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Canal Irrigation Management in India : Some Areas for Action, Analysis and Research*

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Potential and Purpose

The unrealised potential of existing canal irrigation systems in India is widely recognised. Lectures, papers, speeches, reports, statistics—presented by political leaders, senior officials, researchers and other informed observers, representing between them a range of disciplines and long and deep experience—have emphasised the scope there seems to be for bringing the benefits of irrigation to larger areas and more farmers, and for distributing and delivering the water in a manner that will be more cost-effective, productive, equitable and environmentally stable. This potential varies by zone and by project. It is perhaps least under the tightly managed canal irrigation of Northwest India (Malhotra forthcoming) where strict rotations are practised both above and below the outlet. But taking India as a whole, one estimate is that only about one half of the officially estimated utilized hectarage under canal irrigation is effectively irrigated, the rest receiving only erratic and partial irrigation at best (Seckler 1981:10). Whether this estimate is exact, high or low, the potential for additional cropped area probably runs into millions of hectares per year and the potential for additional food production linked with improved management should be a matter of at least several million tons per annum.

This paper seeks to identify and discuss areas for action, analysis and research to achieve more of this potential. The sequence "action, analysis and research" is deliberate, since research and analysis can delay action, and so much action (in improving the distribution of water on main systems, in introducing warabandi type rotations, in rehabilitating and modernising structures, and in training irrigation staff, etc.) is already taking place and has a growing momentum. Analysis and research can contribute to the content and direction of action, and are often most useful where it is the action itself and its effects which are analysed.

Criteria and Definitions

Criteria for good irrigation management in the distribution and delivery of water are taken to be :

productivity of water and other scarce resources

equity in their distribution, including a fair deal for tailenders, and other disadvantaged people

stability of infrastructure, environment and production low cost

The trade-offs between these criteria pose problems of measurement and judgement. Methods for quantifying and comparing productivity and equity have been devised by Lenton (1981) but not yet used.

Other terms in this paper are best defined for the sake of clarity :

"canal irrigation" refers to major and medium irrigation in India

"chak" refers to the area under command below an outlet

"communal" refers to an irrigation system in which water is not supplied through outlets from a larger canal system but from a local source, with the timing and amount of water distribution determined by irrigators

"management" has three senses :

the management of natural resources, especially water management

the management of people, both within bureaucracies and members of the public

the management of information and controls

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"main system" refers to canal irrigation and includes the water source, headworks, canals, branch canals distributaries and minors down to the outlet. It also refers to drains below the chak.

"outlet" refers to the structure through which water passes, usually from a distributary or minor, into field channels which supply farmers' fields. It often corresponds with the point at which water moves from the control of an Irrigation Department to that of farmers and farmers' groups

"warabandi" is a system of equitable water distribution by turns according to a pre-determined schedule specifying the day, time and duration of supply to each irrigator in proportion to landholdings in the outlet command" (Singh 1980: 46)

"predictable" means coming at times and in amounts known about in advance

"steady" means with a constant or near constant flow

"timely" means at a time desired by farmers and productive for their crops.

Scope and Caveats

Some of the limitations of this paper are best stated :

(*i*) it is concerned with canal irrigation in which water is distributed to farmers' fields by a combination of a bureaucracy and of farmers themselves. It is not directly concerned with communals or with small-scale lift irrigation.

(*ii*) the orientation is largely that of an undifferentiated social scientist. There are many vital engineering, hydrological, soils, and agronomic aspects of all the topics discussed, which are not covered, not least the crucial significance of the physical structures of distribution systems and of agronomic conditions.

(*iii*) generalisation about canal irrigation is difficult. It is tempting to study one system or a few, and then generalise. There are, however, great differences between systems, in terms not least of scale and of relative scarcity and abundance of water. If there is one clear lesson emerging, it is that each system is unique in its combination, of resources, structures, institutions, procedures, conventions, problems and opportunities. Even if the universe taken is only India, or only one State within India, generalisation is often precarious.

(*iv*) much of the evidence cited is from India, but there is still a dearth of Indian and other published material on most of the topics discussed. Many assertions should therefore be treated as tentative.

The Water Distribution Gap

Irrigation systems can be seen to include four domains: first, the physical (structures, channels, fields, soils); second, the biological (especially the growth of crops); third, the human and economic (including both irrigation staff and farmers and their households, household economies, institutions, and behaviour); and fourth, centrally, pervading and linking the other three, water itself and its distribution. The first two domains—physical and biological—have been and continue to be extensively studied by irrigation engineers, agricultural engineers, agronomists and soils scientists. The third, human and economic, domain has until recently been less examined (except from within the concerned irrigation organisations), with rather little researched about irrigation bureaucracy and staff, and about irrigators' organisations and behaviour in the chak.[1] The fourth domain, water, has been examined in detail in some of its hydrological aspects, but the actual distribution and delivery of irrigation water, from headworks to the crop in the field, has not received major attention as a subject.

The relative neglect of water distribution and delivery as a subject is surprising until one reflects on some of the reasons. Many biases influence—what aspects of irrigation receive professional attention.[2] First, practitioners and researchers alike are directed to certain aspects of irrigation by their training and preferences. The point has often been made that engineers are trained in construction, and to a lesser extent maintenance, but not much in operation of canal systems; that sociologists and social anthropologists are trained to make studies at the village level, and to examine communities rather than bureaucracies; that economists are preoccupied with inputs, outputs, costs, benefits and prices; and that other disciplines—agricultural engineering, agronomy, social anthropology, and so on—all have their central concerns and corresponding blinkers. There is no discipline for which the distribution and delivery of water in canal irrigation systems is a primary focus.

