# Protecting irrigation investment: the drainage factor

There is no sign of irrigation falling from favour with farmers, governments, or aid donors. it remains the plincipal means by which climatic constraints are overcome to increase food supplies, and it is assuming an increasingly important role in the Third World, where. according to World Bank estimates, there are now 160 million hectares under irrigation. While this is only 20 per cent of all harvested land, it receives 60 per cent of applied fertilizer and accounts f0: 40 per cent of all crop output. The cumulative investment is $15 billion and it is still growing at two per cent per year. It is the favourite ’ sector for aid donors, receiving one-fifth of all assistance allocated for food and agriculture.

But irrigation investment also has had loud critics who emphasize such matteis as the huge costs ($2 000 10 000/ha) which are often underestimated, the delays in construction, the yields below forecast. the poor financial performance, and the environmental damage to human health and to the soils. l

This article concentrates upon the growing problem of soil waterlogging and salinity, which threaten to destroy

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the food-producing capacity of the irrigated lands of the Nile, Euphrates, Indus, Ganges. and many other arid-zone river basins. Drainage is also required in the humid tropics where rice is the dominant crop in order to bring about sound water control necessary to obtain high yields. The aid lobby, such as those responsible for Brandt Report, specifically men. tion large-scale irrigation basins as a major area for agn’cultural investment and production expansion. But in most irrigation areas drainage, reclamation, and water control projects are needed now. FAO estimates that 50 per cent of the world’s irrigated land is salinized to the extent of affecting productivity. In Iran, Iraq, Egypt, and Pakistan more than 70 per cent of the farmland is so affected. India has 5-7 million hectares affeeted. Whnevet evapontion exceeds rainfall, salinity is a risk. Where high sodium content leads to alkaline soils, with a consequent toxicity, loss of structure and permeability, then reclamation is technically extremely difficult and expensive. Where alkaline conditions occur, there is virtually no economic solution, and this problem is reputed to be increasing in parts of northern India, Pakistan, southern Russia. Afghanistan, and Iran. 3

Conscious Meet. Drainage has not - been undertaken because the effect of waterlogging and salinity is generally slow to become apparent; remedial measures are expensive; in already irrigated areas, the loss of land and disruption to existing farm structure, roads, and canals wuses local op--position; maintenance of drains is costly and requixes careful management. Governments, already hard-pressed for financing, will have to regard drainage ass a public sector investment; there is very little scope for levying charges against farmer beneficiaries. - _

Drainage has been consciously neglected by iniption advocates. In mid India and Pakistan, developers have long recognized eventual drainage needs but they deferred expenditure on grounds of political expediency

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and finance. As has been noted, unlike irrigation, drainage is unpopular with farmers since it requires substantial amounts of land, approaching 15 per cent in the case of open drains. and gives in return a benefit that is not obvious, is delayed, and is indirect at a relatively large cost. SH. Johnson brilliantly reviews the irrigation experience of Pakistan and argues that now massive investment in drainage is inevitable if the Indus Plains are to sustain, at targeted living standards, the 130 million who will inhabit the region in the year 2000. 3 He concludes that no alternative is available and, most depressingly of all, that most of the costs must be borne by the users of irrigation. This is daunting because the Pakistan Government has not managed to make even the rich, among what are mostly low. income farmers, pay more than 50 per cent of the recurrent costs of irrigation supplies. We can anticipate that drainage levies will be politically and administratively more problematical, even if the present trend to pay farmers higher prices by reducing indirect taxation of agriculture continues.

Waterlogging, and most forms of salinity, are the direct consequences of poor water management and inadequate drainage or selection of wrong sites in the first place. Various symptoms of damage from defective drainage are still all too often regarded as an unexpected indirect cost of irrigation development. For example, in Egypt, with its long experience of irrigation, there was disappointment verging on surprise at the extent and form of the deleterious effectsoflthe large additions of irrigation water from the Aswan dam, first on the groundwater regime then later on crop yields. The damage has forced the Government to adopt a nationwide drainage programme that has absorbed the major part of the Ministry of lrrigationis capital budget in recent years.

The best technical means of drainage and the optimum operating system are not well tested. There is a need to assist poor countries with finance, technical assistance, and pilot projects.

potranspiration of plants and any lateral export by underground seepage or removal by drainage.

