Are we utilizing our water resources wisely?

B. P. Radhakrishna

Modern technology has been used in building high dams and storing water. But in the matter of conveying the precious water to the field and making it available for plant growth, technology has lagged behind. Accurate quantitative appraisal of resource availability, and its utilization is urgently needed. Water conservation measures have to be adopted taking lessons from Israel, a country which has made a success of its agriculture. Greater attention should be paid to groundwater. Porous and fractured rocks below ground function as a vast interconnected reservoir. This natural storage which nature has provided should be allowed to get recharged with rainwater. These measures can be best attempted through the organization of autonomous River Authorities for each major river basin and sub-basin.

The year 1992 has witnessed an acrimonious debate on the sharing of the waters of the river Cauvery. Disgruntled people instead of debating the issue, took to a futile orgy. Violence and arson fanned by virulent speeches by politicians, marked the reaction of the people affected. In this imbroglio the more important question of whether the available resources were being used efficiently or not was not given due consideration. Hence, I feel compelled to focus attention on the aspects of water conservation which offer the best means of successfully managing our water resources. Special plea is made to scientists of all disciplines to take particular interest in solving problems of our countryside, especially the question of wise utilization of our soil and water resources.

The problem

'I can foretell the way of celestial bodies, but cannot say anything of the movement of a small drop of water'— so said Galileo, the great astronomer, a long while ago thereby emphasizing our ignorance about such a common and seemingly abundant commodity as water. Most of us have taken this resource for granted and failed in properly estimating the extent of its availability and utilization. The average annual rainfall over our land is 1170 mm. Even the more arid parts receive a minimum of at least 200 mm of rain. Many parts of the world do not receive as much rainfall as we do in this country. If people have started complaining of shortage, it can only be due to adoption of wrong technologies and policies leading to mismanagement and inefficient utilization of a precious resource.

In the first flush of Independence, there began a craze for building high dams across major rivers for storing water and making it available for irrigation. Large sums of borrowed money were spent over the construction of these structures and water conveyor systems. A considerable extent of good fertile land was incidentally allowed to get submerged, causing wholesale displacement of population and submergence of rich agricultural and forest land. No doubt, a vast area was brought under irrigation, but very little thought was given to the wise utilization of the stored water. There was also no attempt at making people aware of the value of water since no part of the cost in providing it was charged to the beneficiary. Fields were allowed to get freely flooded despite the fact that too much of water to the crop was as bad as too little.

Water judiciously used can assure better production. The example of groundwater irrigation can be cited. This is 100% privately managed but helped by subsidies for small marginal farmers. The farmer invests his own money on sinking a well within his field and in fitting it with a pump set. He also pays the cost of diesel or electric power to run the pump. Having spent so much of his hard-earned money, he knows the value of water and uses it sparingly and efficiently. It may surprise many to learn that the highest yields of paddy per acre are from fields benefited by groundwater irrigation.

In the period between 1951 and 1985, the area irrigated by major reservoirs increased from 7.5 to 15.4 million hectares (M. ha.) at an expenditure of about Rs 15,000 crores. In the same period, groundwater irrigation registered a spectacular growth from 5 to 20 M. ha., a net increase by 15 M. ha. with no part of the cost of development being borne by the State. This is an example of what can be achieved through individual effort even in the field of irrigation. Our present day need, therefore, is not so much on heavy invest-

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ments on major irrigation projects, but on proper water management of available resources.

Adequate data, a primary requisite

Presently, there is no reliable data on both the availability of water and the extent of its utilization for agricultural, domestic and industrial purposes. Stream-flow information is inadequate. Even limited data being collected by official agencies are kept as closely guarded secret and not made freely available for analysis and evaluation. Information on how much water is really necessary for assuring a good crop in different soil and climatic regions is again inadequate and even when specified, has not been applied in practice. Reliable quantitative appraisal of the availability and extent of utilization of surface as well as groundwater resource in different regions of the State is, therefore, the first prerequisite for wise management of the resource. Broad forecasts (which are no more than guestimates) are, no doubt, projected from time to time but these are just not enough. Specific studies over smaller catchments, quantification of data and free and unfettered dissemination of knowledge are essential. Data should not only be gathered but shared. Secretive ways are detrimental to progress. In the same way as meteorological data are published in daily papers, stream flow data and groundwater level data should also get published at specified intervals and their implications discussed. Modern irrigation is a specialized operation and has to take note of a number of factors. Unmeasured and, in almost all cases excessive application of water, are the root causes for the ills associated with our major irrigation projects.

