PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Summing up and Forward Look

Charles Pereira

Phil. Trans. R. Soc. Lond. A 1986 **316**, 369-373
doi: 10.1098/rsta.1986.0015

Phil. Trans. R. Soc. Lond. A **316**, 369–373 (1986)
Printed in Great Britain

Summing up and forward look

By Sir Charles Pereira, F.R.S.

Summary

The meeting began with a survey of the world irrigation scene by four leading engineers of wide international experience and authority. They raised a number of important philosophical questions about the aims and operational policies of major irrigation schemes in developing countries.

(1) In spite of sound engineering design and construction, most irrigation schemes in tropical countries are not making any return on their capital investment and some are not even meeting their running costs. These are verdicts by accountants and economists: they raise the urgent philosophical question of the value to be assigned to food. Food is now being flown into African countries to relieve large-scale famine at costs which are an order of magnitude above the market value. Some major irrigation schemes will need to continue to be subsidized for security of food supply.

(2) Government bureaucracies in developing countries are notoriously inefficient. This is demonstrated acutely by their poor management of large-scale irrigation schemes. A policy swing towards 'small is beautiful' has resulted among some aid organizations which are concentrating on the poorest of small-plot farmers. It was suggested that for irrigation this policy needs rethinking. The use of new technology starts only among farmers who can afford some risk. It is those with a spare hectare or two who try out new crop varieties and demonstrate crop responses to fertilizers. Those on small plots which provide only bare family subsistence can afford no such risks. Thus, to create large irrigation schemes of small, equally sized, family subsistence plots may be setting up a barrier to rural progress. A mixed pattern of farm sizes offers more economic and social promise. For success, irrigation schemes require more than good physical planning: a range of other constraints need to be overcome, including security of tenure; seeds, fertilizers, and insecticides, with credit to buy them; competent technical advice and leadership; markets, and transport to reach them.

(3) All countries that have made major progress in agricultural productivity per hectare have also reduced their labour forces. This relationship plotted over the range of some thirty countries between Bangladesh and the U.S.A., is consistently exponential, over different sets of years, with a fit that accounts for 92% of the variance.

(4) The next major point in irrigation philosophy is that maintenance is critical to success, but receives no political support. Priority for funds goes to new vote-winning capital projects. Both the U.K. and the U.S.A. have similar difficulties. Capital aid projects should therefore include the costs of regular monitoring and could, with advantage, include provisions for the training of maintenance staff.

(5) A philosophical point that is deeply enmeshed with the cultural traditions of Asia and the Far East is whether rice should be replaced by cereals less demanding of water: there is certainly need for more study to reduce the lavish use of water in land preparation and weed control.

(6) The final philosophical issue was presented as a paradox. Whatever we do for the needy

in the Third World, their population growth rates rapidly overwhelm our efforts. Birth control is apparently being achieved in China and in Singapore; in Africa we see the grim alternative of limitation by famine. We cannot rely on irrigation to support the rapid population growth of the Third World.

Research in the supporting sciences continues to prepare for better technologies. The interactions of leaf growth, increasing the supply of metabolites, with root growth, increasing the supply of water, can affect irrigation demand, at least until full canopy is reached.

From irrigation scientists overseas we have learned of the remarkable success of the Israeli national water distribution system in overcoming annual fluctuations of rainfall to maintain farm water supplies within a 5% variation. Research has steadily reduced water demand and increased crop response so that the number of kilograms of crop produced per cubic metre of water supply has risen from 1 to $2\frac{1}{2}$ in two decades.

The enormous irrigation opportunities in Egypt presented by the over-year storage capacity of the High Dam at Aswan come as a fitting climax to the only major historic arid-zone river scheme to have survived over the millennia. Salinity is now a dominant hazard, with six million tons of salts accumulating annually in the absence of flooding. Egypt has the world's largest piped drainage scheme, with $2\frac{1}{2}$ Mha, mainly to be drained by plastic piping manufactured locally. Over 100 international contractors, some using very modern equipment with laser-beam levelling, work all year round. I was intrigued to observe that they could work through standing crops and yet be welcomed by the farmers. I learned that agents preceded them, buying the standing crops at a little above market prices.

Satellite imagery is offering a direct assessment of the water régimes achieved by large-scale irrigation within the compass of a single centre-pivot sprinkler equipment, by comparisons of imagery at different wavelengths.

The practical outcome of advanced research on the mechanisms of ion exchange between soils and irrigation waters has been illustrated clearly. Without such research, irrigation managers would surely not have been able to solve problems of sodium excess by mixing up to 25% of sea water with the river water in the irrigation channels! The advantages of distributing gypsum and other nutrients in solution in the irrigation supply were outlined. Although such drip irrigation and subsurface irrigation methods are too costly for many developing countries at present, they are extremely appropriate for harsh environments, as seen in Israel and in Jordan.

