IRRIGATION MANAGEMENT NETWORK

CROP-BASED IRRIGATION IN PAKISTAN: INITIAL EFFORTS IN THE NORTH WEST FRONTIER PROVINCE

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CROP-BASED IRRIGATION IN PAKISTAN: INITIAL EFFORTS IN THE NORTH WEST FRONTIER PROVINCE

D J Bandaragoda and Carlos Garces-Restrepo[1]

1. INTRODUCTION

There is a general appreciation that a shift from the traditional system of supply-oriented irrigation operations to one that is based on realistic crop-water requirements is among the most challenging issues confronting the irrigation sector of Pakistan. The issue is compounded by the peculiar complexity and size of Pakistan's canal irrigation system, and the dominant social and institutional influences associated with its operation.

A recognition of these difficulties is reflected in the cautious approach adopted at the policy level. While a closer link between the irrigation supplies and the crop-water requirements was seen as a necessary step, crop zoning and water scheduling which might be needed for this purpose were to be taken up initially on a pilot scale before their wider application (National Commission of Agriculture, 1988: 300).

As two modernised systems in the North West Frontier Province (NWFP) of Pakistan seemed to offer special opportunities for such an effort, Pakistan authorities requested the International Irrigation Management Institute (IIMI) to carry out a study in these systems. IIMI conducted preliminary investigations and started a programme of research activities aimed at a pilot trial on crop-based irrigation operations. The study is being conducted in selected areas within the two modernised systems in the NWFP, and includes an action research component to be implemented in close collaboration with irrigation-related agencies of the province.

The use of the terminology 'crop-based irrigation operations', serves to distinguish between two systems: the 'on-demand' system operations, where individual farmers control when and how much water they receive, and the intended 'crop-based' system management. The latter aims to supply water to the watercourse head and the farms on the basis of crop water requirements, determined from monitored information on aspects such as cropping patterns and environmental factors.

This paper derives from the preliminary investigations carried out so far, both during the study development stage, and the inception phase of the study started in July 1991. The paper examines policy, organisational and technical concerns regarding modernisation and perceived management flexibility. With special reference to the case studies, the paper also discusses some constraints and opportunities that can be identified at this stage in embarking upon a study of crop-based irrigation operations.

2. IRRIGATION IN PAKISTAN

2.1 The Supply-Oriented System

Pakistan has an arid sub-tropical climate with an average annual precipitation less than 300 mm. The country's natural endowment of glacier-based water resources in the northern mountainous region overlooks a vast flat valley with an average slope of about 0.2 m per km, which extends for more than a thousand kilometres to the southern coastline. The present diversion capacity of the canals of Pakistan is 7,318 cubic metres per second. The network of canals of about 64,000 km in total length, and watercourses totalling to about another 1.6 million km in length delivers water to the fields through 89,100 farm outlets.

The irrigation system of Pakistan has been designed as a run-of-the-river system with an objective to command maximum area with the available supplies in the river, ensuring "equitable distribution" between various canals, branches and distributaries and also between individual outlets. The concept was to provide 'protective' irrigation. The duty of water was fixed relatively low in order to irrigate maximum command, the typical duty being 210 to 280 litres/sec per 1000 hectares (3-4 cusecs per 1000 acres). The irrigation intensity was also designed to be kept low at about 75% for the two seasons, rabi and khariff.

Following what is now called the 'Regime Theory' of Mr Lacey, an irrigation engineer of the Punjab Irrigation Department in the late 1930s, the canals were designed with slopes, velocities and sections to minimise silting and scouring. The canals were to run most of the time at authorised full supply level, or at least at 75% of the full supply discharge to avoid silting.

An additional design objective has been to keep the administrative and operational requirements as low as possible. The "equitable distribution" of

water was to be effected without much interference by the operators. The number of control structures in a canal was kept to a minimum. Finally, the distributary outlets were not gated, but had fixed structures to provide discharges proportional to the area to be irrigated in the watercourse commands.

