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Canal irrigation at night

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Abstract. Most canal irrigation water in South and Southeast Asia and elsewhere continues to flow at night and much is badly used or wasted. Yet what happens to water at night is a neglected subject, a matter for anecdotes more than analysis. Darkness, cold, fear, normal working hours, and desire for sleep deter irrigation staff, farmers and labourers from activities at night. At the farm level, irrigation at night entails extra labour and costs. It requires smaller streamflows and well shaped fields. Paddy and trees are the easiest crops to irrigate, and younger, lower and more thinly spread crops are usually easier than those which are older, taller and denser. On the lower parts of main systems, control at night often passes informally from irrigation staff to irrigators. Potential productivity of water at night is slightly raised by lower evaporation losses, but this gain is negligible compared with losses from breaks in channels, inefficient water application, and wasted water flowing into drains. Reuse of night drainage water lower down sometimes makes waste less wasteful than it appears. Equity effects at night are mixed: some farmers poach at the expense of others, but some get water at night who are denied it during the day. Night irrigation increases costs and inconvenience to small farmers, but raises labourers' incomes. Flooding and waterlogging can result from uncontrolled water flows at night.

Practical implications are of two types: a) *reducing irrigation at night*, especially where water can be saved and stored by regulating releases from main reservoirs; in storage or by travelling in canals; by use of intermediate reservoirs; by pondage on-farm; or as groundwater. Care is needed in analysing what is waste and what is water saved. b) *improving irrigation at night* – by making flows predictable and manageable; by improving convenience and efficiency including lighting, ease of movement and field shaping; by choosing easy crops; by zoning for night flows; and by phasing for short nights, warmth and visibility. The potential for better performance on canal irrigation systems is probably large. It is hoped that this paper will encourage and provoke system managers, designers and researchers to explore the practical potential of this neglected subject about which much more needs to be known. Canal irrigation at night is too important to remain a blind spot any longer.

A day has a period of 24 hours (i.e. it includes the night).

B.C. Punmia & Pande Brij Basi Lal, *Irrigation and Water Power Engineering*, 7th ed., 1983, p. 48

The magnitude of waste involved in not irrigating at night is so huge that savings from other sophistications in the field of water management like the lining of watercourses etc. pale into insignificance.

S.P. Malhotra, 1983.

Night irrigation and what we know about it is truly a blank page in our books.

Gabriel J. Tibor, 1985.

Canal irrigation at night: Another blind spot

This article draws on experience in South and Southeast Asia. There, as elsewhere, observation analysis and policy for canal irrigation have been distorted by biases. These include paying more attention to construction than maintenance, to water supply than drainage, to head reaches than tails, and to on-farm development below the outlet than to scheduling on the main system above it. Main system management has been a blind spot (Wade & Chambers 1980). These biases have been increasingly recognised, and efforts are being made to correct them. But canal irrigation has another blind spot, reflecting an almost universal bias of human activity and perception: that of day rather than night.

Canal irrigation at night is a subject of anecdotes more than analysis. Many knowledgeable people have provided information which has contributed to this article.* Most people with experience of canal irrigation have stories to tell, though often these are based on hearsay and inference rather than direct observation. Farmers, too, are very willing to talk about it, in their case drawing on direct experience. Yet despite much interest in the subject, once raised, informants have been able to draw my attention to only two papers specifically concerned with night irrigation – Don Campbell's (1980) monograph *Design and Operation of Irrigation Systems with Supply to the Field Confined to Daylight Hours Only*; and El Antaki & El Bekri's (1984) article on night irrigation on

* To reduce the space required for this article, definitions, footnotes, and acknowledgements have been omitted. I wish to thank the many people, 68 of whom were named, who have contributed comments and information. Opinions and errors are my responsibility alone and do not necessarily reflect the views of any organization.

the Beni-Amir system in Morocco. Both of these, moreover, are concerned with avoiding rather than improving irrigation at night. The neglect of the subject is perhaps most starkly illustrated by failure to find 'night irrigation' or 'irrigation at night' in the index of any book consulted.

This oversight is less surprising when one reviews the reasons. Field visits occur during the day, mainly between about 8.00 a.m. and 4.00 p.m. Nights are for sleeping. At night it is also dark, sometimes cold, sometimes dangerous, and people are difficult to find or asleep. Official hours of work are usually for 8 hours; actual hours may be even less, but in any case during the day not the night. It is rare indeed (and only in crisis) that irrigation staff works shifts round all 24 hours. In addition, officials usually prefer not to stir up trouble by finding out about, and being known to know about, what happens at night. Research, too, suffers the same temporal biases. Night is sometimes assumed by researchers to be a time of inactivity, an assumption which can be self-validating: a farm family time use survey applied in Sikar District in Rajasthan was coded from 0400 to 2400 midnight, with no spaces for entries for the 4 hours from midnight to 0400, when much irrigation took place but which in consequence would not be recorded. Scientific measurements are found being made not just during the day, but during normal official working hours: for example, average humidity values at Vasad on the Mahi-Kadana Project are reported only for 0800 and 1400 hours (Ashok Raj & Nathan 1983: 43). When an attempt is made to study what happens at night, it may fail: Mark Svendsen tried to get investigators to measure night flows in the Philippines but could not induce them to do so. I must also confess that despite interest in irrigation at night, I have found it difficult to observe: it requires determination, stamina, inconvenience, sometimes discourtesy to one's hosts, abnormal hours for others and a good torch. And observations are themselves likely to be biased to the first hours of the night. Travelling around an irrigation system at night also smacks of an investigation of something illicit. Life is easier if irrigation at night is ignored.

For many farmers, irrigation at night is anything but a blind spot. Not only do they practice it, but they are articulate in discussing it. Moreover they see it differently from officials. The neglect of night irrigation in official thinking can lead to an underestimate of benefits from improvements designed with other purposes in mind. Watercourse reconstruction in Pakistan was seen by the Pakistan Government and USAID officials as a means of reducing transmission losses and distributing water more equitable between head an tail. They did not see greater ease of irrigating at night as a gain. But farmers did perceive this value, and almost always mentioned it when asked about benefits from watercourse improvement (Merrey 1985). Here, and generally, the contrast in perceptions and priorities between farmers and irrigation officials is sharp.

Scale and importance

The first step in assessing the scale and importance of what happens to canal irrigation water at night is to define the period with which we are concerned. There are different dimensions here: the period during which irrigation staff abdicate control of the tertiary level of an irrigation system may be as long as from 1600 to 0800 hours; the times when farmers freely take water from their neighbours may be only the middle and later periods of darkness. For our purposes, however, darkness itself is a good starting point.