The plant breeders have been able to adapt lowland tropical crops to cool high-altitude conditions and to adapt temperate-zone crops to the harsh environments of hot deserts. Water is saved by the highly successful shortening of the rice growth season from five to only three months, achieving three crops a year as a practical farm routine. Rice production is beginning to outpace the long-term international forecasts. Their methods of selection for pest and disease resistance have proved to be very effective. Recent rice varieties from I.R.R.I., such as IR 56, are resistant to six major diseases and to six major pests, including different biotypes of the same species.

The continuity in both space and time provided by the large areas and the continuous-cropping régimes of the major irrigation schemes offer big advantages to pests. These are adapted to wide dispersal in search of hosts and to long survival times between seasons. They are therefore capable of very rapid expansion of population numbers when a good habitat is found. When

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

all these constraints are lifted the results are great bursts of population growth. Chemical pesticides have brought both good successes and acute failures. They need to be used more like scalpels than sledge-hammers. Irrigation can be manipulated as a pest control, as it has been in the U.S.A. for pink bollworm and in the U.K. for cut-worm. This needs to be considered in scheme design as well as in operating schedules. Field ecological studies have shown how planned gaps in the planting sequence and separation of crops beyond the known distances of insect flight can prevent the production of additional generations of insects within a season.

A major defence must remain within the plant by subjecting hundreds of varieties to intensive attack in the insectary and by breeding from the few survivors. We were warned that genes for pest and disease resistance are few and precious and can too easily be squandered by using them singly in varieties to which both pests and diseases adapt all too rapidly. The advantages of interdisciplinary discussion were very evident in this subject.

The needs have been presented for more research in the complex of interactions between the inputs of water, fertilizers and pesticides. We do not yet have enough information to make the best use of our inputs. Where the interactions are site-specific, simple experiments on limiting factors can be devised, and some classic early experiments in the tropics were illustrated. The loss of nitrogen into groundwater has been given much popular press coverage. It was reassuring to learn that recently published studies show that this is not a hazard to human health in the U.K. The leached nitrogen does not all come from fertilizers; the ploughing-in of a field of clover releases more nitrogen to groundwater than the farmer could afford to apply.

Our last speaker summed up the worldwide assessment that skills in project management are the factors most in need of improvement. Design has altered rather little in 40 years, but modern high-technology agriculture is making new demands on the flexibility of water distribution.

The Consultative Group for International Agricultural Research, (C.G.I.A.R.), chaired by the World Bank, has developed excellent centres to promote the 'green revolution' but has given far too little support to water management studies. Outside of the C.G.I.A.R. network a group of donors has set up a small organization in Sri Lanka, the International Irrigation Management Institute, but resources are as yet quite inadequate to bridge this large gap in international research and development. The Australian Government is believed to be setting up a national laboratory which may be on a more adequate scale.

The first objective must be to make better use of present resources. Redesign may be needed later, but at great cost. Smaller sums for refurbishing may pay better. It had already been noted, however, that international aid for refurbishing irrigation projects without a reorganization of the faulty maintenance systems is merely inviting a further waste of resources.

In this symposium we have been debating technologies on which the survival of perhaps a quarter of the world's population will depend. In an intensive two-day programme we have covered most of the major issues which arise in irrigated agriculture. I am sorry that it was not possible in the time to broaden the programme to include two more menaces to which tropical irrigation schemes are vulnerable. Fortunately neither of them occur in temperature-zone irrigation. These are the susceptibility of the farming populations to malaria, bilharziasis and other water-borne diseases and of irrigated lands to damage by floods, sedimentation and debris derived from misuse of land in the upper watersheds. Both have been mentioned by several speakers.

It is in both cases largely a matter of administrative, technical and social organization to

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

apply the scientific solutions and the practical experience already available; research for better solutions should continue, because in neither problem is the battle yet turning in our favour. Throughout the tropical world we are losing ground figuratively in the medical case and quite literally in the matter of soil erosion.

We have been reminded that the vast surge of population increase in the developing tropical countries is overwhelming the abilities of all of their governments to cope with the increased numbers in the field. The governments are failing to achieve the organization essential for the health of both people and their farmland. Malaria was almost eliminated, but is now spreading again in increasingly drug-resistant strains.