2.2 Policy Concerns on System Limitations

With the introduction of Green Revolution technology, irrigated agriculture in Pakistan underwent some rapid changes. Irrigation intensity increased far beyond the design stage expectations, partly aided by the development of groundwater. New and improved crop varieties were introduced to produce high yields, most in combination with inputs and highly sensitive to irrigation water. Cropping patterns changed, requiring increased quantity and reliability of farmgate water supply. Thus, a departure seemed necessary from the traditional approach of 'protective' irrigation to that of 'productive' irrigation[2].

An instance of official recognition of the perceived inadequacy of Pakistan's traditional 'protective' irrigation system can be seen in the Report of the National Commission on Agriculture (1988: 287). Here, two specific problems relating to the canal irrigation system have been noted: (1) the persistent tendency of the supply-based system to spread existing supplies widely and thinly; and (2) the consequent difficulty of varying the water supply according to crop water needs. The Report also notes that "not only does the availability of canal water vary seasonally, the distribution process itself suffers from certain chronic inequalities, the worst sufferers being tailenders" (p 289).

Another instance of national level concern in this regard was seen at the series of deliberations that took place in finalising the Water Sector Investment Plan (WSIP) of October 1990.

[2] The concept of 'productive' irrigation aims to increase irrigation water availability and to manage irrigation deliveries to meet the consumptive water requirements of the crop (crop demand), and thus create opportunities for improved agricultural production.

In a working paper for the WSIP on policy and management issues, Kirmani[3] isolates the major factors depressing crop yields as: (1) inequitable distribution of water; and (2) lack of adequate matching of water supplies with crop requirements. The latter problem was linked to the practice of using historic withdrawals as the index for water allocation[4].

3. MOVING TOWARDS CROP-BASED IRRIGATION

3.1 Modernised Physical Systems

The NWFP, which has only 5% of Pakistan's irrigated area, but is primarily an agricultural region, has responded to some of these policy concerns. In an effort to improve irrigation performance, the province has introduced some changes in the planning of its new irrigation systems, leading to a substantial increase in the water duty (rate of water delivery per unit area).

These changes can be seen in two major projects of the NWFP: the Chashma Right Bank Canal (CRBC) off-taking from the Indus and the Lower Swat Canal (LSC) which derives its supplies from the Swat river. The design of CRBC and remodelling of LSC are based on main canal capacities of about 0.60 lps per hectare and 0.77 lps per hectare respectively, compared to the more traditional system capacity of 0.28 lps per hectare.

The change represents a shift in the philosophy of designing systems from 'protective' to 'productive' irrigation (see Section 2.2). The revised water duties for channel and outlet designs attempt to provide channel capacities that permit more appropriate matching of water deliveries to crop water needs, as reflected by an anticipated or desired cropping pattern with optimum productivity levels.

The main features of these two systems are given in Table 1.

[3] 'Comprehensive Water Resources Management: A Prerequisite for Progress in Pakistan's Irrigated Agriculture', by S S Kirmani was one of three main working papers at the Consultative Meeting on the WSIP.

[4] Kirmani's paper concludes: "More water can be made available for productive use by changing the historic withdrawal pattern to a crop needs pattern, by ensuring equitable distribution and by conjunctive use of surface and groundwater storage. These management methods will not affect the water rights of the canal commands ..."

TABLE 1: MAIN FEATURES OF CRBC AND LSC SYSTEMS

Feature (Unit)	CRBC	LSC
Year Built	1986, still under construction	1885, remodelled in 1935 and 1987
Supply source	Indus, Kabul river	Swat river
Source regulation	Chasma barrage	run of river
Type of system	gravity flow	gravity flow
Design discharge (cumecs)	138.07	54.90
Average water allowance (1ps/ha)	0.60	0.77
Length of main canal (km)	271.92	35.40
Type of main canal	partially lined	unlined
Length of network canals (km)	603.37	112.63
Number of distributaries	40	10
Type of outlets	pipe	gates/APMs
Drainage system	No	under Mardan SCARP
Cultivable command (ha)	230,675	50,040
Design cropping pattern (total %) (kharif, rabi)	150 (60,90)	180 (90,90)
Other features	integrates old Paharpur canal system	none

3.2 Technical Constraints in the Modernised Systems

3.2.1 CRBC System

Although there seems to be no problem of feeding the CRBC at the head as it draws its supplies from the Indus River at Chashma Barrage having a small storage component, consideration of crop water requirements does not enjoy any primacy. The monthly pattern of water allocation has been fixed taking account of two more factors: the inter-provincial character of the canal and the barrage limitations.

