MAB report series No. 40

Alexandria
24-27 February
1976

Programme on Man and the Biosphere (MAB)

Regional meeting on integrated ecological research and training needs in North East Africa and in the Near and Middle East, with emphasis on the ecological effects of irrigation derived from large river basins

Organized jointly by Unesco and UNEP

Final Report

Unesco 1978

Previous reports in this series :

1. *International Co-ordinating Council of the Programme on Man and the Biosphere. First session. Paris, 9-19 November, 1971.*

2. *Expert panel on the rôle of systems analysis and modelling approaches in the Programme on Man and the Biosphere (MAB). Paris, 18-20 April, 1972.*

3. *Expert panel on Project 1 : Ecological effects of increasing human activities on tropical and subtropical forest ecosystems. Paris, 16-18 May, 1972.*

4. *Expert panel on Project 12 : Interactions between environmental transformations and genetic and demographic changes. Paris, 23-25 May, 1972.*

5. *Expert panel on Project 5 : Ecological effects of human activities on the value and resources of lakes, marshes, rivers, deltas, estuaries and coastal zones. London, 19-22 September, 1972.*

6. *Expert panel on Project 3 : Impact of human activities and land use practices on grazing lands : savanna, grassland (from temperate to arid areas), tundra. Montpellier, 2-7 October, 1972.*

7. *Expert panel on educational activities under the Man and the Biosphere Programme (MAB). Paris, 5-8 December, 1972.*

8. *Expert panel on Project 6 : Impact of human activities on mountain ecosystems. Salzburg, 29 January-4 February, 1973.*

9. *Expert panel on Project 13 : Perception of environmental quality. Paris, 26-29 March, 1973.*

10. *International Co-ordinating Council of the Programme on Man and the Biosphere. Second session. Paris, 10-19 April, 1973.*

11. *Expert panel on Project 7 : Ecology and rational use of island ecosystems. Paris, 26-28 June, 1973.*

12. *Expert panel on Project 8 : Conservation of natural areas and of the genetic material they contain. Morges, 25-27 September, 1973.*

13. *Expert panel on Project 11 : Ecological aspects of energy utilization in urban and industrial systems. Bad Nauheim, 16-19 October, 1973.*

14. *Working group on Project 6 : Impact of human activities on mountain and tundra ecosystems. Lillehammer, 20-23 November, 1973.*

15. *Consultative group on Project 9 : Ecological assessment of pest management and fertilizer use on terrestrial and aquatic ecosystems (Part on fertilizers). Rome, 7-9 January, 1974.*

16. *International working group on Project 1 : Ecological effects of increasing human activities on tropical and subtropical forest ecosystems. Rio de Janeiro, 11-15 February, 1974.*

17. *Task force on the contribution of the social sciences to the MAB Programme. Paris, 28 February-2 March, 1974.*

18. *Regional meeting on integrated ecological research and training needs in the Sahelian region. Niamey, 9-15 March, 1974.*

19. *Expert panel on Project 2 : Ecological effects of different land use and management practices on temperate and mediterranean forest landscapes. Paris, 16-19 April, 1974.*

20. *Task force on pollution monitoring and research in the framework of the MAB Programme. Moscow, 23-26 April, 1974.*

21. *International working group on Project 5 : Ecological effects of human activities on the value and resources of lakes, marshes, rivers, deltas, estuaries and coastal zones. Paris, 13-17 May, 1974.*

22. *Task force on criteria and guidelines for the choice and establishment of biosphere reserves. Paris, 20-24 May, 1974.*

23. *Regional meeting on integrated ecological research and training needs in the Andean region. La Paz, 10-15 June, 1974.*

24. *Expert consultations on Project 9 : Ecological assessment of pest management and fertilizer use on terrestrial and aquatic ecosystems (Part on pesticides).*

25. *International working group on Project 3 : Impact of human activities and land use practices on grazing lands : savanna and grassland (from temperate to arid areas). Hurley, 2-5 July, 1974.*