Second, most disciplines prefer to study what can readily be counted; but water is maddening to measure: it is devious, unstable and elusive—it does not just flow, it also seeps, percolates, evaporates, transpires, escapes in drains, and is unpredictably added to and subtracted from environments by climatic change. As though this was not enough, the difficulty of measuring it is aggravated by its movement all round the clock, including the night. Not surprisingly, those who try to measure it become preoccupied with methodology, leaving little time or energy over for other investigations, or for relating findings to a broader picture.

Third, there are spatial biases in analysis of canal irrigation: analysis tends either to start with the water source—a river or catchment, a diversion weir or reser-

(1) But there is a growing literature. See especially Bottrall 1981c, K.K. Singh 1980, and papers by Wade.

(2) For an elaboration of some of these points, see Bottrall 1981b, Chambers 1978, and Wade and Chambers 1980.

voir, and sees the system from the topdown; or it starts from crop water requirements and farmers' fields and sees the system from the bottom up. The difficulty is that these two approaches—of supply and demand respectively—may never meet. In between lies the great gap—of water distribution and appropriation across the spaces of the irrigation system.

Finally, irrigation water is valuable. Competition for it leads into political economy, and questions of who gets what, how, why and with what costs and benefits, a sphere which some are neither trained nor eager to enter, but which is vital for understanding and changing actual human behaviour and performance.

It is precisely because the domains of human organisation and of the distribution and delivery of canal irrigation water have been relatively neglected that they now promise some of the largest gains in trying to achieve the objectives of productivity, equity, stability and low cost, realising more of the potential of canal irrigation.

The Outlet as Pivot

If we abjure conventional analysis from the top down or from the bottom up, and instead examine water distribution from the centre outwards, the obvious place to start is the outlet. In the words of S.P. Malhotra writing of Northwest India.

> "An outlet is the masonry structure through which water is admitted from the government distributary into a farmer's watercourse. It is the border where the State management ends and the farmer's management starts. It acts as a water-measuring device and hence is a subject of great interest to both the government and the farmer. Under the Warabandi system it plays a vital role in distributing water and its working can be called the cornerstone of the entire distribution system".
>
> (*Malhotra, Ch. 4*)

If the outlet is a cornerstone, it lies in a no man's land. It is situated below the traditional major concerns of engineering with larger structures, and above those of other disciplines such as agronomy concerned with crop growth, agricultural extension concerned with the farmer and the farm level, and sociology concerned with irrigation communities. For economists it is also list to sight-somewhere between the inputs into the larger system (capital and operating costs) and the outputs from agriculture (revenue, returns to the farmers, returns to the economy). For rural development tourists (departmental officials, aid agency staff, academic researchers on short rural visits) there is so much else that is more visible and interesting (headworks, storage reservoirs, large canals and control structures at one end, and fields, farmers and crops at the other). The humble outlet goes unseen; or if seen, it is only noticed at one point of time and the adequacy, fluctuations and predictability of flows through it are not visible.

It lies too on an administrative and social boundary. It is at or beyond the limit to which irrigation engineers and their staffs extend their detailed control. It is also often the official border between the Irrigation Department on the main system and the Command Area Development Authority which, like most new organisations, had to establish itself on unoccupied territory and which it found below the outlet. The fringe status of the outlet may even be reflected in budget discussions about rehabilitating structures when it may not be clear whether upgrading outlets fails under the budget for "above the outlet" or that for "below the outlet". It can be seen too, as a sort of border post through which a commodity of value passes from one jurisdiction to another.

The outlet has, too, a pivotal position in proposals to improve the productivity and equity of water distribution. Allowances must be made for local conditions, but there is a weight of informed professional opinion (expressed for example at the Conference on Warabandi for Irrigated Agriculture in India in April 1980 (Singh 1980) that tighter distribution and rotation of water supplies both above and below the outlet are required. Programmes and proposals based on this consensus have various names and forms, including Integrated Water Management (IWM) (Ali 1980), Rotational Water Supply RWS), and Rotational Water Distribution (RWD). A recent definition of RWD is:

> "...a system of water control designed to deliver to each individual farmer in the command area of an irrigation project a proportionate share of the total amount of available water in a reliable way. By proportionate share it is implied that each farmer receives the same amount of water per unit area and by reliable supply that the water is received at fixed times and in fixed amounts known in advance by each farmer".
>
> (*Roberto Lenton, personal communication*)

This objective is exceedingly difficult to achieve unless three conditions are met :

- management of the main system to deliver through the outlet a predetermined steady flow at predetermined times
- timed rotation below the outlet to supply fixed amounts of water at the fixed times to each farmer
- a measuring device at the outlet which enables both farmers and irrigation staff to monitor the amount of water being delivered and received.

These preconditions direct our attention to three aspects of water distribution and delivery: below the outlet and within the Chak; above the outlet, through main system management; and across the outlet, connecting farmers and their demands and irrigation staff and their responses.

Below the Outlet

Conditions and practices of water distribution below the outlet cannot be discussed sensibly without distinguishing different conditions. As Bottrall has pointed out (1981b), studies at the community or Chak level have been subject to biases internationally, with a predominance of attention to small rice-growing communals in semi-humid Southeast Asia. The lessons from these studies may or may not apply to other conditions and areas, for example to the conditions of Chaks on the huge irrigation svstems of the Gangetic basin. Two contrasts stand out here as general problems.