Here at once there are intriguing differences between beliefs and reality. There may be a habitual underestimate of the hours of darkness. After all, since we sleep much of the night, we do not experience its duration in the same way as the day. This makes it less surprising that one author should for planning purposes take night as 8 hours. To calculate capacity for night storage requirements on a canal sytem, Shankara Iyer (1983: 35, 36), assumed that '... the distribution system will be operating during the day time hours only i.e. 16 hours per day', and calculated the required capacity of a night storage reservoir to save water, allowing for no irrigation during the 8 hours period of the night. However, nowhere in South or Southeast Asia, at any time of the year, are the hours of darkness as short as 8 hours.

The most obvious definition of night would be the period between sunset and sunrise. However, visibility for purposes of field irrigation persits after sunset and starts before sunrise. Personal observations suggest that 20 minutes in each case is a reasonable allowance for this period of twilight. On this basis, and with rounding to the nearest ten minutes, the average hours of night (darkness) in North India (Delhi) range from 9 hours 20 minutes at midsummer to 13 hours at midwinter, and in South India (Madras) from 10 hours 30 minutes to 12 hours (see Table 1). The average for all India at all seasons is about 11 hours 10 minutes, or some 47 per cent of the 24 hours. Darkness is lessened when there is a good moon without cloud cover, but even then other difficulties and disincentives for irrigation at night persist.

Observations about the waste of irrigation water at night are widespread, and not confined to any region. Waste at night is reported from as far afield as the Guenare Project in Venezuela and the Beni-Amir Project in Morocco. where cold and long winter nights are said to have led to significant losses of water (El Antaki & El Bekri 1984). In South and Southeast Asia, it has often been remarked upon. Of the Chambal Project in India, Bottrall (1981: 206) wrote that '... the farmers' unwillingness to practise night irrigation contributed further to high levels of water wastage'. Of the Gambhiri Project in Rajasthan, Katariya (1983: 48) wrote that '... the farmers do not take water in the night causing considerable wastage of water ...'. Of the Morna Project in Maharashtra, before changes in main system management, Joshi wrote that a

Table 1. Estimated hours of darkness, North and South India

	North India (Delhi) Delhi 28° N 39′				South India (Madras) 13° N 34′			
	sunrise	sunset	hours sunset to sunrise	hours of darkness	sunrise	sunset	hours sunset to sunrise	hours of darkness
December 22	07.10	17.29	13.41	13.01	06.27	17.48	12.39	11.59
March 21	06.25	18.32	11.53	11.13	06.13	18.20	11.53	11.13
June 22	05.24	19.22	10.02	09.22	06.44	18.37	11.07	10.27
September 21	06.09	18.20	11.49	11.09	05.58	18.06	11.52	11.12

Source for sunset and sunrise: GOI: 1982.
Hours of darkness are calculated by subtracting 40 minutes, allowing 20 minutes for twilight at both dusk and dawn.

'lot of water was wasted during night time' (1983: 169). Of the Parambikulam Aliyar Project in Tamil Nadu, Sivanappan & Ghandi (1982: 117) wrote of '. . . system farmers wastage of irrigation water. Some farmers preferred to let the water go down the drain at nights fearing too much submergence, thus resulting in scarcity of water at tail end even for the irrigated dry crops'. Of the Gal Oya Project in Sri Lanka, Murray-Rust & Moore (1983: 69) similarly noted waste of water at night. And no doubt very many other cases could be found on similar medium and large-scale irrigation projects. On smaller reservoir systems, below say 200 hectares, waste also occurs: sluices may be left open at night either from negligence, or because those who cultivate the foreshore want to drain the tank. To find little waste of water at night (as with NW Indian warabandi) appears exceptional.

Statements like these, combined with the calculation that 47 per cent of the 24 hours is a time of darkness, give the impression of great scope for improving irrigation system performance though reducing waste of water at night. In an earlier paper (1984a: 8) I wrote of Indian canal irrigation that:

> It is difficult to estimate how much water is currently saved at night – through intermediate storage in tanks or canals, diversion to travelling, or closure of headworks, but it is probably quite a small proportion. A reasonable estimate may be that 40 per cent of the canal irrigation water on medium and major systems (i.e. with commands over 2,000 ha) is either applied in night irrigation or sent into drains at night . . . Night irrigation is often inefficient. Supervision is difficult and minimal. Neither engineers nor farmers willingly work at night. Night flows are often diverted to crops which tolerate flooding, mainly paddy, or are allowed to flow into drains. In Northwest India, where water is scarce compared to need, warabandi is practised at night (Malhotra 1982). But elsewhere warabandi at night is rare. It may be a

reasonable estimate that outside Northwest India, over half the night flows, perhaps some 25 per cent of the total water resource, is wasted at night and much of the 15 per cent which is applied at night is used inefficiently.

Opinions will differ about these estimates. They deserve to be based not on casual observation, anecdote and conjecture, but on scrupulous empirical investigation.

They also deserve to be analysed in terms of the true, feasible potential for improved performance. This will be limited in two respects. First, 'waste' is often thought of in terms of a discrete and bounded irrigation system, but water which flows out of such systems is often reused lower down, either by other recognised systems, or by unofficial 'encroachers' who may be productive farmers. Second, potential for improvement depends on there being alternatives to the 'waste' of water at night or to its inefficient application. This depends on the range of actions which can feasibly reduce irrigation at night and save or redeploy the water, or which can improve irrigation at night. How much potential there is for improved performance depends on the conditions of each system and of each part of it.

For all these caveats and qualifications, however, it is important to bear in mind the scale of the subject. If only half of the 25 per cent estimated to be wasted at night could be saved or efficiently applied, this would still amount to an increase of 25/75 × ½ or one sixth in the effectively available canal irrigation water supply. The potential may be very large indeed. Such scales of opportunity are not to be treated lightly, and the past neglect of canal irrigation at night makes it all the more imperative to find out more.

Against this background, an attempt will be made, with the evidence available, to examine canal irrigation at night, to identify types of intervention to improve performance and to suggest further action.

Night irrigation below the outlet

Farmers' plusses

Exceptionally, the supply of irrigation water at night is welcomed or valued by farmers. There are four general reasons.

First, where it is very hot, farmers sometimes prefer to irrigate at night. A farmer interviewed at El Fayyum in Egypt said that the worst time for a turn was midday because of the heat. In his view, a turn at night was preferable to midday. In this case the main reason for the night preference was personal comfort. In general, the warmer the climate, the more acceptable it is to be up and active at night.

Second, where farmers are part-time, and have work during the day, they may prefer water supplied in the evening or at night when they can be present to apply it. On a very small reservoir system, Sukhomajri near Chandigarh in India, a problem arose when the supervisor was switched from payment by the hour to payment by the day: before when paid by the hour he had been willing to supply water at night, but when paid by the day he had no financial incentive and was reluctant to do so. Most of the farmers did outside work during the day, and were inconvenienced as a result (Groenveldt c. 1983: 10).