26. *Regional meeting on integrated ecological research and training needs in the South East Asian region. Kuala Lumpur, 19-22 August, 1974.*

27. *International Co-ordinating Council of the Programme on Man and the Biosphere. Third session. Washington, D.C., 17-29 September, 1974.*

28. *Regional meeting on integrated ecological research and training needs in Latin America, with emphasis on tropical and subtropical forest ecosystems. Mexico City, 30 September-5 October, 1974.*

29. *Expert panel on Project 4 : Impact of human activities on the dynamics of arid and semi-arid zones' ecosystems, with particular attention to the effects of irrigation. Paris, 18-20 March, 1975.*

30. *Regional meeting on the establishment of co-operative programmes of interdisciplinary ecological research, training and rangeland management for arid and semi-arid zones of Northern Africa. Sfax, 3-12 April, 1975.*

31. *Task force on integrated ecological studies on human settlements, within the framework of Project 11. Paris, 2-6 June, 1975.*

32. *Task force on Project 14 : Research on environmental pollution and its effects on the biosphere. Ottawa, 5-8 August, 1975.*

33. *Regional meeting on integrated ecological research and training needs in the humid tropics of West and Central Africa. Kinshasa, 29 August-5 September, 1975.*

34. *Regional meeting on integrated ecological research and training needs in the southern Asian mountain systems, particularly the Hindu Kush-Himalayas. Kathmandu, 26 September-2 October, 1975.*

35. *Regional meeting on integrated ecological research and training needs in tropical deciduous and semi-deciduous forest ecosystems of South Asia. Varanasi, 5-11 October, 1975.*

36. *Regional meeting on integrated ecological research and conservation activities in the northern Mediterranean countries. Potenza, 27-31 October, 1975.*

37. *Expert consultations on Project 10 : Effects on man and his environment of major engineering works.*

38. *International Co-ordinating Council of the Programme on Man and the Biosphere. Fourth session. Paris, 18-26 November, 1975.*

39. *Regional planning meeting of the MAB National Committees of Andean countries, with particular attention to Project 6. Lima, 2-5 December, 1975.*

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SYNOPSIS

A regional meeting on integrated ecological research and training needs in North East Africa and in the Near and Middle East, related to ecological effects of irrigation derived from large river basins, was held in Alexandria, Egypt, from 24 to 27 February, 1976. This was the first regional meeting to take place in the framework of MAB Project 4 entitled "Impact of human activities on the dynamics of arid and semi-arid zones' ecosystems, with particular attention to the effects of irrigation". The meeting was jointly organized by Unesco and UNEP, with the co-operation of the Egyptian Academy of Scientific Research and Technology and the MAB National Committee of Egypt.

The main objective of the meeting was to identify priorities for research and training activities and to explore ways and means of implementing these activities within the MAB Programme and with the co-operation and financial assistance from national, regional and international institutions and agencies concerned.

The meeting was attended by delegates representing the MAB National Committees of Afghanistan, Egypt, Iran, Iraq, Pakistan, Sudan and Syria. Specialists from countries outside the region and representatives of UNEP, FAO, WHO, and ICSU also participated.

The importance of an integrated approach to studies and research. Although the very nature of irrigation schemes shows the interdependencies between physical, biological, technological, human and socio-economic problems, most of the research which has been undertaken on irrigation inside large river basins has too often taken a sectoral approach. A full understanding of the comprehensive and complex "human use systems" based on irrigation is far from being achieved. Guidelines for planners and decision-makers have consequently the same shortcomings. Very often in attempting to deal with problems such as salinization or waterlogging, new difficulties are provoked. The meeting therefore strongly recommended that new efforts be made to apply a more integrated approach to the planning of irrigation schemes.

With this overriding integrated and systems approach in mind, the regional meeting felt it necessary to differentiate between areas where new irrigation schemes are planned or about to be implemented and those existing irrigation schemes which urgently need rehabilitation. For both situations, all participating countries made concrete proposals concerning sites where integrated demonstration projects might be undertaken in the framework of the MAB Programme.