The CRBC has been designed as a gravity canal to run at nearly full supply discharge to maintain its regime and avoid siltation. For demand-based operations CRBC will run only 40% of the time with discharges above 75% of the full supply level (FSL), while 60% of the time it will run with variable low supplies (with 20% of the time running at less than 50% of the FSL). This running of variable low flows can have serious repercussions on the regime conditions of the canal, primarily related to siltation and potential damage to the lined portion if changes in the discharge are made abruptly.

Although the capacity of the CRBC system has been worked out on the basis of the maximum requirements of the culturable command area, no infra-structure has been provided to run the system with variable discharges according to the crop requirements. In the 79 km length of the main canal in Stage I, there are only two cross regulators: one at 19.5 km and the other one at 49.5 km downstream of the head regulator. These control structures as provided are insufficient at main canal level. While three escape structures are contemplated in the main canal (for construction and safety-related reasons more than for managerial purposes), escapes at distributary level have not been provided which greatly hampers the flexibility required to introduce demand-based operations. If the option of varying flows in the main canal is not or can not be exercised, then escape structures in the distributaries should have been the obvious next choice; as indicated this was not the case.

The design of CRBC envisages a conventional system of distribution of supplies from the distributaries to the outlets, i.e to deliver fixed discharges at full supply level without any managerial intervention. The conventional outlets (open flume or APM) have been redesigned to only deliver increased discharge. No provision of gates have been made to deliver variable discharges according to crop water requirements. It may be interesting to

note that resistance to installation of gates has come more from the Irrigation Department than from the farmers, On the grounds that the farmers cannot be made to understand how these devices ought to be managed. Also, the operating agency would see the gates as an extra burden on their supervisory activities.

The communication system is also inadequate. Only few regulating structures have been provided with telephone connections and therefore regulation messages are sent through messengers to other regulation points. An efficient communication system is essential between all regulation points along the main canal and the distributaries for introduction of demand-based operations. Automation or remote control of some key control points may be required for efficient operation. In addition, a communication system between the water users and managers of the delivery system, for timely intimation of demand and subsequent delivery schedule, is a basic need. No such system exists nor is being contemplated.

Finally, the old irrigation system of Paharpur Canal (which is now incorporated into the CRBC after being remodelled for the increased discharges), poses an additional issue for management. Neither the operating staff nor the farmers appear to be running the system or using the water in the field according to the requirements of the crops. They seem to be delivering and using the additional water to increase the acreage of cash crops. This trend is likely to continue, to the limit of available water. The ability to deliver additional water during periods of peak need appears to be inadequate under conditions of full development with water demanding crops like rice and sugar cane[5]. Thus, if this trend were to continue, the objective of matching the deliveries to crop-based needs is unlikely to be met.

3.2.2 LSC System

The design for remodelling the LSC System to meet the crop water requirements of its command area, included two main features: (1) increased system capacity, and (2) regulation at both the distributary and the watercourse heads. The capacity of the canals is being increased, and some of the existing watercourses are being converted into minors due to increase in discharge (a rule of thumb prevailing is that any watercourse having a discharge of 140 lps or more as a result of the water-duty increase would

[5] Known locally as 'high delta crops'.

automatically become a minor, and come under agency or joint control). The outlets are being redesigned and provided with gates to deliver varied discharges at different times as per water requirement of the area. However, the system is still not ready to switch over to crop-based operations. The issues which need further consideration are given below.

The system has been redesigned on the assumption that run-of-the-river supplies will be available for ten months of the year to meet the crop water requirements of the area. This gap in supplies can widen in case the demand rises due to increase in intensity or shift in cropping pattern from the design assumptions. With the increase in water supply at the outlet head, the farmers have a tendency to grow water demanding crops like rice or sugar cane. Eventually, they will demand more water which the system will not be able to deliver, the supplies will fall short over a longer period of time and thus affect the crop production.