Inefficient practices

Irrigation engineers themselves admit that water in the case of major irrigation works is used inefficiently. Steps, however, are not initiated to improve matters. Irrigation continues to remain as the largest sick industry. The craze for big dams and long systems of canals still continues unabated despite the fact that major projects cost enormous amounts of money, and take unduly long time to complete. There is hardly any return on the huge amounts invested. Those entrusted with the execution of these works do not seem to be concerned about ensuring a reasonable early return on the capital. Small-scale alternatives like smaller dams, lift irrigation schemes and water-harvesting tanks which are less costly, easy to manage and more flexible, are not given the importance that they deserve. In the case of smaller projects, there is a sense of participation in management which is lacking in the case of major irrigation projects which remain as examples of wasteful utilization of a precious resource. In the existing irrigation system, there are very few regulatory structures in the main canals, and hardly any in the minor canals for exercising effective control of water. In the delta regions, fields are literally allowed to get flooded with practically no attempt at adopting water conservation measures. Such irrigation practices, apart from wasting a resource in short supply, have led to degradation of land. Heavy irrigation of the black soil tracts in the valleys of Tungabhadra, Bhima, Ghataprabha and Malaprabha are glaring instances of wrong practices adopted. Black soils are moisture retentive and are more saline than other types. Heavy irrigation without adequate drainage and adoption of wrong cropping pattern have tended to degrade the once fertile soil. Black soils have tremendous potential if only their physical and chemical properties are appreciated and the right quantity of water provided at the right time. Excess irrigation has ruined this priceless resource and reduced rich agricultural land into worthless saline tracts. This has happened in Punjab, parts of UP and Rajasthan and is happening in Bellary, Gulbarga and Raichur districts of Karnataka.

Water to be priced

As long as farmers are kept ignorant of the cost involved in supplying water, they will continue to clamour for more and more of the resource and will refuse to see reason and adopt water-conservation practices. They also turn a blind eye to the fact that by feeding excess water, they are causing permanent damage to their own land besides seriously affecting productivity. It is inevitable in the modern context that water should be priced.

It has been estimated that losses through percolation in unlined canals can be as high as 30 to 50% of the water entering the canal head. The country cannot afford such colossal wastage. Supply of measured quantities of water through a network of pipes instead of through open channels, should be seriously thought of and relative economics worked out. This is possible when a value is fixed for the water supplied. Where land holdings are small, supply of regulated quantities of water by means of pipes will assure better results and more efficient use of water.

In the irrigation practice that is presently prevailing, regulatory structures and measuring devices are conspicuously absent. No thought is given to providing drainage for the excess water used in flood irrigation and in making effective use of the water so saved.

In Israel, measures have been initiated to strictly regulate water supply and feeding measured quantities of water through adoption of water-conservation practices. By conveying water through pipes, installing

meters for regulating the supply and adopting sprinkler and drip irrigation, they have been able to use 85% of the water that is potentially available. In the system of flood irrigation, which we continue to indulge in, as much as 60% of the water stored, at great cost, is wasted through evaporation and percolation.

Maximum water conservation can be achieved by adopting modern irrigation techniques, conveying and delivering water through pipes and applied directly to the root zones of plants at controlled rates. Irrigation engineers are likely to dismiss the suggestion as impracticable for a developing country like India on account of its high cost. This is a wrong approach. One should not close his eyes to the immense benefits that will accrue through controlled irrigation. Effecting improvements in our irrigation practices is not an impossible task, if irrigation engineers, laboratory scientists, agriculture experts and social workers get together to hammer out procedures for better utilization of water. Spectacular results can still be achieved if there is a will and if only the problems are tackled on scientific basis and solved.