The snail vectors of bilharziasis can be controlled and the disease can be contained, but only among a well organized and disciplined population. Excellent medical research, supported by the major drug companies, has developed specific cures for infection by each of the main species of bilharzia, but the only effective field solution is to prevent infection by controlling the vector. Education of the population helps, but the casualties include irrigation managers and well educated farmers. (I speak with some feeling, because in the past year both a son and a baby granddaughter in Zimbabwe have been infected. Both have been cured by new drug therapy.)

Medical aspects were not treated in separate papers because we did not expect enough of the medical profession to be here to support a discussion. Dr Barton Worthington has reminded us that this field was recently explored at a joint meeting of the Institute of Civil Engineers and the medical fraternity.

Similarly the problems of land use in the upper watersheds cover a wide set of problems which could not be fitted into a two-day programme.

Population pressure has broken down traditional forms of land use and many at this symposium will have seen the stripping of hillside forests by firewood cutting and relentless, profitless, overgrazing. Some will have seen irrigation schemes buried under sediment and debris as a result.

This land misuse is a major contributor to the scarcities of both food and fuelwood which are now causing crises in tropical Africa, Asia and Latin America. Trees of fast-growing leguminous species, with irrigation, are being used as 'energy plantations'. Irrigation is a powerful weapon against these scarcities but it is deteriorating where population pressure has overwhelmed administrative management of the upland watersheds.

Soil erosion in the uplands raises the levels of streambeds in the lowlands and widens the areas of flooding – putting at hazard the design and operation of irrigation systems based on stable bed levels.

The problems of land use, soil conservation, agriculture, forestry, hydrology and the building and life expectancy of storage dams for flood control together form another set of subjects appropriate for a full interdisciplinary symposium.

Forward look

We have been reminded that irrigation is an important factor in British farming, already covering 150000 ha. The area is expanding and will probably grow to 200000 ha. While irrigation systems in the developed countries will continue to evolve more efficient and sophisticated technology I believe that it will be in the tropics that the main action will take place.

First, this is because tropical problems of food production are developing into crises. Many

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

of us here today have had ample opportunities to see the suffering caused among tropical subsistence populations disadvantaged by the tidal wave of population growth that has overtaken them. Western science and the machinery of international aid has been totally inadequate in helping the tropical developing countries to delay their population increases until they are more able to give the newcomers a better chance.

We can be certain that for the next three decades the precarious balance between people and food supplies will remain critical. The 1984 *World Development Report*, published by the World Bank, makes very sober reading.

Some 80% of the world's next two billion people will be born into the inter-tropical convergence zone, so that although there is no evidence of overall climatic change, the human race is concentrating in more difficult agricultural climates. The trade winds system is not likely to change and this vast area of meteorological instability will continue to generate droughts and floods, making food supplies erratic. Irrigation will therefore become ever more important as populations increase. For both engineers and agriculturalists, irrigation will also become more difficult as less favourable soil and water resources must be used. The problems are growing faster than the tropical developing countries can cope with them so that more professional and technical help will be needed. More scientists and engineers of the developed countries will be called on for help in reconnaissance, design, construction and trouble-shooting.

Pests and diseases multiply abundantly in the rich substrate of tropical irrigated crops. The battle to harvest what is grown and to store it safely will need much continued effort by the disciplines represented here today. The research, as has been convincingly demonstrated, will need to be increasingly multidisciplinary and multifactorial. More research is needed for scientific improvement of the labour-intensive systems to increase crop production without mechanization.

We need much closer planning between engineers and agriculturalists. The engineering problems of vast new projects such as the Victoria Dam newly opened in Sri Lanka are so pressing, and the economic demand for hydropower is so urgent, that there is often far too little time spent on the study and design of the agricultural outcome.

We are fortunately, I believe, discarding the myth believed by engineers in the tropics for more than a century, that the peasant farmer knows what to do with water and that the engineer's job ends at the out-turn of the minor canal.

The problems of distribution, of drainage, of timeliness of application, of the use of crop rotations to fit seasonal variations in supply; the need for leaching to control salinity; all these should be planned by engineers and agriculturalists together.

The primary reason for arranging this symposium was to help specialists in the range of disciplines involved in irrigation to understand more of each others' problems and opportunities. I hope that we have been communicating successfully and I look forward to more such occasions.

I would like to end this Discussion Meeting, as we began it, by paying tribute to the contributions to irrigation science made by Dr Howard Penman. He helped to plan this meeting and would, I believe, have enjoyed it and contributed notably to it.

On behalf of the Society I would like to thank the speakers for the time and effort which they have put into their papers; also the chairmen of the sessions and those who have taken part in the debate. I know that my colleagues, Professor Hamlin and Mr Mansell-Moullin, will join with me in thanks to the staff of the Royal Society who have worked hard on the preparations.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES