilot projects which allow learning-by-doing both by farmers and by managers. Innovative management does require a trained and motivated workforce, which is often lacking. Accountability of bureaucracy to farmers is also hampered by the absence of organised producer groups able to monitor and exert demands on the administration. Kirpich proposes that engineers be given a broader education, to include subjects such as economics, sociology and business management, so that they have a wider understanding of the problems likely to be encountered in operating and managing irrigation facilities.

The Annual Report for 1986 from ILRI, the International Institute for Land Reclamation and Improvement, has two useful articles on traditional irrigation in Africa. The first, by Oosterbaan, Kortenhorst and Sprey investigates flood-recession cropping in the Okavango delta of Botswana. Relatively little is known of the farming systems operating in this area, which combine dryland cropping and flood retreat farming with livestock, fishing, gathering and other off-farm activities. The Molapo Development Project, carried out in this area from 1983, has tried to control flood water by building small check dams. These should allow for an earlier sowing date and thereby lengthen the growing period in those years when there is a significant flow of water. However, in 2 years out of 5 rainfall is so low that no flooding occurs. The second article, by Oosterbaan, Gunneweg and Huizing describes water control methods for rice cultivation in small valleys of West Africa, where flooding is far less reliable than in river flood plains and occurs in flash floods. Using a case study in Sierra Leone, (where 50% of rice produced comes from small river valleys and swamps) the authors investigated the returns in improved rice yields of building contour bunds. These gave much greater control over water, enabling land to be ploughed when most convenient for the farmer and increasing returns from fertilizer use, as this input is not washed away.

Difficulties in eliciting farmer involvement in scheme management, operation and maintenance are the subject of two WMS reports recently published. The first, WMS Report No 44 by James Nickum from Utah State University, *Direction, inducement and schemes: Investment strategies for small-scale irrigation systems* investigates ways in which to tailor agency involvement in setting up small scale schemes in order to generate greater farmer participation in managing the scheme. He notes that responsibilities for management and maintenance will usually be associated in farmers' minds with ownership of the land in question and that farmers are unlikely to assume major responsibilities without also gaining rights. Where the terms are not favourable to farmers, they may well prefer to let government or an agency remain responsible for managing the scheme. Care needs to be taken by agencies to encourage participation by farmers in scheme design and construction, not just as part of the labour force. The second report, from Department of Development Sociology, Cornell University, *Social and economic influences on perimeter management and operation: Findings from research in the Maggia Valley, Niger* by Luin Goldring, discusses the results of research on scheme farmers in the light of the government's desire for greater self-management of schemes. The report notes in particular the variation between farmers in terms of their access to resources and patterns of income earning which make it difficult to generate a common policy for cropping patterns and cultivation practices for all farmers to follow. A balance must be sought between the benefits gained on the one hand from some degree of homogeneity in farm practices being followed and on the other the need for flexibility and rights of farmers to adapt their operations to suit their particular needs and constraints. Self-management is likely to be easier where there is relative homogeneity between farmers on the scheme towards which goal policies could be directed, such as in the selection of farmers to have land on the irrigated perimeter, or in prohibitions on the sale of land. (Note the conflict here with the previous report; if farmers need to own land to have the motivation and will to manage irrigation themselves, governments must take the risk that there will be land accumulation by some. In judging the degree of this risk, they should consider inheritance patterns; in many societies such accumulation is only for one generation.) If self-management is to be pursued, relations between the various agencies and committees must also be clarified; in particular, the responsibilities and rights of ONAHA (the government agency in charge of irrigation development), farmer committees and the political authorities must decide on who has the ultimate power to fix cropping patterns or to dismiss farmers who transgress the rules of the scheme.

WMS Report *Labour Demand and Employment Generation in Irrigation Systems*, by Ruth Meinzen-Dick, Department of Rural Sociology, Cornell University, examines the extent to which different aspects of irrigation development and operation generate employment. It starts from the widely held view that irrigation development is good for employment, by increasing demand for labour for project construction, maintenance and water management, increased cropping intensities and secondary employment effects and looks at the evidence for employment growth from a number of case-studies. Emphasis is placed on the variability of employment effects and consequent benefits to different groups. Factors influencing these benefits including: choice of technique, land tenure patterns, the division of labour and availability of different kinds of labour in relation to demand.

WMS Professional Paper 2 is a short paper by E Walter Coward on *Designing projects for irrigation development: Using external consultants* which outlines the necessary steps in planning the work of a consultancy team. For a successful irrigation project, technical soundness must be combined with the establishment of institutions able to manage and operate the physical facilities. To ensure this happens, the external team must be carefully selected and institutional analysis conducted early on in the process of project design. The institutional requirements of different technologies should be explicitly considered and the assumptions upon which these are made must be laid out clearly. Both these papers are available from the Office of Agriculture Science and Technology Bureau, Agency for International Development, Washington DC 20523, USA. WMS have also published recently many country studies.

Community managed irrigation in Eastern Nepal by S E Howarth and M P Pant, in Irrigation and Drainage Systems, 1(3):219-230, outlines the characteristics associated with successful scheme management. These include strong formal management structures with one or more committees responsible for management and maintenance, officers of the scheme having a direct interest in the continued success of the scheme and a land holding system dominated by medium-sized farmers. By contrast, government initiated irrigation schemes have frequently failed, due to factors such as ignoring traditional water rights, and the very rapid implementation period of modern schemes. As a result of the latter, there is not sufficient time for the appropriate social institutions to develop, in contrast to the many years over which farmers in self-managed schemes developed ability to co-operate. Greater farmer involvement in scheme design and construction would engender greater commitment from the community and should clarify the rights and responsibilities of different actors within the new scheme.

Satish's paper in the October issue of Wamana summarises the potential difficulties behind the transfer by government of scheme management to water users' groups, who will buy water and collect fees. Satish considers that this will make water user associations largely an arm of the Irrigation Department, rather than responsive to the particular needs of farmers. And if farmers were to be asked whether they would value such an association, the answer would be likely to vary between farmers according to their location in the scheme, with tail-end farmers perceiving a much greater need for more effective water management and distribution than farmers at the head and middle regions.

Franks and Harding's paper in the 1987:3 issue of Irrigation and Drainage Systems summarises the work they have been doing on problems that arise during the commissioning of an irrigation project. In particular, they address themselves to the following questions: what in terms of water use can be expected to happen during the early stages of project commissioning? What management practices should be adopted in the light of this? And what effect will this have on the long term viability of the project? As a result of their research, they found that water use in the first season of scheme operation was about twice its estimated value at full development and, although water use decreased as time went on, by the third season it was still a third larger than had been estimated. They emphasize the need to establish a rotational water supply system as soon as possible, so that farmers do not become used to being able to take water on demand.

The need for drainage to combat problems of waterlogging and salinity is the subject of a couple of articles in the *Indian Journal of Agricultural Economics* (vol 42(2), 1987). Gangwar and Toorn assess the consequences of adverse groundwater conditions for farm production in Haryana State, to identify those areas likely to be particularly badly hit in future and to compare the costs of lost production with various measures to remedy salinization. The authors emphasize that prevention through investment in drainage brings far higher returns than rehabilitation of land that has already become badly salinized. Rates of return on drainage investment varied from 12 to 25% depending on spacing between drains and cropping intensities on the reclaimed land. Joshi et al look in more detail at the costs and benefits of drainage for reclamation of land that has become waterlogged. Overall benefit-cost ratios vary from 1.29 to 4.00, depending on the spacing of drains and the crop mix subsequently grown, indicating that such investment is economically viable even without considering the external benefits such drainage confers on neighbouring plots.

The Proceedings of the Symposium on Planning, Operation, Rehabilitation and Automation of Water Delivery Systems, held at Portland, Oregon in July 1987 have now been published by the American Society of Civil Engineers, 345, EASt 47th Street, New York 10017-2398, USA. The main emphasis of the papers is the need to design for flexible but also reliable water supply that enables farmers to take the water needed for their crops in a convenient way. There are contributions from Merriam, Repogle, Clemmens and Plusquellec among others. It is intended for engineers and provides them with useful reviews. The papers are grouped under the following headings: Delivery System Scheduling; Canal Control Concepts; Pipeline Control Concepts; Pumping Plant Control Concepts; Instrumentation and Finance and Economics. In *Structuring distribution agencies for irrigation water delivery* Clemmens and Freeman note the importance of institutional relationships in water supply provision: "if the distribution agency or irrigation district is responsible to a central water authority and not to farmers or a farmers' organisation, then deliveries most likely will not be made according to farmer needs" (p 74). Establishing a chain of contact between the different elements in the water distribution systems is essential for information about farmers' needs to be relayed to people higher up in the distribution system. The authors also emphasize the need for a close feedback on the financial front, whereby the cost of managing and distributing water is linked to farm profitability. Where such links do not exist, there is much less chance of good delivery system performance. In the section on *Finance and Economics*, financial viability is again stressed, the cost recovery system set up creating a sense of accountability between farmers and water delivery staff. Olivares discusses the particular cost and benefit flows likely to be associated with a rehabilitation project and the difficulties of assessing the likely 'without project' situation, for example the risk of total collapse of irrigation structures. Account must also be taken of the cost of foregone output during the period of rehabilitation, which will be substantial if the scheme is out of operation for any length of time.

In an article in the Geographical Review of Japan vol 6 (series B (1)), 1987: pp 41-65, Akira Tayabashi presents a clear and useful background paper on irrigation development in Japan, its history and the geographical distribution of different kinds of system.

The last two issues of the International Journal of Water Resources Development have a number of stimulating articles. Volume 3(2) is devoted to management of the Upper Nile and includes a paper by Guariso and Whittington on the implications for Egypt and the Sudan of a programme of irrigation development by Ethiopia on the head-waters of the Blue Nile. The current lack of cooperation between Ethiopia and the other two countries is seen to have a heavy cost, whereas development and regulation of the Upper Blue Nile by Ethiopia should increase the amount of water available for agricultural development in Sudan and Egypt by reducing storage requirements and evaporation losses from dams further downstream. Bailey and Levine examine water management within the Gezira scheme and note the need for greater flexibility over crop scheduling, given constraints on the quantity of water that can be supplied by the canal network. An article by Mahdi Beshir looks at the history behind planning for the Jonglei canal in southern Sudan. Volume 3(3) includes an article by Roy, Rao and Sunder on *Labour-intensive and capital-intensive technology in irrigation development* which picks up a number of the issues raised by Meinzen-Dick above, about the potential for generating considerable employment from irrigation development. The authors caution against a bias towards heavily labour intensive methods of construction, given the much greater magnitude of secondary employment associated with irrigated agriculture as opposed to direct employment in scheme construction, and the need to consider trade-offs between a labour-intensive method of construction on the one hand and factors such as speed of construction and the quality of work required on the other. For example, a labour-intensive construction technique could slow completion of the scheme and hence postpone secondary employment benefits expected from increased irrigated area. Dhillon and Paul present designs for harnessing ephemeral streams through channels and spillways and an article by U Win provides an overview of irrigation in Burma.

We have been sent Irrigation for Agricultural Modernization by R K Gurjar which looks at the importance of irrigation in the semi-arid Indian state of Rajasthan. Considerable detail is provided on the performance of irrigated agriculture, cropping patterns and crop yields. It would make a useful starting point for those working on agricultural development in this state. (Publishers: Pawan Kumar, Jodhpur, India.)

7. TRAINING COURSES

International School for Agricultural Resource Development (ISARD), Colorado State University, Fort Collins, Co 80523, USA. June 3 - July 1 1988: *Applied Agricultural Production Management and Policy Analysis.* June 6 - July 29 1988: *Agricultural Marketing in Developing Countries.* July 5-July 29 1988: *Applied Management Skills for Economic Development.* July 11 - July 29 1988: Microcomputer Workshop on *Irrigation Data and Project Management.* The Department of Sociology, Andrew G Clark Building, Colorado State University, Fort Collins Co 80523, USA. June 20 - July 23 1988. *Social and Technical Aspects of Irrigation Organization.*

International Irrigation Center, Utah State University, Logan, UT 84322-8305, USA. Basic Course January 10 - February 20 1988, two week add-on options extend to March 5 1988: *International Course on Applied Microcomputer Use in Irrigation and Drainage* (English and Spanish). March 20 - April 30 1988: *International Course on Waterlogging, Drainage and Salinity Control.* April 6 - April 30 1988: *International Waterlogging and Salinity Technical Study Tour of US Western States.* May 8 - June 18 1988: *On-farm Irrigation Design and Evaluation.* June 10 -July 24 1988: *Applied Remote Sensing in Agriculture.* June 19 -July 9 1988: *On-farm Irrigation Scheduling.* July 10 - July 30 1988: *Main System Irrigation Scheduling.*

CEFIGRE, International Training Centre for Water Resources Management, Sophia Antipolis, BP 13, 06561 Valbonne Cedex, France. May 9 - June 10 1988: *Maintenance and Rehabilitation of Large Irrigation Schemes.* June 13 - July 8 1988: *Modern Irrigation Techniques.* November 14 - December 16 1988: *Small Irrigation Schemes* (all in French). It also has courses, in French and English, on environmental issues in water resource development, and some of them are in Asia. Write to them for further details.