Reducing famine risk. On the large alluvium river basins, before modern barrage controlled irrigation, there was very little problem from waterlogging as the watertable was generally below four metres and annual inflows and outflows were in balance. Even

Once this phase is over there will be

a major role for aid donors with large resources, a long-term perspective, and an environmental consciouness. The economics of drainage shares some of the problems of conservation. soil erosion, and tree planting. Primarily because of delayed benefits the rates of return are likely to appear low. but the instinct is to proceed in spite of this. On long-term irreversible matters, the economic calculus sometimes appears fragile and deficient.
Drainage is going to be required whenever the groundwater equilibrium is disturbed so that the watertable rises to the plant root zone. This will happen when the sum of incoming vertical seepage from precipitation, rivers, canals, watercourses, and fields plus lateral seepage exceeds the sum of evaporation from the capillary fringe of the groundwater and eva-
Salinity is a risk
wherever evaporation exceeds
rainfall
the huge nineteenth- and early twentieth-century barrage canal commands of the Indian subcontinent did not lead to a general rapid rise in underground watertable levels because the design aimed to spread water thinly over a large area. Certainly in some areas there were local problems when, for example, badly aligned canals cut across natural drainage lines increasing the risk and duration of period flooding. 4 For the most part any rise in groundwater levels was slow because the main objective was to protect as large an area as possible from drought to minimize famine risk and to provide the financial benefits of irrigation to as many landowners as possible, which was in turn expected to benefit the government exchequer. Typically

these early irrigation projects lead to cropping intensities less than half that theoretically achievable.

The effect of protective irrigation was primarily to encourage farmers to under-irrigate in trying to cover as large a part of their land as possible. This was rational for them because water was the scarce factor of production. compared withtland and labour, and the highest average return to water came from light irrigations. With simple. traditional agricultural technology and poor infrastructure, the irrigation water response function for a given season is low and very flat; hence the optimum water application is much less than the potential evapotranspiration which is usually advocated by extension agents. Rational farmers, maximizing the return per unit of scarce water by increasing the area cultivated, helped prevent watertable buildup as seepage losses from field were negligible. Unfortunately under this irrigation regime the small quantities of salt present in irrigation water ( for example. 300-400 parts per million total dissolved solids in Indus water) gradually build up in the profile, and soil leaching is eventually necessary to prevent saline soils and salt damage to crop growth.

Researchers who focus at the watercourse or farm level have found under extensive and intensive systems losses ranging from 25-30 per cent to 40 per cent.5 Others report team findings that indicated most losses occur through the banks and at junctions. t ,. They recommended realignment and consolidation of the banks and concrete structure at junctions. saving up to half the water while achieving more than double the crop production. 6

Leaching of salts by heavy irrigation. plus seepage from rivers. canals. and watercourses, caused a normally-slow rise in watertable in many irrigation projects. Poor field application efficiency and unlevel fields add to the problem. For example, in Khairpur. Pakistan, the watertable rose by 10 cm per year between the early 19305, when Sukkur Barrage was opened, and 1965. By this time the position of farmers was serious because the average watertable depth was now less than two metres. This led to evaporation-from the watertable resulting in a rapid increase in surface soil salinity. Furthermore, as watertables rise there are serious negative effects upon the rooting patterns of .deep-rooting plants. such as tree crops and cotton, at first. then eventually upon shallow-rooting plants, such as wheat (see Figure l). 7
Unfortunately. farm-level data on

the relationship between crop yield and waterlogging or salinity is not available in sufficient quantity to service the large-scale and diverse public investment programmes. Drain designers and economists are both working with limited and crude information. Furthermore. where field trials exist, the evidence is obscured by other factors affecting yields so a clear relationship to aid detailed design is seldom found. 3

An accelerating problem. Over the last 25 years the rate of salt build-up and insidious rise in watertable in irrigated lands has substantially increased. This has arisen because of a switch from ’iprotective irrigationv to a drive for increased intensity of irrigation. There are technical, engineering, agricultural. and economic reasons for a switch in approach toward intensive irrigation.

Productive projects to supply more water to agriculture came as a result of the ready availability of capital finance and subsequent advances in the engineering field in water storage dam design and earthmoving and other construction technology, an increase in the demand for hydropower and improved ways of creating it, new approaches to groundwater exploitation and appreciation of opportunities for water saving at the field level. All these developments contributed to the creation of attractive projects to supply more water to agriculture. However, these opportunities were seldom lowcost, and it appeared most economic to put additional water into the existing network of the under-used irrigation facilities. In Egypt, India, and Pakistan, the best lands were already irrigated, so intensification began by 1 switching seasonal canals to perennial operation. The next stage was to remodel the existing canals and watercourses to take additional surface water. Subsequently, since the late 196053’groundwater development has been undertaken on a grand scale.

At first this was not efficiently handled by the farmers and the seepage increased. This wastage added to the growing drainage problem.

Whenever there is fallow land laid out for irrigation there will be various pressures upon the engineers. who typically manage schemes, from the cultivators and landowners for additional water. Many water managers have succumbed to those pressures and many canals have been run bankfull, much above design. with increased seepage and much waste when canal-bank breaches occurred.