The main canal and the distributaries, from the headworks up to the outlets, are all unlined. These have been designed for maximum discharge on the 'Regime Theory' concept, and are supposed to run at near design discharge (see Section 2.1). However, the operation of the system with less than 75% of design discharge most of the time as required for crop-based irrigation in its command area, would upset the regime of the canal.

No cross regulators have been provided for feeding the off-taking distributaries. It will not be possible to feed these distributaries without control structures when the canal will be running with low discharges most of the year. The operation of distributaries with partial supplies, already a difficult proposition as seen above, will be further exacerbated with the provision of gated outlets. Farmers in head reaches will be tempted to draw more water, which will encourage inequity in distribution of water. An increased need for patrolling of canals is a foregone conclusion. However, how to cope with the additional cost of this intervention has not been seriously considered.

Escape structures have been provided only on the main canal, and not on the distributaries and minors to dispose of surplus water. This results in flooding of tail reaches during low demand period. Farmers in these areas are already requesting for an effective drainage system. The area is in fact being provided with drainage facilities under the salinity control and reclamation project (SCARP Mardan).

3.3 Mismatch between Physical and Management Systems

3.3.1 Unchanged management systems

While steps have been taken to redesign and remodel these irrigation systems and to provide larger water allocations for more intensive cropping, this effort has not been accompanied by the development of irrigation management procedures to achieve more appropriate matching of delivery and crop water requirements. The additional water allocated through the usual timed water-turn *(warabandi)* system provides capability to: (1) increase cropped area; (2) produce at a higher level in the same cropped area; and (3) change the cropping pattern. A combination of all three options appear to be taking place in the project areas, but it is unlikely that performance is at an optimum, technically, economically or socially. Also, there is a general recognition that the additional opportunities associated with the greater flexibility in water use may bring with them the danger of increased inefficiency, and that the higher water allocation through the remodelled system in this context may exacerbate drainage problems.

Although substantial improvements in system performance and agricultural production are possible using the 'productive' concept of irrigation, changes in system management and operation must occur, both in terms of physical control and organisational procedures. However, if the traditional supply-oriented operational practices are allowed to continue in these systems, inefficiencies in water use will aggravate existing drainage problems, and depress the productivity of water and overall system performance because of the higher water availability. This in turn will have a severe negative impact on benefits from the substantial investments in irrigation infrastructure.

3.3.2 Organisation for increased management needs

Some elements of the modernised physical systems required changes in the organisation for system operation. This was particularly felt in the case of the LSC. Although the design of the LSC required gates to be installed in the distributary outlets, apparently there was no plan to establish the necessary organization for operating them. It is not inconceivable that the planner's intention was to use farmer organisations or their representatives for this purpose. However, there is no evidence that any preparation in this direction had ever been thought about.

During a protracted period of construction, the gates installed in the upper reaches of the system are already found to be either damaged or unusable due to neglect. The Irrigation Department has not taken them over yet from the constructing authority, WAPDA, and this situation has led to a total organisational vacuum in this regard. This lack of preparedness for effectively handling the operational aspects of the new physical features of the system, coupled with farmer resistance to new features is likely to delay the process of using the LSC for crop-based irrigation operations.

Lack of coordination between the concerned agencies throughout the various stages of planning and implementing the rehabilitation work in the LSC is clearly discernible from the current ground situation, and poses a significant management issue for the future. This situation is likely to affect the CRBC as well, since the same agencies are involved in design, construction and operation activities in both project areas.

Another striking feature of the current organisational arrangements for operating the new systems in both project areas is the low profile of the extension staff. Any preparedness or enthusiasm for exploring the opportunities and avoiding the constraints embodied in the new design of the physical system, and for paying attention towards increased agricultural production in this new context, cannot be clearly seen in the field.

3.3.3 Water users associations

A move towards crop-based irrigation operations requires the efficient use of water at the farm level. Water users associations (WUAs) are the essential part of this effort. There are no WUAs in either of the two project areas, except on watercourses where physical improvements have been done with some farmer involvement under the On-farm Water Management (OFWM) programme. The absence of any agency charged with the specific responsibility of promoting farmer organisation for irrigation is a conspicuous feature in the context of a profusion of state agencies for numerous other activities. This particular deficiency may significantly contribute to the difficulties which are likely to confront any attempt towards more flexible management.