Institute of Irrigation Studies, University of Southampton, Southampton SO9 5NH, UK. May 9 - 16 July 1988: *Rehabilitation and Management of Irrigation.*

Economic Development Institute, The World Bank, 1818 H Street NW, Washington DC 20433, USA; attention: Ms Edith A Pena, Room G-1067. Audio-visual training material on *Improving the Operation of Canal Irrigation Systems* (English, soon available in Spanish and French). Write to them for further details.

8. NEWS FROM ODI

Apart from the evaluation already referred to, the most important news is a change in ODI's telephone number. The general reception and switchboard can be called on 01-487-7413. The Irrigation Network Secretary can be dialled direct on 01-487-7566. Dr Mary Tiffen can be called on 01-487-7582. The fax number for Regent's College is 01-487-7545. Documents should be addressed clearly to the Overseas Development Institute, and the particular individual for whose attention they are intended. Please make a note of these changes.

For me the sad news is that Dr Camilla Toulmin will be leaving at the end of the year to take up an appointment with the International Institute for Environmental Development. Network members will miss particularly the reviews of new literature which she has contributed to this and other Newsletters. She has also been an important partner in ODI's research programmes, particularly the analysis we are currently undertaking into farm budgets and other factors influencing farmers' willingness and ability to manage schemes themselves and to farm in an innovative and productive manner. We are using Nyanyadzi Irrigation Scheme in Zimbabwe as a case study and are working in conjunction with Hydraulics Research, Wallingford and Agritex, Zimbabwe. We are hoping to appoint her successor early in the new year.

There have been other important changes at ODI. Dr Tony Killick came to the end of his five year tenure as Director of ODI; he is staying with us, but resuming his research interests. The new Director is Dr John Howell, formerly Deputy Director and Chairman of the Agricultural Administration Unit. Dr Mary Tiffen is now Chairman of the Agricultural Administration Unit, and also remains in charge of the Irrigation Management Network.

Sociology in farming systems research by Alistair Sutherland is a new paper published by the Agricultural Adminstration Unit of ODI. Taking eastern and southern Africa as its focus, it addresses four basic questions relating to: the role of sociologists in farming systems research (FSR) at the national level; the research methodologies best suited to achieving this role; how to institutionalise this role and foster good interdisciplinary teamwork; and, how best to achieve training in a relevant sociological perspective and method. Good sociological work involves intuitive skills which are less easy to demonstrate than the quantitative methods of economics or natural sciences, which means that the social researchers role and work plan with a FSR team is less clear. However, if FSR is to yield the benefits hoped from it, sociological research must be closely incorporated into the work of the research team, for example by developing ways of testing new techniques which involve farmers closely. Details of this publication, together with information on the sister Network, Agricultural Administration (Research and Extension) is available from Jennifer Dudley, at ODI. The last issue of this Network was devoted to farmer experimentation and participation in agricultural research.

Two recent lunch-time meetings were:

4 November 1987: *Deriving lessons from experiences of project management*, by Mr G L Ackers, formerly of Sir M McDonald and Partners.

11 December 1987: *Dambos and micro-scale irrigation: technical and social aspects in Zimbabwe*, by Pat Hotchkiss and Bobby Lambert of Loughborough Technological University.

Mary Tiffen December 1987

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IRRIGATION MANAGEMENT NETWORK

REHABILITATION AND PARTICIPATION: THE VIEWS OF THE ENGINEERS

Mary Tiffen

ODI/IIMI Irrigation Management Network Paper 87/3b December 1987

Papers in this set

87/3a: Newsletter
87/3b: Rehabilitation and Participation: The Views of the Engineers by Mary Tiffen
87/3c: a) Checklist for Including Consideration of Operation and Maintenance in Project Preparation and Appraisal by Harold D Fredericksen
b) Planning Implication of Socio-Economic and Institutional Findings by Mary Tiffen
87/3d: a) Matching Crop Water Requirements in Large Systems with a Variable Water Supply — Experiments in India by Jeremy Berkoff
b) Situational Compatability — The Example of Warabandi by Walter Huppert
87/3e: Developing Effective Extension Irrigation Programs with Appropriate Technology by Marvin N Shearer

Please send comments on this paper either to the author or to

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Comments received by the Editor may be used in future Newsletters or Papers.

The opinions represented are those of the author and do not necessarily reflect the policies of the ODI, IIMI or any organisation with which the author is connected.

ISSN: 0951 189X

REHABILITATION AND PARTICIPATION: THE VIEWS OF THE ENGINEERS

Mary Tiffen

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Mary Tiffen is in charge of the Irrigation Management Network at the Overseas Development Institute. She was nominated by the British Committee of the ICID to be an expert panel member on the question of Rehabilitation and Modernisation at the Thirteenth International Congress on Irrigation and Drainage at Casablanca, Morocco, in September 1987.

REHABILITATION AND PARTICIPATION: THE VIEWS OF THE ENGINEERS

Mary Tiffen

1. THE SETTING

The Thirteenth Congress of the International Commission on Irrigation and Drainage, held at Casablanca in September 1987, was a very splendid occasion, due in no small part to the hard work and very great hospitality of all connected with the Moroccan National Committee. The Congress had a very high profile in Morocco, and was under the patronage of the King, who besides receiving representatives of the National Committees present, provided a memorable banquet as the finale. The Prime Minister attended the opening session and visited the associated exhibition. Irrigation is an important element in Morocco's plans for improving agricultural productivity and for feeding its increasing urban population as well as providing a basis for industries and exports. Mr Othman Lahlou of Morocco was elected as ICID's new President.

A remarkable feature of the Congress, which is primarily an organisation of engineers, was the concern for active participation of all concerned parties at all stages. These concerned parties include central government ministries such as Irrigation, Water Resources, Agriculture; local government authorities and those responsible for legal issues; the staff who have to operate and maintain the system, and above all, the farmers.

The general theme of the Congress was Improving Water Management in Developing Countries, and different aspects were considered in a Special Session, a Symposium on the design and operation of systems with insufficient capacity to meet peak water requirements in semi-arid regions, and two Questions. The Questions provide the main topics on which the irrigation community is invited to provide papers, or Replies, and three sessions were devoted to each of the two Questions, 40 on Rehabilitation and Modernisation and 41 on Training. Full reports on the Colloquium should be available from your national committee of the ICID. We are grateful to the outgoing President, Dr Marvin Jansen, and to the Scretary, Mr B C Garg, ICID, 48 Nyaya Marg, Chanakyapuri, New Delhi 110 021, India, for permission to summarise the Resolutions of the Casablanca Congress and to reprint or to publish extracts of some papers. The Resolutions and the General Reports containing summaries of all papers will appear as Volume II of the Transactions of the Casablanca Congress. The General Reports are particularly valuable as guides to the most outstanding and useful papers. For further information on avilability, contact your National Committee or Mr Garg. This paper will deal particularly with the debates on rehabilitation and modernisation since I was a member of the panel considering this Question, but the conclusions there were echoed in the other sessions. We plan to discuss the papers on Training in the next issue.

2. THE GENERAL RESOLUTIONS OF THE CONGRESS

The Special Session considered the role of irrigation, drainage and flood control in the national development plans of developing countries. It was concluded that a rational water policy should be one of the objectives of national planning, and that detailed plans for particular schemes should take into account the general economic effect and the social and environmental dimensions. The complementarity of irrigated and rainfed agriculture, and of large and small scale irrigation systems should be encouraged. The sequence of actions leading to an irrigation project requires the active participation of all concerned and particularly the farmers, beginning with the discussion of the initial concept. It is also important to establish clear contractual arrangements which define the roles and responsibilities of the public authorities and the private sector in the development of irrigation.

The Symposium, looking at arid areas where water is likely to be short in relation to demand, also emphasised the need to take a regional view, and to develop complementarity between deep and shallow groundwater sources, and surface water. The design of irrigation projects that will have a structurally insufficient supply can be attractive from the economic point of view, but should not be implemented without the full consent of the future farmers. In the application of mathematical models and optimisation techniques, the best solution should not be considered simply as a technical problem since optimisation depends on a socially accepted decision-making framework.

This particular resolution deserves further comment. In a regional context farmers may have to compete with other users for scarce water and to accept less than they would like, so the word consent should not mean that they should have exclusive and unchanging rights to as much water as they want. However, it is certain that using scarce water sensibly needs their full understanding, based on adequate communication and warning about changes in the water supply, since they will have to adapt their farming methods. The resolution, for example, refers to the supply of water to a limited part of the root zone only, to monitoring soil water content, and to optimum use of rainwater. Further, in this kind of situation farmers will often need to be encouraged to make additional on-farm investments themselves, for example in wells or in drip systems. Their acceptance of the situation can be facilitated when they have to pay part of the investment costs of the water supply. They could then be convinced that it is better to have a less costly system that meets say 70% of their peak water needs, or which rules out certain crops, rather than to pay for a supply that meets full crop water requirement over their entire farm. Any participation in investment costs gives them a moral entitlement to consultation on the type of system to be installed.

Turning to training, the Congress considered this as a necessary part of effective business management. The recommendations at the end of the session were:

a training needs analysis related to clearly stated and agreed organisational objectives

parallel programmes for management, operating, maintenance and administrative staff

water users and their associations should be involved in developing training strategies as well as receiving training. Their training should be as close to the field and canal systems as possible, to ensure practical orientation.

3. CONSULTATION AND NEGOTIATION PRIOR TO REHABILITATION

The Question attracting the largest number of papers at the Congress (93 in all) was on Rehabilitation and Modernisation of Irrigation and Drainage for Improving Water Management. The intention was that question 40 should focus on how plans for rehabilitation should be influenced by consideration of the human element, the users and operators. Some papers concentrated too much on purely technical aspects. Fortunately, Professor C A Fasso of the Politecnico di Milano, Milan, Italy, had made a masterly summary of the papers in his General Report[1], focussing attention on the managerial issues. Although it is sometimes difficult to separate rehabilitation and modernisation, an ICID working group had made the distinction that rehabilitation is made necessary mainly by internal factors[2], and while modernisation is a response to a change in the external environment. Professor Fasso's diagram, Fig 1, is very useful in differentiating between the two, diagnosing the types of action likely to be necessary in different cases and showing the role of user involvement in discussion of required design changes, and in operation and maintenance. In some countries, in some cases, there would also be user involvement in some types of construction.

The final resolution advocated:

> Approaching rehabilitation and especially modernisation of irrigation and drainage projects from an integrated point of view, taking into account not only the agricultural system, but also the inputs and feedback from technical, socio-institutional, economic, historical and other external factors; this integrated approach is necessarily multi-disciplinary;

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[1] Fasso, C A. Thirteenth International Congress on Irrigation and Drainage (September 1987) General Reports, Question 40, "Rehabilitation and Modernisation of Irrigation and Drainage Projects for Improving Water Management".

[2] L S Pereira and W McCready, "Rehabiitation and Modernisation of Irrigation Projects: Identification of concepts, main questions and priorities", ICID Bulletin, July 1987, Vol 36, No 2.