At the time that engineering developments gave an incentive to irrigation investment there were advances in agronomy characterized as the green revolution technology which added further impetus. New varieties of crops emerged from research institutes. particularly wheat. rice. maize. and sugar cane. that responded to fertilizer, that could more than repay the costs of crop protection and additional attention to soil cultivation techniques. This shifted the optimum irrigation strategy of the farmer from extensive cultivation of a large area to intensive cultivation. In economic terminology, there was a complementary, or more than additive, response to simultaneous application of the package of modem agricultural inputs including irrigation water. This implied an upward shift in the response curve for water, giving higher yields for any level of water supply. In short. it paid to apply more water per hectare and the drainable surplus was again increased.

The effect of these changes in irrigation intensity is illustrated in part of the Lower Indus in Pakistan. Before 1923 when perennial irrigation was introduced the watertables were below four metres; 50 years later 75 per cent of these areas had watertables less than 2.4 m.

There are limits to the process of waterlogging. Water would not rise



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to the surface throughout the irrigation areas. Increased salinization of land would reduce irrigated demand and canal discharges would have to be cut. The high watertables would in tum result in greater rates of evaporation from the subsoil watertable. Reduced inflows and increased evaporation would in time produce an equilibrium and watertable would stabilize at an average of perhaps 0.5-1 m. To farm this successfully requires high standards of farm management and a regular and reliable irrigation supply. Even with good management, it is likely that severe problems would arise if the groundwater is highly saline (more than 3000 ppm) and after storms (a lO-cm storm can raise watertables by a metre) for several days. If the millions of hectares of irrigated land that are at risk, but which promise so much for low-income farmers in the arid zones, are to be safeguarded from disastrous deterioration, there appears to be no alternative but to drain them.

Salt export is generally required.

It is extremely rare for a satisfactory local solution to be found for disposing of salt that is also a satisfactory long-term solution. Each year rivers such as the Nile and the Indus with total dissolved salts of 200-1000 ppm bring in millions of tons of salts. Whereas in the past most salt would be flushed to the sea in floods, now most water is stored and consumed by irrigation. For many months of the year such great rivers as the Nile and Indus discharge no water to the sea. Therefore the irrigated land: have virtually become'Huge evaporating pans and salt stores.9

Alternative technical solutions.

Drainage engineers have to determine the best technical means of obtaining watertable control and the optimum depth to the watertable. We can see from Figure 2 that if we reduce the watertable below 2 m there is no drainage constraint to typical crops. Figure 1 also showed that in Indus alluvium to reduce evaporation from the watertable to onetifth of the maximum level the watertable should be below 2 m.

The economic problem is that the greater the depth that the water is drained the higher the costs. Pumping costs are directly proportional to height lifted and capital costs, especially for open drains, also increase substantially. The main technical alternatives _to irrigated land drainage being consider in Pakistan are horizontal drains-open or tile drains, and vertical drainage with tubewells.

To appraise projects for drainage

investment these options have to be compared with each other and the ildo nothingll alternative. This will result in the abandonment of certain areas where salt will accumulate as it is leached from cultivated areas. Abandoned land becomes a salt sump and in effect provides lldry drainage?

Open drains use land, and once installed the government would face enormous costs for bridges and other structures over disposal channels in addition to land compensation costs and some, if not all of the operation and maintenance costs. Economists argue that land compensation costs are merely transfer payments and therefore donlt affect the economic assessment. Although this is technically correct, we should note that eco nomics is butone test of feasibility, and planners know that raising revenue to pay compensation costs is neither simple nor costless. In addition to presenting funding problems relating to compensation, open drains present management problems in that they are the most disruptive choice of drainage technology to the existing pattern of agriculture and will create the most political problems. General maintenance and weed control problems are inevitable-and drains are often a source of health hazards. Poorly maintained drains are breeding grounds for mosquitos, bilharzia, infected snails, and other harmful vectors of disease. In silty alluvium soils, slumping sides of drains will cause difficulties. In short, open drains, while a technology that is simply executed, presents severe fman; cial problems in construction and management problems in operation.

Tubewell boom. Tile drains have received a big boost in recent years by development of new tile-laying machines and long-length perforated plastic pipes. Relatively static oil prices have made plastic pipe a relatively cheap material compared with brick or earthenware alternatives. Nevertheless tile drains are extremelyex- K pensive-about four times the capital 0 a cost of tubewells with similar running costs unless the topography allows a gravity outfall. In order to obtain a minimum of 1.5 metre depth between collectors, the tiles ’ must be about 2 metres deep and spaced at 60 to 150 metres depending upon the soil permeability (say 0.5m/ day on heavy soils ranging to lm/ day on light soils).