Third, tail-end farmers, as on the Lower Bhavani Project in Tamil Nadu sometimes say they prefer to irrigate at night because the water supply is more adequate and reliable, not being extracted to the same degree by upstream farmers. However, this preference is dictated by circumstances, and no doubt they would prefer a similarly adequate and reliable supply by day.

Fourth, irrigation at night can be valued socially. Max Lowdermilk, one of the few who have done sustained research at night, reports (1985) that often several young men get together and drink, tell jokes, do pranks, and listen to transistors. People smoke and make tea.

> A lot goes on at night that is social even with their women or someone else's in the field. Sometimes husband and wife irrigate together in order to have some privacy from the crowded joint family.

Douglas Merrey also observes (1985) that:

> among Pakistani Punjabi farmers, there is a strong 'machismo' value attached to night irrigation. Men boasted to me about their ability to stand in the watercourse for hours on the coldest January night . . . irrigating. When, early in my fieldwork, I accepted an invitation to accompany farmers whose turn began around midnight, there was great commentary for months thereafter about my irrigating at night . . .

Farmers' minusses

It is, however, much more common for farmers to dislike irrigating at night. The reasons are:

- *Loss of sleep.* This includes tiredness and the inconvenience and perhaps financial and social costs of needing to sleep during the day, besides the disruption of normal habits of sleep. In Sri Lanka, tailenders (who have to irrigate at night) are known as 'red eyes'.
- *Discomfort.* Nights can be cold, especially in Winter and Spring (rabi) sea-

sons, and it is harder at night to keep clean and move about in sticky soils and mud.

- *Danger and fear.* Snakes and scorpions are feared, though cases of snake or scorpion bite at night are rare. Ghosts and spirits may also be feared. If water is poached at night, physical danger is often involved. There may be immediate violence, including murder, or other subsequent severe sanctions. In a village on Mahi-Kadana dominated by a high-caste Patel family, a Scheduled Caste farmer stole water from a Patel during a night irrigation. About 50 Patel farmers with sticks threatened to beat him to death if there was ever another offence against a Patel (WMSP 1983: 46). Law and order conditions can also deter irrigation at night: dacoits can be a risk, and farmers near Coimbatore in South India also fear robbery and harm to their wives and families left in their houses. At night physical harm is also more likely through accidents such as getting cut on sugarcane fronds, getting pricked or scratched by thorns, and slipping, falling, and stubbing toes.
- *Costs.* It usually costs farmers more to irrigate at night. Especially on sloping lands, with difficult soils, and with standing crops, irrigation at night requires additional labour. Breaches in supply channels are harder to see and harder to mend, and sometimes an extra person is needed to hold a light. Family labour is less likely to be used at night especially women, old people, and the very young, so that a family which is self-sufficient for labour during the day can need sharing arrangements or to hire in labour in order to irrigate at night. Wages are higher at night, often between half as much and double that for work during the day. Firewood and beverages may have to be provided. Lighting is another cost. Farmers in Nepal asked about the costs of cultivating paddy first mentioned torch batteries (Martin & Yoder 1982).
- *Inefficient applications.* In darkness it is harder to judge the correct applications of water, to see whether all of a plot has been irrigated, or to notice and mend a breach. Inefficiency and losses are especially marked if irrigation is unsupervised or labour inadequate.

The intensity of the dislike for irrigation at night is illustrated by value farmers place on not having to do it. In a case of group action to secure a better water supply on a large project in South India, farmers 'considered the experiment to have been remarkably successful. A common refrain, from small and big farmers alike, was that for the first time in years they were able to spend their nights at home, and not stuck out in the fields trying to get enough water to their fields during the hours when upstream irrigators were safely in their beds.' (Wade 1982: A105).

Factors affecting ease and difficulty

The ease or difficulty of irrigating at night also depend on field conditions, the water supply, and the crop:

Field conditions. The smaller and more sloping the fields, the more difficult night irrigation becomes. Some large flat fields can be left to flood all night. An extreme case is the Gezira Scheme in Sudan, where exceptionally impervious soils and flat fields make them like table tops over which water can be left to spread unsupervised. Similarly in some large-scale Californian irrigation, fields with runs of a quarter, half or even one mile can be left at night, and changes made during the day. At the other extreme, sloping fields with small basins are very difficult. It is common for farmers in India to irrigate such fields during the day, and divert night flows to their larger and flatter fields. Night irrigation can be especially difficult in new areas where fields have not been fully developed and flattened. On the other hand, night flows are sometimes used to flood precisely those fields which are not level in order to cover the high spots.

The ease, difficulty and efficiency of irrigation at night also depend on soils. It is easier on soils which are not sticky, and which make stable bunds. Henry Hart, in an article which opens up several questions about irrigation at night, observed (1978: A-129) of the Ghataprabha Project in South India

> Whether black cotton soil can be safely irrigated for particular crops by the light of a hurricane lantern is a question which, significantly, has not yet been subjected to research by all those official agencies which insist upon 24 hours warabandi. (Punjab soil is, of course, quite different)

Water supply. For farmers who are deprived of water during the day, usually tailenders, water at night may be more reliable, as on Lower Bhavani in Tamil Nadu where headreach farmers leave night flows to go on tailenders. More generally, flows at night are less reliable, as reported in Western Uttar Pradesh where farmers upstream make illegal extractions at night. Flows at night can be either much more or much less than during the day. On the Sihol Minor on Mahi-Kadana, a discharge of 55 cusecs during the day was found to drop only 10 to 15 cusecs at night (WMSP 1983: 96).

Universally, handling stream flows is harder at night. On difficult terrain a manageable night flow for a farmer may be perhaps half the size of a daytime one. The implications for irrigation planning and design have often been overlooked: indeed, the proposal for sub-chaks, with full supply rotated between them including night warabandi, implies conditions which farmers would find hard to handle. In one farmer's view, a smaller flow could be left running into a field at night, but a larger flow was best left to run waste rather than risk the damage it could cause. Smaller chaks rotated with larger streamflows could thus lead to waste rather than saving of water.

Crop types and conditions. The ease and efficiency of water application at night depend on the type of crop and its stage of growth. The easiest crops are paddy and trees: paddy can be flooded, and if the water flows out at the lower end of fields, nothing other than costless water may be lost to the farmer; trees are similarly tolerant. Most tall trees are easy to walk between with good visibility between the trunks if a torch is used. Crops which are low, wide apart or in early stages of growth are easier to irrigate than those which are high, dense, or in later stages of growth. Thus, for example, a farmer with an advanced wheat crop and a gram crop and who gets water only at night may prefer to irrigate the wheat for economic reasons but the gram for convenience. Tall cotton is said to be very difficult. Opinions differ about sugarcane: it is awkward to enter and move about in at night, but on the other hand it tolerates flooding. The probability of having to rely on water received at night is one factor influencing a farmer's choice of crop.