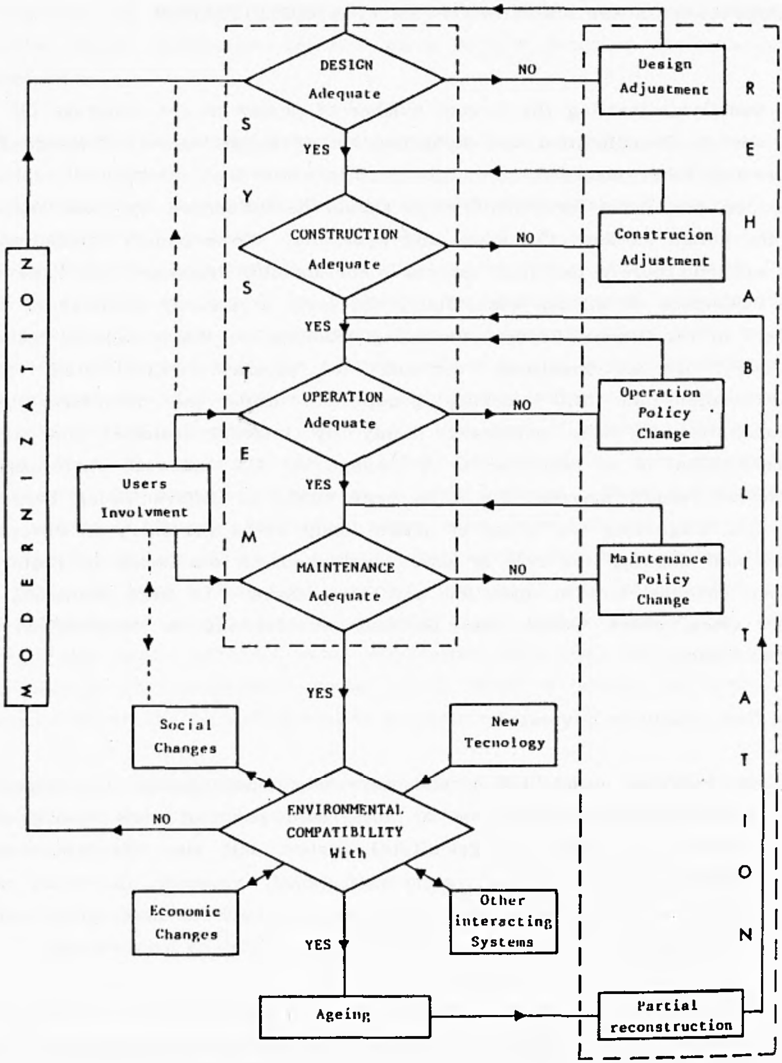

Fig. 1: Rehabilitation and modernization: WHY ?

Involving farmers and operators not only in O&M, but in all stages of rehabilitation and modernisation, including planning, with the goal of getting agreement on objectives from all the interested parties;

Carrying out careful diagnosis of the causes of the situation that makes rehabilitation or modernisation necessary and testing solutions on pilot developments, taking as much time as necessary;

Considering the balance of advantage between least-cost measures, and measures which have a higher initial cost, but which may be more effective in avoiding O&M difficulties, or in postponing another rehabilitation, or which give greater flexibility in the way water is supplied in response to new trends in farmers' activities;

Choosing between advanced techniques and practices and simpler, lower capital cost ones, by considering site-specific and regional environmental conditions.

It was also realised that the kind of approach recommended is not *necessarily always feasible in present conditions. Therefore, governments,* funding agencies and researchers were asked to give attention to the following:

Developing mechanisms to improve communication between the various actors at all stages of a project;

The conditions necessary for developing effective water user associations;

Developing new economic, technical, social and environmental criteria to provide a sound basis for deciding when and how to rehabilitate or modernise irrigation and drainage projects;

Developing methods of ensuring adequate operation, maintenance and management after rehabilitation and modernisation;

The need to allow adequate preparation time and financial resources for the recommended integrated approach;

It was also suggested economists and other social scientists should be invited to take part in some ICID Working Groups, National Committees, etc, to ensure a multi-disciplinary approach.

It is perhaps particularly worth emphasising that the recommended approach requires more time at the preliminary planning stages, for consultation, negotiation and diagnosis, and additional time to consider the results of pilot studies. This may make the planning stage more expensive, but planning costs are usually substantially less than 5% of the total costs. An increase in planning costs could be worthwhile if they result either in a scheme substantially cheaper to construct, operate and maintain, or substantially more durable and productive, than would otherwise be the case. The consultative approach may require a re-orientation of some politicians, some government departments of irrigation or water resources, and some funding agencies.

When a proper diagnosis is made, the priority steps for an improvement in irrigation performance will often be found to lie in the "software" rather than the "hardware". Paper 86 by F R Rijsberman and N S Rigg reported on the results of a survey amongst US experts having experience in developing countries on the kind of measures most likely to improve performance. Altogether 81 potential improvement measures were listed. The priority measures selected all had to do with system management more than system performance as shown in Table 1. Rijsberman also reported on a parallel survey amonsgst Indian engineers in Maharashtra and Tamil Nadu states which was undertaken later. There was considerable similarity in the results, and ten of the top 15 improvement measures in the US experts survey appeared in the top 20 of the Indian lists (Table 2). The main difference was that the Indians ranked higher problems caused by the erosion of watersheds and inadequate marketing arrangements.

The need for a diagnosis, and the fact that this may reveal the need for institutional rather than physical improvements, applies also in developed countries. An interesting paper by G Damian of France stressed the need for a comprehensive diagnosis. His example was a small system managed by users in France where the obvious problem was seepage losses from the main canal. However, investigation showed that this "lost" water was recharging the groundwater of farmers outside the scheme. The

Table 1. US Experts' Ranking of Irrigation System Improvement Measures According to Relative Importance for Improving System Performance.

Ranking	Improvement Measure	Score
1	improve communication between management agencies (institutional arrangement)	8.0
2/3	close distribution system management gap (main system - farm level)	7.9
2/3	develop institutional arrangement for farmer feedback	7.9
4	train staff	7.8
5/6	develop water user association	7.7
5/6	higher output prices	7.7
7/8	improve reservoir operating rules	7.6
7/8	give priority to system maintenance	7.6
9	seek local input in planning and design	7.3
10/12	gather data on expected demands (for reservoir operation)	7.1
10/12	improve career prospects for officials involved in O&M (including salary)	7.1
10/12	provide incentives to management agencies, based on system performance	7.1
13/14	implement irrigation scheduling	6.7
13/14	provide farm credit	6.7
15/16	improve on-farm water control structures	6.6
15/16	improve distribution system regulation structures	6.6

Source: RIJSBERMAN, F R and GRIGG, N S. 1987. Identifying priorities in irrigation system problems and solutions. Question 40 Response 86. ICID, New Delhi, India.

Table 2. Indian Experts' Ranking of Irrigation System Improvement Measures, According to Relative Importance, for Improving System Performance.

Ranking India	Ranking US	Improvement Measure	Score
1	-	reforestation in the watershed	9.0
2	5/6	higher output prices	8.8
3	13/14	implement irrigation scheduling	8.7
4	7/8	give priority to system maintenance	8.6
5	-	improve distribution system maintenance	8.4
6/7	-	terracing in the watershed	8.3
6/7	2/3	close distribution system management gap (main system - farm level)	8.3
8/9	-	on-farm land levelling	8.2
8/9	15/16	improve on-farm water control structures	8.2
10/12	1	improve communication between management agencies (institutional arrangement)	8.1
10/12	-	land use planning in the watershed	8.1
10/12	5/6	develop water user association	8.1
13/15	-	farmer co-operative for marketing of products	8.0
13/15	-	improve drainage system	8.0
13/15	-	farmer co-operative for purchase of inputs	8.0
16/20	10/12	improve career prospects for officials involved in O&M (including salary)	7.9
16/20	-	improve on-farm maintenance	7.9
16/20	13/14	provide farm credit	7.9
16/20	-	improve distribution system regulation structures	7.9
16/20	4	train staff	7.9

Source: RIJSBERMAN, F R. 1987. Development of Strategies for Planning for improvement of irrigation system performance. Chapter 5. Delft Hydraulics Laboratory.

solution was the restructuring of the institution and the tariffs, to bring in all those benefitting from the water.

Following, or concurrently with, the diagnosis stage, it is also necessary to get agreed new objectives for the rehabilitated scheme from all the interested parties. This will naturally include the central government, particularly as it will often be the funder and will be concerned for best use of national resources. It may also include the local government with plans to develop its area. In rehabilitation it also includes experienced farmers and experienced operating staff. In practice these last two groups are likely to determine how the scheme is operated. As their pursuit of their own objectives has often proved capable of thwarting official aims it is foolish to ignore their aims. It would also be foolish, and costly, to ignore their contribution to the diagnosis.

4. REHABILITATION PROCESSES IN FRANCE AND THE UNITED STATES

The process of diagnosis and negotiation hand in hand with interested parties was well illustrated in some papers from France and the United States. Paper 57 by D Renault and M Goenaga described the rehabilitation of a decayed system of surface irrigation in the Tarascon area of France. Farmers had individually been turning to sprinkler systems based on private wells. This had resulted in falling groundwater tables. The prior investigations included not only the hydrogeological balance, but also detailed consultations with almost all the users, through surveys and meetings. The result was to identify certain common interests, such as desire for more security in surface water delivery, a preference for surface over sprinkler systems both because of strong winds and because they were felt to be cheaper, a preference for an on-demand water supply system rather than a rotational supply because of its greater convenience, and a preference for continuing to cultivate field crops with relatively small profits rather than high value crops associated with high risks. This last imposed an economic constraint on the system design, and a need to reconcile the desire to have water on demand, to have low recurrent costs and water charges, and the management need to be able charge according to supply. The solution selected was a low pressure pipeline, tested in a pilot area. It was realised that physical degradation is usually related to institutional problems, and as the farmers' associations for the nineteenth century gravity system had more or less ceased to function, the local authority took charge of the new works until new farmers' associations could be built up to look after operation and maintenance. (It is still too early to say how well this will work). D Renault, in his verbal presentation at the Congress, drew attention to the useful role of a mediator in the rehabilitation process, and also, to the usefulness of a pause for reflection after the pilot study.

Paper 62 by R Tourette discussed rehabilitation in an area of France where 72 farmers associations controlled and operated a complex gravity system. The study identified the following needs:

reducing the labour costs and social costs associated with a rotational supply (including night irrigation);

overcoming water shortages to enable irrigation to be both *intensified* (because crops were changing) and spread to larger areas;

adaptation to the very mixed topographical and soil conditions.

A new dam in 1976 provided an increased supply for a potential command area of 10,500 ha, of which 6,700 ha were already irrigated. One of the principal associations decided to go ahead with a modernisation programme for its area of 1580 ha, contracting out the design to a specialist organisation which would also operate the new system and guarantee its durability. It was agreed that the modernisation should be carried out sub-sector by sub-sector, over a period of years, as the concerned farmers agreed and as the Association authorised, in order to spread costs, and to allow later modernisations to be adapted to local conditions, experience learnt, and new conditions.

Paper 83 by J W Ervin and C Rothwell of the USA illustrated the intense negotiations with various interested parties on a rehabilitation in that country which aimed to provide extra municipal water by the reduction of seepage losses from an irrigation project. The legal rights and financial obligations and benefits of different parties had to be carefully reconciled. Other US papers show consultation of users, indeed often the initiation by users of a rehabilitation, to be normal. A common feature of both the French and American papers is discussion of various technical with the users before the installation of new equipment. T R Haider in paper 84 suggested the following steps:

a survey of the system (diagnosis)

alternative proposals, and discussion of their positive and negative aspects

comments and feedback from interested parties, if necessary through the constitution of an appropriate committee

preparation of environmental statements

preliminary designs including cost estimates

final designs.

As one of the panel members for this question, I suggested that we should commend France and the United States for their processes, rather than for their technology. The choice of the appropriate technology arises out of the process of consultation and negotiation on objectives and means, and through consideration of how costs will be divided amongst the interested parties. The latter is important. Erica Daleus and Jan Lundquist, in a recent study of a village tank system in Sri Lanka found that when outsiders asked farmers their solution for water shortage, most replied by advocating physical measures - raising the bund, putting in a new sluice, etc. As they point out, farmers expect that kind of measure to be funded from outside, so they stress it to outsiders. However, as I have observed in India and Zimbabwe, when you start talking to farmers in terms of only limited sums of money being available, or in terms of what they can afford to borrow and repay, they respond by prioritising rehabilitation measures in terms of costs and benefits in achieving their objectives.

Coming out rather less clearly, but mentioned by several participants in passing, is the need to consider not merely alternative technologies, but also alternative strategies. It is possible that a problem can be tackled either by changing structures, or by changing control systems, or by changing cropping patterns, or by changing institutional practices and organisational responsibilities.