One of the most remarkable features of the last two decades in the Indian subcontinent has been the rapid expansion of groundwater development using public and privately installed tubewells. In Pakistan there are 186 000 private wells installed and

12 500 bigger capacity public wells. According to one World Bank esti. mate, the private wells in 1983 accounted for about 80 per cent of the pumpage and approximately 30 per cent of irrigation water reaching crops.

Where aquifers are suitable tubewell drainage is in principle more efficient than any alternative. Tubewells are potentially relatively cheap, easy, and quick to install, a proven technology, albeit presenting management problems, and they can control the watertable at any depth. In practice in Pakistan public wells have proved difficult to install, maintain, and manage in saline and fresh groundwater areas. Private wells in fresh groundwater areas often have poor designs and suffer from interrupted power and fuel supplies. m Tile drains are more expensive to install

’ (3850-1250/ha) than tubewells ($100-400/ha) and have slightly higher operating costs. Open drains are vastly more expensive and present unacceptable levels of maintenance problems.

Despite engineering confidence that there are effective technological solutions to the admittedly growing salinization problem, not all analysts agree. One recent llecological" critique concluded: ttWe have become trapped on a technological treadmill, which can only result in long-term ecological destruction. In that respect. the experience of the US Southwest is. as we have seen, particularly eloquent. Thus. in their thirst for water, the inhabitants of the Southwest have sunk tubewells and built huge reservoirs. In their fight against salinization. America has spent a fortune on technological measures of a type which less prosperous countn’es can ill-afford. Thus, they have lined irrigation canals, dug horizontal drains and built evaporation basins. Now that those measures have failed to solve the Southwestls water and salinization crisis, the search for new ttechnicall fixes has become increasingly desperate: n’ver basin transfers and the development of genetically-engineered salt-tolerant crops have become the order of the day, but at what financial-l’et alone ecological-cost? Sooner or later, the technical fixes will run out: even now, as we have seen,. many are proving too costly to implement-ewitness the massive water transfer schemes which have been proposed for the area.

The future is thus bleak for the US Southwest-as. indeed, it is for Sind, Iraq, and South Australia. How long will it be before vast areas of those regions are abandoned, their best farmlands being transformed into uninhabited salt encrusted deserts?" H

It is difficult to assess the drainage component of irrigation improvement because the drainage makes feasible and- in turn depends upon rehabilitation of the irrigation supply system

An early drainage experiment on one of India ’5 biggest in’igation schemes. in the Chambal Valley

Fig. 2

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Depth to watertable . " l

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Yield percentage

of max.

and other complementary investments in water and agricultural improvement. The inadequately named Left Bank Outfall Drain in the lower lndus includes additional surface water supplies, surface water storage, canal remerlling, intercept or drains for canal seepage, on-fann water management, projects. It is also dependent on a host of ongoing agricultural projects, including credit, seed supply, and improved extension. Indeed there is a danger that if each project component is forced to justify separately its inclusion in a programme, then essentially the same benefit may be claimed by drainage engineers, agricultural extension. workers, and others, to bet the fruit of their own endeavours. Where the overhead costs of development are large and incompletely provided the attribution of all marginal increases in production to one known additional investment is incorrect.

Impossible task. The interlinking of these components creates an enormous design problem. Selecting the appropriate scale of any particular part of this investment obviously requires some form of partial budgeting but the possibility of so doing is limited by specification problems and correlation among the components. In practice

Fig. I

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a core model of the final plan is developed and refined by marginal adjustments tested using a variety of criteria including technical, economic, financial, political, administrative legal, and environmental criteria. 1 2 .

The impossible task of attempting to estimate the returns to components of an interdependent system is further complicated by the failure of experts


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to find any agreement on the overall economics of schemes.

Conventionally drainage of irrigated land is considered to be a collective good that cannot be economically undertaken by individuals. This assumption must be questioned because farmers in various parts of the world have produced individual, privately financed, micro-drainage projects. Indeed in those areas where extensive irrigation has been developed with average intensities over the gross area at say 50 per cent or less of potential, it is doubtful whether "regional drainage by groundwater pumping will ever be economic. Schemes will have to be localized public or private tile drains or open drainage schemes.

Private investments in drainage are likely to be most critically evaluated by farmers, and as a result the form and extent of drainage will be more in line with market signals benefits than will public schemes. However, in many circumstances public sector analysts will find that markets are providing distorted price signals. such as high indirect taxes on crops or overvalued exchange rates that prevent farmers receiving appropriate economic indicators. This will distort their private investment and consumption patterns but in principle subsidy or tax policies can be devised to correct these distortions.