The first is the difference between a communal and a Chak. The water supply on a communal comes from nature in the form of rainfall, runoff, or river flow, and is usually supplied or stored by manmade structures under the control of the community. Measures to improve that water supply in quantity and reliability may be seen to entail propitiation of the Almighty or physical works by the community or both. In contrast, the water supply to a Chak outlet on a large canal irrigation system, though depending on nature to a degree (in the form of rainfall, river flow, and runoff to supply the system as a whole) is controlled and allocated, deliberately or by default, by people—the staff of the irrigation bureaucracy. In addition to the three fundamental tasks of water allocation, system maintenance, and conflict management which Coward (1980: 19) has described and which are found in communals, chak irrigators may also organise (as Wade 1979 has shown for a canal in Andhra Pradesh) to raise funds, to post guards higher up the canal, and to induce irrigation staff and influential persons to assure or augment their water supply.

The second difference concerns relative water scarcity. There may be two polar conditions in which organisation for the distribution of water with in a communal or chak will be minimal. At one pole, the water supply (irrigation plus rainfall) is abundant and relatively reliable, as perhaps usually on humid and semi-humid communals and on the head reaches of much Indian canal irrigation. In these conditions, field to field irrigation with paddy may make the most sense. Organisation is less needed because water is adequate and accessible. At the other pole, water supply is scarce and unreliable, as on semi-arid and arid communals, and on the tail-ends of many canal systems. Water quantity and reliability may then be below a threshold at which it becomes feasible and worthwhile to attempt to organise its distribution systematically or equitably.

The situation with which we are concerned lies between these poles. The familiar reasoning is as follows: There are canal systems, it is true, where water is abundant in relation to commandable land; but on most canal systems there is more land potentially under command than there is water to irrigate it. In the common syndrome (outside Northwest India and parts of the deltas), farmers in the head reaches—of canals, branch canals, distributaries, and minors, and of chaks themselves—receive abundant and sometimes excessive water, and the corresponding tail-enders receive water that is both unreliable and inadequate. This presents an opportunity to achieve higher productivity, equity and stability through the redistribution of water from heads to tails. In Keller's expression, the physical objective of an irrigation project can be seen as "to stretch the water like a membrane uniformly over the intended command area" (1981 : 4). This leads to the question which will be increasingly important, and increasingly asked, of how large the commanded area should be. In order to judge answers to that question, the trade-offs for farmers and for the economy between quantity, timing, steadiness and predictability of water supply will need to be better understood, a task particularly for farming system agricultural economists. The optimal condition will be one of induced scarcity, where farmers receive less through the outlet than they would like, but where timing, steadiness and predictability of supply compensate partly, fully, or more than fully, for the lower quantity.

But whether a restricted but timely, steady and predictable water supply at the Chak outlet results in higher production and improved equity and stability will depend on the way the water is distributed within the Chak. If head reach farmers in the Chak take all they wish, the outcome may be that they cultivate thirsty crops like paddy, and others at the tail grow nothing, or only low value drought-tolerant crops. On the other hand, with a steady and predictable water supply. Warabandi in one of its forms is possible. In that case, a larger area may be irrigated, and farmers can decide for themselves what crops to grow with the fixed amounts and timings of water they receive.

The benefits from such rotations within the Chak are quite widely asserted as follows, but are best put with questions which research can verify or qualify, case by case :

(*a*) *Productivity*: Farmers who know what scarce water they will receive and when they will receive it, tend to adopt higher-yielding practices: to grow crops with a higher value to water ratio; to plant higher-yielding varieties; and to use complementary inputs like fertilizer and pesticides. To what extent does this occur? With what private profitability and thus incentives to what sorts of farmers?

(*b*) *Equity*: Warabandi is designed for more equitable distribution of water. To what extent does this in practice occur? What are the actual as opposed to theoretical water distribution practices within the chak?

(*c*) *Maintenance*: Farmers receiving large amounts of water have little incentive to maintain field ditches. Similarly, farmers receiving irregular and inadequate supplies may not feel it worth investing their time and energy in maintenance when they cannot be sure they will benefit from it. In contrast, farmers who are assured of a small but predetermined amount of water will be anxious to maintain ditches so that they receive it with minimum losses enroute. Does this in fact occur?

(*d*) *Diminished conflict within the Chak*: Is conflict between farmers restrained by a precise, clearly understood, and legitimated system of turns by time? The tension between farmers may be there, but does this act to make the system work, since the sanctions for default may be intense? Does this make incidents less common and arbitration less important?

(*e*) *Diminished conflict between Chaks*: Does a Warabandi system diminish conflict between chaks and between different geographical areas on a canal system, and if so in what circumstances?

(*f*) *Less interference and poaching*: On the Pochampad, (Sreeramasagar) Project in Andhra Pradesh, interference with water and poaching has been reduced following the introduction of warabandi (Ali 1980). Is this a general experience?

More needs to be known about the relationship between these benefits and the adequacy, timeliness, steadiness and predictability of the water supply at the output. On Pochampad, where the outlet supply has evidently been steady, these benefits have been reported (see, e.g. Hassan 1981). On part of Mahi-Kadana in Gujarat, however, the flow through an outlet where warabandi had been set up was observed to vary between less than 0.5 cusecs and 2 cusecs in the course of a day(3). This meant that allocation of quantity of water by time was impossible, and farmers presumably took what water they wanted, before allowing the flow to pass on to the next person. This raises the question of what methods of distribution are and can be used where the water supply through the outlet is not steady and predictable enough for warabandi. In South India, where common irrigators distribute water for paddy, there is a concept of "adequate wetting" for fields: each field is adequately wetted by whatever flow is available, before the flow is passed on to the next one (personal communication, Robert Wade). With this method, as water becomes scarcer, tighter organisation may be instituted. Wade (1979 : 10) has described a village in Andhra Pradesh where the village irrigation committee started a more formal roster for the sequence in which lands were to be given water, in response to scarcity and to the introduction of rotations on the distributary: it was necessary to ensure that when irrigation resumed after a rotational break, the first fields to get water would be those not irrigated during the previous period rather than those closest to the outlet. There is much to be investigated and learnt here. Comparisons of benefits from different matchings of

outlet water supply characteristics
cropping patterns (especially the paddy-non-paddy contrast)
types and degree of chak or village organisation
methods of water allocation within chaks

would now be useful, not least to verify or refute the current wisdom that a steady and predictable flow is a precondition for high levels of benefits.