On the technological side, Mr Kenneth Shepherd, the Australian expert on the Panel, felt the most important advances mentioned concerned canal lining materials, computers to assist scheduling, and industrial microprocessors to assist in operation of systems to minimise energy consumption. However, he also stressed processes rather than technology, summarising the important steps in the pre-rehabilitation process as:

- establishing the present status of the system
- establishing objectives for the system (users to participate in objective formulation)
- establishing how objectives should be achieved

One of the issues not sufficiently dealt with in either the papers or the discussion was on economic evaluation methodology as applied to rehabilitation, though some dissatisfaction was expressed with present practices. This is clearly an area requiring further work.

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IRRIGATION MANAGEMENT NETWORK

CHECKLIST FOR INCORPORATING SYSTEM OPERATION AND MAINTENANCE IN DESIGN

Harald D Frederiksen

PLANNING IMPLICATIONS OF SOCIO-ECONOMIC AND INSTITUTIONAL FINDINGS

Mary Tiffen

ODI/IIMI Irrigation Management Network Paper 87/3c December 1987

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87/3e: Developing Effective Extension Irrigation Programs with Appropriate Technology by Marvin N Shearer

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Comments received by the Editor may be used in future Newsletters or Papers.

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ISSN: 0951 189X

CHECKLIST FOR INCORPORATING SYSTEM OPERATION AND MAINTENANCE IN DESIGN

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PLANNING IMPLICATIONS OF SOCIO-ECONOMIC AND INSTITUTIONAL FINDINGS

Mary Tiffen

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INCORPORATING SYSTEM OPERATION AND MAINTENANCE IN DESIGN

Harald D Frederiksen

This Checklist was developed by Harald Fredericksen to assist in the development and appraisal of irrigation projects in which the World Bank is involved in funding. He would welcome comments, particularly those drawing attention to any gaps.

1. Operation and Maintenance - Considerations for Project Planning

Greater emphasis than hitherto should be placed on project operation and maintenance in the course of the project formulation, appraisal and execution. The purpose is to assure that Operations and Maintenance (O&M) receives a comprehensive treatment and is considered fully as important as any other project component and objective. This requires that it be reflected in every activity including the planning, design and construction phases, as well as in institutional arrangements and related policies.

2. Components of O&M Planning

Specific provisions must be made for the timely preparation and implementation of a Project Operation and Maintenance Plan by the respective irrigation department or any other agency responsible for O&M. This should include such items as policies, scheme of operation, procedures, facilities, equipment, manuals, organization, personnel, training and implementation schedule. The services to the farmers must be explicitly stated and clearly presented in a project design criteria document covering both water supply and the control or removal of excess surface and groundwater. Thus, a great many concerns need to be resolved in the process. The primary factors affecting O&M that are to be assured so that a successful project can be realised are listed.

3. Water Supply

3.1 Hydrologic data (surface and subsurface waters) are fully adequate for use in confirming the project supply.

3.2 Project water rights are fixed with priorities established for irrigation, municipal and industrial uses (M&I), power and other uses.

3.3 The basis for any differential allotments among project sub-areas is clear, equitable and known by affected farmers.

3.4 Farmers' allocations of surface and groundwater are unambiguous especially that the basis for allocation determinations, (eg, volumetric amount proportional to farm area served) and seasonal constraints are set out.

3.5 Classes of water reflecting users' "rights" during periods of project build-up, years of surplus flows and years of deficits are defined.

4. Service to Farmers

4.1 Clear criteria establishing the supply to farmers in terms of total annual, seasonal, and shorter-term volumes are established.

4.2 Limits on farmers' choice of size of irrigations, minimum interval between irrigations, size of stream, delivery schedule and short-term modification of schedules are explicit.

4.3 The dates for setting delivery schedules for defined time frames and the lines of required communications are established and understood by farmers.

4.4 The type for distribution facilities and level to which the agency will construct are set.

4.5 The magnitude of storms for which protection is to be provided and the associated inundation periods are stated.

4.6 The level to which groundwater will be controlled is established for each area including any seasonal deviations.

5. Services to M&I Users

5.1 Constraints to use of water are clearly established including peaking, seasonal limits and permitted outages.

5.2 The receiving system is located and described in terms adequate for defining operations.

6. Characteristics of Hydropower

6.1 Receiving system is described and connecting point is located.

6.2 Characteristics of receiving system in reference to state and regional systems are described.

7. Primary Facilities and Equipment

7.1 The principal surface and groundwater supply facilities are of a configuration to permit the contemplated delivery in compliance with the water rights.

7.2 Layout and composition of conveyance and distribution systems are fully adequate to permit the service defined including capacity, control and measurement and to allow safe operation to protect the facilities in adjacent areas in time of emergency.

7.3 Layout and composition of the collection and removal facilities for handling excess surface and groundwater including structures, pumping plants, wells, and natural channel modifications are carefully detailed.

7.4 The structures, fixed and moveable equipment, vehicles, communication system and supplies are designed and selected to meet the specific project needs.

8. Scheme of Operation and Operating Rules

8.1 Reservoir operating rules are described in terms of forecast runoff, actual runoff, priority among users, M&I, farmers and power and carry-over storage.

8.2 Rules for seasonal and long-term withdrawals of agency groundwater and introduction into system are spelled out.

8.3 Rules for system operation for accommodating farmers' requests for modifications during rainfall season are clear.

8.4 Rules for system operation during emergencies and to allow major maintenance, if affecting deliveries, are formulated.

8.5 The scheme of operation is detailed and will provide the service described within the capability of the physical facilities. The description is to include detailed example operations during build-up period, years of surplus, and years of shortages.

8.6 Operations under emergency conditions are to be detailed and illustrate all reasonable examples including extreme precipitation, floods, foundation failures, structural failures and loss of power.

9. Farmers' Organization

9.1 Discussions with individual farmers and farmers' groups are completed with the comments on rights, services, operating rules, O&M responsibilities and channels of communications documented.

9.2 Formal means of exchanges with farmers for establishing schedules, monitoring results, reviewing procedures and improving operations are described in detail with points of contact, roles and responsibilities for both farmers and agency clearly set out.

9.3 The actions to support the establishment of farmer organizations for dealing with O&M including incorporation of existing formal and informal groups are formulated.

10. Institutional Arrangements

10.1 The position of the project O&M agency in relation to the primary state departments and points of reporting are clear.

10.2 The structure of the project O&M agency including all units and sub-units, their function and geographical location are presented in detail.

10.3 Staff definition including position descriptions, minimum qualifications, and schedule of induction is set.

10.4 Training programs noting participants, subjects, course content, schedule, instructors, and facilities are detailed.

10.5 Agency personnel policies, particulary as they relate to development of expertise, retention in the agency, and promotion are firm and consistent with needs.

10.6 Any special arrangements for interface with state and regional power entities are documented.

11. O&M Documents and Procedures

11.1 A "Project Operation and Maintenance Plan", presenting all aspects of O&M is prepared.

11.2 Procedures manuals, personnel manuals, equipment manuals, maintenance manuals and rules are prepared or scheduled to be available when O&M staff training commences and before the project operations are to be initiated.

11.3 Accounting and invoicing procedures are resolved including charges for water and the time for initiation.

11.4 The basis for water charges reflecting equitability and different classes of water and the means for cost adjustment are set.

PLANNING IMPLICATIONS OF SOCIO-ECONOMIC AND INSTITUTIONAL FINDINGS

Mary Tiffen

One of the main conclusions of the study which I carried out for the British Overseas Development Administration in 1986, and which surveyed the findings of some 50 evaluation reports on irrigation schemes funded by a variety of agencies in Asia, Africa and Latin America, was that failure to achieve objectives was often related to a bad fit between the scheme design and circumstances in the local region in which the project was located. Choice of technology and choice of institutional management mode has to be related to the locally prevailing circumstances, and not simply to national objectives and overall national resources.

The Table below illustrates some of the linkages between the local socio-economic and institutional situation and the appropriate choices for technology or organisational structures. For example, population density is an important preliminary indicator of whether complete reliance on irrigated farming is likely to be acceptable way of life to the people concerned, or whether it should be viewed as a supplement to rainfed farming and livestock rearing. Where population densities are low, there is likely to be no local urban market to absorb high value crops, and also an absence of suppliers of local services and inputs; difficulty in purchasing staple foods, and therefore a necessity for allocating land to staple crop production; the likelihood that extensive rainfed farming or cattle rearing will give higher returns than irrigated farming to the scarce factor, labour; that equipment, construction materials and imported farm inputs such as fertiliser will suffer both high transport costs and delivery uncertainties; that export crops will be similarly handicapped; and that officials will dislike serving in the area so that the efficiency of government services will be low. In consequence, only two types of irrigation are likely to succeed; either low cost technology not dependent on a constant flow of inputs (eg fuel), on a small scale appropriate to the local market, and manageable by local people; or, a larger scheme if the technology can be kept relatively cheap (eg where it is possible to have gravity canals on clay from a relatively nearby water source) and if the principal crop can be compacted before transport, so that output has a high value relative to weight and bulk. By contrast, in areas of high population density, land or water are more likely to be the scarce factor, people will be more willing to accept discipline and rules to make the most of the scarce resource; markets for both output and inputs are likely to function well, etc.

In the case of a rehabilitation project, it is inherently likely that some of the socio-economic and institutional parameters will have changed since the original scheme was designed. For example, population density may have increased, farms become smaller, farm equipment changed from animal drawn to tractor based; local urban markets may have grown in size and capacity to provide services; farmers will have become more experienced and educational levels improved. This is likely to mean that modernization, rather than a simple rehabilitation to restore old capacities, is what is required, (using the definitions of the two terms proposed by the ICID and discussed in Paper 87/3b).

Table 3. Planning Implications of Socio-Economic and Institutional Findings

FINDINGS	IMPLICATIONS
1. Preliminary Indicators	
Population density	Suitability of area for irrigation; choice of crops; cropping intensity; construction methods and repair needs.
Identification of the scarce factor: water, land, labour, capital, recurrent funds, management skills	Design to maximise return to land or to spread water; flow rates; willingness to accept rules; role of government ministries; division of water by time or proportionality; canal lining; night irrigation and canal capacity; etc.

2. Local Economy and Farm Level Profitability

Existing income generating activities and probable irrigated income level	Irrigated income must exceed by a substantial margin activities it will displace. The greater level of individual farmer investment in construction or on-farm improvement, the greater the income increase needed as incentive.
Existing farming system, including livestock	Livestock watering points, crossing points, etc; sources and cost of lifting power and draught power; fertiliser requirement and cost
Marketing situation, price levels, irrigated farm incomes	Cropping patterns, cropping intensity, size of service area, length of main canal.
- output - essential inputs including repair services, spares - essential foodstuffs - credit	
	Selected cropping patterns, farm size and water supply technology must minimise risk of failing to achieve target income and food security.
- irrigation equipment - construction material and skills	Choice of technology according to local availability and skills, with future repair and replacement in mind.

Existing and future water use - above and below project area - needs for hydro-electricity, industry, etc. - existing law and customs on water use and water rights for different groups - secondary water sources	Scheme priority compared with other uses; amount of water available; infrastructure requirements for non-farming use; prior legal requirements and indemnity requirements; possible supplementation by individual/group/public wells; choice of water division by time (rotation systems) or by proportionality.
Labour - availability within family; sexual roles; children's contribution - cost availability of hired labour at peak seasons - availability of machinery to substitute for labour - slack season availability for maintenance, improvements, etc. - previous experience and record in irrigated agriculture	Farm size Field size Machine access and channel layout Degrees of farmer involvement in tertiary development, on-farm improvement, preferred flow rates and techniques, day/night utilisation and canal capacity, on-demand versus other systems.
- previous record in adopting innovations and new crops	Build up of productivity, desirability of design that accommodates changes in crops.
- education	Ability to operate formal organisations: verbal and visual versus written procedures; control structure design.