Above the outlet: Control at night

Above outlets and at the lower levels of main systems, it seems that two management regimes alternate diurnally: the formal, visible operation of the day, or at least of some eight or more hours of the day; and the informal, invisible operation of the night.

It is commonplace that night is the time for illicit appropriation of water: for breaching bunds, removing checks, blocking streams, opening pipes, and pumping out of channels, all to secure water for an individual or a group. It is the time when farmers organise themselves to raid upstream of their outlets and fields, and also when they guard their supplies against raids from others lower down (Chambers 1984b). Svendsen observes (1981: 19) that for the Philippines

> When water is tight, farmers all along the sublateral will normally know the status of upstream checks and the length of time they have been in place. When a raid is made, it is often with the foreknowledge of minimal resistance to the action . . . (and) . . . it will usually be undertaken at night to minimize the chance of encountering the farmers who placed the check. If the check is being guarded at night, the assumption is that the need for water there is serious and the check will usually be left alone. Unguarded checks, on the other hand, are assumed to be diverting unneeded water and will be opened.

Irrigation staff, unless specially organised to handle an emergency, abdicate control for a period which may be longer than the night, namely all or most of the time which lies outside their normal working hours. For the Philippines, a general observation has been made that 'in many systems, effective control of structures that are nominally under the authority of the irrigation agency passes to the farmers at night' (Barker et al 1984: 63). Another source states that 'Farmers often take control with their own wrenches as the Ditchtender or the WMT (Water Management Technician) leaves at 5.00 p.m.' (Early et al 1980). Where automatic clock recorders were installed, they recorded no flows in a lateral during the night because farmers had diverted the flow elsewhere until about 4.00 to 5.00 a.m. when they returned it, before officials reported for duty (Tapay 1985). The same switch of control to farmers at night is found in India. On Mahi-Kadana in Gujarat farmers operate the minor gates at night (Lowdermilk 1985). On Perambikulam Aliyar Project in Tamil Nadu, low-level staff are more actively involved in the different management regime of night. Farmers induce laskars (the lowest paid employees of the Irrigation Department) to take the keys to structures off their hooks in the Junior Engineers' offices at night, open the gates for them, and closes them again before dawn and return the keys. The Junior Engineers wink at the practice, and both they and the laskars receive paddy in payment.

It is not surprising that irrigation staff should wish to hand over control at night, or even for the longer period which lies outside their normal working or office hours. It can relieve them of work, reward them materially, and reduce the need to allocate water and arbitrate, especially if those who cannot get water during the day can get it at night. Such devolution of responsibility may not, however, always work. A Technical Assistant working near the tailend of the Kaudulla Project in Sri Lanka tried handing outlet keys to Vel Vidanes (farmers' irrigation leaders) but one abused the trust and caused trouble by opening at night and shutting at dawn so that the Technical Assistant had to withdraw the keys and take back more responsibility himself. One cannot generalise with confidence from such scattered evidence and hearsay. But the sources known which touch on this subject, and the inherent plausibility of the behaviour described, indicate that informal night operation under greater control by farmers is widespread, if not the norm. For often it can enable disadvantaged or aggressive farmers to get more of what they want, and irrigation staff, in a convenient and profitable manner, to trade hassle for income.

Types of conditions

As a simple step in analysis, four types of situation can be distinguished according to the scarcity or abundance of water and whether regulation of access is tight or loose. The four types scarce-tight, abundant-tight, abundant-loose, and scarce-loose, are associated with different propensities for activities at night (see Table 2).

Table 2. System conditions and day and night activity

	Water Supply in relation to demand	Regulation of turns	Where found	Periods where farmers actively apply water to fields	Conflict between farmers & groups
A	Scarce	Tight (in practice)	NW Indian warabandi. Sometimes RWS (Rotational Water Supply).	Day and night equally.	Low
B	Abundant	Tight (in theory)	Indian systems especially in headreaches where warabandi or RWS have been 'introduced'.	Day only (no need to apply at night).	Low
C	Abundant	Loose	Headreaches of many large systems. Periods of seasonal abundance.	Day only (no need to apply at night).	Low
D	Scarce	Loose	Tailends of many large systems. Periods of seasonal scarcity.	Day water taken by headreaches and powerful. Much activity at night.	High

To summarise:

a) In NW Indian warabandi (Malhotra 1982), water is scarce but strictly rationed by time. Water is taken at night according to schedule and conflict is low. There is little waste water at night. Farmers know when to be up at night to take their shares. Irrigation staff have little scope for benefitting from concessions.
b) Where water is abundant and tight rotations and rationing are introduced, they will operate during the day, if at all. All farmers will try to get water during the day and will probably succeed. Any who fail during

the day will get water at night. Most night water is wasted. Irrigation staff have some limited scope for benefits from permitting day irrigation out of turn.

c) Where water is abundant and regulation loose, water will be taken during the day only. Any farmers who fail to get water during the day will get it at night. Most night water is wasted. Irrigation staff have little scope for benefitting from concessions.
d) Where water is scarce and regulation loose, day water is taken by head-enders and the powerful, and the night is lively. These conditions are the source of most anecdotes, especially those about poaching, raiding, guarding and violence. Many farmers lose sleep.

Several obvious points can be made. When water is abundant, farmers tend to avoid night irrigation. Different parts of the same system can have different conditions. A system can have different conditions in different seasons, or at different times in the same season. There may thus, for any system or part of it, be a series of transitions between one set of conditions and another. Many degrees and gradations can be expected, and many subtle complications which are not captured in crude categories. One benefit to farmers of moving from a looser to a tighter system can be a reduction of activities at night. Before farmers' organisations were established on Gal Oya in Sri lanka, one farmer said 'There were a lot of conflicts among farmers over water. Sometimes farmers would stay awake till morning guarding their poles (offtakes to field)' (Abeyratne et al 1984: 18). With the more ordered allocations which followed organisation, this inconvenience, it would seem, was eliminated.

Irrigation performance at night

Canal irrigation at night can be evaluated against the three criteria of efficiency, equity, and evironmental stability.

1. Efficiency

Reduced evaporation at night, and negligible evapotranspiration (ET) (Montieth 1956; Tomar & Toole 1980), are factors tending to increase efficiency of water travelling or applied at night. Pai & Hukken (1979: 100) consider that

> Where there is scarcity of water and farmers are resourceful to arrange for labour and lighting for night irrigation, night irrigation may be even more efficient than day irrigation because of lower evaporation losses in the night.

However, seepage losses are unlikely to differ significantly between day and night, and the most important differences are generally considered to lie in water control and wastage. These several factors can be examined at three levels: on main systems; between outlets and fields; and in field application.

Considering main systems and escapes, water flowing at night near outlets and escapes can be expected to have lower efficiency than similar water during the day. This is because of the frequency on some systems of water flowing direct into escapes and drains at night, or overtopping, where a large illicit night flow occurs.