The example of Israel

Israel is a small country compared to India, covering an area of just 25,000 km^2 in extent. A good part of it is arid and a desert region receiving annually less than 200 mm of rainfall. Yet, this nation has demonstrated how wisely and efficiently water resources can be managed. The entire potential water-supply has been brought under control and utilized. Hydrologic exploration has been perfected, adopting the most modern technology. Isotopes have been used to determine aquifer boundaries, and recharge rates have been calculated. Computer-based models have served to simulate the dynamic balance of water and evaluate the consequences of alternative water use scenarios.

Israel has also formulated a comprehensive law reserving for the State the exclusive right of ownership of water, and allowed use of only prescribed quantities under licence. Norms for water use have been established for different regions and for specific purposes after a good deal of study and experimentation. Wells are monitored continuously to ensure that there is no over-exploitation of the aquifer. Groundwater is not considered as a private resource. Its use is also effectively controlled. Nearly all water is conveyed through pipes and under pressure. Meters are installed to regulate supply and prevent wastage. In addition, municipal sewage is reclaimed and used for irrigation and industrial purposes. An irrigation efficiency of over 80% has been claimed. Water application for unit area has been reduced and the yields increased dramatically. Value of agricultural production is stated to have increased by more than 100 per cent as a result of the above measures. Israel has thus demonstrated how to combat water scarcity with the adoption of modern technology. The example of Israel is worthy of emulation.

Conjunctive use of surface and groundwater

It should be emphasized that surface and ground water, both form part of the same hydrological system and that in any wise scheme of utilization, one should supplement the other. River deltas are rich both in surface and groundwater resources. A good part of the water used for irrigation recharges the groundwater body and is available for re-use. The adoption of practices aimed at the conjunctive use of both surface and ground water is, no doubt preached, but never seriously practised. Agencies going into the question of assessing the extent of water that is available for distribution must take into account the groundwater potential of irrigated tracts.

At present, there are two different standards adopted in respect of surface and groundwater irrigation. Groundwater is considered as a private resource and left to the free will of the farmers for its development. The farmer finds the money for constructing the well and installing a pump set. In the case of surface water, however, governments assume full responsibility of providing water, and delivering it literally at the doorsteps of the farmer. It is not clear why such differing standards, one for groundwater and another for surface water, are adopted. Like all other benefits, costs of operation and interest on the investment, whether on surface water or groundwater, have to be passed on to the beneficiary. It is only then that the true value of the resource will be realized and better practices of using water sparingly will get adopted.

Large-scale utilization of groundwater especially in the delta region is particularly feasible. Every effort should be made at utilizing this untapped resource in summer months when surface water supplies diminish. According to an UNDP estimate, the groundwater potential of the Cauvery delta is 3650 M m^3, which is nearly three times the storage at Krishnarajasagar (1269 M m^3). Is it wise to allow this quantity of water to remain unutilized?

Cropping pattern

Multi-cropping pattern, as against the present practice of monoculture, is expected to provide adequate water for year-round irrigation. Paddy should be grown in the rainy season while in the succeeding season, moisture prevailing on the soil should be used in growing crops

like maize, ragi, soyabean, cotton and pulses whose yields are expected to be 4 to 5 tonnes per hectare as against just 1.5 tonnes of paddy for the same cropped area. Sugarcane consumes enormous quantities of water and it is unwise to promote growth of such crops in areas of water scarcity.

Considerable experimentation in deciding the cropping pattern suited to different soil characteristics and the food habits of the people is necessary. Ragi is the most suited crop for the arid and semi-arid parts of Karnataka State. Yet, its cultivation has been most neglected and large extent of suitable land has been allowed to lie fallow. After Independence, there has been an unfortunate trend in food habits, wheat and rice taking the place of ragi. Instead of becoming self-reliant, the population of these regions has to depend more and more on outside sources, requiring avoidable expenditure on transport and wastage.