For example, in Egypt some private farmers are digging deep open drains through their farms. If this fails to drain effectively all their farm (as revealed by differences in condition of crops close and distant fronl the drain), they dig two parallel drains on either side of the first drain. The spacing can be halved again until the whole fann has the desired fall in watertable. The water may be pumped from a sump back onto their fields, into a canal or to low lying abandoned areas. Gotch and Dyer make an appeal for study of such lihomesteaderi, endeavours before large-scale public schemes are under taken. 13

In this way private farmers are coping with the twin problems of waterlogging and salinity. Private farmers are doing this in a country where farm product prices are depressed far below world prices by government actions designed to maintain low urban food prices and to tap agricultural exports for revenue. The opportunity cost of labour is low at certain periods of the agricultural calendar in Egypt which makes the digging of drains feasible. However, it is unlikely that the drainage water would be pumped if the subsidized

1n the last 20 years, public and private tubewells have proliferated in India energy prices were raised to world levels while output prices stay under the present price regime. In such economies economists can play an important part in devising tax and subsidy or modifying existing policies that will encourage farmers to make an optimal level of investment from the public sector viewpoint.

Once a public sector drainage scheme is installed the problems for the public sector will be far from over. For example, the prospects for revenue generation from farmers served by new drainage are not very promising. In addition to the normal problems of taxing low-income farmers that are encountered with irrigation charges. drainage faces additional problems including:

- psychological and political attitudes of the farming community that regard drainage like roads. not directly productive and an overhead and therefore a Government responsibility: ,
. it is argued that on-farm drainage will not be completed and maintained l if charges are levied. Indeed many farmers will be looking for financial compensation for lost land rather than face paying charges;
- downstream farmers will argue, often correctly, that it is upstream salt disposal problems which in part at least create the need for downstream reclamation and drainage. Hence it follows that downstream costs should be shared with upstream users. This is an argument that is not likely to have much appeal to upstream farmers whether they are on the upper reaches

of the Colorado or of the Indus;
- current drainage problems were created by past mistakes. Farmers in years past have reaped an external economy by farming without drain- i age thereby raising the watertable and adding salt. Should current farmers pay for these historical unpaid costs, or should the government pick up the bill for their previously short-sighted regulatory policies.

A challenge for arid zone development authorities in the 19905 will be how to protect the increasingly profitable and politically important irrigation areas from self-destruction. This will require all the technical, financial. economic, social. legal. political, management. and administrative skills that can be mobilized and some very harsh choices on priority areas will have to be made.

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Since agriculture claims the bulk of

most nationsl water budgets and is by far the largest consumer, saving even a small fraction of this water frees a large ambunt to meet other needs. Raising irrigation efficiencies world-wide by just 10 per cent. for example. would save enough water to supply all global residential water uses. Yet vast quantities of water seep through unlined canals while in transit to the field, and much more water is applied to crops than is necessary for them to grow. The rising cost of new irrigation projects, the limited supplies available to expand watering in many areas, and the high cost of pumping are forcing governments, international lending agencies,’and farmers alike to find ways of making agricultural water use more efficient.

Most farmers in developing as well as industrial countn’es use gravity-flow systems to irrigate their fields. The oldest method, and generally the least expensive to install, these systems distribute water from a groundwater well or surface canal through unlined freld ditches or siphons. Typically. only a small

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portion reaches the crops root zone; a large share runs off the field. Sprink-ler systems. which come in many varieties. apply water to the field in a spray. They use more energy than gravity systems and require a larger capital investment to install, but they have brought irrigation to rolling and steep lands otherwise suited only for Idryland farming. One design-the centre pivot system-was largely re-sponsible for the rapid expansion of irrigation on the US High Plains in recent decades.

Drip or trickle irrigation systems, developed in Israel in the 19605, sup. ply water and fertilizer directly onto or below the soil. An extensive net-work of perforated piping releases water close to the plants roots, minimizing evaporation and seepage losses. These costly systems thus far have been used mainly for high-value orchard crops in water-short areas. Today drip irrigation is used on about 10 per cent of IsraePs irrigated land, where experiments in the Negev Desert have shown per-hectate yield increases of 80 per cent over sprinkler systems. Introduced into the United States in the early 19705, these sys-tems new water nearly 200 000 hec-tares and are slowly being used on row crops too. In Brazills drought-plagued northeast, a project sponsored by the

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lnter-American Development Bank is experimenting with one design to irrigate crops where farm incomes are low and water supplies are scarce.