New irrigation areas. The meeting underlined the opportunities provided by new irrigation areas to develop, through co-operative efforts between research workers, planners/decision-makers and the populations concerned, rational land and water management schemes which correspond to the needs and aspirations of the local people. With these points in mind, the following subsystems of the overall irrigation system (or human use system) were identified as possible focal points for interdisciplinary studies:

(1) the land-water interface subsystem at the end of the final canal (soil/plant/water relationship problems, but also legal and cost problems of water distribution, etc.);

(2) the canal subsystem (hydrology and biology of the canals, impact of engineering arrangements, role of canals in community life and health aspects, etc.);

(3) *the economic subsystem (cost benefit analysis, including the account of social costs of disease, resettlement and economic change, structure and functions of the local market system, etc.);*

(4) *the socio-cultural subsystem (family structures, education, role of women, aspirations, housing, etc., and their influence on the functioning of the overall irrigation system).*

Integrated demonstration projects will focus on permanent monitoring of these subsystems and their parameters as well as of the functioning of the overall system during the implementation of a new irrigation scheme. An assessment will be made of the changes provoked by these new irrigation schemes and in particular of the extent to which these changes diverge from original expectations. Co-operation between research workers and responsible planners and decision-makers will ensure that unexpected negative side effects receive attention at a very early stage. Further, integrated demonstration projects in new irrigation areas will also have to deal with a series of specific problems such as the re-use of irrigation water, drainage, the sedentarization of nomads, displacement of people and use of human wastes.

Rehabilitation of existing irrigation schemes. *Integrated demonstration projects of existing irrigation schemes will deal with essentially the same parameters and subsystems as outlined for new irrigation areas, and will also focus on gaining an understanding of the functioning of the overall system. A fundamental difference stems from the fact that the negative side effects of irrigation schemes, such as salinization, waterlogging, water weeds, malaria, schistosomiasis, etc., have existed for a long time, and that rehabilitation of a system which is not functioning properly is the key issue. Consequently, a historical case study approach, rather than long-term monitoring, is particularly appropriate here. Integrated demonstration projects on the rehabilitation of existing irrigation schemes are of extreme importance as the number of people concerned is already high and continuously increasing.*

The meeting again underlined the interactions between economic, socio-cultural, human health and physical and biological environmental problems. Integrated demonstration projects would trace the history of these problems and their interactions in order to reach conclusions useful for planning rehabilitation measures. The meeting noted that the problem area considered most serious is not necessarily the same in each country. The meeting felt that projects in different countries should be complementary in a way that their major foci differ according to the major problem area identified in each country.

Proposed sites and studies. *The following sites for integrated research and demonstration projects were proposed by the delegates.*

In North Afghanistan, the new Kunduz Khan Abad Scheme covers 30,000 ha. To be completed in 3 years, this scheme is destined for wheat, barley, corn and cotton production. The water source is the Khan Abad River. The project area is not populated at present. Little research has been conducted so far. The Helmand Valley rehabilitation project is Afghanistan's biggest irrigation project, comprising 60,000 ha. Settlement and land allocation are still in progress. The main problems are waterlogging and salinization.

In Egypt the West Nubareya Project can be the focus of both new and rehabilitation research work. Begun 15 years ago, reclamation is still going on by phases. Situated in the northwestern part of the country, the project area covers 120,000 ha. Irrigation water comes from the Nile. Research in the newest areas should be directed towards increasing irrigation efficiency and controlling the groundwater level. Problems in the older areas are waterlogging, salinization, human disease, and social problems.

In Iran, the Mahabad Project (21,500 ha) is in an area in which irrigated agriculture has been traditionally practised for many years. A new development project is planned to make more efficient use of land and water resources so as to increase crop and dairy production. Major problems encountered to date are water pollution, salinity and diseases.

In the Thartar Project of Iraq, 6,000 km^2 of the Thartar basin are to be reclaimed with water brought by a 50 km canal from the Tigris River. Background studies have been carried out on vegetation dynamics, fish, fauna and geology. Also in Iraq, the Dujaila Project failed to rehabilitate land reclaimed between 1937 and 1949, due to a faulty drainage system. The soil and groundwater became increasingly saline. The new Five-Year Plan provides for a big agricultural development project in this area, including the creation of agro-industries. Technical questions, resettlement problems, and the introduction of new agricultural practices will be among the objectives of research.

The main objective of the new Tarbela scheme, located in the Indus Basin in northwest Pakistan, is to provide a livelihood through agriculture for persons displaced because of the construction of a dam. Water for irrigation will be drawn from a reservoir on the Indus River. The Mona scheme in the Indus Plain (rehabilitation of 55,000 ha) has been selected for pilot studies in agriculture, groundwater hydrology, and extension work with farmers.

In Sudan, water from the Blue Nile will irrigate the new 150,000 ha Rahad Project, the major aims of which are to produce export crops and improve the welfare of the local population, exptected to approach 100,000 persons. Research efforts will concentrate on developing a procedure for successfully integrating the new tenants, formerly pastoral nomads, into the scheme. In the 11-year old Khashm El Girba Scheme (rehabilitation), composed of 200,000 ha gravity irrigated by the Khashm El Girba Dam, obsession with "modern" development and transformation has resulted in a general negligence of the traditional patterns of people involved. The general low production in the scheme is attributed to human as well as technical factors. In addition to the integration of pastoral nomads, other problems requiring research are crop-water requirements, efficient use of water, and control of endemic diseases.

The Euphrates Project in Syria is proposed for research related to new schemes. The Ghab Project in western Syria (rehabilitation) was the country's first pilot project for irrigation and drainage. It has run into difficulty due to the flooding over of the main drainage canal. Salinity, waterlogging, health problems and sociological problems have also contributed to a decrease in crop production, mainly cotton and sugar beets.

Information and documentation. The meeting recommended a number of activities to be undertaken at national and regional level in order to improve the accessibility and diffusion of information related to integrated research on irrigation and drainage schemes.

Training. Priorities for training activities aimed at several different target groups (scientists, technicians, farmers, project directors) were identified. The organization of regional seminars on topics such as salinity and its control, water and soil management, and health problems was advocated.

Follow-up and implementation. Considering the ways and means of assisting countries in the region to implement MAB Project 4 activities and to strengthen their MAB National Committees, the meeting proposed the establishment of a co-

ordinating committee for Project 4 in the region. This committee would be constituted by the chairmen or delegates of the MAB National Committees of North East Africa and the Near and Middle East. The meeting expressed its wish that UNEP consider providing financial support for launching Project 4 integrated demonstration projects and related training and information activities in the region. The countries of the region also welcome technical co-operation with countries outside the region and bilateral and multilateral arrangements for financial support with these countries.

PREFACE

A regional meeting on integrated ecological research and training needs in North East Africa and in the Near and Middle East, related to ecological effects of irrigation derived from large river basins, was held in Alexandria, Egypt, from 24 to 27 February 1976. This meeting was organized jointly by Unesco and the United Nations Environment Programme with the co-operation of the Egyptian Academy of Scientific Research and Technology and the MAB National Committee of the Arab Republic of Egypt. Its theme is related to Project 4 of Unesco's intergovernmental Programme on Man and the Biosphere (MAB) entitled "Impact of human activities on the dynamics of arid and semi-arid zones' ecosystems, with particular attention to the effects of irrigation." The meeting was attended by representatives of the MAB National Committees of Afghanistan, Arab Republic of Egypt, Iran, Iraq, Pakistan, Sudan and Syria. Specialists from countries outside the region having research experience on irrigation and drainage also participated. UNEP, FAO, WHO and WMO were represented, as was the International Council of Scientific Unions (ICSU). The list of participants is given as Annex 1 of this report. Professor El Damaty (Egypt) was elected chairman of the meeting. Mr. Ahmad Dalaki (Iran) and Mr. Musa M. Musa (Sudan) were elected vice-chairmen. The meeting was opened by the Deputy Prime Minister and Minister of Higher Education of the Arab Republic of Egypt, H.E. Dr. Mohamed Hafez Ghanem (Annex 2).