3. Social and Political Factors

Land tenure - farm size distribution - differences, top, tail, irrigated, non-irrigated - current value of land, sale and rentals, as above - fragmentation, inheritance rules - types of land rights, legal and customary - requirements for compensation, rights of way, reservoirs	Time-table of implementation if consolidation required; Distribution of benefits and dis-benefits; Choice of water distribution system to equalise water availability; Channel layout; number of outlets. Centres of opposition to project concept and their strength; persuasion versus compulsion in project concept; project costs.
- resettlement of displaced persons - recruitment of new irrigators	Training provision; degree of management supervision, structures and flow rates that can be handled, etc; credit provision; housing and infrastructure provision.
Local political and administrative structure - local project supporters, and opponents, reasons and strengths - administrative infrastructure, village, district - local associations and groups, formal and informal, methods of functioning, efficiency - local conflicts, causes	Desirability of project; possible conflict central versus local aims, possibility of excluding areas on technical grounds Block layout Institutional arrangements for project management, construction. Allocation of maintenance duties between farmers and government.

- degree of social cohesion	Interface, farmers and project authority; project and local government. Maintenance methods and technology choices. Location of responsibility for water allocation, and technology choices.

<u>4. Project Level Organisation and Economics</u>

Efficiency record of central government departments and local government; capabilities of farmer groups.	Design of project authority for operation and management.
Co-ordination record Legal and political obstacles to new types of institution	Allocation of responsibility for maintenance and operation between farmers and Ministries.
Staff availability for different skills, salary levels, staff incentives; years of experience. Probabilities of long service in one project or province	Contracting out versus direct labour. Choice of technology and layout, centrally controlled water distribution or farmer controlled. Drainage and escape requirements.
Financial management - ability, sources of income, budgetary procedures, expenditure heads. Recurrent budget difficulties in existing projects Foreign exchange difficulties in implementing existing projects Staff/ha ratios and costs on existing schemes O&M costs/ha cf farm income/ha Private sector capabilities in construction, repair, marketing, processing, etc. Provision for responsiveness to farmer requirements.	Design of implementation arrangements, co-ordination of ministries, choice of lead Ministry, etc.

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IRRIGATION MANAGEMENT NETWORK

MATCHING CROP WATER REQUIREMENTS IN LARGE SYSTEMS WITH A VARIABLE WATER SUPPLY — EXPERIMENTS IN INDIA

Jeremy Berkoff

SITUATIONAL COMPATABILITY — THE EXAMPLE OF WARABANDI

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ODI/IIMI Irrigation Management Network Paper 87/3d December 1987

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ISSN: 0951 189X

MATCHING CROP WATER REQUIREMENTS IN LARGE SYSTEMS WITH A VARIABLE WATER SUPPLY - EXPERIMENTS IN INDIA

Jeremy Berkoff

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SITUATIONAL COMPATIBILITY - THE EXAMPLE OF WARABANDI

Walter Huppert

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MATCHING CROP WATER REQUIREMENTS IN LARGE SYSTEMS WITH A VARIABLE WATER SUPPLY - EXPERIMENTS IN INDIA

Jeremy Berkoff

1. SYSTEMATIC CANAL MANAGEMENT IN THE SOUTHERN STATES

Increasing attention is being given by State Governments in India to the potential for improving the performance of existing irrigation schemes through changes in management. Recent initiatives have included a number undertaken in association with the World Bank. These have led to the recently-signed National Water Management Project (NWMP), a broad-based irrigation management programme, initially to be confined to three southern states (Andhra Pradesh, Karnataka and Tamil Nadu) but which - if successful - could be extended more widely.

An illustration of what the programme hopes to achieve is given by experience since 1984 on the 900,000 ha Nagarjunasagar project in Andhra Pradesh. Building on earlier initiatives, a co-ordinated programme was implemented which included:

- carry-over of reservoir storage to ensure an early and guaranteed start to the main kharif crop

- water budgeting to provide equitable allocations to individual sub-commands

- the staggered completion of paddy transplanting: systematic closure of canals for one or two days a week on completing of transplanting to save water and push it to the tail ('systematic canal operation', a well-established Andhra Pradesh practice)

- the intermittent operation of canals for non-paddy crops once the paddy was completed

- associated institutional, management and public relations measures.

Further improvements are being contemplated for 1987/88 including the consolidation and early closure of paddy zones, the extension of systematic canal operation and the development of re-use systems. Despite some initial problems, the 1984/85 programme was generally successful and was extended during the following two years. The area under irrigation has expanded significantly faster than water use: there was a major shift from paddy to less water intensive crops (although this was not fully maintained in 1986/87 owing to a severe pest attack on cotton in 1985/86). Paddy yields on the 350,000 ha or so of early planted paddy rose significantly above previous levels (from 3.5-4.5 tons/ha to 4.5-6.0 tons/ha); and, following the early completion of the paddy crop, the area of pulses grown on residual moisture increased substantially. Farmers are reluctant to establish nurseries without some early rains (deliveries in general need to respond more systematically to rainfall) but have demonstrated versatility in responding to the more disciplined water regime (for instance, by growing paddy and dryfoot crops side-by-side through the simple device of separating the two areas with a temporary drain).

Experience at Nagarjunasager illustrates the value of delivering water according to clearly defined rules which respond to the agronomic requirements of the predominant (and evolving) cropping pattern but which do not attempt to meet the individual demands of innumerable small farmers. Not only is the management task clarified, and the system made easier to control, but the farmer can plant his crops and arrange his farming activities to fit in with a pattern of water supply which, even if not absolutely guaranteed, is more reliable and predictable. Radical change in such massive schemes is clearly neither possible nor desirable, given established rights and practices. Nevertheless, a process of innovation, evaluation and modification of operational practice can clearly lead to a more equitable supply and to increased agricultural output and farm incomes. Under the NWMP, this process - at Nagarjunasagar and in other schemes - will be supported by selective physical investments, and by a co-ordinated approach to training, monitoring and related management improvements.

2. WARABANDI SYSTEMS IN NORTHWEST INDIA

2.1 Features of Warabandi

In the large, inter-connected systems of North-West India and Pakistan, such a system of clearly defined rules and operating procedures has been in existence from the start of major irrigation development. This is the warabandi system, which in principle allocates the right to water in proportion to land holding, and which is designed for low cropping intensities, thus providing strong incentives for the development of groundwater and efficient water use on farm. Even here, however, there may be possibilities for delivering water in ways which, while retaining the basic strengths of the warabandi system, more accurately meet the requirements of the crops.

In warabandi systems, the infrastructure is sized so that the capacity of successive channels is proportional to the area served. So long as river flows exceed the capacity of system, all canals run full and each outlet automatically obtains its 'proper' share. Below the outlet, the flow in the field channel is rotated during the week with the time allocated to each farmer proportional to his land holding (the warabandi schedule). The farmer thus knows the exact time each week that he is entitled to the full flow in the field channel.

In these northwestern warabandi systems, which are in many ways the most successful in India, distribution below the outlet was initially supposed to be arranged by the farmers who prepared their own 'wari' or turn system. However, under Section 68 of the North India Canal and Drainage Act of 1871, provision was made for a legally enforceable 'sanctioned' warabandi schedule prepared and enforced by the Irrigation Department. Farmers who wish to, can apply for such a schedule, which is formally registered. This is now the predominant system of enforcement in NW India. Farmers groups are therefore not a necessary condition for its working. Although the turns are in principle enforced by Government, and certainly Government acts on complaints from farmers, in practice the main control is by one farmer over another. If a farmer takes water out of turn, then he is directly 'stealing' the water of another specific farmer who either complains to Government or acts directly on his own behalf. Vigilance by farmers acting in their own interest (given that all the flow in the field channel is allocated to a particular farmer at a particular time) is one of the major strengths of the system.

2.2 Provision for periods of low flow

A second major strength is that farmers know what will happen in conditions of shortage. In the event that river flows fall below the combined capacity of the system to absorb them, a schedule is adopted which rotates priorities between groups of canals, the number of groups being determined by the variability of supply (for instance, three groups if water availability never falls below a third of the system's capacity). In week one, Group I has first (A) priority, and is guaranteed supplies; Group II has B priority and may receive water only if supplies are between one-third and two-thirds of the system's capacity; and Group III has C priority, receiving water only if supplies exceed two-thirds. In week two, Group I has C priority, Group II A priority, and Group III B priority, with a similar progression during week three. Since canals are only run full, when any minor is running the flow in the field channel is maintained and the warabandi schedule is unaffected. However, when water is scarce, the farmer can only be sure that he will obtain water once in three weeks (for a three group system).

2.3 Improvement trials

Although the priority system in warabandi is easy to manage and explain to farmers, it nevertheless results in unplanned inequities, not only between groups - Group I may be lucky and obtain flows when it has A, B, and C priority whereas Group II may be unlucky and obtain water only when it has A priority - but also within Groups (canals run full or not at all, so that individual canals must be progressively closed within each group as supplies decline even though they are of the same priority). Furthermore, the schedule of deliveries does not respond - except informally - to cropping patterns or groundwater development, both of which can be very variable through these massive systems.

One approach tested in both Haryana and Rajasthan is to fix a schedule for a particular area which responds to crop requirements but which may give less total water than the area is due under strictly proportional to area considerations. Clearly, the extent of the command that can be given assured supplies for its crop water needs depends on the variability of total receipts, while assuring supplies to part of the command inevitably reduces predictability elsewhere. If timing and security of supply are of more value than total amount over a season, as is suggested by the two pilot programs, then these other areas suffer.

An alternative, developed by Narayanamurthy, a World Bank consultant, is to keep a running total of what has been given to each command, comparing this at each stage to a target schedule (the ideal if supplies could be controlled). At each moment, canals would opened or closed in response to availability with the aim of allocating water as closely as possible to the target schedules, in other words, minimizing the mismatch between the actual pattern of deliveries and the ideal. While farmers would not be guaranteed water every three weeks (as under a three priority system), they would be guaranteed equity over the total season and a schedule which responded to variable cropping patterns in different parts of the command. In the long term, it might also be possible to modify schedules to take into account other factors, such as saline groundwater areas, the number of tubewells in a sub-command, etc.

Clearly, combinations of these approaches are possible. For instance, it may be desirable to give assured supplies to saline groundwater areas (since they cannot respond to uncertainty by pumping) while adopting the target schedule approach for fresh groundwater areas. Again, it may be desirable to retain the A priority - guaranteeing farmers water every three weeks on the pattern to which they are accustomed - while confining the target schedule approach to the B and C priority turns. Narayanamurthy has developed a computer package which can handle these possibilities, and pilot programs to test the alternatives are continuing or are proposed in Haryana, Punjab, and Rajasthan, each of the three States concerned.

SITUATIONAL COMPATIBILITY - THE EXAMPLE OF WARABANDI

Walter Huppert

In this abbreviated version of a paper given at the Thirteenth Congress on Irrigation and Drainage, Walter Huppert argues the need for the technical and organizational design to be compatible with:

goals/outputs
resources/inputs
the environment: technical, social and ecological.

He uses the example of the introduction of systems modelled on warabandi into other parts of India, which is why it is useful to consider his points in relation to those made by Berkoff above. However Huppert emphasises his conclusions were the result of a relatively short investigation; what he is really putting forward here is a method of analysis which he calls the compatibility matrix. It can be compared with the matrix used by Shearer in Paper 87/3e. It could also be used with elements from the table on socio-economic and institutional factors which should influence technical and organizational choices to be found in Paper 87/3c. (Mary Tiffen)

1. INTRODUCTION

Compatibility considerations supported by the use of a "compatibility matrix" may be a planning aid in rapid appraisals of rehabilitation needs. Such a matrix can be of help in tracing hidden interactions within a system and incompatibilities with respect to the situational fit.

To demonstrate the usefulness of such compatibility considerations, an example from India will be looked at. Although the author only has a second-hand knowledge of the projects mentioned through brief project visits, they appear to be particularly useful examples to discuss problems of situational compatibility since an attempt was made to transfer a highly successful organizational and technical system design to a "foreign" situation.

In the early 1980s it was observed there was a marked difference in capacity utilization in India: about 25% of the systems, predominantly in North-West India were estimated to operate at water-utilization-efficiencies of about 70%, while the remaining 75% operated at only about 25% efficiency (Seckler, 1981). The high efficiency systems corresponded largely to the irrigation schemes where "warabandi" was practised. These positive results induced the Indian Government in the mid 1970s, supported by the World Bank and FAO, to promote the introduction of new water management concepts now called "Rotational Water Supply" (RWS) in a number of projects throughout the country. Partly in accordance with traditional warabandi principles, the RWS concept presumes that the allocation of varying water dosages to different crops in accordance with differing crop requirements throughout the season, taking into account soil moisture conditions of locally varying soil types and hence requiring differing irrigation intervals, was not practicable under conditions of small, fragmented holdings. Warabandi radically simplified water distribution in order to bring about organizational feasibility on the one hand and ensure a reliable, timely, predictable and equitable water allocation on the other hand.

