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Part II

ENVIRONMENTAL ASPECTS

Impact of Irrigation on Environment with Special Reference to the ECWA Region

I. Nahal

INTRODUCTION

Irrigation is the most productive input for agriculture in arid regions. Compared with rainfed agriculture, irrigation can lead to a sixfold increase in yields of cereals and a four to fivefold increase in root crops. Therefore, irrigation in arid regions can play a vital role in meeting the food requirements of the region. Irrigation increases the stability and efficiency of cropping systems and diminishes the risks of drought and desertification. The planting of trees and a more permanent vegetation cover, which may replace fallowing, becomes possible. Irrigation can be used to reclaim desert lands by supporting a plant cover and leaching of saline soils. An irrigation system serves as an important economic resource to provide a basis for settlements and related social amenities in areas that otherwise support sparse populations.

However, the history of irrigated agriculture in the ECWA region, particularly in the plains of the Euphrates and Tigris rivers, has not always recorded success. Some past schemes - and some very recent ones - suffered severe setbacks through silting, waterlogging, salinization as well as social and political changes. Some schemes proved excessively expensive. In other projects farmers never felt at home in their new setting or abandoned their land. In the ECWA region the development of irrigation can be justified from the point of view of economic necessity, but due care should be taken of health hazards.

Irrigation is often costly, technically complex and requires skill and experience to realize full benefits. Moreover, it triggers changes in all the major ecosystem regimes (soil, water and atmosphere) which may have undesirable consequences leading to desertification, unless appropriate countermeasures are incorporated into the system. Irrigation also interferes with the prevalent soil regime by introducing moisture in a quantity and sometimes quality which modifies the arid and semi-arid ecosystems. The ecological changes create conditions for foreign plant and insect species, including the vectors of malaria and schistosomiasis. It is on record that the percentage of one population infected with schistosomiasis increased from 2 to

75 per cent when perennial irrigation was introduced (Obeng, 1977). Again, interference with the hydrological cycle may cause underground flooding and waterlogging which, with the deposition of salt, may defeat the entire purpose of irrigation. Fortunately, however, in most development projects which produce environmental hazards, timely precautions can minimize the adverse effects. Thus, efforts should be focussed on maximizing the benefits of irrigation in arid and semi-arid zones on a sustained basis with provisions to overcome the detrimental effects on the environment and man himself.

IMPACT OF IRRIGATION ON SOIL AND WATER REGIMES

The ultimate goal of irrigation is to maintain the moisture content of the unsaturated soil zone, especially the root zone, within the range ensuring optimum crop yields. The modification of the moisture content due to irrigation may, however, considerably alter the hydrological cycle, quantitatively and qualitatively, because the conditions prevailing in this relatively thin layer determine the ways in which precipitation, having reached the land surface, returns to the atmosphere, creates surface runoff or infiltrates. The hydrological changes caused by irrigation are not always localized but may influence large areas interconnected by the hydrological cycle extended to large regions covering international river basins. The problems may thus require multinational efforts for their solution or mitigation. An international symposium on arid land irrigation in developing countries held in 1976, in Alexandria, Egypt, summarized the changes expected from alterations of the moisture content of the root zone in arid lands due to irrigation. Some details are given as follows:

a. Modification of the atmosphere branch of the cycle:

Increase in evaporation due to irrigation is only limited because the total amount of water evaporated and transpired cannot be higher than the potential evapotranspiration (taking into account the oasis effect). The maximum possible increase in evapotranspiration provides a relatively small amount of vapour related to the moisture transported by the air masses. Thus, only minor changes are expected in the total amount and pattern of precipitation as a result of irrigation. A statistical climatological study made in the Great Plains of Texas in North America has speculated that under very dry conditions, the additions of water vapour produce clouds and precipitation (Scheckedanz and Ackermann, 1976). For planning and power design, however, the difference between potential and actual evapotranspiration has to be calculated.

b. Modification of surface runoff:

Increase in the amount and intensity of catchment runoff results in higher erosion potential and greater sediment transport. Control of river discharge by reservoirs and decrease of solids transported in streams because of reservoir retention result in deterioration of river beds due to smaller sediment transportation. The settling of suspended load in reservoirs causes not only decrease in the available storage capacity, but also removes a part of plant nutrients from the water.

c. Modification of the ground water regime:

The positive accretion increases, the negative accretion decreases and water table below irrigated lands rises. The development of horizontal ground water flow from the irrigated area towards the neighbouring non-irrigated lands raises the water table of the latter and develops a "dry-drainage area". Leaching of the irrigated soils and transportation of salts by ground water flow accelerates salt accumlulation under the dry drainage areas.

d. Modification of water quality outside soil moisture zone:

Salt concentration increases during storage, conveyance and distribution of water due to evaporation. Other qualitative changes include change in temperature and suspended load, pollution caused by nutrients and pesticides from surface runoff and by salts transported by water percolating into the canals, and deterioration caused by the effluent of the drainage systems.

Qualitative changes caused by high salt content of the effluent water are the most serious. The Euphrates river is an example where the increasing salt content raises international problems. Entrophication of waters occurs due to fertilizers applied on cultivated lands. Data collected in the U.S.A. and Hungary show that most of the nitrates and phosphates in rivers and lakes originate from agricultural lands (Hotes and Pearson, 1977; Kovács, 1977). In some instances the extraction of underground water may cause intrusions of sea water or connate brines into the aquifers which may render the water in the wells in the intrusion path unsuitable for domestic, industrial or irrigation purposes. The deterioration is usually gradual. Reduction in pumping drafts, artificial recharge by flooding or injection wells and barrier injection or withdrawal wells can successfully halt and in some cases reverse the intrusion.

Inefficient water management in the arid and semi-arid zones leads to water wastage and, hence, loss of productivity. Such wastage occurs at several points in the system through seepage and evaporation during storage, conveyance and distribution as a result of bad timing of water application or poor techniques of field application. When soils are inadequately leached and poorly drained, excess evaporation and transpiration results in salinization and alkalinization of soils. It is particularly a problem where artificially raised water tables, waterlogging and capillary rise or pollution from salinized outflow prevent proper leaching of salts. Salinization also occurs when the irrigation water has a high salt concentration. This results in lowered yields, restricted choice of crops and, finally, the loss of irrigable lands.

Salinity and waterlogging are common problems in the ECWA region, because of inefficient water use, lack of adequate drainage and poor water quality. The percentage of salt-affected and waterlogged soils already amounts to 50 in the Euphrates Valley in the Syrian Arab Republic and 30 in Egypt (El Gabaly, 1977). In Iraq, in the year 1950 about 60 per cent of the agricultural lands in the south Mesopotamian plains was affected by salinization as a result of improper irrigation and drainage. Twenty to thirty per cent of these lands became unfit for agriculture and were finally abandoned. It has been estimated that one per cent of the land is lost each year as a result of salinization. In 1970, less than a decade after Jordan initiated irrigated agriculture in the Jordan Valley, 12 per cent of the project area was affected by salts, and the damage has increased every year since then.

Some irrigated regions are blessed with adequate natural underground drainage or an efficient flow of surface water. In Egypt, for example, the annual flooding of the Nile river flushed salts out of the soil each year. This is why the Nile Valley, in contrast with the Euphrates and Tigris plains, has remained one of the world's most productive and densely populated areas for thousands of years. Egyptian irrigation projects outside the Nile flood plain have over the last century developed severe salinity problems. The Aswan Dam, which harnessed Nile waters in the sixties, allowed extensions of the irrigated area but eliminated the natural soil desalination process in the Nile Valley. Improper watering and tillage as well as leaching of soils containing gypsum can also damage the soil structure and cause compaction resulting in poor aeration, reduced transportation of irrigated water and lowered yield. Therefore, irrigation and tillage call for special skills to increase and sustain productivity. Insufficient provisions for drainage in many countries have caused serious problems for irrigation development. Dams and major canals are always prestigious projects. But development of systems to deliver water on time and in adequate quantities to the individual farmers and proper field drainage are often overlooked.