Distribution of water within a watercourse has always been the responsibility of the farmers. New or more explicit institutional arrangements will be required to make this responsibility be effectively discharged in view of the new situation with additional supplies. Developing mechanisms for equitable

distribution of water in the present context of dominance by a few farmers will require special consideration on the potential for viable farmer organizations. To utilise water and to ascertain the timing and quantity of water to be given to the crop, such alternatives would need the farmers to be trained more systematically, which in turn seems to require a re-orientation of many others interacting with the farmers.

4. MYTH AND REALITY OF WARABANDI

4.1 Tradition of *Warabandi*

The term *warabandi* means "fixed *(bandi)* turns *(wahr)*"[6]. *Warabandi* is described as a water management system which aims to achieve high efficiency in water use by imposing water scarcity on each and every user, and by focusing on equity in distribution (Malhotra, 1982). Its origin can be traced to the early period of irrigation development in the north-western part of the sub-continent, when irrigation had to be extended to a much larger area than could be supported by the lowest available supply.

According to this *warabandi* system, a central irrigation agency is to deliver water at the head of the tertiary level watercourse through an outlet *(mogha)* which is designed to provide a quantity of water proportional to the watercourse's culturable command area. Farmers within the watercourse are expected to manage on-farm distribution of water according to an agreed (and most often officially ratified) rotation of water delivery for a duration proportional to the area of each farm plot, taking account of the practice of both day and night irrigation. The rotation begins at the head and proceeds to the tail of the watercourse. Usually, a seven-day rotation forms one complete cycle in which each parcel of land in a watercourse receives its water once per week.

During each farmer's turn, he has the right to all the water flowing in the watercourse. Once this arrangement of turns has been agreed upon, the agency does not interfere unless a dispute arises among the farmers.

[6] The Punjab PWD Revenue Manual (Reprint of 1987:3) defines it as "*Wahr-Bandi*- the scheme or list of rotational turns or times at which each share-holder in a watercourse obtains his supply, or each outlet in a distributary is allowed to be open".

There was flexibility in the old farmer-established *kacha warabandi* system, ensuring water for all the farmers. However, increased frequency of disputes among farmers led to increased agency involvement. In an attempt to formalise the traditional arrangement, a more regulated *"pucca waraband"* system emerged in which a weekly rotation was fixed by the canal officer on request by the disputing farmers in a watercourse[7]. Once fixed, it assumes common agreement; the turns are supposed to be followed unaltered and become binding on all the farmers who have to take water at his turn irrespective of his need. The previous practice of assigning day and night turns to two sets of farmers permanently, however, has been changed to allow for each set of farmers to shift between day and night irrigation on an annual basis.

Although *warabandi* is practised within the watercourse command, for some of its features to be ensured, the agency that delivers water has to establish some essential conditions in the canal system above the *mogha*. These conditions add to the assumed pattern of behaviour, and together they form the concept of a *warabandi* system.

Thus, theoretically the *warabandi* system in Pakistan is characterised, among other things by:

(a) a shortage of the water supply;

(b) main canal operating at full supply level;

(c) distributary operation at no less than 75% of full supply level (when this is not possible, distributaries are rotated);

(d) only 'authorised' outlets;

(e) outlets which are ungated and delivering a flow rate proportional to the area commanded (they remain open all the time);

(f) each farmer receiving the total allocated flow of the watercourse for a duration proportional to his area;

[7] Appendix E of the PWD Punjab Revenue Manual provides detailed instructions for preparation and modification of *wahr-bandis*, and explains the responsibilities of Patwaris, Zilladars and the Canal Officers.

(g) maintaining the designed hydraulic characteristics of the channels to ensure the intended system performance;

(h) 'equity' of water distribution being the central value commonly perceived by those concerned with the *warabandi* system.

4.2 The Reality as Seen in the Two Systems

The technical and institutional imperatives to make this system fully operational might have been satisfied some decades ago, but they seem to have gradually eroded with the changes occurring in the physical, social and economic environment of Pakistan's irrigation.

Preliminary field observations indicate that the idealised conditions for the *warabandi* system as understood in its traditional 'image' no longer hold true in either CRBC or LSC. In fact, it appears that there is already a move towards a flexible system of incipient crop-based irrigation operation.