Opinions and evidence vary concerning losses in transmission from outlets to fields. The only empirical evidence available (Lowdermilk 1985) comes from day and night comparisons in Pakistan, and is presented in Table 3.

Table 3. Day and night efficiencies compared

	No of farms	I Field delivery efficiencies mean %	II Field application efficiencies mean%		III Total farm irrigation efficiencies mean %
Day summer (March-Oct.)	241	53	×79	=	42
Day winter (Nov.-Feb.)	19	52	×79	=	41
Night summer (March-Oct.)	16	63	×79	=	50
Night winter (Nov.-Feb.)	36	53	×79	=	42

I Field delivery efficiency is the percentage of total water released to a farmer at the public outlet which reached his farm turnout; II Field application efficiency is the percentage of water applied to a field basin which is stored in the root zone; III Total farm irrigation efficiency is the percentage of water released to a farmer at the public outlet which is stored in the root zone.
I × II = III
All figures are weighted for farm size.

This indicates almost identical field delivery efficiencies for summer days, summer nights and winter nights, but higher efficiencies, though with a small sample, on summer nights. This is difficult to interpret. Lower evaporation losses in transit would be one explanatory factor, together with greater ease of avoiding losses from leaks and breaks during the shorter warmer nights of summer than during the longer colder nights of winter. At the same time, the sample was small and difficulties of measurement, especially at night, are severe. A contrary view is widely held that transmission at night from outlet to field is generally less efficient than in daytime. In this view savings from evaporation are usually more than offset by wastage: water below outlets often flows straight through into drains, or floods fields, and breaks in bunds and field channels occur and are difficult to detect.

Similar conflicting evidence and views apply with field-level applications. ET gains do indeed seem likely at first sight, but themselves evaporate somewhat on closer examination. ET savings through night irrigation are sensitive to local soil, soil moisture and micro-climatic conditions. Gains can be expected where water infiltrates quickly during the night. However, in most conditions, ET over the life of a crop will vary little according to whether water is first supplied by night or by day, since whenever it is supplied, it will be subject to losses and use for a number of subsequent days and nights which will tend to even out the effects. Thus total ET is probably only significantly lower with night irrigation where soils are porous and water infiltrates quickly, or in hot dry windy conditions, or where both apply together. More generally, the many problems of field-level application – visibility, movement in the crop, water control, ensuring that irrigation is complete, avoiding overwatering – are accentuated at night. The consensus of most informants is that field-level efficiency is less at night, with underwatering leading to yield losses and overwatering to waste.

In sum, whether water is more efficiently distributed and applied at night depends on local conditions: factors tending towards higher efficiency are reduced evaporation in transmission, and conditions of water abundance, anarchy in management, poor control, difficulty of water application at the field level, and farmers' low commitment and inadequate equipment. Irrigation at night in India may be at its most efficient in the controlled warabandi conditions of the Northwest. In general, however, expert opinions canvassed in South Asia agree with R.K. Sivanappan's (1983) judgement that evaporation and ET savings from applying irrigation at night are negligible compared with physical losses in transmission and through inefficient application.

2. Equity

Some equity effects are clear from the discussion. Farmers who have to irrigate at night feel themselves worse off than those who can irrigate during the day. Anarchy favours the strong and ruthless, and penalises the weak and timid. It is common for headreach or otherwise powerful irrigators to have gained preemptive rights to irrigation flows during the day. Commercial groups and organised groups of farmers exercise pressure to gain such rights. Thus, a group organised on a South Indian canal counted as one of the benefits from its efforts to capture water that night irrigation was eliminated (Wade 1982). On the Gal Oya Right Bank in Sri Lanka the sugar plantations claimed and exercised the right to all the flows during the day, leaving the night flows for farmers' paddy. The Mohini Cooperative Society on the Ukai Kakrapar Project in Gujarat has been reported to have a supply of 10 cusecs during the day and only 1 cusec at night.

In contrast, some negotiated and formal rotational systems provide for sharing the inconvenience and losses of night irrigation. In Northwest India, warabandi turns rotate each year between day and night: a farmer who has day in one year has night in the next. in South Asia, the prominence of the 7-day warabandi system lends an aura of inevitability to the idea that a turn should be at the same time on the same day of the week, and this fits with an equitable sharing of night time irrigation through switching day times for night times every year. But other methods also work. Arthur Maas describing irrigation in Utah points out that:

> the rotation period usually includes a fraction of a day so that a farmer's successive turns will occur at different times of day and no farmer will have to irrigate at night on every rotation. By the same token, many companies have avoided a rotation interval of seven days or multiples of seven so that farmers' turns do not fall on the same day of the week throughout the season. (Maas & Anderson 1978: 344)

The Mormons arranged their rotation schedules so that no farmer would have to irrigate by night or on Sunday on every rotation and so that the benefits and costs of diurnal variations in stream runoff would be shared broadly (*ibid*: 358).

Other equity effects are less obvious. Small farmers lose from employing labour and paying more, but labourers gain higher wages and more work. Large farmers with scattered plots may, as reported in Indonesia, lease out some of their plots when they have to be irrigated at night because they wish to avoid the difficulties and inconvenience of managing them. But if larger farmers do decide to cultivate them, they can be better placed to do so because they can afford to employ labour and avoid disrupting their personal daily routines (Wade 1979: 17).

The reuse of 'waste' water which flows away at night has mixed equity effects. Tailenders on the formal irrigation system often lose, but others 'encroachers' or 'squatters' – who may be rich or poor farmers – may reuse head reach drainage water and come to depend on it. Similarly, where there is a cascade or chain of tanks, wastage through night flows in the upper tanks may be necessary to supply those lower down. Such effects are common in the Dry Zone of Sri Lanka, and defy facile generalisation about the equity, or for that matter, productivity, effects of water 'wasted' at night.

The most important point is that in default of a management and distribution system which ensures equity, night is the time when, at considerable inconvenience, those who are deprived often manage to get water.

3. Environmental stability

Most physical damage by water and by irrigation probably occurs at night. Night is also when detection and remedial action are least likely and when they will take longest. Where a breach is involved, the resulting delay means that the damage will be greater.

Damage takes many forms. Erosion, especially in steep minors, watercourses and field channels, is caused by large flows at night when extractions cease upstream. Uncontrolled flows at night lead to flooding, as often observed in the morning. On the Morna Project in Maharashtra cart tracks were damaged by excessive flows of water at night (Joshi 1983: 1700). Water flowing permissively through minors, watercourses, field channels, fields and drains at night contributes to problems of rising water tables. Waterlogging and associated soil salinity and alkalinity are thus aggravated by water flows at night. Restraining water supplies at night is thus one way of reducing, halting of reversing a trend towards waterlogging.

Practical actions

The evidence and analysis to this point indicate that water flows and irrigation at night present major problems. The question now is how far they also provide opportunities for saving water and making better use of it. There is a distinction here between losses which are unavoidable, and those which are avoidable and therefore waste; and between inefficiencies, inequities and physical damage which cannot be mitigated and those which can. In seeking practical actions to reduce waste and damage and to improve efficiency and equity, there are two main approaches: *reducing* irrigation at night and *improving* irrigation at night.

Reducing irrigation at night

Reducing irrigation at night can be either with or without saving water for subsequent use.

Without water saving

Reducing irrigation at night without saving water can take three obvious forms (but see discussion below):

1. *stopping river diversion flows*: Stopping a river diversion at night can eliminate night irrigation on a small, though not on a large system.
2. *redistributing day water*. If less water is issued to headenders during each day, there may be enough for tailenders also during the day. Alternatively, the introduction of a system of rotations may eliminate the need for irrigation at night, by allowing headenders certain days, and tailenders others. While redistributing day water in these ways sounds feasible, no empirical case has come to light where this has been done.
3. *passing water to drains and escapes*. Night irrigation can also be reduced by passing water to drains and escapes instead of the outlets. Uncontrolled, this can result in erosion, especially at the tails of minors. But this may be a useful measure especially when the aim is to avoid waterlogging from a rising watertable.

With water saving

More important are measures to reduce irrigation at night with water saving. These all involved storage of water, defining 'storage' broadly. Storage can be achieved in five main ways: in main reservoirs, in canals, in intermediate storage reservoirs, on-farm, and in groundwater. While each will be considered separately, some of the most effective measures will be combinations of two or more of these.

1. In main reservoirs. The feasibility of regulating sluice releases to reduce the delivery of water at night is a function of size of irrigation system. In practice, in small systems with commands below about 200 hectares, sluices are usually closed at night, and in India, above 200 hectares they are usually left open. On very large canals, regulation of head sluice openings from reservoirs to reduce deliveries at night is not feasible because of the long distances and travelling times involved, in India quite often over 100 miles, and because of the flattening of water slugs the further they travel so that over long distances fluctuations in releases tend to even out. There is, however, a very important class of reservoir of intermediate size where the potential deserves investigation.

The scope for reducing night deliveries is shown by management innovations reported by N.M. Joshi (1983) for the Morna Project in Maharashtra. This is based on a storage reservoir and pick up weir. The maximum distance from the pickup weir to the tailend of a reach is 28 km. In the late 1970s, flooding and waterlogging were a problem in the head reaches, with ponds forming and cart tracks rendered impassable. Water was relatively abundant and night irrigation was not practised. The tailend of the system was not receiving water during the day when it was required, presumably because of heavy daytime extractions in the head reaches. At the same time, water was increasingly demanded for a third summer crop of groundnuts.

The management response was to see how water issues could be reduced at night and assured during the day. This was approached through a simple calculation. Water was assumed to be needed at the outlets only for 10 hours in the 24, from 0800 to 1800. Velocities at difference flow rates were observed in the canal and averaged to 1.5 km/hr and observed transit losses were put at 50 per cent. A schedule of discharges was then calculated so that the water required would arrive at the different parts of the system during the 10 hours and water arrivals at night would be reduced or eliminated. A rotation schedule was also prepared as a result of which flow days were more than halved. Evidently the results were quite dramatic. The hectare: Mcft ratio was raised from 1.02 (1978-79) to 1.40 (1981-82). Transit losses were reduced. Water was saved. Waterlogging, flooding and resulting insanitary conditions were largely eliminated. While the rotational schedule to reduce flow days complicates evaluation, the significant point is that these calculations could be done, and changes in the setting of the pickup weir appear to have been manageable and effective.

A further example, reporting an experiment, comes from the Beni-Amir Project in Morocco (El Antaki & El Bekri 1984). Night irrigation in the winter was unpopular and wasteful. Winter was also the time when water demand was at its lowest, so that canal capacity was adequate to supply all requirements during the day. Scheduling to avoid night irrigation was successful but there were problems of filling and emptying times, extra work for irrigation staff, and less time for network maintenance. Cultivators assured of a daily supply of water reduced their demand. Reporting on the experiment, El Antaki and El Bekri conclude that they lack a basis for judging whether the procedure could be generalised to the whole project.

Comparing these two examples, it seems that where main system management has been permissive, as earlier on Morna, big gains can be made through simple measures. Where main system management has been tighter, as on Beni-Amir, more accurate calculations, smaller margins of gain, and more problems of system and staff management are entailed in restricting irrigation to the daytime. But these two examples do suggest considerable scope for improving irrigation system performance through scheduling to reduce irrigation at night.

2. In canals. Outside South Asia some projects have been designed for night storage in canals. The most famous is the Gezira Scheme in Sudan where the original design was for continuous flows in distributaries and night storage in minors, which were equipped with spillover weirs for the purpose (Farbrother 1973). Much debate has been generated by this system and despite beliefs to the contrary, there is strong evidence that water continues at night to flow into watercourses and onto fields. Another example is the Bura Project in Kenya, but there the night reservoirs on the canals 'are quite impossible to operate properly' (Horst 1983). On some South Asian systems, such as Mahi-Kadana in Gujarat and Jayakwadi in Maharashtra, canals are also used to some extent for night storage.

A variant of a static view of night storage in which crossregulators would be closed, is diversion of water to travelling. This is applicable to both reservoir and run-of-the river systems. The Morna example is a case of this. Although they were not designed for it, it is also quite widely practised on large systems in North India (Kathpalia 1985). In an ideal simplified model, a main canal might have two distributaries, one at the head, and one at the tail, with an average travelling time of 12 hours between them. A continuous flow at the canal head (either from a reservoir or from run-of-the river) might be sent into the head distributary from 0500 to 1700 for daytime irrigation from, say, 0700 to 1900 (depending on filling time). The offtake of this head distributary would then be closed and the water would travel down the canal during the night, arriving at the offtake for tailend distributary at 0500 for a similar period of irrigation there. All irrigation would then take place during daylight.

More detailed and professional calculations have been made by Campbell (1980) for a notional canal 100 miles in length with a gradient of one foot per mile, supplying distributary canals generally 5 or 6 miles in length. The aim is to supply water for paddy during the monsoon season with continuous flow which run through the night, but with supply during the winter and spring seasons limited to daylight hours for more exacting crops. In this model, modulation of flows and pondage are in the main canal, and distributaries and minors receive inflow only during daylight hours, confirming the theoretical feasibility of a combination of design and management, without intermediate reservoirs, to limit farm-level supplies to daytime on a large system.

Storage in canals has three main disadvantages. The first is cost. One reaction to the example of the Morna project system has been that for the system of rush irrigation to supply water only during the day to be feasible means that the original canals were overdesigned. Night storage in canals requires wider canals and more crossregulators, and steepness of terrain will be reflected in steepness of costs. The second disadvantage is silting, notably where the silt load is heavy and the canal design is for continuous flow which would avoid dropping silt. The third, is diurnal variations in flows delivered to outlets making timed allocations below outlets difficult if not impossible.