If such benefits from a steady and predictable flow are assumed, then some conjectures can be expressed in the form of a table (Table I).

TABLE I

Farmers perceive quantity of water as	Inadequate				Adequate	
Quantity of water through the outlet is	Low		Medium		High	
nature of water delivery to the outlet	U and U	S and P	U and U	S and P	U and U	S and P
timed rationing feasible	No	Yes	No	Yes	No	No*
productivity of water	L	H	M	H	L	M
equity in its distribution	L	H	L	H	M	M
maintenance by farmers	L	H	L	H	L	L
harmony within the chak	L	M	L	H	M	M
harmony between chaks	L	H	L	H	M	H

U and U = unsteady and unpredictable
S and P = steady and predictable
H = high, L = low, M = Medium

* With an abundant supply of water, it is assumed that paddy is grown with field to field irrigation. Strictly speaking, timed rationing is possible, though unlikely.

Any investigation of these relationships should include other sources of water, and the slack, surplus or cushioning in the system. Elumalai (1980) found no farmers' irrigation organisation on the Parambikulam-Aliyar Project where many farmers had alternative sources of water in wells and so did not have to rely heavily on canal irrigation. There is usually, if not always, some slack or surplus, even where water is scarce. Even the tight warabandi of Haryana, with its seven day rotation within the chak, has an eighth day of flow in distributaries and branches to allow for transmission time and to ensure that tail-end chaks receive their full seven days; and this means that chaks at the heads of distributaries receive more than the seven days of water.(4) Again, the tight distributary management on Pochampad allows 10 percent extra as a safety factor. But it is night

(3) Personal communication from Wayne Clyma, T.K. Jayaraman, Max Lowdermilk, and Barry Nelson.
(4) For detailed discussion see Reidinger 1980 and Malhotra.

flows which are often the largest slack. For reasons of convenience, low visibility and even safety, they have been little studied. Yet night flows often seem to represent a major waste of water. On Pochampad, a few chaks have a warabandi at night, but for most the night water simply flows through the chak to be used by any one or no one. On part of the upper Ganga, farmers are reluctant to take their turns at night because illicit extractions upstream diminish the night flow and they get less water (Personal communication, D. Tyagi). Night flows may also be linked with paddy cultivation (which may or may not be a good use of water) as Elumalai has found on Parambikulam-Aliyar:

> "Since irrigating the dry crops during night time is considered not advisable, the flow in the channel during night time is mostly diverted to wet lands raising paddy and no rotational system is followed. The distribution of water during nights is either based on *mutual adjustments* or influence of the *head reachers/tail-enders*".
>
> (*Elumalai 1980 : 18. His emphases*)

For field research, night irrigation is one of the next black boxes to be opened up.

A research priority below the outlet is participant-observation of a social anthropological sort to find out what happens to water in the chak, and who gets how much, when, how, why and with what results. This, coupled with study of the institutions and interactions at the chak level, should shed light on relationships between quantity, timeliness, steadiness and predictability of supply at the outlet, and benefits through productivity, equity, maintenance and reduced conflict. Such studies would investigate, the fit between the theory of Warabandi and other methods of rotation, and the practice. There is a danger that Warabandi will be seized upon as a panacea for all conditions and on a massive scale without such insights. It may or may not be such a panacea. The Training and Visit system of agricultural extension (Benor and Harrison 1977) may provide a parallel. It has been introduced in most Indian States and in many countries in the world. Its benefits may be large, but there has never, to my knowledge, been feedback from an evaluation with the bottom-up view of a person living in a village and observing the behaviour of staff and farmers over a season or more. In the case of new Warabandi, the benefits from knowing just what happens to water under the outlet might be very high. A number of careful, detailed and sensitive studies might reveal opportunities for improving Warabandi, the way it is introduced, and its adaptation to local circumstances. Otherwise Warabandi in new areas may become a mythical solution, supposed to happen, said (by staff and farmers to visitors) to happen, but not actually happening, or happening in some different manner. The challenge is to bring theory and practice together. To do that, the reality must be known.

Above the Outlet

(*a*) *Distribution on the Main System*

Which outlets get water, and how much they get, when, and with what steadiness and predictability, depends on how water is managed on the main system. There are here two potentials for raising productivity, equity and stability.

The first is to redistribute water so that top-ends (which may suffer from over-irrigation, waterlogging and salinity) get less, and tail-ends get more. Such redistribution depends on there being adequate physical structures. Recent experiences in Andhra Pradesh suggest that even with present structures or with only minor rehabilitation, much water can be so redirected. For example, following some structural upgrading and the introduction of a simple rotation between outlets on some majors on Nagarjuna sagar Right Bank Canal, some 3,400 additional hectares received irrigation water for the first time for many years in kharif 1980[5] (personal communication, M. Narayana). Similarly, on the Vantivelagala Distributary on the Tungabhadra Project, in kharif 1980, a redistribution of water from head to tail is reported, in spite of less water being available than in 1979, to have led to a rise in irrigated acreage from 361 to 560 (CADD, AP, 1981 : 13).