The main objective of the meeting was to identify priorities for research and training action in integrated ecology in countries of North East Africa and in the Near and Middle East where projects of large scale river basin development based on irrigation already exist, to design integrated demonstration projects and training activities related to these irrigation schemes and to explore the ways and means of implementing all these activities within the MAB Programme and with the co-operation of, and financial assistance from, national, regional and international institutions and agencies concerned.

Each participating delegation compiled for the meeting a national report describing the major problems encountered by irrigation schemes in their country and on-going or planned research and training programmes relating to them.

These reports, in summarized form, are given as Annex 3. All reports were discussed at the meeting. Another important reference document was the report of the expert panel on Project 4, which met in Paris in 1975 (MAB Report Series No. 29).

1. INTRODUCTION

1.1 General content and approach of MAB Project 4

At its first session, in November 1971, the International Coordinating Council for the MAB Programme decided to include in the Programme a project on the "impact of human activities on the dynamics of arid and semi-arid zones' ecosystems, with particular attention to the effects of irrigation" (Project 4). The Council decided at its second session (April 1973) that the topic of grazing lands in semi-arid lands would be included in MAB Project 3 concerning grazing lands and that Project 4 would focus particularly on irrigated ecosystems.

The meeting of a panel of experts on Project 4 was organized by Unesco in March 1975, in cooperation with FAO, WHO, WMO, UNEP and ICSU. The panel gave ample consideration to the impact of irrigation on various elements of arid and semi-arid zone ecosystems, including water regime, ecology and land use, soil and atmospheric conditions, flora and fauna, and population. It suggested that the following research themes be pursued within MAB Project 4:

(1) identification and analysis of the undesirable consequences of major irrigation schemes, based on studies carried out in long-irrigated areas, where it is possible to reconstruct the evolution of the natural environment to its present state;

(2) systematic monitoring of various changes in the environment at the sites of new irrigation schemes;

(3) detailed examination of problems peculiar to isolated and small-scale irrigated areas, especially in small-scale ecosystems with well-defined limits.

The panel furthermore emphasized the need for pilot schemes, training, and cooperation, particularly closer cooperation among traditional research centers in climatically similar regions.

The panel proposed that the first Project 4 activity on a regional scale be the organization of a meeting of the countries in North East Africa, the Middle and Near East in which there are extensive irrigated areas depending on large river basins. As priority was being given by UNEP to arid zone problems and as the International Co-ordinating Council had expressed the hope that cooperative activities be developed by MAB and UNEP in this field, it was decided that this meeting would be organized jointly by Unesco and UNEP.

1.2 The impact of irrigation on arid land

Irrigated agriculture has developed most extensively in arid regions where natural precipitation is inadequate for the production of many crops. Many regions having relatively high annual rainfall may have periods of drought in which there is no crop production or in which crop yields are seriously reduced by lack of moisture. Irrigation in humid and subhumid areas is called supplemental irrigation. However, all irrigation is supplemental to natural rainfall and no definite line can be drawn between areas where irrigation is essential and areas where it is not needed.

While the importance of irrigation in tropical and subhumid areas is recognized (rice is mainly grown on irrigated fields.), the full problems of irrigation agriculture arise only in arid and semi-arid conditions, where agriculture depends on careful management of soil and water. An average annual precipitation of 500 mm is usually taken as the minimum rainfall necessary for agriculture without irrigation. Where rainfall is less than 250 mm, desert conditions exist and water for irrigation must be provided. Arid and semi-arid land forms about 55 percent of the total land area of the world.

The report of the expert panel on MAB Project 4 (see MAB Report Series No. 29, Section 2) views the effects of irrigation by man. The panel emphasized that the effects are on the whole stronger with increasing aridity and with larger areas under irrigation. The topic of this report is the ecological impact of irrigated large river basins in arid and semi-arid zones, which is an extreme, yet very common situation.