3. Intermediate storage. Intermediate storage can be either higher than, or at, the field level.

Outside South Asia, intermediate storage reservoirs are found in several countries. In Indonesia, many older projects were designed and constructed with night storage reservoirs which are, however, now largely disused. The Chinese system of 'melons on the vine' with canals supplying small reservoirs lends itself to the storage of night flows. In Sri Lanka, many canals on major schemes pass through old minor tank basins, but no case is known where these have cross regulators or are used deliberately for storing night flows. On Periyar-Vaigai in Tamil Nadu the new canal system supplies numerous old small tanks and these are sometimes used to retain night flows. The World Bank in India has advocated investigation of night storage on new projects, and calculations of requirements have been made (e.g. Shankare Iyer 1983). Night storage reservoirs had been constructed by 1983 in a water management pilot project near Morva in the Panam Irrigation Project in Gujarat, but the experience of managing them was not reported (*ibid*: 38).

Night storage in intermediate reservoirs is an attractive idea. On paper at least, it can reduce night irrigation, save water and introduce flexibility into management. It may also reduce erosion by capturing storm runoff water. It can also be used to reduce the design canal capacity of the main canal, in the case of the Panam Project by 7½ per cent (Shankara Iyer: 38). The argument has also been put that future design should include reservoirs under the control of villagers and supplied with agreed amounts of water from the main system. This would enable villagers to adopt more water-sparing irrigation techniques, since they should have greater control over their supply.

The scope for night storage reservoirs is limited by problems of topography, cost, and operation. On flat ground, as in the Gangetic basin, small reservoirs would have to be dug down and then the water pumped out. Elsewhere, land may be too undulating. Reservoirs also take up land which cannot then be cultivated, with costs both in compensation to landowners and in subsequent production foregone. In operation, siltation and maintenance may be problems. On the positive side, where feasible small intermediate storages might both reduce waste at night and transfer control to farmer groups.

4. On-farm. Storage of night flows by farmers on their fields is common where physical conditions and crops are suitable. It is most common with paddy. In Sri Lanka water is held as far as possible in the upper paddy fields and then the following days released to the lower ones, if soil conditions allow. Hart (1978: A-129) comments on the supreme price a black cotton soil farmer in a tailend village on the Ghataprabha Project in India was prepared to pay to avoid night irrigation. The farmer

> had dedicated four per cent of his tiny two-acre plot to construct his own balancing reservoir. He fills it at night when alone the field channel carries

water; then irrigates by day. After seven years of trying, he had found it impossible to get water to the end of his furrows at night without breaches of the furrows that washed out his seed (e.g. jowar).

Similar practices are found with groundwater lift irrigation when electricity comes at night: a wealthy farmer in Sikar District in Rajasthan constructed a cement reservoir into which he pumped at night, and in 1983 smaller farmers in Veerasambanur village, North Arcot District, Tamil Nadu had begun to store night water in paddy fields adjacent to their pumps, releasing the water in a controlled manner to lower fields in the morning.

5. *As groundwater*. Rising groundwater is often treated as a problem rather than opportunity, but if there is conjunctive use it can be a major asset, especially for those who have difficulties with main system supplies. Night irrigation flows which percolate and are stored underground may later be used during the day, or in the more controlled night conditions which can be achieved with pumping. Some of the water regarded as 'wasted' at night may in fact go into the ground and be subsequently reused. Deliberate recharge of groundwater through percolation tanks for night storage deserves consideration wherever conditions are favourable.

Waste and saving

In assessing potential from reducing irrigation at night, care is needed in assessing whether water is truly saved and there are net benefits. The conditions in which water is saved for use later are given in Table 4. Whether water is saved depends on current uses of the night flows both on the irrigation system and lower down, and on reservoir capacities and spilling probabilities. Water 'saved' in a reservoir is not additional if its equivalent spills later in the season and the spill water is not used lower down. On the other hand, saving it in a reservoir early in a season can have other benefits such as assuring farmers that they will receive a supply later, encouraging them to cultivate and invest in inputs. Most important is an appraisal of existing uses of 'waste' water, especially by headend 'encroachers' who stand to be hidden losers from water 'savings'. Questions of waste and saving are not simple and deserve careful analysis case by case.

Improving irrigation at night

Irrigation at night can be improved in five main ways.

Table 4. Conditions in which night flows are saved for use

Intervention	Night flows are saved for use if
• spilling to drains and escapes	water in drains is used lower down when otherwise it would have been wasted
• redistributing day water	night flows are saved
• regulating main reservoir sluice releases	a. reservoir does not spill later an amount equivalent to that saved and stored b. equivalent amount does not spill but is used lower down
• regulating run-of-the-river diversion flows	flow not diverted is used lower down
• storage of water in canals including travelling	
• intermediate reservoir storage	water stored would otherwise have been wasted
• storage on-farm	
• storage as groundwater	

1. Making flows predictable and manageable. Anarchy at night is labour-intensive and tiresome as farmers compete to capture water and guard their supply as well as to apply it. It is also likely to lead to inefficient application of water. Variable flows also make agreements about timed allocations inequitable and difficult to sustain. Larger flows which are manageable during the day can be unmanageable at night.

In contrast, a predictable, constant and manageable streamflow is labour-sparing and hassle-free. Where conditions for warabandi exist, including scarcity of water, the advantages are obvious of the strict NW Indian system. Farmers know when their times will come, and therefore when they need to be up during the night, and do not need to recruit labour to capture and guard their supplies.

The acceptability of such a system to farmers is confirmed by Niranjan Pant's (1985) account of his visits in Ganganagar District in Rajasthan.

> I was very much impressed the way warabandi was accepted by all farmers – big or small and rich or poor. I found farmers ready and alert for their turns. Those who had turns at night irrigated all night without question, with the help of lanterns and torches. Warabandi in that area appeared to me a socially accepted fact, which nobody tried to question. The measuring devices and control structures there were no better than what we find in other parts of the country. The courses and field channels were generally unlined and outlet points kachcha [not pucca] like in other parts of India. But adherence to warabandi made all the difference. Therefore, creation of scarcity through warabandi and getting it social recognition seems to be the answer for night irrigation . . .

Where night irrigation is anticipated, design and management should work backwards from farmers' requirements at the field level, including the intended system of water allocation between farmers. The implications include design for a suitable and convenient streamflow bearing in mind that on irregular terrain farmers cannot handle as large flows at night as during the day, and that ease or difficulty of handling also depends on the crop. Sometimes it may be necessary to subdivide and share streamflows at night.