Yields under flood irrigation as practised in India are too low, amounting to less than one tonne per hectare. With effective control, use of hybrid varieties and fertilizers, Japan has been able to step up production to as much as 5.5 tonnes per hectare (see Figure 1). Yields of even up to 8 tonnes are stated to be possible by a combination of relevant practices. This gives a measure of what can be achieved through wise management of water resources and adoption of modern agriculture.

Resource management

Water resource management is not the business of irrigation engineers alone. It should be the concern of an interdisciplinary team of engineers, ecologists, geologists, planners and administrators. They should lose no time in drawing up a programme of research about optimum use of water, posing questions and trying to find answers for them. There should be a vigorous effort at preparation of manuals and popular books and dissemination of knowledge. A willing participation of the people is essential to make a success of our agriculture.

Consolidation of land holdings

If perceptible progress has to be registered and progressive policies in efficient water management have to be adopted, it is inevitable that some type of co-operative endeavour should replace the excessive fragmentation of land into uneconomic units. Cooperative or collaborative village is not a new concept. The ancient agrarian system was based on cooperative endeavour. Such self-governing village communities should be revived. The adoption of modern technology will become easier and practicable if the units to be

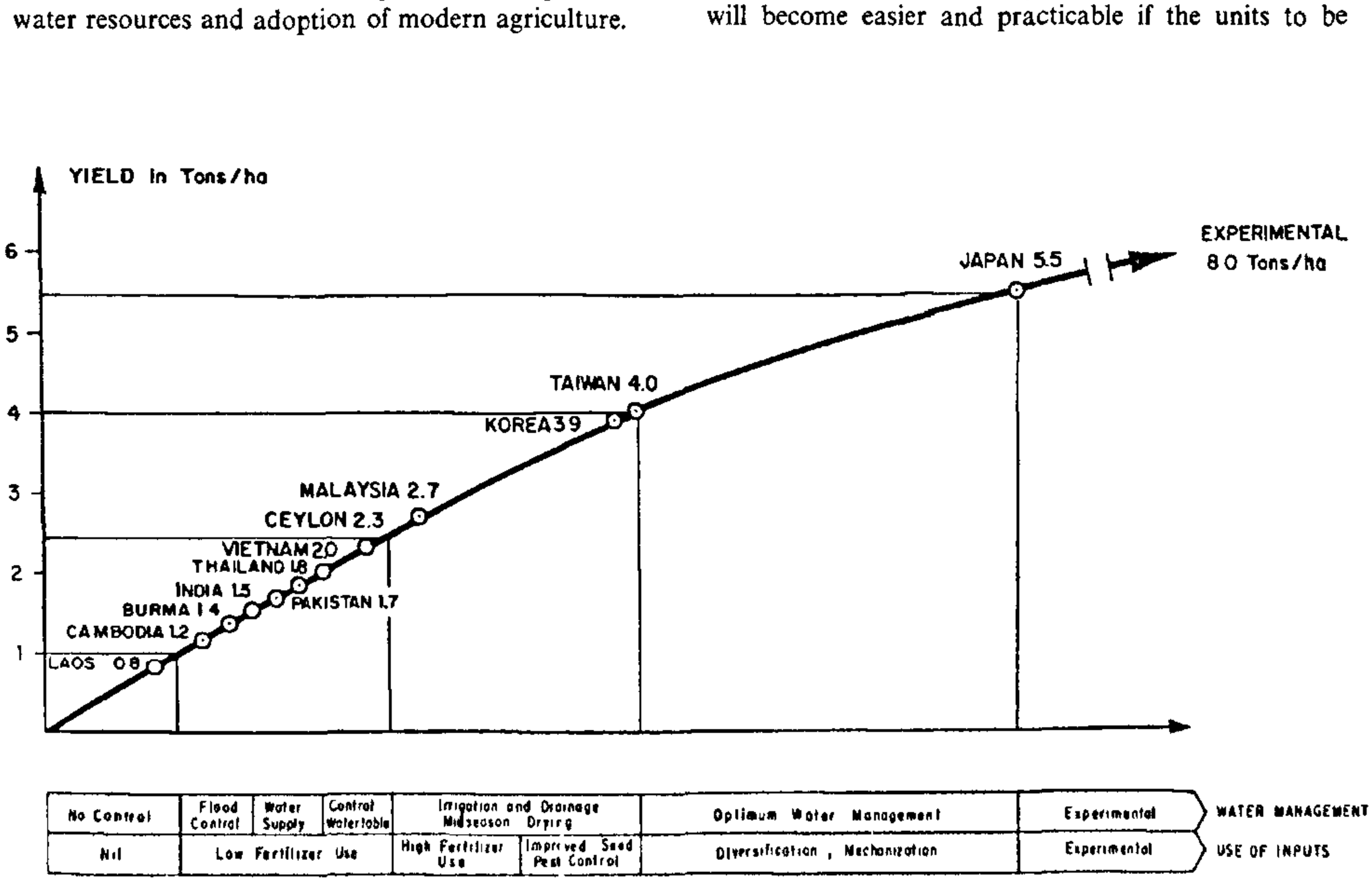

Figure 1. The role of water control and use of additional inputs on rice yields on a countrywide basis (after Cheong, C. L., Integrated Farm Management, FAO, Irrigation and drainage paper no 10, 1971).

benefited are large and viable. Equitable supply of water for irrigation on measured volumetric basis, which is the only scientific way, will become practicable if land-holdings are large. It is inevitable, therefore, that farmers in their own interests should get together and form themselves into cooperatives. Finances then will become easily available. What is more important, it will then become possible to hire experienced scientists and technologists for improvement of their farms. Greenhouses, model farms, fruit gardens, coconut groves, should enliven the landscape of the countryside. Flight of labour to cities should stop. When agriculture becomes a prosperous industry, we can expect a reverse trend to set in with scientists, technologists and doctors moving towards villages. It is scientific agriculture that can bring prosperity to the countryside.

Recharging groundwater reservoirs