Predictability and reliability of allocation together with an equitable distribution of scarce water are essential design characteristics that adapt the system to the farmers' objectives of risk avoidance and food security.

Since warabandi was highly efficient in Northwest India, the RWS projects attempted to transfer its organizational and technical design characteristics to projects elsewhere. One of the goals of RWS projects was thus to achieve a substantial increase in water utilization efficiencies and hence profitability through "soft" organizational inputs with low capital intensity.

2. TRADITIONAL WARABANDI - A SYSTEMS VIEW

Warabandi as practised traditionally in Northwest India is not an ideal system and has been criticised for:

a) heavy water losses entailed by the system
b) lack of adjustment of water supply to crop water requirements
c) impending problems of waterlogging and salinization due to over-irrigation in certain periods of the cropping cycle.

(Raj, K N, quoted in Thornton, 1966).

In Table 1 the compatibility of environmental parameters (institutional aspects, resources and farmers' goals) and resources and project goals are listed on the left-hand side and the organizational and physical design characteristics of the system listed along the top of the table. The row/column intersections indicate compatibility (+) or non-compatibility (-). It presents in a simplified manner some of the predominant design features of traditional warabandi as practised in parts of the Bhakra canal system in Haryana.

The goal systems are incomplete and the farmers' goals indicated are based on assumptions only. The objections to the system, listed above, are shown by the negative signs at certain intersections. However, these negative effects have to be balanced against the multiple objectives of traditional warabandi projects and the system interaction between environment, goals, and design characteristics.

The project goals of disaster prevention and drought protection typical for traditional warabandi imply the provision of little irrigation water for many people instead of intensive irrigation for the few. This goal necessarily conflicts with the individual farmer's objective of profit-maximization, whose viewpoint is taken into consideration in criticism (b). However, the project goal of drought protection is in line with the farmer's aims of risk avoidance and food security. To bridge the gap between these conflicting goals, organizational and physical design characteristics had to be selected taking into account the prevalent environmental parameters:

Table 1

DESIGN-CHARACTERISTICS / ENVIRONMENTAL PARAMETERS + RESOURCES + GOAL SYSTEMS				DESIGN CHARACT. OF TRADIT. WARABANDI														
				ORGANIZATIONAL							TECHNICAL							
				RESPONSIB. FOR REGUL. AT OUTLET: NON-EXISTANT (FIXED FLOW)	HIGH STANDARDIZ. OF IRRIG. SCHEDULING (FIXED TURN, FIXED FLOW)	RESPONSIB. FOR MAINTEN. OF INFRASTRUCT. AT FARM LEVEL: INDIV. FARMERS	COORDINATION-ENTITY BELOW OUTLET: FARMERS	COMMUNICATION LINE FOR REGUL. OF DISPUTES: FARMER-DEPUTY COLLECTOR	PARTICIPATION-STATUS OF FARMER: INDEPENDENT	BASIS FOR WATER-PRICING: AREA OF SPECIFIED CROP GROWN	TYPE OF CROPS: INDEPENDENT	1 CUSEC PER 400 ACRES	CROPPING CALENDAR: INDEPENDENT	FLEXIBILITY OF IRRIG. INTERVAL: STAGGERED PLANTING	FIXED FLOW AT OUTLET: ~1 CUSEC	NO ADJUSTMENT TO VARYING CROP WATER REQUIREMENTS	WATER ALLOC. ONCE A WEEK AT FIXED TIME	NO TIME ADJUSTMENT FOR DELIVERY
BHAKRA-CAN./HARYANA				a	b	c	d	e	f	g	h	i	k	l	m	n	o	p
ENVIRONMENT (INSTITUT. ASPECTS)		1	• STRONG + TRADIT. IRRIGATION-LEGISL.		+		+	+	+									
		2	• MEDIUM ADMIN. CAPACITY	+	+	+	+		+	−					+	+	+	+
		3	• POOR SOCIAL COHESION (STRONG COMPETITION FOR WATER)				−		+			−			+		+	−
RESOURCES		4	• HOLDING SIZE MEDIUM (~4 ha)				+	+	+					+				
		5	• HIGH WATER SCARCITY									+			−	−		+
		6	• SCARCE FINANCIAL RESOURCES FOR O + M	+	+	+	+								+	+		
GOALS	FARMERS GOALS	7	• RISK AVOIDANCE				+	+	+		+		+	+	+	.	+	
		8	• FOOD SECURITY								+	+	+	·			+	
		9	• SECURE WATER-RIGHTS				+	+										
		10	• MAXI. OF NET RETURNS									−		+	−	−		−
		11	• EQUITABLE WATER RIGHTS		+		+	+							+			−
	PROJECT GOALS	12	FINAL: • POVERTY REDUCT./DISASTER PREV.															
		13	1. ORDER: • DROUGHT-PROTECTION • HIGH PRODUCTIV. OF WATER															
		14	2. ORDER: • CROPPING-INTENSITY ≈ 40%									+						
		15	• IRRIG. OF LARGEST FEAS. AREA									+			−	−		
		16	3. ORDER: • TIMELY + PREDICT. DISTRIB. OF 1 CUSEC PER 400 ACRES												+	+	+	−
		17	• EQUITABLE + PREDICTABLE DISTRIBUT. OF 1 CUSEC PER 400 ACRES		+		+	+							+			−

[+] DESIGN CHARACTERISTIC TAKES ENVIRONMENTAL PARAMETER OR RESOURCE AVAILABILITY INTO ACCOUNT OR SUPPORTS SPECIFIC GOAL IN QUESTION

[−] DESIGN CHARACTERISTIC IN CONFLICT WITH ENVIRONMENTAL PARAMETER, RESOURCE AVAILAB. OR WITH GOAL to provide little water to many people entails corresponding extension of the canal system and hence unavoidably increases water losses (see criticism point a);

objectives to enlarge the canal network tend to be in conflict with the situation variable "medium administrative capacity". Hence, to be able to achieve this objective, design features were selected that take into account the constraint mentioned: fixed flows at chak outlets do not require regulation operations, and hence save manpower otherwise required for operation and administrative purposes. However, such fixed flows, again unavoidably, entail increased water losses and cannot match varying crop water requirements (criticisms b and c);

to cope operationally with differing water requirements of a large number of users and to prevent stronger farmers from taking more than their due share - trying to satisfy their profit maximization goal - a simple system of reliable, timely and easily predictable rotation had to be introduced: the fixed turns once a week. By necessity, this mode of distribution conflicts with the individual farmer's goal to satisfy optimum crop water requirements (criticism b).

However, the above objections seem to neglect the fact that a remedy for these conflicts, which undoubtedly exists, would necessitate adjustments of design characteristics which would then in turn induce other conflicts with existing goals and environmental conditions. "Improvements" in such a multiple objective systems context can thus only be judged by the overall changes in the system which they bring about.

3. THE TRANSFER OF WARABANDI - SYSTEMS INTERACTIONS

As mentioned before, the intention of the World Bank supported RWS projects in India was to transfer the "successful" principles of warabandi into irrigation schemes elsewhere in the country. One of the most frequently mentioned projects of this kind is the Sree-Rama-Sagar, or Pochampad, project in Andhra Pradesh, where 600,000 hectares of potential irrigation area are supplied with water from the Ghodavari river system by means of three storage and diversion dams[1]. Looking at the situation variables and the project goals, however, reveals substantial differences from the conditions under which warabandi is used in Haryana: the matrix in Table 2 represents, again in a *simplified* manner, environmental conditions and goal systems of the Sree-Rama-Sagar project related to the design characteristics of traditional warabandi as described in Table 1. The greater number of negative signs show that traditional warabandi, if used in the Sree-Rama-Sagar context, induces substantial conflicts and problems. Table 3 then shows modifications in design characteristics, environmental parameters and goal systems that have proved to be necessary due to incompatibilities in systems interactions.

Some of the major problem areas in the system that have emerged in this "transfer of technology" are:

a) the project goals are substantially different from drought protection and maximization of water productivity as pursued in Haryana: the objective is a cropping intensity of 100%, ie, the aim is to achieve one optimal crop per holding per year (non-rice crops in the dry season or paddy in the monsoon season) and thus contribute to increases in the "environment/goals/design characteristics" relationships.

The constant flow at the chak-outlet had to be fixed according to the estimated peak water requirements of the average cropping pattern in the chak, and was estimated at 1 cusec per 40 ha in the dry season for non-rice and 1 cusec per 16 ha in the monsoon season for paddy (as compared to 1 cusec per 160 ha in traditional warabandi). Such a substantial increase in irrigation duties seriously aggravated the problem of over-irrigation in time periods outside peak requirements due to fixed flows at the chak outlet already mentioned: serious problems of waterlogging and subsequent yield depressions forced the management to abandon the warabandi principle of constant flow, and flow regulating structures had to be installed (see Table 2, 15-m; Table 3, 15-m).

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[1] *The paper by K K Singh, Sc, 1983 "Assistance needs of Water User Associations in their first years – the example of Pochampad" is still available to those interested.*

Table 2

		DESIGN-CHARACTERISTICS / ENVIRONMENTAL PARAMETERS + RESOURCES + GOAL SYSTEMS	MODIFIED DESIGN-CHARACTERISTICS OF WARABANDI: [illegible]														
			ORGANIZATIONAL							TECHNICAL							
			RESPONSIB. FOR REGUL. AT OUTLET: FIELD-CHANNEL, IRRIG. ADM.	MEDIUM STANDARDIZ. OF IRRIG. SCHEDULING (FIXED TURN, MONTHLY FIXED FLOWS)	RESPONSIB. FOR MAINTEN. OF INFRASTRUCT. AT FARM LEVEL: FARM-COMMITTEE	COORDINATION ENTITY BELOW OUTLET: FIELD-COMMITTEE	COMMUNICATION-LINE FOR RESOL. OF DISPUTES: FARMER-GROUPS-COMMITTEES-ADM.	ENTITLEMENT-STATUS OF FARMER: GROUP-NUMBER	BASIS FOR WATER-PRICING: AREA	TYPE OF CROPS: INDEPENDENT BUT NO RICE OR ONLY RICE (AMERIC.)	1 CUSEC PER 100 ACRES (NON RICE) 1 CUSEC PER 40 ACRES	CROPPING CALENDAR: INDEPENDANT	FLEXIBILITY OF IRRIG.-INTERVALS: STANDARD PLANTING	FLOW REGULATION ACCORDING TO CROP WATER REQUIREMENTS	MONTHLY ADJUSTMENTS TO VARYING CROP WATER REQU.	LARGE ALLOCATION ONCE A WEEK AT FIXED TIME	TIME ALLOCATIONS FOR DELIVERY
SMCC-NARA-SAGAR PROJECT			a'	b'	c'	d'	e'	f'	g'	h'	i'	k	l	m'	n'	o	p
ENVIRONMENT (INSTITUT., SOCIETAL)	1	-NEW + WEAK IRRIGATION-LEGISL.		−		+	+	+									
	2	-WEAK ADMINISTR.-CAPACITY	−	−	+	+			+					−	−	+	−
	3	-POOR SOCIAL COHESION	−		−	−	−	−						−		+	+
RESOURCES	4	-SMALL SIZE OF HOLDINGS (av.~0.4 ha)				+	+	+	+				−			−	
	5	-RESTRICTED WATER SCARCITY									+			+	+		+
	6	-SCARCE FINANCIAL RES. FOR O + M	−	−	+	+								−	−		
FARMERS GOALS	7	-RISK AVOIDANCE				+	+	+		+		+		−	−		
	8	-FOOD SECURITY									+	+					
	9	-SECURE WATER-RIGHTS				+	+	+									
	10	-DEV. OF ALT. VENTURES									+			+	+		+
	11	-EQUITABLE WATER RIGHTS		−		+	+	+						+			+
GOALS: PROJECT GOALS	12	FINAL: IMPROVEMENT OF LIVING STAND.															
	13	1.ORDER: -GROWTH IN INCOMES-INCREASE IN AGRIC. PROD.-ADJUSTM. OF BENEFITS															
	14	2.ORDER: -CROPPING INTENSITY ~150%									+			+	+	−	+
	15	3.ORDER: -PROVISION OF CROP WATER REQU. FOR SPECIFIED CROP (ONE SEAS.)		+						+	+			+	+	−	+
	15'	-STRENGTHENING OF ADMIN. CAPACITY												+	+		+
	15''	-FUNCTIONING WATER USERS ASSOCIATION	+		+	+	+	+					+				+
	16	-TIMELY + PREDICTABLE DISTRIBUTION OF 1 CUSEC PER 100 ACRES												−	−		+
	17	-EQUITABLE DISTRIBUTION OF 1 CUSEC PER 100 ACRES		+		+	+	+						+			+
	17'	-FUNCTIONING EXT. SERVICE					+	+									

[+] DESIGN CHARACTERISTIC TAKES ENVIRONMENTAL PARAMETER OR RESOURCE AVAILABILITY INTO ACCOUNT OR SUPPORTS SPECIFIC GOAL IN QUESTION

[−] DESIGN CHARACTERISTIC IN CONFLICT WITH ENVIRONMENTAL PARAMETER, RESOURCE AVAILAB. OR WITH GOAL

However, in the same way as the change in goals (from drought protection to 100% cropping intensity) and the subsequent change in design characteristics (from 1 cusec per 160 ha to 1 cusec 40 ha or 16 ha) induced changes in situation parameters (waterlogging problems and farmers' goals with *emphasis on profit maximization*) the attempts to remedy this problem by the introduction of flow regulation brings about new conflicts with environmental factors as well as with the existing goal system.