The second potential lies in the complicated and challenging task of ensuring and adequate, timely, steady and predictable supply to outlets. This may require new or modified structures, especially on distributaries and minors, together with careful measurements and planning of times and amounts of supply. Minors and distributaries vary in the rotations they permit and each minor and distributary requires a separate analysis. The outcome of careful distributary and minor management,

(5) Without questioning this figure, a note of caution is in order. There are problems of measurement in determining additional area irrigated following a reform of this sort. It is possible that some farmers who were previously getting water no longer do so. For example, some farmers at the tail-ends of outlets at the heads of the majors might receive less water, or even not irrigate at all. However, even if there were instances of this, the overall benefits of this reform could hardly fail to remain substantial. The estimation of costs of new irrigation per hectare is complicated where dams are also used for power, and all figures should be treated with caution. However, the benefits achieved by the redistribution of water on this part of Nagarjunasagar at negligible cost can be compared with the costs of developing the same area of new irrigation. The capital cost of 3,400 ha of new irrigation on the Srisailam Right Bank Canal to be constructed in Andhra Pradesh at about Rs. 28,600 (UNIAS 1981) or $3,600 per hectare is over $12 million; and if the higher figures cited by Levine and others (1980 : 97) of $7,000 to $10,000 per hectare where storage is involved, the cost of 3,400 hectares of new irrigation becomes $24.0 million to $34.0 million. The comparison is not exact, but even if the capital costs were only one-tenth of those estimated, interventions on existing canal systems to increase the irrigated area would still be likely to appear dramatically cost-effective by comparison with the construction of new major irrigation systems.

coupled with Warabandi below the outlet, can be a sharp reduction in total water requirement and a sharp increase in cropped area, yields and returns to farmers (Hassan 1981).

Alternative methods of water distribution and methods of analysing and managing water on minors, distributaries and main systems as a whole, are not a subject that is widely studied, analysed, or taught, either in engineering or in economics. In Taiwan there is an institute set up to analyse, develop and teach methods of water rotation (Personal communication, Robert Wade). Anderson and Maass (1971) have gone into these questions in detail, identifying many alternatives but in general the subject still seems a cinderella, at least for much third world irrigation. And even for the United States, a recent manual on *Operation and Maintenance of Irrigation and Drainage Systems* published by the American Society of Civil Engineers (ASCE 1980) devotes only some 3 pages to the different methods of water delivery, and its brief discussion of demand, continuous flow and rotational methods does little more than tantalise the reader. Nor does academic research appear to have been pointed in this direction: the abstracts of 216 post-graduate these presented in 1970-1975 in hydrology and related subjects at 22 Institutes of Technology, Engineering Colleges, or similar institutions in India, do not include a single mention of methods of distributing water on canal irrigation systems (INC for IHP 1977). The subject is mentioned in a leading textbook on Irrigation Engineering (Singh 1979:169-169) but the main professional concentration in the section on regulation and control of the canal system is on discharge measurement and the assessment of canal revenue. Two recent studies are, hopefully, precursors of much more description and analysis. Proposals for the water distribution systems of the Mahanadi Canal System and Hasdeo Bango Project are a rare example of a presentation of alternatives for canal flow levels and methods of rotation (WAPCOS, New Delhi, n.d. 598-599). And a further treatment is in S.P. Malhotra's *The Warabandi Systems and Its Infrastructure*, especially the chapter on "Distributary Design and Rotational Running".

The impression remains that alternative methods of water distribution on main systems are an underdeveloped subject both internationally and in India. Much is learnt and known from hard experience, commonsense and improvisation. But that learning does not appear to have been analysed comparatively for third world operating conditions and embodied in methods for identifying and choosing between alternatives. Is it better on system X to rotate between outlets, between minors, or between distributaries? It is better to run a channel continuously at one-third capacity, for half the time at two-thirds, or for a third of the time at full capacity? What rotation intervals are best in what circumstances, with what mixes of what crops, and how should they be determined? What are the procedures for analysing the requirements of the outlets on a distributary, and then organising the water supply so that they are met? What data are needed for such decisions, and how should such decisions be made? Economists, to my knowledge, have not yet turned their minds to critical questions like these. Engineers, who often face them, have not, to my knowledge, often seen these questions as major professional challenges; and if they have so seen them, they have not written about this much in professional journals. And yet on the manner in which these questions are answered, channel by channel, depends whether millions of hectares will or will not receive water, and whether that water will be received in a manner which permits and encourages farmers to improve distribution among themselves.

As irrigation engineers and agriculturalists alike know from hard experience, the questions are not simple, and the possible solutions are often numerous. It is not just a question of timing, quantity, continuous flow or rotation, and sequences of water issues. Optimal water supplies are tied in with cropping patterns, labour constraints, planting times, and rainfall probabilities. The questions are also political, since they can concern whether certain areas will or will not receive water, and how much they will get. The development and teaching of methods to determine and execute water distribution on main systems appears a major need.

(*b*) *Irrigation Staff: Motivation, Management and Behaviour*

Until the last few years, the problems, motivation and actions of irrigation staff were not a concern of social science research. Terms of service, transport, communications, financial regulations and the like have not appealed much to social scientists. But a number of studies(7) have now illuminated some aspets of the work environment, incentives and behaviour of irrigation engineers engaged on Operation and Maintenance. The Jayaramans' study (1981) found from a survey of 289 irrigation engineers in Gujarat that they preferred construction and design to operation and maintenance. The differences they affirmed were that compared with operation and maintenance, construction and design were

- more for "hard" applied science people
- offered more independence of action
- were less monotonous and offered more variety of experience
- carried better promotion prospects
- involved less public relations
- were less vulnerable to transfers by dissatisfied politicians

(6) There is one conceivable exception—"Studies in the Regulation and Operation of the DVC" by R.N. De. This was a flow regulation study but the abstract gives no indication that alternative methods of distribution were considered.

(7) Especially those of Bottrall ,Jayaraman, and Wade (see references in each case). Bottrall 1981c is a comprehensive review.