In recent years there has been some tendency to emphasize the detrimental environmental effects of big irrigation schemes in arid zones and to underpay the benefits which such schemes have on mankind. The increase of diseases, reduction of fisheries, change in the erosion pattern, salinization of soils, social disturbances etc., however well predicted and taken into account, have received publicity, while the main purposes of the schemes, bringing water and a better standard of living to millions of people, is apt to be taken for granted. As with most of man's large-scale environmental changes, a price must be paid for the added benefit, but only a real understanding of how the system functions can keep this price to a minimum.

For a better understanding of how an irrigation system in the middle of an arid environment functions, a few principles must be clear: First, before irrigation there was a kind of ecological balance in the area, provided that it was not overgrazed. Second, the introduction of irrigation initially upsets the balance thoroughly but a new ecological balance will slowly be replacing the old one. Third, this new balance could result in an unfavorable (i.e. waterlogged and saline) or a favorable (fertile) situation. Fourth, irrigation, drainage and reclamation are three complementary processes which are essential in directing the balance in the desired direction. Fifth, only when the ultimate balance turns out to be "favorable" can one speak of a permanent irrigation system.

The effects of irrigation are many and the interactions between them numerous and complicated. The picture becomes slightly more orderly if we concentrate on analysing the ecological effects of irrigation in a large river basin including its entire watershed. A river basin is a hydrological and often also a geographical unit. A schematized diagram of such a river basin is presented in Fig. 1. Many of the disturbances manifest themselves in the three different areas indicated in the Figure: Section A represents the zone from which the water is taken i.e. the catchment area, generally a mountainous area with higher rainfall. Section B is the irrigated area; it is subdivided into the upper reaches (B2), and river delta (B3). Section C represents the zones adjacent to the irrigated area.