Although rainfall is plentiful, it is confined to just four months in the year which points to the need for storing the excess water at places where it falls. Dams are, no doubt, one way of storing flood water, but these structures built at enormous expense will benefit the favoured few living in river valleys, leaving the large majority of farmers unprovided. The needs of this larger section is more urgent. Stored water on the surface is subject to heavy losses through evaporation. Pervious and fractured rocks below ground, on the other hand, offer the best medium for storage of water. Nature has provided inter-connected reservoirs of vast extent underground. Skills have to be developed for arresting rain water where it falls and allowing it to recharge the groundwater reservoir. Afforestation of catchment areas, contour bunding, levelling of land, creation of farm ponds are measures aimed at arresting the flow of water on the surface and directing it below ground. Presently no serious thought is being given to this important aspect. Water and, along with it, soil are getting washed away. Apart from this grave loss, through soil erosion, there is the greater risk of rapid siltation and reduction in storage capacities of reservoirs.

Organizing agriculture as an industry

Coffee and tea are plantation crops and present a picture of success in agriculture. In fact, India is a leading producer of tea and coffee in the world with higher yields recorded per hectare. This has been made possible through wise management and adoption of modern technology. The same is not the case with rice or wheat. India occupies a low position in respect of these crops, producing only a fifth of the yield attained by advanced countries. The reason is not far to seek. While in the case of plantation crops, holdings are large and production scientifically manipulated, in the case of rice and ragi, holdings are fragmented and developments are left to the whims and fancies of innumerable individual farmers who lack the resources for adopting modern scientific agriculture. Nothing significant can be achieved under these circumstances. Agriculture, if it is to become successful, should get organized as an industry with adequate finance and organizational input.

Improvement in arid and semi-arid lands

It is not enough if irrigation engineers restrict their attention to river valleys alone. There are large areas of arid and semi-arid land which have to be assured of water. Drip irrigation by tapping groundwater offers the best way of bringing benefits of irrigation to such lands. There is greater need for concentrating on such programmes rather than on building large dams. Planned use of surface and groundwater offers the best means of providing water for irrigation all over the country and not necessarily restricted to river valleys. Strict control in utilization of the resources is, however, necessary. Unrestricted exploitation may end in disaster. Well-owners should be permitted to utilize only a prescribed quantum of water and nothing more. Withdrawal of groundwater in excess of annual recharge will lower the water table and makes wells go dry. Water will not be available even for drinking purposes, let alone for irrigation.