Management the key. Most irrigation experts agree that the actual

Saudi Arabia. Pivot irrigation system on out fodder crop

efficiency of water use obtained in the field depends as much on the way the irrigation system is managed as on the type used. Although drip irrigation may be inherently more efficient by design, the wide average range of efficiency for each system-40-80 per cent for gravity flaw, 75-85 per cent for a centre pivot sprinkler. and 60-92 per cent for a drip system-shows that management is a key determinant. Farmers using conventional gravity-flow systems, for example, can cut their water demands by 30 per cent by capturing and re-cycling the water that would otherwise run off the field. Some US jurisidic-,tions now require these tailwater re-use systems. Farmers are also finding, however, that they often make good economic sense because pumping tailwaters back to the main irrigation ditch generally requires less energy than pumping new water'from the source, especially from a deep well.

Partners can also reduce water withdrawals by scheduling their irrigation according to actual weather conditions, evapotranspiration rates, soil moisture, and their cropsl water requirements. Although this may seem like fine tuning, careful schedulv ing can! cut water needs by 20-30 per cent. At the University of Nebraskals Institute of Agriculture and Natural Resources, a computer program called itIRRlGATE" uses data gathered from small weather stations across the state to calculate evapotranspiration from the different crops grown in each area. Farmers can call a tele-

Sprinkler systems, which come in many forms, apply water to the field in a spray

phone hotline to find out the amount of water used by their crops the preceding week, and then adjust their scheduled irrigation date accordingly. The California Department of Water Resources is launching a similar management system with a goal of saving 740 m3 of water annually by the year 2010. The Department is also demonstrating irrigation management techniques through mobile laboratories equipped to evaluate the efficiencies of all types of irrigation systems-gravity, sprinkler, and dn’p-and to recommend ways that farmers can use their water more efficiently.

Israel has pioneered the development of automated irrigation, in which the timing and amount of water applied is controlled by computers. The computer not only sets the water flow, it also detects leaks, adjusts water application for wind speed and soil moisture, and optimizes fertilizer use. The systems typically pay for themselves within three to five years through water and energy savings and higher crop yields. Motorola Israel Ltd., the main local marketer of automated systems. has begun exporting its products to other countries; by 1982 over 100 units had Saudi Arabia.

Travelling-gun inigation on a sorghum plantation i been sold in the United States. IsraePs overall gains in agricultural water use efficiency, through widespread adoption of sprinkler and drip systems and optimum management practices, have been impressive: the average column of water applied per hectare declined by nearly 20 per cent between 1967 and 1981, allowing the nations irrigated area to expand by 39 per cent while irrigation water withdrawals rose by only 13 per cent.

The best prospect. In the Third World, where capital for construction of new projects is increasingly scarce, better management of existing irrigation systems may be the best near-term prospect for increasing crop production and conserving water supplies. Lining irrigation canals, for example, can help reduce water waste, prevent waterlogging, and eliminate the erosion and weed growth that makes irrigation ditehes deteriorate. Yet canal lining is expensive, and other options may prove more cost-effectiVe. Seepage from canals is not necessarily water wasted since it increases the potential groundwater supply. By coordinating the use and management of groundwater and surface water, as in the case of the Indus Valley, the total efficiency of water use in an agricultural region can be increased.

Farmers also need control of their irrigation water in order to make good use of fertilizer and other inputs that increase crop yields. Concrete turnouts that allow farmers to better dictate the timing and flow of water to their fields, for exahiple, are being built in India, Pakistan, and elsewhere. At a pilot project in Egypt, funded by the US Agency for International Development, improved management of irrigation systems is largely credited with boosting hce yields 35 per cent. Water savings alone will often justify such investments. By some estimates, better irrigation management in Pakistan could annually save over 50 km3 - four times the storage capacity of the nationis Tarbela Dam- at one-fourth the cost of developing new water supplies.

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Reliable evaluation of the impact of irrigation projects is a difficult process under the best of circumstances. Not only are there methodological problems that need to be resolved in order to find a cost-effective and reliable technique for the evaluation of a specific project, but often there is also built-in institutional inertia to be overcome before a serious evaluation can be undertaken. Unfortunately, far too much pseudo-evaluation is carried out at present by both national and donor agencies more concerned with the protection and enhancement of individual and institutional reputations than with determining the real costs and benefits stemming from projects. One would indeed be hard-pressed to identify irrigation projects in developing countries that have been monitored and evaluated seriously and comprehensively on a regular basis. Poor management, including lack of proper monitoring and evaluation, has meant that many projects are not producing the benefits expected of them. There have been many disappointments during the past two decades.