IMPACTS OF IRRIGATION ON AQUATIC ECOSYSTEMS

Large irrigation projects in arid and semi-arid zones cause serious ecological changes such as (a) creation of new ecological systems related to water bodies (reservoirs, irrigation canals, drainage ditches, etc.) and (b) modification of the terrestrial ecosystems related to practices of irrigation, ploughing, farming, etc. Man-made lakes, irrigation canals and drainage ditches become perennial water bodies that provide media for aquatic life alien to the arid lands. These changes should be taken into consideration by the planners before the implementation of the projects. Canals and distribution systems, rich in organic matter and nutrients but unsatisfactorily maintained, are invaded and choked by dense growth of algae and aquatic weeds. In Iraq, when irrigation was introduced in the Greater Mussayeb Project, the growth of many hydrophyllous plants, including Phragmites communis, Typha angustata and Cyperus rotundus was observed along canals and ditches. Due to lack of proper management of irrigation and drainage networks, the plant growth increased and often blocked the water flow. In the Nile, there occurred changes in the aquatic weeds and the associated system following the construction of the High Dam. Water hyacinths suddenly became a serious problem in 1964.

In certain cases, the presence of aquatic plants may yield some benefits. Some are food for fish and protection for fish fry and invertebrates, which are essential for the ecological balance of the medium. However, the spread of certain vectors of diseases of man and animals is perhaps the main cause for the general concern over the irrigation systems. For example, although weeds are not necessary for <u>Bulinus</u> and <u>Biomphalaria</u>, which are intermediate hosts for schistosomiasis (or bilharziasis), the snails tend to flourish under their protection and support.

Modification of the aquatic ecosystems may also increase disease transmitting mosquitoes.

The problem of aquatic weeds in irrigation systems should be seen as an ecological response of the environment to the manipulation of hydrological resources by man in the arid and semi-arid zones. It is a problem which solution requires an interdisciplinary approach. The need for cooperation between aquatic biologists, hydrologists, engineers, economists and agriculturists at all stages of planning, implementation and management of irrigation systems is essential. Programmes to deal with potential aquatic problems must be incorporated in the project planning and management proposals.

IMPACT OF IRRIGATION ON NATURAL VEGETATION AND WILD FAUNA

The introduction of irrigation in arid and semi-arid zones causes disturbances in the natural vegetation, flora and fauna. In the Greater Mussayeb Project area in Iraq, before the introduction of irrigation, the natural vegetation and wild fauna were in a balanced ecosystem, typical of arid lands. The natural vegetation was of secondary origin, particularly halophytic communities (mostly Chenopods). Thorny shrubs were very common in uncultivated lands. This vegetation served as primary producer and hiding for many wild animals, such as pigs, hyaenas, rabbits, foxes and wolves. The ecosystem's secondary producers and consumers were equally well-adjusted. When irrigation was introduced, these balanced ecosystems were disturbed. Hydrophyllous plants increased and a large variety of other weeds appeared and flourished. Disturbances also affected the wild fauna. Wild pig and deer almost completely disappeared and fowl such as wild duck increased. The populations of birds such as sparrows, pigeons, doves and rooks increased, while birds like black kites and partridges decreased. Some wild birds such as falcons almost disappeared from the area. Reptils, in general, decreased. Similar changes in natural vegetation and wild fauna have been observed in Egypt after the construction of the High Dam (Imam, 1977; Mahir Ali, 1977).

In Egypt some unpleasant changes appeared after the construction of the High Dam. Some of the perennial weeds such as Cynodon dactylon, Cyperus rotundus and Convolvulus are now very common. There was a noticeable increase in the number of gazelle herds, ibex and barbary sheep. There was also an increase in some insect pests like grape moth (Polychrosis botrana), corn stalk borer (Chile agamemnon) and cotton leafworm (Spodoptera littoralls), (Mahir Ali, 1977). In Egypt irrigation also had a great effect on the microbial populations of desert soils (El Abyad, 1977), and on soil fauna (Ghabbour, 1977). Therefore, in irrigation schemes efforts should be made to preserve and propagate beneficial flora. In schemes for drainage of wet lands consideration should be given to the preservation of the water fowl habitat. In land use policy due attention should be paid to wildlife conservation.