The observable deviations from the traditionally accepted *warabandi* norms are as follows:

- The water supply has been enhanced substantially through increased canal capacity. For peak requirements, this increase means a capacity for a water duty of about 0.60 lps per hectare in the CRBC and about 0.77 lps per hectare in the LSC as against the traditional duty of 0.28 lps per hectare.

- Distributaries are operated at levels that range from above the full supply level (FSL) to less than the accepted minimum requirement of 75% of FSL.

- The outlets are closed by the farmers at times when no water is required, and the distributaries are obstructed with temporary (illegal) checks to increase flows into specific outlets.

- Watercourse outlets have been modified, either permanently or temporarily, to alter flow rates (this can be more clearly seen in the LSC). Some of the outlets draw water at rates exceeding design water duties, often causing some others to draw less water.

- The farmer turns are influenced by large land-owners and other 'influentials'.

- 'Equity' is no longer a strong shared value among the officials, farmers and politicians.

These observations are common to both study areas. The reality that emerges in these situations dispel several myths associated with the popularly known concept of the *warabandi* system, described earlier. Some of the myths relate to the way *warabandi* is (or ought to be) applied and practised and some to the effect *of warabandi*. Foremost among them is the notion that *warabandi* corresponds to equity in water distribution. On the contrary, equitable distribution is eroded by both the physical conditions such as less than FSL deliveries in the canal, as well as the institutional factors such as power and influence of the large land-owners. At best, it remains as an equitable distribution of time, and not of water.

Although the observations are limited to two specific system areas and as mentioned below, the two systems differ from each other in terms of the maturity of their irrigation practices and therefore might not be representative of the whole of the well established irrigation sector in Pakistan, the story of myth and reality of *warabandi* appears to be having a wider application[8].

The LSC which was built in 1885 and therefore has a longer irrigation tradition, offers better information on the types of change that have taken place in the *warabandi* practice at the watercourse level.

A rapid appraisal conducted during October 1991 brings out some interesting features of this change[9]. They need to be studied further before a firm assessment can be made, but as can be seen in a rapid appraisal, the following features emerge:

[8] See Merrey (1987: Chapter 17, and 1990: Chapter 28). He questions the long term sustainability of the present *warabandi* system in Pakistan while acknowledging the limitations of available technical alternatives and the 'imbeddedness' of *warabandi* in local social structure.

[9] A team consisting of a social anthropologist, an agronomist and an irrigation engineer conducted a rapid appraisal in the study area in the LSC (Ref: EDC, 1991).

- *'Warabandi'* as a broad concept has become deeply imbedded in local irrigation tradition in the area.

- Attempts to escape from the *warabandi-imposed* rigidity in the allocation of water have caused many water-related conflicts among the farmers.

- The conflicts have led to a heavy involvement by irrigation staff in conflict-resolution. The approach is officially on the basis of formal rules provided in the Canal and Drainage Act and the related Manuals of Procedure, but it actually has resulted in (rent-seeking) informal behaviour.

- In an administrative structure which is ostensibly for equitable access and distributive justice, *warabandi* has become vulnerable to manipulation by powerful and influential landowners.

- In some parts of the LSC, state regulation does not operate, and instead, an indigenous *khangi warabandi* (internally- decided *warabandi)* form is practised. In this, the water turns are determined locally by the farmers themselves, but often the decisions are with the big landowners, and the turns are usually inequitable.

- Observed deviations from the time-based 'rota' system of *warabandi* includes the sharing of water by farmers.

- In some places, farmers at the head reaches and those who are powerful tend to apply water during the day time and let the water flow at night. Tailenders complain that they are being turned into permanent night irrigators.

Although the water supply is becoming insufficient for increasing needs in the LSC, the few years of indiscipline in irrigation since the rehabilitation work was started has generally resulted in the collapse of any equitable form of water distribution that may have existed before. In some places, the small farmers in particular wish to see the return of a regulated normal *warabandi*.