Flow regulation adjusted to crop water requirements requires evapotranspiration measurements and regular gate adjustments and increased maintenance and repair work. This however conflicts with environmental factors like weak administration capacity due to *limitations of staffing* and scarce government financial resources for O&M (Table 3, 2-m'+n'; 6-m'+n'). This leaves basically two options: either new goals are added, ie, strengthening administrative capacity and improving O&M (Table 3, row 15), and additional government funds are provided, or *goal achievement levels* are reduced, eg to lower percentage values of intended cropping intensity. If neither of these options is taken, the system may equilibrate itself at a lower goal achievement level; the inconsistency in the goal/environment/design constellation may result in "project failure" as the *achievement* levels envisaged *may not be* reached.

b) Not only the project goals, but also the environmental conditions are substantially different in Sree-Rama-Sagar from traditional warabandi schemes: while the average *size of holdings* in the Haryana section of the Bhakra Canal system is approximately 4 ha, the average holding in Sree-Rama-Sagar comprises only 0.4 ha.

Again, this change in system parameters entails the *need* for *substantial adjustments*; a regular weekly water-turn - the core of traditional warabandi design characteristics - poses no major problems in Haryana if crops and soil conditions require a two or three weekly irrigation instead. The farmer can subdivide his holding into several parts and stagger his *cropping* and water allocations accordingly.

Table 3

DESIGN-CHARACTERISTICS / ENVIRONMENTAL PARAMETERS + RESOURCES + GOAL SYSTEMS			DESIGN CHARACT. OF TRADIT. WARABANDI: ORGANIZATIONAL							TECHNICAL							
			RESPONSIB. FOR REGUL. AT OUTLET: NON-EXISTANT (FIXED FLOW)	HIGH STANDARDIZ. OF IRRIG. SCHEDULING (FIXED TURN, FIXED FLOW)	RESPONSIB. FOR MAINTEN. OF INFRASTRUCT. AT FARM LEVEL: INDIV. FARMERS	COORDINATION ENTITY BELOW OUTLET: FARMERS	COMMUNICATION • LINE FOR REGUL. OF DISPUTES: FARMER-DEPUTY COLLECTOR	PARTICIPATION-STATUS OF FARMER: INDEPENDENT	BASIS FOR WATER-PRICING: AREA OF SPECIFIED CROP GROWN	TYPE OF CROPS: INDEPENDENT	1 CUSEC FOR 400 ACRES	CROPPING CALENDAR: INDEPENDENT	FLEXIBILITY OF IRRIG. INTERVAL: STAGGERED PLANTING	FIXED FLOW AT OUTLET: ~1 CUSEC	NO ADJUSTMENT TO VARYING CROP WATER REQUIREMENTS	WATER ALLOC. ONCE A WEEK AT FIXED TIME	NO TIME ADJUSTMENT FOR DELIVERY
SREE-RAMA-SAGAR PROJECT			a	b	c	d	e	f	g	h	i	k	l	m	n	o	p
ENVIRONMENT (INSTITUT. ASPECTS)	1	• NEW + WEAK IRRIGATION-LEGISL.		–		–	–	–									
	2	• WEAK ADMINISTR. CAPACITY	+	+	+	+			–					+	+	+	+
	3	• POOR SOCIAL COHESION				–		–			–			+		+	–
RESOURCES	4	• SMALL SIZE OF HOLDINGS (av. ~0.4 ha)				–	–	–	–				–			–	
	5	• RESTRICTED WATER SCARCITY									–			–	–		–
	6	• SCARCE FINANCIAL RESOURCES FOR O + M	+	+	+	+								+	+		
GOALS: FARMERS GOALS	7	• RISK AVOIDANCE				–	–	–		+		+		+			
	8	• FOOD SECURITY								+	+	+					
	9	• SECURE WATER-RIGHTS				–	–	–									
	10	• MAXIM. OF NET-RETURNS									–			–	–		–
	11	• EQUITABLE WATER RIGHTS		+		–	–	–						+			–
GOALS: PROJECT GOALS	12	FINAL: • IMPROV. OF LIVING STANDARDS															
	13	1. ORDER: • INCREASES IN PER CAP. INCOMES • INCREASE OF AGR. PROD. • EQUIT. W-DISTR.															
	14	2. ORDER: • CROPPING INTENSITY OF ~100%									–						
	15	3. ORDER: • PROVISION OF CROP-WATER REQU. FOR SPECIFIED CROP (1 SEASON)									–			–	–	–	–
	16	• TIMELY + PREDICTABLE DISTRIBUTION OF 1 CUSEC PER 100 ACRES												+	+		–
	17	• EQUITABLE DISTRIBUTION OF 1 CUSEC PER 100 ACRES		+	–	–	–	–						+			–

[+] DESIGN CHARACTERISTIC TAKES ENVIRONMENTAL PARAMETER OR RESOURCE AVAILABILITY INTO ACCOUNT OR SUPPORTS SPECIFIC GOAL IN QUESTION

[–] DESIGN CHARACTERISTIC IN CONFLICT WITH ENVIRONMENTAL PARAMETER, RESOURCE AVAILAB. OR WITH GOAL

In Sree-Rama-Sagar, however, such strategies encounter problems. To divide a smallholding of a fraction of a hectare into several subsections and then stagger planting and irrigating will be impossible: to provide all the different labour inputs from land preparation to harvest, at different times for different small land segments will be uneconomical for the farmer, especially if he lives some distance from his irrigation plot. He will hence try to co-operate with his neighbours and take his turn only every second or third week, but then take double or triple his usual water allowance. This adjustment, however, curtails the project objective to make water allocation reliable and easily predictable, and may therefore eliminate or weaken one of the major advantages of warabandi (Tables 1, 2, and 3, column 0).

c) Warabandi as practised in Northwest India satisfies the farmers' goals of access to secure water rights by direct communication with the administration in the case of conflicts between water users. These direct farmer/administration contacts are feasible in Haryana owing to relatively large holdings - and hence a limited number of farmers to be dealt with per unit area - and owing to age-old warabandi traditions which restrict the number of conflict cases. Rights and obligations of the users have been firmly established since the 1871 legislation. Penalties for violations of rules are known to be fierce.

In Sree-Rama-Sagar, however, smallholding sizes, and hence large numbers of users per unit area, combined with poor administrative capacity owing to lack of staff and relatively new and still largely unknown irrigation legislation make warabandi practices much more difficult (Tables 1 and 2, row 9).

To overcome this problem, water users' associations have been created with the functions of conflict regulation, control and co-ordination. This substantially changed the institutional environment faced by the farmers and meant that project goals for the creation and maintenance of such associations had to be added to the goal system of the project, including establishment of corresponding extension services (see Table 3, rows 15" and 17').

The introduction of water users' associations and the corresponding change in organizational design characteristics (see Table 3, columns a' to f') may solve the administrative problems if they function properly. However, it may be difficult to achieve this in a context of relatively poor social cohesion (see Table 3, row 3) and thus to ensure secure water rights even to a socially weak smallholder.

The foregoing observations show that the transfer of warabandi from the "environment/goal/design" circumstances prevalent in Haryana to the different circumstances prevailing in Sree-Rama-Sagar, necessarily affected goals, design features and environment, and changed the warabandi character of water management system nearly beyond recognition.

4. CONCLUSION

The admirable achievements of warabandi in bringing about equitable water distribution to smallholders mean they deserve consideration for introduction elsewhere - if local systems inter-relationships allow.

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Dr B K Narayan of ICSIM, Bangalore, feels that it is possible to design a water turn schedule that meets crop water requirements even in an area with many small farmers; we hope to carry information of experiments in the Hemavathy Command in a later issue. (Mary Tiffen)

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IRRIGATION MANAGEMENT NETWORK

DEVELOPING EFFECTIVE EXTENSION IRRIGATION PROGRAMS WITH APPROPRIATE TECHNOLOGY

Marvin N Shearer

ODI/IIMI Irrigation Management Network Paper 87/3e December 1987

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ISSN: 0951 189X

DEVELOPING EFFECTIVE EXTENSION IRRIGATION PROGRAMS

WITH APPROPRIATE TECHNOLOGY

Marvin N Shearer

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DEVELOPING EFFECTIVE EXTENSION IRRIGATION PROGRAMS WITH APPROPRIATE TECHNOLOGY

Marvin N Shearer

1. INTRODUCTION

Questions relating to technology transfer are as relevant in third world countries as they are in developed countries. The philosophies and procedures used in developing and executing the successful extension program described in this paper were based largely on what the author has learned over a period of thirty years while serving as an extension specialist in the United States. Technology transfer dictates a change in the way people do things and the way they think. Successful transfer of technology therefore requires that objectives deal with expected behavioral changes of people rather than simply the physical transfer of new technology into what is frequently a strange environment.

The project described in this paper was initiated to improve on-farm irrigation methods and management by training Tunisian extension staff to identify opportunities and demonstrate simple, inexpensive, understandable solutions which could have a substantial impact on the conservation of water resources and the standard of living of farmers in the Kasserine area. It has been exceptionally successful in view of the short time that it has operated. This success can be largely attributed to the original planning, which was based on proven technology transfer procedures, dedication of on-site staff in following those procedures, and the excellent working relationships established between the Tunisian and American project staff.

2. THE PROJECT AREA

Oregon State University has been contracted by the Government of Tunisia to carry out a number of regional development activities, with a strong emphasis on extension. One amongst these is the Extension Irrigation Project, initially approved for a single year's operation in 1984, which has been concerned with improving on-farm irrigation methods and water management.

The project is located in an arid zone of western Tunisia, to the north of the Sahara Desert. It encompasses 13 local districts (or delegations) where the Tunisian Government has been settling nomadic people, since the 1960s, on small farms approximately 5 hectares in size. The main crops grown are vegetables, grain, forage and fruit trees, part of the harvest being used for consumption and part for sale. The farmers have been given financial assistance in establishing irrigated farms and technical assistance in their farming operations. They have faced a dramatic change both in their way of life and in technology. While the duration of this project (initially one year) might appear rather short, Oregon State University already had staff working on other extension programs in operation in the area.

Before the project started, farmers received water either from shallow hand-dug wells 3 to 5 meters in diameter and 10 to 30 meters deep, or from perimeters. Perimeters are small irrigation districts developed by the government that deliver water from deep wells to individual farmers through concrete flumes or pipeline distribution systems.

The shallow wells functioned somewhat like cisterns in that water entered the wells at very low flow-rates until the surface of the water in the wells rose to about the same elevation as the water table. Farmers were then able to pump at flow-rates of 5 to 10 liters per second for a period of 2 to 4 hours before the well ran dry. They usually waited until the following day for the water supply to be replenished, then repeated the process. Farmers in perimeters received water at a flow-rate of about 25 liters per second for a time period of 2 to 4 hours every 7 to 10 days. This schedule resulted in farmers handling a surge of water for a short period of time.