IMPACT OF IRRIGATION ON PUBLIC HEALTH

The establishment of an irrigation scheme may render a region more vulnerable to diseases. Serving as a transfer medium and a habitat for vectors and intermediate hosts, water can carry toxic chemicals and many communicable diseases. Very often, the negative effects of irrigation are related to wrong irrigation practices and can be alleviated by appropriate management. Case studies of the Greater Massayeb Project in Iraq and the Mona Experimental Reclamation Project in Pakistan have revealed that the transmission of water-related diseases such as schistosomiasis, malaria and typhoid fever is accentuated by mismanagement of irrigation water resulting in the formation of stagnant pools. Lack of clean water supplies and sanitation under conditions of dense irrigation settlements is associated with typhoid fever and intestinal parasites (United Nations, 1977). Many diseases are transmitted by water. Malaria and schistosomiasis pose serious health problems. Therefore, it is necessary that close collaboration should be established between irrigation and health authorities at an early stage of the project life.

The United Nations Environment Programme (UNEP) is seriously concerned about the ecological and habitat control of schistosomiasis. Although molluscicides provide the best known method of breaking the disease cycle, they are used sparingly because of adverse side effects. Also, they are expensive beyond the means of most developing countries. Therefore, UNEP advocates an effective mobilization of all available resources and methods in an integrated action-oriented programme which views health as an essential element of the overall development process, especially in irrigation development schemes. The recommended measures include drainage, stream canalization, lining of canals, land levelling and filling to eliminate low spots and borrow pits, seepage control, piped or covered canals and drains, weed control and improved water management.

SOCIO-ECONOMIC IMPACT OF IRRIGATION

Many irrigation schemes in the ECWA region are faced with social and economic problems arising from the new skill requirements in farming, high investments in labour and capital and high population density. The Greater Massayeb Project in Iraq has demonstrated that sociological problems in the irrigation schemes are more difficult to tackle than the technical ones. The adoption of a system which requires the combined presence of special managerial skills, a well organized administration, teams of engineers, researchers, economists, technicians, social workers and a farming population receptive to new methods and advice, often means a complete change in the life style of the technical personnel as well as the farming population (United Nations, 1977). Furthermore, efforts in this field are unlikely to succeed if not backed up with a competent extension service and satisfactory credit and marketing systems. In government-contracted projects involving resettlement, it is important to determine the appropriate size of the farm unit, taking into account farmers' needs and their capacity to cultivate under intensive farming conditions. Another sensitive issue is housing for the settlers. In the case of the Greater Mussayeb Project, for example, most settlers had build mud houses. These structures were naturally adapted to the climate and local lifestyle. Most of the masonry houses build by the government were, therefore, not occupied. The rejection of government housing was due to the lack of traditional style intimacy, small size, too modern design and location too far from farms.

The experience in the ECWA region suggests that development of irrigated agriculture needs (i) well-organized agricultural extension services, (ii) demonstration farms, (iii) cooperatives to assist with purchasing, marketing and credit, (iv) ancillary agricultural activities such as poultry and livestock farming, (v) amenities and services appropriately close to settlements, including schools, health services and housing and (vi) agriculture-based industries.

RESEARCH NEEDS

In arid ecosystems, human intervention through irrigation necessitates understanding the physical, biological and social processes which it triggers or interrupts. Knowledge of these processes would increase the capacity of the nations to cope more effectively with possible environmental effects from irrigation and drainage. Nothing short of a long-term research programme on an international scale can provide answers to the whole array of questions. Such researches should be carried out by a multi-disciplinary team orchestrated under a single authority so that different judgements can be combined. There should be no illusions about the obstacles to this type of effort. Yet, without such an attempt, answers to irrigation and drainage problems in arid zones cannot be found.