In its present form, the management of water distribution in the area seems to have reached a dilemma. In one direction, the collusion between the officials and the big landowners has subverted the regulated *pucca warabandi* and made it very ineffective as an equitable mode of management. In another direction, the period of flux due to the construction phase of the project has re-introduced the informal *warabandi* in which the small farmers have lost their due share due to discriminatory decision-making by the influential farmers. In either case, the equity image of *warabandi* is overshadowed by its reality founded on power and influence.

5. PILOT EFFORT FOR MANAGEMENT CHANGE

5.1 IIMI's Study on Crop-based Irrigation Operations

Farmers and system operators in completed areas of both CRBC and LSC, are not yet fully aware of the opportunities and constraints of the newly introduced systems and increased water allowance. They are initially inclined to grow crops with high water requirements. Both wastage of water and the appearance of local waterlogging and salinity problems have been observed.

These trends and the need to formalise policies and procedures for the operation of systems with high water allocations, form the basis for IIMI's study. The following specific points further explains the rationale of the study for a pilot trial on crop-based irrigation operations in the two modernised systems:

(i) water resources are limited/constrained despite increased water availability at the system level;

(ii) inefficient use of increased water availability may result in waterlogging and deprive downstream areas of adequate access to required water resources;

(iii) agency personnel and farmers are not geared up to, or prepared for, effective utilisation of the increased water availability.

The study aims broadly to improve the overall productivity of water through improved system management and irrigation operations, in accordance with crop water requirements within the authorised water allocations and subject to available supplies.

The specific objectives are to:

(i) identify a flexible management approach for irrigation operations that responds to crop water requirements under prevailing supply conditions;

(ii) increase understanding of crop-based irrigation operations by agency personnel and farmers, and identify training needs;

(iii) field-test and refine the management approach identified for crop-based irrigation operations;

(iv) evaluate the benefits of crop-based irrigation operations and identify costs and opportunities for implementation on a wider scale.

5.2 Study Interventions

Water distribution: A key issue in the design of the CRBC irrigation system was the increase in water duty from the traditional value of 0.21 lps/ha (3 cusecs/1000 acres) to 0.60 lps/ha (8.56 cusec/1000 acres). The water supply in the selected distributary and watercourses will be closely monitored. These figures will be matched with the requirement at different levels of the system to determine the real impact of the modification.

Delivery Performance Ratio (DPR), water losses, Relative Water Supply (RWS) at distributary and watercourse level, and crop areas and cropping patterns will be determined as the key parameters.

Crop data has been a fairly unreliable element in the information available, and this problem can be compounded by the fact that, unlike Punjab, where the land has been divided in a square grid fashion, the NWFP presents a very irregular scheme which makes assessing the cropping pattern a rather difficult undertaking. To tackle this particular problem, a combination of three different approaches will be taken into consideration: (i) the cropping pattern reported by the revenue agency, (ii) the cropping pattern derived from an intensive field assessment, and (iii) the cropping pattern derived from a 'transect' approach where, depending on shape and area of the watercourse, a number of 'runs' in the field will be made to determine the crop configuration along those transects.

Simulation of main canal management: In Pakistan's traditional systems the design criteria for a main channel requires that it runs near the design discharge all the time in order to keep the canal in regime. Moving towards an increased management level by trying to better match the needs of the agricultural system (that is, not only the crop requirements per se, but also cultural practices such as land preparation or harvesting, etc) may require, at least as an option, that the traditional management of the main canal be modified. It is seen as pertinent that the effects of such potential changes be carefully assessed. The best way to assess the impact that flow fluctuations in the main canal can have on system performance is through a simulation model.

Water management at distributary level: To document both agency and farmer activities, special observations are made throughout the season. Under the ideal *warabandi* conditions discussed earlier, farmers' interventions at this level in the system should be non-existent; but this is not the case according to our observations. The type and reasons for these illegal or 'unauthorised' interventions will be recorded to help us better understand the inter-relationships between farmers and irrigation agency personnel.

Water management in Girsal Minor: Because of the integration of the old Paharpur Canal Irrigation System into the new CRBC system, Girsal Minor is essentially a continuation of distributary number 3, which we have selected for our main study. Flows at selected points of the Minor will essentially reflect the management of the tail-end of the distributary. Information obtained here will also be useful to compare farmers' water-related responses in the new developed areas of CRBC vis-a-vis the old areas of Paharpur.