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For example, a review by the Club du Sahel and CILSS concluded that the area under modern irrigation doubled in that region between 1960 and 1979, but ugenerally speaking, during the past few years, the development of new areas has barely surpassed the surface (area) of older ones which had to be abandoned? A major conclusion of a workshop on uAid to Irrigation", convened by the Development Assistance Committee of the OECD, was not only an expression of general dissatisfaction with the performance of large-scale im’gation projects in developing countries, but also the radical suggestion that for some areas of Africa itirrigation should not be generally promoted until existing schemes were shown to be productive and until well-tested technology and comprehensive plans have been prepared? 1

There have been othef reasons for pessimism. Nearly half of the world’s irrigated area is afflicted with some degree of salinity or alkalinity. During the United Nations Water C onference it was estimated that by 1990. out of 92 million hectares of irrigated land in developing market economies of Africa, Asia, and Latin Ameh’ca, 45 million hectares would require improvement at an estimated cost of more than US$22 billion at 1975 prices.

Inigation projects generally do not appear to have contributed to equity. An analysis of the experience of the United States Agency for lntemational Development (USAID) indicates that irrigation is i'at best a re-affirmation of the existing social and economic distribution of assets. but more often, it will tend to exacerbate differences in both income and social prestige". 2 Often the estimates of cropping patterns and intensities. average yields, farm prices, employment, and income generation, and the availability of credit and inputs such as pesticides, fertilizers, and seeds, extension services, and marketing facilities have turned out to be pious hopes rather than reality. In addition, environmental and health costs of irrigation projects have been substantial. 3

On the positive side, it is undeniable that timely, reliable and well-managed water supply and its effective use is a crucial requirement for the modern high-yielding agricultural production, Although only 20 per cent of the worlds agricultural land is now irrigated, it provides 40 per cent of total agricultural output. Clearly, the world food problem cannot be resolved without adequate water control.

Undoubtedly, one major reason for the extremes of optimism and pessimism concerning irrigation is the lack of effective monitoring and evaluation of irrigation projects. While this process has received much lip service during the past decade, it has seldom been carried out comprehensively on a continuing basis. The analysisof USAID's experience in irrigation projects indicated that monitoring and-evaluation activities of both donor and recipient countries have ticome in for criticism from each group about its own organization and about the activities of its counterpart", and that iitoo little of it gets done by either group".

Evaluation framework. lnigation projects are complex to monitor and evaluate, since a large number of specific and specialized tasks have to be performed, both concurrently and sequentially. in a coordinated manner, by a variety of professionals with decisions being made by local. regional, national, and international institutions which may have direct impact on the project. In addition, all the project benefits and costs, both direct and indirect, are not confined to the project boundary: some of them can, and do. occur far from the immediate area. Thus it is not easy to define an area which could be said to embrace all of the projects im-

pacts.
The time dimension of the impact presents another complication. Sometimes the impact is immediate and can be identified during implementation phase or soon thereafter. At other times, however, it may be delayed and thus may not be easy or even possible to monitor in the early stages. For example, some unanticipated changes in the environment might not easily be identified until the project has been operating for more than a decade. Salinity development in irrigation projects. can take 15 to 20 years under certain circumstances, but under others it may take only two to three years, depending on physibal conditions, drainage provided, effectiveness of operation, and maintenance procedures. This time _dimension also makes the comparison of impact among different projects a difficult task.
Agricultural development projects involving irrigation can logically be arranged into four interrelated levels for monitoring and evaluation purposes. The first covers the planning, design, and construction of the physical facilities; the second, operation and maintenance, especially of irrigation, drainage, and hydropower generation facilities; third, agricultural production; and finally, achievement of socio-economic objectives.
The easiest task. Of these four levels. probably the easiest one to handle in terms of monitoring and evaluation is the first. This is also a discrete phase, which is completed once the construction of physical facilities is complete. In contrast, the other three levels require continual monitoring and evaluation during the project life to ensure that the system is operating at the desired efficiency, and that the objectives of the project continue to be met.
Some forms of monitoring and evaluation of planning, design, and construction have always been a common practice among engineers and surveyors to ensure that projects were proceeding on schedule and
If projects are designed to be labour-intensive, the poor are more likely to share the benefits

costs were within budget estimates. Thus. for engineering and technical aspects there would normally be technical inspection and cost-accounting systems integrated within the project. However. it is always worthwhile to review such existing or proposed systems to see if any further improvements can be made.

There are some areas at this level where monitoring is needed but seldom carried out. except in an anecdotal fashion. For example. the , employment that is created during the planning. design. and construction phases of water development projects is rarely considered to be an important criterion and. in most developing countries. is seldom explicitly evaluv ated in order to maximize potential benefits. If projects are designed to use labour-intensive methods from the beginning. the poor. and especially large numbers of unskilled workers. including women. are more likely to share in the benefits. To ensure that women are rewarded on a par with men for the same amount of work. it is necessary to monitor wage levels. It is also important to ensure that children are not employed in contravention of agreed international conventions. Subcontracting to small firms should be encouraged as much as possible to stimulate local Overemphasis on mechanized agriculture could reduce employment potential and leave the poor worse off than before business development.