Wherever water resources have been harnessed through small tanks and wells, the environment and the lives of the people have got transformed without the governments having to incur heavy expenditure. Embankments can be constructed through local effort by employing local labour. Desiltation of tanks is a continuous process and the fertile silt can be put back to the fields.

Construction of contour ditches to collect water from hill slopes is an important water-harvesting technique. Hardly any attention has been given to this essential practice which aims at arresting the flow of water allowing it to percolate and charge the groundwater reservoirs. Construction of such ditches and planting of trees in the catchment area will prevent soil erosion and will greatly augment groundwater storage.

Need for new approach — River Authorities

Establishment of River Boards or River Authorities with responsibilities for developing the entire basin or

sub-basin is a step which should no longer be postponed. A start has to be made towards collection of accurate hydrological data relating to resource availability as well as extent of utilization for every major basin and sub-basin in the country. Public should have access to information so collected by official agencies. Educating the intelligent farmer and making him understand the paramount need for conservation of water is the primary task that awaits our scientists, technologists and administrators. A system of licensing is inevitable if water has to be allocated among different users equitably. All users of water, whether surface or groundwater, should be subject to such a licensing system by the river authority. Such authorities should be manned by representatives of the user organizations ably assisted by scientists with knowledge of public water supply. Decisions should not be imposed from above, but arrived at through general consensus. In such a system, the beneficiaries can be expected to come forward to pay the full price of the irrigation water they utilize. In fact, the spectacular developments in groundwater irrigation has been made possible through initiative of individual farmers.

Water conservation will become effective when the whole system is self-supporting, the users of the resource willingly coming forward to share the costs of distribution. Administrative expenses will then get spread among all the water users equitably. The whole system should be based on self-reliance and autonomy without interference from any outside agency.

The above is not an impracticable suggestion. It should be given a trial in respect of a few smaller basins initially and extended to larger basins as the benefits of the scheme become apparent. In fact, enlightened farmers have taken to progressive methods like drip and sprinkler irrigation. These efforts are on an individual basis. No organized effort by village communities as a whole has been attempted. What is urgent today is the realization that construction of large dams and persisting with wasteful practices like flood irrigation is not going to improve agricultural production. Bold innovative thinking is necessary. Clamour for doles and subsidies on the part of farmers should end. They should become self-reliant. Agriculture should get organized as an industry with maximum scientific and technological input.

River authorities should also concern themselves about the up-keep of tanks within the basin. Tanks are an essential part of village life. They serve to recharge the groundwater reservoir and making water available to dry-land areas downstream by means of wells. They afford the best means of storing rain water where it falls. Priority attention should, therefore, be given to renovation of tanks, by desilting them, and lining the canals. Managemenet of tanks should be left to river authorities which can sell the water to farmers and thereby find the resources for maintenance and upkeep.

I am here tempted to quote the eloquent words of Burke, in praise of work leading to the construction of tanks. Speaking about the tanks of the Carnatic, he has said:

> These are the monuments of real kings, who were the fathers of their people, testators to a posterity which they embraced as their own. These are the grand sculptures built by ambition; but by the ambition of an insatiable benevolence, which not content with reigning in the dispensation of happiness during the contracted time of human life, had strained with all the reachings and gropings of a vivacious mind to extend the dominion of their bounty beyond the limits of Nature and perpetuate themselves through generation and generations the guardians and protectors and nourishers of mankind.

It is this spirit of service that should animate our scientists, and our governments. Bold persistent experiments in making the country self-sufficient in food and water is the need of the hour. Agriculture has to be modernized. The country cannot afford the luxury of uncontrolled flood-irrigation any longer. If things are allowed to drift without corrective action being taken, the country will face a major water crisis by the end of the century. Unless urgent action is initiated for adopting water-conservation measures, chaotic conditions will prevail causing distress and a great deal of unrest. Scientists in the country have not given as much attention to the solution of these basic needs of our people. It is time they concern themselves with the problems of agriculturists and problems of the countryside. A reorientation in their outlook and setting of priorities is necessary.