One way of tackling these problems is through greater professionalisation of irrigation management. It would be naive to suppose that this would directly or quickly confront the problem of transfers. But it is encouraging that the Jayaramans' study did not identify an objection to learning the multi-disciplinary skills necessary for operation. Indeed, the multi-disciplinary and complex questions involved in irrigation management should make it professionally far more challenging than design and construction. It is more difficult to do well. The recommendation, often made, for an O and M cadre is one step. The development of simulation games for use in the training of irrigation managers is another. In the longer term, the content of training for the irrigation management cadre is critical. But a basic problem remains the system of sanctions through transfers which, while it persists, will inhibit irrigation staff from taking the unpopular measures which are sometimes necessary and which may discourageable and committed staff from taking up O and M[(8)].

One approach which has been proposed is the development and introduction of a management system which is more concerned with outputs (area irrigated, yields) and which monitored these to indicate performance (see Seckler 1981). It is also important that irrigation staff who take pains to control and operate canals more tightly should be recognised and rewarded, for they may be taking not only trouble but also risks. Part of the social science contribution here can be to examine and describe the actual conditions and problems of those who work in irrigation bureaucracies. This applies not only to engineers but also to lower level staff like lascars. Is there any description anywhere of a week in the life of a lascar? Yet unless the real activities and relationships of staff and farmers at the lower levels are understood, measures to improve performance may well fall short of expectations.

Across and up from the Outlet

The assumption so far has been that there is an organisational break or boundary at the outlet, and that it is at the outlet that water passes from one jurisdiction—that of the irrigation bureaucracy, to another—that of the farmers. This is usually or perhaps always the case with existing warabandi. But it is not inevitable, nor is the outlet always the boundary. Two examples have been reported which show a different pattern. Water distribution to the 18 villages on the 1645 ha under the Dusi-Mamandur tank in Tamil Nadu is controlled by an elected organisation with 54 representatives. The organisation, which is seeking registration under the Societies Registration Act, has replaced an earlier Irrigation Panchayat Board which was performing unsatisfactorily. The new organisation makes itself responsible for ensuring water supplies into the tank (which entails, among other things, carrying labour by lorry to a point 15-20 km from the command), for maintenance of facilities, for water distribution, and for the settlement of disputes (Elumalai 1980). Similarly, an organisation for 550 farmers on three minors at Alampur has elected a President to be responsible for the distribution of the 45 cusecs received by the area under command (Sitapathi Rao, n.d.). Such farmers' organisations, extending above the outlet, may be both more common and more feasible than supposed, especially in South and Central India.

This raises more pointedly the question of farmer organisation and representation above the outlet. Such representation is increasingly proposed. Kathpalia (1980:41) has mentioned organising and training farmers not only for distributing water among themselves within the Chak, but at a later time to operate the minor as well. Jayaraman and Jayaraman (1981) have gone further and suggested a three-tier system with an outlet committee, a distributary committee, and an apex committee for a project as a whole. Such supra-outlet organisations or committees might simplify the work of irrigation staff in these ways:

(*i*) by appointing and paying staff to control and distribute water. This would make the equivalent of the lascar accountable to the irrigators as a whole. (Such a system is found within communals, for example with the neerthoddis of Tamil Nadu. It has also been found below the outlet on canal irrigation in Andhra Pradesh, where cases have been reported of common irrigators responsible for distributing water to the fields being dismissed for failure to do their duty' (Wade 1979:20). In Korea, farmers nominate and pay for patrollers, and similarly can get them dismissed if their performance is unsatisfactory (Wade 1981b)).

(*ii*) by handling conflict and disputes at the lower levels:

(*iii*) by providing a sounding board and a means of communication.

(*iv*) by aggregating farmer interests and negotiating with other water groups, thus reducing political pressures on irrigation staff, and making it easier, through tailenders' pressures, to redistribute water from headreaches to tailends.

Such farmers' bodies would complement a shift from an upstream, supply approach to water distribution, to a downstream demand approach (Kathpalia 1980). There are many questions involved in any such complete or partial reversal, and one may expect them to be on the agenda for action research for several decades. They include the communication upwards of local conditions and needs, and the speed and accuracy of response; the division of responsibility for maintenance; and the resolution of conflict and competition between segments of an irrigation system. At this stage, research could be

(8) For further proposals see Jayramaan 1981.

useful on "spontaneous" examples of farmer organisation above the outlet, coupled with monitoring and interpretation of experiences with committees or organisations which are encouraged officially at minor level and above. One question is whether the conditions which favour spontaneous supra-outlet organisations exist, or should be reproduced, on canal irrigation generally. There is here, perhaps, an irony. It may be easiest for such bodies to form and function where there is a clear collective interest in action to ensure their water supplies. If the Dusi-Mamandur organisation did not exist, the farmers in the 18 villages might not receive water, or might receive much less. But where there is a strictly managed and routinised system of water distribution, as in Northwest India, the water arrives without such interventions. Most farmers will only invest their time and energy in activities which they see make a difference to their benefits. To the extent that the future lies with rigidly administered rotations to the outlet, as at present in the Northwest, supra-outlet committees may be difficult to sustain. However, the aggregation and articulation of farmers' interests at different levels are a necessary precondition for some of the redistribution of water that is necessary.

Practical Political Economy

This last statement can be understood from the point of view of practical political economy, from examining who gains and who loses. Political economy is sometimes treated as a moral subject; but it is also practical. If changes in water distribution on canals mean that some have to lose, then political problems, requiring political solutions can be anticipated.