The basin method of irrigation predominated; however, there were also some farmers using furrow, strip-border, and controlled flood systems of irrigation. The fields are usually small, with individual basins ranging in size from about 2 meters by 2 meters to 3 meters by 10 meters. Water distribution to basins, furrows, or borders has been through small ditches, the banks being cut or ditches dammed with soil to direct water to the desired locations. Low flow-rates from the wells and the light soil characteristics have made it extremely difficult to convey water and irrigate efficiently from earth ditches that have no structures or other water control devices. Consequently, considerable quantities of water were lost through ditch seepage.

3. SPECIFIC IRRIGATION PROBLEMS

A number of specific problems were identified as needing attention if growers were to become more efficient in water management. These included but were not limited to the following:

1. Extreme water supply limitations.

2. Water delivery flow-rates that were either too high or too low for efficient water application with existing farm irrigation systems.

3. Excessive seepage losses in farm ditches.

4. Excessive labor required to distribute water during irrigation.

5. Inefficient pumping plant installations.

6. Improperly oriented basins on sloping land.

7. Inadequate land smoothing for surface irrigation.

8. Soil erosion in ditches having even moderate slopes and where water fell from pipes or flumes.

9. Inadequate maintenance of wells, pump installations, delivery systems.

10. Lack of effective water control and water measurement devices.

11. Lack of scientific irrigation scheduling procedures.

Plans to remedy these problems were developed and outlined in relation to likely farmer behaviour and objectives, irrigation operating procedures, work plan schedules, and evaluation criteria.

4. DEVELOPMENT OF PROGRAM STRATEGIES

The primary long term goal of this project has been to improve on-farm irrigation methods and water management in order to maximize farm profits. To achieve this goal required a number of decisions and selection of specific activities. At the start of the program, it was decided to pursue certain key strategies, which were:

1. to begin with the current level of technology and give farmers an opportunity to learn new technologies from a reference point with which they were familiar.

2. to provide opportunities for farmers and extension staff to learn, rather than trying to teach people by telling them what to do.

3. to include in the program only those technologies that have a high chance for success until strong support for the program has been developed. Success is built on success, not failure.

4. to enable extension agents to become familiar with and accept new technology themselves before asking them to disseminate such ideas to farmers. Extension staff cannot "sell" to others what they have not already "bought" for themselves.

5. to work principally with agents who are willing to commit their time and be active program participants, knowing that others will ask to be

included later when the rewards received by those who are active become known.

6. to evaluate progress in terms of greater understanding, acceptance, and promotion of the new technologies by officials, technicians, and farmers, rather than by how much new equipment is in place. Material objects are not in themselves signs of lasting progress, without the associated changes in the way people do things.

5. SELECTING APPROPRIATE TECHNOLOGIES

Selection of appropriate technologies has been critical for successful completion of this project. The problems identified would have been relatively easy to attack in developed countries where private industry and research organizations search for and develop solutions to problems. For example, the Extension and the Soil Conservation Services, in the United States, are committed to sharing new knowledge and promoting adoption of new practices, products, or equipment which make farming more profitable or conserve resources. As a result, there is rapid take-up by farmers of the most advanced irrigation technologies almost as soon as they are developed.

However, this take-up is neither so rapid nor easy in many developing countries where information is not so freely available or shared and where some persons view information as power. The authorities may not provide sufficient encouragement or incentives to technicians and field workers to promote creativity, nor adequate rewards in the form of recognition, salary increases, and promotion for exceptional performance by their staff. Many farmers in developing countries want to innovate and to adopt new technologies. The problem for extension agents is to identify these innovators and capitalize on their enthusiasm as a means of influencing others.

The stocks of abandoned equipment found in a number of developing countries serve as a monument to the dangers of promoting new technology too rapidly and with too little attention to training, back-up and support facilities. Choice of technologies used to solve identified problems must be made in response both to physical and to cultural influences. The physical influences are rather straightforward and relatively easy to evaluate. Decision makers any wish to choose the "most advanced technology" available, but this will be inappropriate where it has been developed to solve specific problems which have been identified in relatively well-developed countries, with different resources and constraints and with greater familiarity with irrigation technology. Developing countries and even specific areas within developing countries must be considered individually when identifying appropriate technology. For example, farming areas along the Tunisian coastline and those in the Kasserine project area are vastly different in their level of technological development and ability to make good use of advanced techniques.

Table 1 was prepared to provide a general comparison of irrigation system characteristics and major physical and cultural influences which were considered during the selection of appropriate technology for this project. With a projected project duration of only one year, the selections made had to be simple and easily understood by technicians and farmers.

Only existing surface irrigation methods, with modifications, were finally selected for use in the project area. This proved to be a wise decision, as farmers, with their experience and understanding, could assist with the installations and frequently offered suggestions on how to improve them. Farmer suggestions were encouraged and acted upon whenever possible because through this process part of the design became their's and they assumed a responsibility for its successful operation.

The ratings applied to different technologies in Table 1 would have changed considerably if there was local expertise available to repair equipment and train operators and if preventive maintenance was practiced regularly.

From Table 1 it can be seen that:

Drip systems were down-rated considerably because of cost and because of the training required to enable both farmers and extension agents to operate them successfully. Drip systems also require preventive maintenance, which is not clearly understood by either farmers or extension agents in the area. There are no established local dealers willing to carry a stock of spare parts or capable of providing adequate advice on equipment needs, layout designs, and operational procedures.

In one case, a small drip system to irrigate one hectare of apples had been installed on an extension demonstration farm prior to the initiation of this project to provide a learning experience for extension agents. The installer, from a foreign country, had provided no instructions on operation, fertilizer injection, or maintenance. In less than six months the emitters began plugging with calcium. When the installer returned, he found that the by-pass fertilizer injection tank had not been properly installed. But he still did not provide the instructions necessary for applying fertilizer, nor did he give instructions to the operator on methods of cleaning emitters or preventing them from plugging in the future. Until someone is available in the area to advise farmers, provide design expertise, and provide a ready supply of hardware, there is no justifiable basis for introducing drip systems to small farms in the Kasserine area.

By contrast, a large government farm adjacent to Kasserine, had a drip system covering about 1,000 hectares of orchard. This farm was large enough to have its own spare-parts inventory, and it had its own professional staff to advise its workers. But in this case, staff and equipment were not available to small farmers. On the east coast of Tunisia drip irrigation is now expanding successfully. Farmers were trained on the operation of drip systems before they were installed and expertise was available to assist farmers as and when problems developed.

In Table 1, center pivot and side-roll sprinkler systems were down-rated because of their cost, the level of operating and maintenance technology required, the small fields existing in the Kasserine area, and the characteristics of the water supply. There were a few large government farms in the area where these systems could operate very successfully, but there were no dealers to supply spare parts when they were needed. Parts had to be imported which could take months, or owners had to keep their own stocks of spares.

Hand move and solid-set sprinkler systems have also been down-rated in the table because of the operating and maintenance technology required, the

Table 1. Relative ratings of irrigation systems and equipment as applied to the Kasserine area, Tunisia.

System	Visibility	Simple, Under-standable	Low-cost	Labor-saving	Minimum preventive maintenance	Fits field sizes	Efficient	Total points
Existing Systems - water distributed by cutting ditch banks								
Flood	5	1	1	5	2	1	5	20
Furrow	5	1	1	5	2	1	5	20
Border	5	1	1	5	2	1	5	20
New Systems - water distributed through pipe and sprinklers or emitters								
Center Pivot	1	5	5	1	5	5	1	23
Side Roll	2	4	4	2	4	5	2	23
Hand Move	2	3	3	3	3	1	2	17
Solid Set	2	3	5	1	4	1	2	18
Drip System	5	5	5	2	5	1	1	24
New Systems - water distributed through pipes and gates or hose								
Gated Pipe	3	1	3	2	2	1	1	12
Modified Gated Pipe	3	1	3	2	2	1	1	12
New Systems - water distributed through ditches and siphon tubes or spiles								
Siphon Tubes	3	1	1	3	2	1	3	14
Spiles	3	1	1	2	2	1	2	12

Note: A rating of 1 or low total points indicates most desirable, or best. A rating of 5 or high total points indicates least desirable, or poorest. These ratings are judgment ratings based on the author's observations of human and physical factors that would influence such ratings in the Kasserine area. The characteristics under which the various systems are rated are not of equal importance. A total rating value for each system obtained by adding the ratings horizontally therefore may not necessarily indicate the most appropriate technology to be introduced.

absence of local dealerships, and the moderate to high investment costs. These systems, however, could meet the physical requirements of the small farms and there was interest by the Tunisian counterparts in introducing them. These systems could have been introduced to small farms successfully if there were local dealers who understood hydraulics, maintained an adequate inventory of parts, and had sufficient practical experience in designing sprinkler systems. Such dealers must also be backed by reliable manufacturers or suppliers who are willing to make the investment required for successful foreign sales and who are willing to provide the necessary continued training of foreign representatives. The few sprinkler systems existing in the area were archaic in both their design and the technologies used, which date back to the late 1930's and thus should not be considered a good indicator of the potential for sprinkler irrigation in the area.

The demonstration technologies finally selected were very simple in design and management skills required but for the Kasserine area of Tunisia they were new and they created widespread interest both from the Governor of the region and from the farming community. The demonstrations included:

Checks and drops

Stilling basins

Siphon tubes

Spiles (small diameter pipes installed in ditch banks)

Gated-pipe

Modified gated-pipe

Land grading and smoothing

Plastic-lined ditches

6. ORGANIZATION AND EXECUTION OF THE PROGRAM

The author provided technical support in planning and execution of the program. The resident leader's role was primarily that of trainer and teacher. Having trained his central staff counterparts, together they trained extension agents who then trained farmers. Field days were also organized by agents in the different districts. The project team worked only with extension agents who were interested and willing to commit time to the program and as a result agents from only 8 of the 13 districts were actively involved in the project. One dynamic and innovative agent from a neighbouring district was also included at his request.

In addition, six Tunisians have been studying for advanced degrees at Oregon State University, one of whom has now earned his masters degree in Agricultural Engineering and returned to Kasserine to provide technical leadership to the extension program.

Farmers could obtain loans for their investment costs. Some were able to *obtain grants for some elements. Others used their own savings.*

7. INDICATIONS OF SUCCESS

This was one of the most successful extension programs the author has been associated with, despite its short duration. The following are quotes from project reports covering the first twelve months work which demonstrate farmers' readiness to adopt and adapt new technology:

> "One agent from the central office, on his own initiative, constructed two modified gated-pipe systems with an agent and farmer during my absence. He also organized and conducted one training session for agents and held one field day for farmers, without any direction or guidance."

> "In Jedlyenne area, an extension agent, did an excellent job demonstrating both the modified gated-pipe and the spile at a field

day. He invited 10 of the most progressive farmers in the area, all of whom had good comments, many questions, and showed a strong interest."

"One farmer stated that after installing a modified gated-pipe, he was able to irrigate his farm in one-half the time it normally took."

"After irrigating with a modified gated-pipe system he helped install, a farmer at Jedlyenne commented, 'This is good! My wife can irrigate now and I can do something else.'"

"In Feriana, one farmer, by converting from a ditch to a modified gated-pipe system on very sandy soil, irrigated 15 times as many trees with the same quantity of water. In most installations water savings of 50 to 60 percent can be made." (This is important in the Kasserine area as water supplies are much more limited than land. Water saved through improved efficiency is the cheapest way of increasing available water and is much more economical than constructing new large storage facilities or digging more wells.)

"Another farmer in Feriana had trouble starting his two-inch siphons rapidly enough to handle the surge of water from the perimeter. After discussing the use of spiles, he was enthusiastic enough to have them in place and operating in less than a week."

"Some farmers suggested eliminating the head ditch and piping directly to the pump outlet. As a result we were able to use a pipe one size smaller bringing a sizeable reduction in cost."

Not all of the demonstrations of new technology were equally popular. Those that provided labor or water savings were most enthusiastically received. All demonstrations were valuable, however, as they frequently demonstrated the advantages of alternative solutions and provided a stimulus to discussion amongst farmers and extension agents as to their relative merits.

During 1986, data was collected on the economic and water impact of the technologies. The average payback period on the investment was 2 years. With the new methods the same water supply could irrigate 2 times the previous land area. Diesel use was cut by half, as were labor requirements.

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