Study activities in the institutional component will concentrate on aspects of irrigation institutions which often are inter-related, such as agency organizations (Irrigation Department, Agriculture Department, WAPDA), farmer organisations, the formal rules underlying these organisations, and informal rules (traditions, norms and practices, etc) that tend to fashion the behaviour of individuals and groups. The emphasis will be to find the relationships between the technical factors and the institutional factors, and to assess what combinations of these two aspects affect performance. This will be useful in the action research phase in finding appropriate management flexibility. While these investigations are being carried out, an effort will be made to develop close collaborative relationships with

operating agencies and with farmers. In collaboration with operating agencies, an attempt will be made to establish mechanisms for field level coordination and farmer organisation.

Economics of Crop Based Irrigation Operations: Through socio-economic surveys and farm records an attempt can be made to determine the costs and benefits of any improvements to be considered in system management. In establishing a benchmark that would allow future comparisons, two situations can be used: (i) the situation prior to the introduction of the higher water duties, and (ii) the current situation, with higher water duties, but with no change in management intensity. For both, the old Paharpur Canal Irrigation System and the new CRBC (Stage I) area provide an ideal setting. Through the use of historical records the changes can be evaluated in the 'before' and 'after' situation, and 'with' and 'without' situation. To evaluate the benefits, it will be necessary to establish some performance indicators that can be used to define the potential areas of benefit. The following may serve this purpose:

(a) Biological efficiency to be determined by assessing the yield per unit of water. This will be specially valuable in evaluating the impact of operational changes on the efficiency in using the resource.

(b) Technical efficiency: The relationship between output (water used by the crops) and input (water supply, including rainfall). This parameter will give a good measure of the substitution of water for management. The physical efficiency can also be assessed by the relationship between the number of hectare-days (theoretical) and hectare-days (actual) that can be covered with the actual water supplies. This would provide at least a rough idea of where on the production function the farmers are operating.

(c) economic return: Rupees/farm; rupees/unit water; rupees/unit land. The first would give information useful for understanding farmer response to changes, as well as a direct measure of the economic benefit. The second would provide the information on the economic efficiency in using the resource. The last probably is the least useful since it confounds within it the decisions of the farmers on how to spread the water supply over their area. It may be useful, however, in comparing farmer water-spreading strategies in different parts of the system.

6. CONCLUSIONS

Modernisation of physical systems in the CRBC and the LSC have served the limited purpose of providing increased conveyance capacity to meet peak water requirements. While there are some significant technical deficiencies remaining, there is also a glaring mismatch between physical and management systems.

Preliminary work carried out under this study in the two modernised systems of the Northwest Frontier Province, indicates that it is not unreasonable to expect positive results from this pilot effort. The process is bound to be long, involving the improvement of compatibility between the physical, management and social structures. The *de facto* intensive water management on the part of the farmers in responding to the changing conditions in the field, as a result of increased water supplies, can be built upon to form a more flexible management system based on crop water requirements.

A distinction is made between the concept of overall *warabandi* system and the farm level *warabandi* practice in support of our observation that there is already a change in the management level in these modernised systems. The former includes the conditions that have to be met within and above the watercourse level. What happens at main and distributary canal level down to the outlet is decisive for the *'warabandi'* practice which takes place only within the watercourse. The changed social values have affected the overall system including both the aspects, the conditions as well as the practices.

While software-related institutional, organisational and management innovations (particularly the organization of farmers) may go a long way in moving towards more flexible management systems, for the idea of crop-based irrigation operations to be fully implemented, the introduction of a somewhat higher level of hardware into the existing physical systems seems necessary.

Some of the physical constraints can be easily overcome; some others may form the framework within which management changes have to be formulated. However, the institutional constraints seem to be linked with a heavy resistance to change, and may pose greater hurdles in the introduction of alternative management approaches.

For instance, the fact that the notion of *warabandi* is deeply rooted in the minds of the farmers and agency personnel, though in reality it does no longer exists as such, is a major constraint towards even the testing of alternatives. To overcome this resistance against the introduction of changes, a long drawn out effort may be needed through the improvement of awareness of both the generic conceptual issues and the costs and benefits involved in a shift towards crop-based irrigation.

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