2. *Improving convenience and efficiency*. Night irrigation is often physically inconvenient and inefficient. These defects can be mitigated in several ways:

- Good lighting, for example using mantle-type pressure lamps, or good flashlights.
- Organisation of cultivator groups for night irrigation where there are mutual benefits, whether in protection from water raiders, dacoits or ghosts, or in patrolling and monitoring common water courses and field channels, or in other shared labour.
- Installing and maintaining structures, channels, fields and water application methods with low requirements for observation, and adjustment.
- Field shaping for ease of water application. Precise land levelling helps. Water in paddy fields is most easily monitored if they are level. Border strip irrigation requires more attention but is easier if fields have been well planed.
- Providing for ease of movement. One of the biggest benefits from farmers' point of view of the watercourse reconstruction programme in Pakistan was that the paths along the new bunds, which were less narrow and free of trees, bushes and weeds, made night irrigation easier (Merrey 1985).

3. *Choosing easy crops*. Night irrigation can be improved by choosing crops which are tolerant of flooding and of variable water conditions, besides being easy to irrigate. Paddy, trees, and young sugarcane are probably among the easiest.

4. *Zoning for night flows*. Where a farm or an outlet receives water throughout the 24 hours, the day flows can be used (as they usually are) for the more difficult irrigation and crops, and the night flows for those which are easier. In South India (for example on the Sriramasagar Project) it is common for an outlet's day flows to be used in a more controlled manner for upland crops in red soils near the outlet, and the night flows to go in a less controlled manner into low-lying paddy on black soils further from the outlet. Another potential solution tried on Tungabhadra is to have separate outlets for light and heavy soils,

and to irrigate the light ones during the day and the heavy ones at night, but the Indian Irrigation Commission of 1972 was told this approach had failed (GOI 1972: 154).

Zoning for night flows also makes sense as between large and small farms, and large and small management units. In their *Manual on Irrigation Water Management*, Pai and Hukkeri suggest that larger holdings should have irrigation starting in the evening and terminating during the day: during the day they can then apply the water to those parts which were not adequately irrigated during the night. Small farmers, on the other hand, should irrigate during the day because of the difficulty of uniform irrigation on small fields during the night. Wade (forthcoming) has observed something like this in practice with sectors of roughly 60 acres in South India, where paddy bunds are placed so that during the night water will spread itself evenly over the whole sector. In the morning the village common irrigators inspect the area and make up shortages before sealing it off and switching to the daytime rotation.

As these examples indicate, zoning for night flows can be according to soil, topography, crop, and size of management unit, or combinations of these.

5. Phasing for short nights, warmth and visibility. The convenience and efficiency of irrigation at night vary with length of night, climatic conditions, and visibility. Regarding length of night, it is not known whether irrigators control night flows better when nights are short; but short nights mean a higher proportion of total flows applied during the day. This consideration is insignificant near the equator, but increasingly important as one moves into higher latitudes. Regarding climatic conditions, irrigating at night is less unpleasant and more efficient when nights are less cold: irrigators are more inclined to stay out and gains should be greater from avoiding the high daytime evaporation losses of the associated hot weather. Regarding visibility, irrigation at night should be cheaper and more efficient when skies are clear and when there is a moon: cheaper because of less need for extra labour or for batteries or kerosene for lighting; and more efficient because of greater ease of water control and application, including seeing breaks in bunds and checking poaching by others; and because of greater scope for irrigating difficult crops.

The implications are that where choices exist there should be advantages, other things being equal, in phasing irrigation at night for times of the year when nights are shorter and warmer, for seasons when nights are clearer, and for stages of the lunar cycle and hours of the night when the moon gives most light. While phasing by the moon may be a refinement difficult to incorporate in canal irrigation, the other factors combine to give night irrigation in clear warm dry weather of the early summer months an advantage over night irrigation in winter and early spring.

Conclusions

The clearest conclusion is that more needs to be known. Much of the analysis in this paper is based on information and opinion from managers, researchers and consultants who have generously shared their experience, and on passing references in written sources dealing with other subjects. More systematic knowledge is required. But even the need for this is not perceived. When the ICID Committee on Water Management listed research priorities, only one member put down irrigation at night. It is not an appealing category. It does not fit in conventional and convenient normal professionalism, but it merits much more investigation and analysis.

A preliminary list of research priorities might include:

a) Measurement. Research to develop and test cost-effective 24-hour measuring devices, coupled with methods of communication which would show managers what was happening to water at night. In the Philippines a measuring device which took automatic readings every 10 minutes was installed. On its first night it showed that at 2045 hours the level in a channel went up one foot, and then dropped back again to its former level at about 0340. The device was said to have paid for itself in one night.

b) Evaporation and evapotranspiration losses. Measurement of losses in different climatic, soil and soilwater status, microclimatic and crop-type conditions.

c) Waste and saving. Assessments of the extent of wastage of water at night, bearing in mind the difference between waste and unavoidable loss, and the benefits of reuse lower down.

d) Main system management. Description and evaluation of costs and benefits of main system management interventions on existing systems to reduce or improve night irrigation, including sluice and diversion regulation, canal regulation, and intermediate storage.

e) Design options, costs and benefits. Analysis of design options and their costs and benefits relating to reducing and improving irrigation at night, including storage (and travelling) in canals, storage in intermediate reservoirs and on-farm, and zoning for night flows by topography, soil type, crops, and farming systems.

f) Diagnosis. A diagnostic algorithm for steps and methods for analysing what happens to irrigation water at night on existing canal irrigation systems, and prescribing how to reduce or improve night irrigation. An early priority is a quick method for picking out projects where quick gains are feasible.

Research at night is hard to do well. The most sustained research conducted at night so far may be that of the Colorado State University Project in Pakistan in the 1970s. For research at night, senior investigators may not be able to rely on delegation and may have to do it themselves. Those who carry it out will often break new ground, though with some minor discomfort and difficulty. Given the importance and ignorance of what happens to canal irrigation water at night, the payoffs from good research and analysis should be high.

Canal irrigation at night is a subject of increasing importance as management tightens up and water becomes scarcer. To what extent irrigation at night can and should be avoided, and to what extent it can be improved depends on local conditions. The repertoire of actions is so large and varied, and local conditions so diverse, that blanket recommendations cannot be applied. More practical will be to consider each system, and each part of each system, in its own right, seeing if from the point of view of farmers, and to work on a sequence of change to improve performance. To understand the options for such sequences of change, much more needs to be known about what happens to water at night.

There is no need, though, for action to wait for research. Where management has been lax, big gains can come easily, on a do-it-yourself basis, as they did for N.M. Joshi on the Morna Project. That the potential is large seems beyond dispute. The practical recommendation is that without delay system managers, together with farmers (who are both clients and experts), should analyse their systems and intervene to reduce or improve irrigation at night. This paper will have succeeded only if it encourages system managers, designers and researchers to investigate, to act, and to publish and circulate their findings. Canal irrigation at night is too important to remain a blind spot any longer.

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