HOW TO AVOID OR MITIGATE ENVIRONMENTAL EFFECTS

In order to avoid or mitigate adverse environmental effects of irrigation and drainage schemes in arid zones, in addition to the economic aspects of perspective flows of costs and benefits, the following questions should be addressed to any proposed irrigation scheme:

a. Has adequate provision been made for drainage and leaching to permanently maintain the quality of soil and water in the root zone?

b. Has the full range of alternative measures for achieving efficiency in water use been appraised?

c. Has the project study examined the possible effects of changing the hydrological and soil regime in the area upon aquatic and adjoining terrestrial ecosystems?

d. Has the irrigation scheme assigned costs to social, health and economic measures which would be required to realize anticipated benefits and social stability?

e. Has the well-being of the population been taken into account?

The funding agency and the project scientists and engineers have a common interest in pursuing these five questions for candid answers to the extent permitted by the current state of knowledge.

UNEP PRIORITIES AND ACTIVITIES

The achievement of development without destruction of and in harmony with the environment is basic to the concept of UNEP. The Environment Fund administered by UNEP encourages activities aimed at continued development towards a better life for all peoples and supports critical components of development programmes which promote environment safety. UNEP encourages a systems approach to environmental considerations. Development programmes normally tend to follow sectional interests which need coordination in order to ensure a balanced and safe environment. The implications of arid land irrigation are so serious that the Governing Council of UNEP has identified it as a priority area. In spite of problems that result from irrigation, UNEP feels optimistic that it can be made environmentally safe. But, a better understanding of the processes which produce adverse effects is required. At its Fourth Session, the Governing Council of UNEP decided that efforts should be concentrated on (i) the quality and quantity of rural water supplies, avoiding damage to the environment and undesirable effects on human health and (ii) the establishment of training centres for water resources management.

RECOMMENDATION OF THE UNITED NATIONS CONFERENCE ON DESERTIFICATION

In 1974 the World Food Conference established two major priorities for the joint development of land and water resources. The first pertains to the improvement and rehabilitation of existing irrigation schemes, which are not being fully utilized, with the result that potential output is lost, water wasted and productive land damaged. It was estimated that remedial action within a ten-year programme (starting from 1975) should extend to some 50 per cent of the 90 million ha irrigated land in the developing countries. Second, a 25 per cent increase in irrigated area is targeted for the ten-year period. In any country the relative importance of new schemes and improvement of existing ones will depend upon economic and social considerations together with other constraints such as the avilability of water or land. At the global scale, the urgency concerns the rehabilitation and improvement of existing schemes.

To help achieve the goals and targets of the World Food Conference, the United Nations Conference on Desertification, held in Nairobi in 1977, adopted the following recommendation : "It is recommended that urgent measures be taken to combat desertification in irrigated lands by preventing and controlling waterlogging, salinization and alkalinization; by reclaiming deteriorated lands; by improving irrigation and drainage systems;by modifying farming techniques to increase productivity in a regular and sustained way; by developing new irrigation and drainage schemes where appropriate, always using an integrated approach; and through improvement of the social and economic conditions of people dependent upon irrigation agriculture" (United Nations, 1977).

For implementing this recommendation, the following national action is called for :

a. Improving water management in order to reduce losses due to irrigation through such measures as :

(i) selection of irrigation methods appropriate to the natural conditions (climate, topography, soils, depth and salinity of ground water, quality and quantity of irrigation water, etc.) and socio-economic conditions (investment and maintenance costs, energy and labour requirements, marketing, etc.), and guaranteeing as uniform a supply of water as possible, thus reducing water losses during irrigation,

(ii) reduction of water losses during storage, transportation and distribution through improved design, lining, construction and maintenance of canals and appropriate irrigation methods,

(iii) adoption of appropriate water pricing policies with a view to encouraging the efficient use of water with due regard to social objectives,

(iv) watershed management to reduce sedimentation and flood risks,

(v) determination of water requirements of crops and establishment and enforcement of appropriate irrigation schedules,

(vi) appropriate design of field and crop systems in schemes based on ground water in an effort to sustain water supplies,