This type of situation can be illustrated by a recent example, the introduction of IWM in kharif 1980 on the Vantivelagala Distributary on the Kurnool-Cuddapah Canal in Andhra Pradesh. Head reach farmers had been growing two crops of paddy a year on land which had been localised for one irrigated dry (i.e. non-paddy) crop. Tailend farmers, meanwhile, although they had been localised for paddy, were able to grow only an uncertain dry crop on less than the whole of their planned command area. Redistribution of the available water to enable the tailenders to grow paddy meant that topenders had to lose. The result was country bombs, a meeting addressed by a senior political leader and the District Collector, the imprisonment of one leading protester, and finally success in the sense that a big increase in irrigated area could be reported (CADD, AP 1981). Such confrontations may sometimes be necessary, and can be overcome with political support. But the political support itself requires the aggregation and articulation of the interests of those (usually tailenders) who are deprived. On the much larger scale of many canal systems the organisation of tailenders and political pressure and support from them may often be a necessary precondition for "stretching the membrane", for creating the induced shortages in the headreaches which are needed for more productive and equitable distribution of water.

We are concerned here not with a search for once-for-all solutions, but for practicable sequences of change over years and even decades. For early success with water redistribution on a large scale, it may be cost-effective in the short run to seek ways in which all irrigators can gain, or in which losses can be minimised. At first sight this looks improbable, since some have to get less water so that others can get more. But it is not necessarily a zero sum situation. Headreaches are widely reported to be over irrigated. The familiar headreach syndrome starts with a new irrigation head-works and abundant water available before the tails of the canals are complete. Headreach farmers then receive more water than they can use, and either opt for paddy or are forced to grow it, sometimes in both Kharif and Rabi. There may, however, quite often be opportunities for them to gain from receiving less water if it is issued to them in a timely, and steadier and more predictable manner. Their benefits may include, for example:

—reduced waterlogging and salinity

—lower labour requirements for water control

—the chance to grow more remunerative crops

—higher returns from complementary inputs (fertilisers, pesticides etc.).

Here is perhaps the greatest and most exciting challenge for multi-disciplinary research: to appraise canal irrigation systems with the headreach syndrome and to work out, with farmers, whether there are conditions in which with less water, distributed and delivered in a timely manner, and more steadily and predictably, farmers could be (and could consider themselves to be) better off. And then, if such ways are found, to work out sequences of changes to achieve those conditions (Chambers 1981).

Such appraisal requires the combined efforts of key disciplines, for example agricultural economics (to assess the private profitability of alternative cropping patterns, their labour and management demands, etc.), agronomy (to identify alternative cropping patterns under different water supply assumptions), agricultural economics (to assess their private profitability, and labour and management demands), irrigation engineering (to assess the feasibility of different water supply regimes), agricultural engineering (to assess the feasibility of water delivery from the outlet to the farm), and sociology and political economy (to assess the organisational and political feasibility of the change). Such appraisal invites the use and development of methods for the rapid and cost-effective understanding of farming systems and farm-level constraints (see, for example, Collinson 1981 and Hildebrand 1981). An early priority would seem to be to try out such methods of appraisal and identify how widespread the opportunities are for all, or almost all, farmers to gain from redistribution, and then to test out and monitor such redistribution in practice.

Conclusions

In conclusion, three themes from this paper can be highlighted:

(i) the need to raise the professional status and satisfaction of irrigation system management, especially water distribution. It is a complex and challenging task, and deserves recognition, resources, and public rewards,

(ii) the need for interdisciplinary collaboration and thinking. One way forward lies through professionals in each discipline learning from others, not least social scientists learning from engineers and agronomists, so that each actor becomes a multi-disciplinarian,

(iii) the need for field research and comparative analysis. This should examine what happens to water, and who gets what, when, how and why, and with what consequences; and investigate and compare relationships between the characteristics of outlet water supplies, the allocation of water within the chak, cropping patterns, chak or village organisation; and benefits and their distribution.

Pursuit of these three themes can be only part of any strategy for achieving more of the potential of canal irrigation; but each has a strong contribution to make.

References

1. Ali, Syed Hashim, 1980: "Integrated Water Management Above and Below the Outlet", Paper for the Workshop on Warabandi, Administrative Staff College of India, Hyderabad, 23-26 April.

2. Ali, Syed Hashim and Syed Turabul Hassan, 1980 "Management of Canal Irrigation Systems and Warabandi", in K.K. Singh ed. *Warabandi for Irrigated Agriculture in India*, pp. 23-37.

3. Anderson, Raymond L. and Arthur Maass, 1971: "A Simulation of Agricultural Systems: the effect of water supply and operating rules on production and income on irrigated farms", Technical Bulletin No. 1431, Economic Research Service, US Department of Agriculture.

4. ASCE 1980: "Operation and Maintenance of Irrigation and Drainage Systems", ASCE Manuals and Reports on Engineering Practice, No. 57, American Society of Civil Engineers, 345 East 47th Street, New York 10017.

5. Benor, Daniel and James Q. Harrison, 1977: "Agricultural Extension: the Training and Visit System", World Bank, 1818 H Street NW, Washington D.C. 20433.

6. Bottrall, Anthony, 1978: "The Management and Operation of Irrigation Schemes in Less Developed Countries" in Carl Widstrand ed., *The Social and Ecological Effects of Water Development in Developing Countries*, Pergamon Press, Oxford, pp. 309-329.

7. Bottrall, Anthony, 1981a: "Water, Land and Conflict Management", *ODI Review* No. 1, 1981, Overseas Development Institute, 10 Percy Street, London WIP OJB (Reviewing Coward 1980).

8. Bottrall, Anthony, 1981b: "Improving Canal Management: the Role of Evaluation and Action Research", *Water Supply and Management*, Vol. 5, pp. 67-79.

9. Bottrall, Anthony, 1981c: "Comparative Study of the Management and Organization of Irrigation Projects", World Bank Staff Working Paper No. 458, May.