Other useful information that could be collected during this phase of the activity include:

- classification of equipment and materials used by type, cost. and country of origin;
- the degree to which farmers participate or are consulted on project planning and design. including such matters as canal alignment. an important consideration in terms of equity;
- the degree to which the project was perceived as essential by local authorities and the degree of their participation in project planning, an essential element for the long-term sustainability of any project.

A low priority. Operation and maintenance is one of the most underestimated aspects of irrigation projects in developing countries. If benefits from such projects are to be realized on schedule and specific target groups are to be reached, it is essential that these functions be carried out efficiently to ensure that irrigation water availability is reliable. electricity-generating facilities properly maintained. farmers in the tail-end of the system supplied with their full quota of water regularly, and the drainage system functioning properly so that salinity and waterlogging will not become future problems. A review of past irrigation projects indicates that most agencies are generally not ready to undertake operation and maintenance when the construction phase of the project is completed. Judged by the actual performances of both governments un- Hahn.



and donor agencies, operation and maintenance appears to have been accorded low priority, at least until recently. Funds available for such purposes are usually inadequate and maintenance efforts are often post-poned until a major crisis appears as a signal of the projectis declining efficiency. In crises, the problem faced is usually technically more com-plex to resolve and involves more expense than if maintenance had been carried out on a regular basis.

Prevailing attitudes and perceptions among technical staff may present another problem. In many coun-tries, the design and construction phases of water development projects are considered to be glamorous; operation and maintenance assign-ments are considered much less de-sirable. The best qualified staff often prefer to work on the former phase. Inexperienced or less com-petent staff tend to be relegated to operation and maintenance.

Thus it is perhaps not surprising that the efficiency of many irrigation systems a decade after their con-struction is often very low: around 20 to 40 per cent. This means that 60 to 80 per cent of the water drawn into the system does not reach farm fields.

But if operation and maintenance standards are poor with respect to irrigation facilities, they are even worse in the matter of drainage.

Poor drainage contributes to salinity and waterlogging, but since these problems often take years to develop, the magnitude of the threat is seldom recognized until it is too late.

Agricultural production. The fun-damental objective of any irrigation project is to provide efficient water control in order to increase the in-comes of people in the project area. But efficient water control per se is not a sufficient condition to maxi-mize agricultural production, which simultaneously requires other essential inputs such as seeds, fertilizers, pesti-cides, equipment, and energy as well as extension, credit, and marketing facilities. All these factors need to be considered in evaluations at this level.

This will involve the collection of information on the most critical times for each cropping season, which can then serve to allow better coordina-tion among the various organizations responsible for different inputs and services. An overall performance review, carried out at the end of each cropping season, will be helpful in preparing improved plans for the next cropping season.

If the immediate objective of irrigation projects is to increase agricultural production, the ultimate goal, presumably, is not only increased availability of food for people, but also higher income for both farmers and non-farmers. How the additional benefits from increased productivity are shared among different groups will determine to a considerable degree whether the socioeconomic objectives of a project are being achieved. It is thus extremely important to monitor the impact of a project upon its proposed beneficiaries.

While it is quite possible that an irrigation project many enhance employment and income potential of landless labourers on famis and in neighbouring towns due to intensified agricultural activities, it is equally possible that an undue emphasis on mechanized agriculture associated with the project could reduce overall employment potential and render conditions for landless labourers worse than in pre-project times. Similarly, benefits from the project could accrue primarily to larger farmers at the expense of smaller ones, resulting in income patterns more skewed than ever before.

Aside from the obvious factor of income distribution, it is equally important to monitor the impact of increased income on some quality-of-life indicators. Has increased income improved the quality of life of people in the project area in terms of higher literacy, improved health services, provision of clean water and sanitation, or is it being primarily used for conspicuous consumptic’m, as has sometimes been the case?

Since some of these results may not become apparent until 10 or 12 years after the project has become operational, the time factor is very important for this type of evaluation. Socioeconomic monitoring need not be carried out as frequently as monitoring of operation and maintenance or of agn’cultural production. Key variables could be monitored annually; others could be surveyed every two to five years.

Overall, from the management viewpoint, it is important that monitoring and evaluation be carried out on a timely and regular basis so that decision makers can be made aware of project results and formulate appropriate alternative policies in time to reverse undesirable trends.

1. "Aid for Development of Irrigation", (Paris: OECD, 1983).

2. David I. Steinberg, "Irrigation and AID’: Experience: A Consideration Based on Evaluations". (Washington, DC: USAID, I 983).

3. Asit K. Biswas, "Environment and Sus-

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