(vii) proper maintenance, control and operation of distribution systems, joint use of surface and ground water and recycling of waste water and

(viii) advising farmers on the efficient application of water and associated tillage to retain soil moisture.

b. Improving drainage and salt-leaching in irrigated lands, where this is economically feasible and sociably justifiable, through such measures as:

(i) investigation of soil-water properties, return flow characteristics, hydrogeology and salinity of ground water and soil geochemistry before and after construction or reconstruction of irrigation schemes,

(ii) providing adequate drainage systems to maintain harmful ground water below the active root zone,

(iii) providing adequate water for the leaching of salts,

(iv) undertaking reclamation of salinized, alkalinized or waterlogged soils and

(v) establishing a network of stations to monitor ground water and salinity conditions.

c. Improving irrigated farming systems through such measures as :

(i) devising appropriate cropping systems in the light of soil surveys and the availability of water,

(ii) establishing pilot or demonstration projects,

(iii) introducing new species and varieties of crops, including the selection and development of salt-tolerance crops where fresh water is limited and agriculture is possible only with saline water and

(iv) advising farmers through effective and sound extension services on appropriate farming and irrigation techniques, the selection of crops to be grown, lands to be irrigated on the basis of water quality and the proper use of fertilizers and pesticides.

d. Establishing new irrigation schemes, as appropriate, taking into consideration the need for:

(i) planning and implementation of irrigation programmes in such a way that the provision of surface and subsurface drainage is treated as an integral and indispensable component,

(ii) environmental impact statements as part of the planning of hydraulic structures for irrigation or energy production, including consideration of the positive and negative consequences of action that influences the environment,

(iii) prediction of salinization, alkalinization and waterlogging hazards (based on factorial salt-balance studies) due to a given action, determination of the possibilities for their prevention, and recommendation of preventive measures,

(iv) appropriate schemes of land division that would facilitate the effective application of the above measures and

(v) studies of soil properties in experimental plots to be established within each irrigation district.

e. Improving the social and economic conditions of people earning their livelihood from irrigated agriculture by :

(i) providing capital and/or purchasing and marketing facilities, for example, through cooperatives,

(ii) encouraging ancillary agricultural activities such as livestock rearing or tree culture,

(iii) providing adequate sanitation, domestic water supplies and control of water-borne diseases and

(iv) providing adequate infrastructural and social services in newly established settlements.

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Natural Equilibria and Irrigated Agriculture

Omar M. A. Mukhtar

INTRODUCTION

Irrigated agriculture dating back to early civilizations is not only a way of producing crops in arid and semi-arid parts of the world or where rainfall is short of crop needs in amount and/or distribution, it is also a way of life. Irrigation is more widely practiced in the developing countries, but the people in developing countries lack facilities and necessary know-how. Modern irrigation technology, promoting the use of sophisticated equipment and thus increasing the efficiency of water use has evolved mostly in the developed industrialized countries.

In many developing countries man exists in arid and semi-arid areas of erratic rainfall where irrigation is a must to produce crops and stabilize agricultural production. But irrigation has some serious implications. The implications and hazards of irrigation technology, particularly in large-scale irrigation projects have necessitated the need for field drainage and land reclamation. An exposé is made here of some important issues and of the concept of irrigation for agricultural development, with an emphasis on nature's environmental balance.

NATURAL BALANCE-CYCLIC CONTINUITY OF ENERGY EQUILIBRIA

Global sciences are receiving more attention as the space sciences are advancing. The phase distribution of water in the hydrosphere is a common introduction to the students of hydrology, in which approximate estimates of the global scale are usually given. In natural sciences, however, the mechanism or the methodology to evaluate natural resources of land and water are not yet quite identified. Efforts have been made at the national, regional and world levels to make inventories of the soil/land and water resources.

Available data and indicators underscore the importance of understanding the mechanism of operation of the Universe. This may sound colossal, yet the major resources available to man are inseparable parts of this mechanism, particularly in respect of hydrological cycles of climate and land masses.