India, it must be emphasized again and again, is fortunate compared to many other parts of the world in respect of her water resources. The resources are adequate. Soil is good. There is enough sunshine throughout the year promoting vigorous plant growth. There is abundant manpower, skilled in agricultural operations. What is necessary, therefore, is a scientific assessment of the extent of resources available and equitable application of that resource to our maximum advantage. Adoption of right technology, avoiding wastages at all points is urgent. Mere shouting of slogans and reverting to the law of the jungle will not solve problems. We are citizens of one country. The prosperity of every part of this vast country should be the concern of every one of us. Inter-State rivalry in these matters of sharing a common resource is most unhealthy and should not be allowed to go out of control. All our energies have to be directed towards ways of making the best use of both surface and ground water resources wherever they are available.

> या आपो दिव्या उत वा स्रवन्ति खनित्रिमा उतवा याः स्वयं जाः ।
> समुद्रार्थाः याः शुचयः पावकास्ता आपो देवीरिह मामवन्तु ।।

[The waters which are from the heaven, and those which flow after being dug, and those which spring up by themselves, the bright, pure waters that lead to the sea, may those divine waters protect me]

{*Rig Veda*, VII, 49.2, Max Mueller, 1891}

The prayer of our ancient seers is as relevant today as it was more than three thousand years ago!

Some reflections on science in the low-income economies*

Roald Hoffmann

Several worlds?

It is, in the end, as it was in the beginning, only one world. While it may useful, pragmatically, to partition this blue, green and beige globe into regions which share roughly common degrees of development, everything operates to defeat the significance of such groupings. First, there is the uniqueness of the human condition. The vagaries of evolution produce a people (usually peoples, contending for the same small piece of tillable land), a language (dialects dividing them), a culture (cultures). Beer and bargaining are there around the world, but the local brew tastes different, and the way I buy a rug is surrounded by a different protocol of niceties with the dealer in the markets of Jerusalem, Moscow and Montevideo. Every 'third-world' country is different: the way things don't work in it, and the way things do, are distinct.

At the same time, the very success of modern technology operates to defeat the assignment of distinguishing features to economic systems or to countries of vastly different gross national products. The air is filled with the same electromagnetic radiation. The high standards and low problems of the affluent societies penetrate via radio and television, via print, into the most isolated crannies of the poorer countries. It is possible for an unscrupulous American company to sell for a while a contaminated fertilizer in country *Y*, but it is impossible to keep the concerns of a European community about antibiotics or growth factors in animal husbandry from reaching the ears of the people of *Y* who are in charge of agriculture, and who have often been educated in Europe.

So, diverse in the extreme, fated by the workings of evolution to be such, the world is uniquely many. And it is one. Which is no excuse for immobility in the face of natural or man-made disasters, of great suffering and a growing economic gap between people.

Science

What is the role of science in this world? Science is a Western European social invention. Together with techology, it has transformed this world. Science is a remarkably successful system for acquiring reliable knowledge (not truth, which has an ethical connotation), for harnessing the mental and physical energies of fallible individuals to understand and change part — not all, only part — of our condition.

Scientific invention, be it the wheel and the making of aspirin, is transplantable anywhere. But its origins are European. Technologies and protochemistries developed everywhere where human beings dealt with survival and aspired to comfort. The achievements of Chinese chemists and the metalsmiths of Benin or the Andes, the skills of Mediterranean dyers, were great. But science as such evolved in 1500–1800 in Europe, and nowhere else. Chinese chemists had incredible successes in the formulation of inks, in metallurgy, and native medicine, but in the end Chinese chemistry could not free itself from its alchemical steering force.

It took the fluid economies of Europe, enriched by colonialism, the contentious ethic of striving religions, the scholarly revival of classical knowledge, the beginnings of social mobility, and the invention of movable type to put into place, ever so slowly, a way of knowing that became science.

In our times, some popularizers of science (authors of books such as 'The Tao of Physics') have claimed that

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