10. CADD, AP, 1981: "Final Report on Integrated Water Management in Vantivelagala Distributary of Revanur Branch Canal of Kurnool-Cuddapah Canal During Kharif Season of 1980 in Allagadda Taluk-Kurnool District", Tungabhadra Project Command Area Development Authority, Anantapur.

11. Chambers, Robert, 1978: "Identifying Research Priorities in Water Development", in Carl Widstrand, ed., *The Social and Ecological Effects of Water Development in Developing Countries*, Pergamon Press, Oxford, pp. 389-398.

12. Chambers, Robert, 1981: "Appraising and Improving Canal Irrigation" (draft for comments), Ford Foundation, 55 Lodi Estate, New Delhi, April.

13. Collinson, Michael, 1981: "A low cost approach to understanding small farmers", in *Agricultural Administration, Special Issue on Rapid Rural Appraisal*, November.

14. Coward, E. Walter, ed. 1980: "Irrigation and Agricultural Development in Asia: Perspectives from the Social Sciences", Cornell University Press, Ithaca and London.

15. Elumalai, G. 1980: "Farmers' Organisations for Efficient Water Use in Irrigated Agriculture: a case study in Tamil Nadu", typescript.

16. Hassan, Syed Turabul, 1981: "Evaluation Study of Warabandi (Rotational Supply System) under Sreeramasagar Project Command Area, Jagtial, Andhra Pradesh (since 1978)", Command Area Development, Deptt. Jagtial, January.

17. Hildebrand, Peter E., 1981: "Combining disciplines in rapid appraisal: the Sondeo approach", in *Agricultural Administration Special Issue of Rapid Rural Appraisal*, November.

18. INC for IHP, 1977: "Water Abstracts 1970-75", compiled by the Indian Institute of Technology, Kanpur, published by Indian National Committee for International Hydrological Programme, Council of Scientific and Industrial Research, New Delhi.

19. Jayaraman, T.K., 1980: "Farmers' Organisations in Surface Irrigation Projects: Two Empirical Studies from Gujarat State, India", Paper for Workshop on Farmers' Organisations for Efficient Water Use in Irrigated Agriculture, Indian Institute of Management, Bangalore, 8-10 August.

20. Jayaraman, P. and T.K. Jayaraman, 1981: "Attitudes of the Irrigation Bureaucracy in India to Scientific Water Management Tasks in Irrigated Agriculture: a case study from Gujarat State", *Zeitschrift Fur Auslandische Landwirtschaft*, Quarterly Journal of Agriculture, Berlin Technical University.

21. Jayaraman, T.K., 1981 "A Case for Professionalisation of Water Management in Irrigation Projects in India", *Public Administration and Development*, Vol. 1, No. 3, July-September.

22. Kathpalia, G.N., 1980: "Rotational System of Canal Irrigation and Warabandi", in K.K. Singh, ed., *Warabandi for Irrigated Agriculture in India*.

23. Keller, Jack, 1981: "An Overview of USAID's Irrigation Investment Options and Strategies for Asia", Paper for USAID/Asia Bureau Agricultural/Rural Development Conference, January 11-16, 1981 at Jakarta. Revised 1 May.

24. Lenton, Roberto, 1981: "A Note on Alternative Forms of Performance Evaluation in Irrigation Systems", typescript, (available from Ford Foundation, 55 Lodi Estate, New Delhi 110003).

25. Levine, Gilbert, Peter Oram and Juan A. Zapata, 1979: Water, report prepared for the conference "Agricultural Production: Research and Development Strategies for the 1980's", Bonn, October 8-12, 1979, DSE, GTZ, BMZ and the Rockefeller Foundation, (Report available from the Rockefeller Foundation, 1133 Avenue of the Americas, New York, NY 10036).

26. Malhotra, S.P. (forthcoming): "The Warabandi System and Its Infrastructure" (manuscript draft, 1981).

27. Rao, C. Sithapathi: "Departmental Report on Alampur Village, Rajolibanda Diversion Scheme", Command Area Development Department, Andhra Pradesh, cited in Ali and Hassan 1980, p. 33.

28. Reidinger, Richard B., 1980: "Water Management by Administrative Procedures in an Indian Irrigation System", in Coward, 1980, pp. 263-288.

29. Seckler, David, 1981: "The New Era of Irrigation Management in India", mimeo, Ford Foundation, 55 Lodi Estate, New Delhi, January (draft).

30. Singh, Bharat, 1979 : "Fundamentals of Irrigation Engineering", Sixth Edition, Nem Chand and Bros., Roorkee.

31. Singh, K.K., ed., 1980: "Warabandi for Irrigated Agriculture in India, Publication No. 146, Central Board of Irrigation and Power, New Delhi, November.

32. UNIAS, 1981: *UNI Agricultural Service*, Vol. III, No. 24, 11 June.

33. Wade, Robert, 1979: "The Social Response to Irrigation: an Indian Case Study", *Journal of Development Studies*, 16, 1, October.

34. Wade, Robert and Robert Chambers, 1980: "Managing the System: Canal Irrigation's Blind Spot", *Economic and Political Weekly*, Vol. XV, No. 39, Review of Agriculture, September, pp. A107-A112.

35. Wade, Robert, 1981a: "The Information Problem of South Indian Irrigation Canals", *Water Supply and Management*, Vol. 5, pp, 31-51.

36. Wade, Robert, 1981b : "Employment, Water Control, and water Supply Institutions: South India and South Korea", typescript, Institute of Development Studies, University of Sussex. Brighton, UK.

37. WAPCOS n.d. 1981 : "Planning of Water Distribution System—Rotational Water Deliveries", (typescript), Water and Power Consultancy Services, Ltd., "Kailash", 26 Kasturba Gandhi Marg, New Delhi.