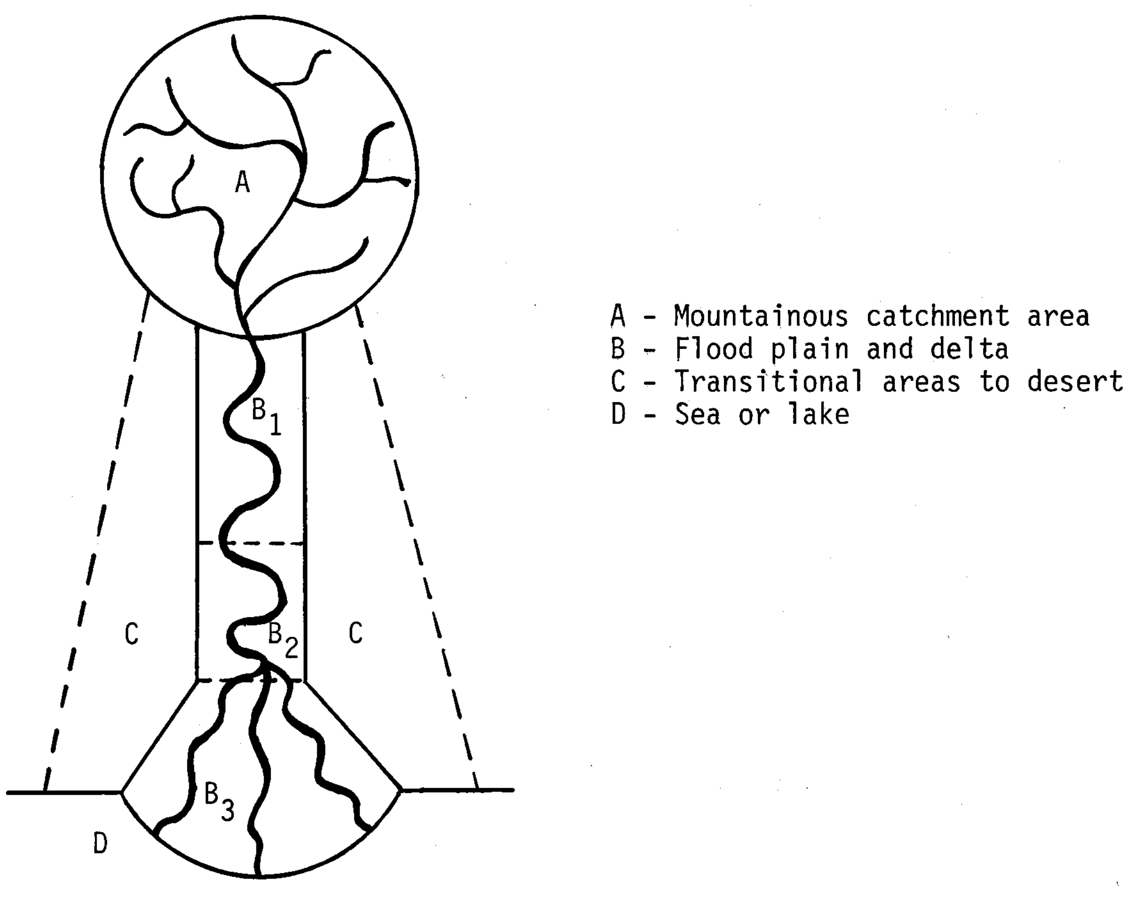

Figure 1. *Schematic diagram of a major river basin in an arid zone.*

The characteristics of these three zones are briefly as follows:

Zone A This is the zone where the water is collected. Dams and storage reservoirs have to be constructed to guarantee a regular flow; soil conservation by afforestation is necessary to keep erosion and hence sediment flow at a minimum. The introduction of irrigation has mainly an impact on the water regime and on land-use patterns.

Zone B This is the area where water is added to dry soil, starting the whole train of activities associated with irrigated agriculture: i.e. crop production, habitation, industry, fisheries, recreation; but also waterlogging, salinity, diseases and resettlement. There is a strong impact on water regime, land-use, atmospheric conditions, flora and fauna, and population. This is the zone which deserves most of our attention as regards research. Solutions to water regime problems in the upper sections of Zone B may cause or aggravate other problems in the lower reaches.

Zone C This zone is less well defined. It comprises the areas bordering the irrigated zone. Occasionally the boundary between B and C is sharp but usually there will be a transition area with occasional irrigation, often supplemented by water from a groundwater source, affecting the groundwater level. The groundwater level is also strongly influenced here by seepage from the adjacent irrigated fields, often causing salinization.

It is from these periferic areas that the nomadic population is taken and resettled in Zone B. However, very often conflicts occur because the previously nomadic people prefer to keep their livestock. In this case it is important to introduce forage crops and imporved pasture in this zone.

The impact is therefore mainly on water regime and on population, but impacts on land use, flora and fauna are also likely to occur .

1.3 Large river basins in the region

Within the region concerned by the Alexandria meeting, there are three very large irrigated river basins with a long history: the Nile basin in Sudan and Egypt; the basin of the Euphrates and the Tigris (Mesopotamia) in Iraq and Syria; the basin of the Indus river (Punjab) in Pakistan.

In Syria, Iran and Afghanistan there are several smaller river basins which contain more recently developed irrigation areas. All existing large river basins in the region in question have their irrigated area in the arid zone and their catchment area in more humid mountain zones. Except for the Helmand River, all rivers empty into the sea forming an estuary or delta area.

The country reports summarized in Annex 3 contain details on the river basins in question. As a background for discussion of the problems of study, some additional information is given below on the three major basins in the region.

The Basin of the Euphrates and the Tigris. The catchment areas of the twin rivers cover an area of 704,500 km^2 of which 359,000 km^2 is in Iraq. The rest is in Turkey, Iran, Syria and Saudi Arabia. A more detailed breakdown is in Table 1.

Table 1. Catchment areas of the Tigris and the Euphrates in square kilometers

River	Mountains	Hills	Plain	Desert	Total
Tigris (S. of Baghdad)	74,385	75,603	15,535	632	166,115
Euphrates (near Hit)	82,330	62,960		118,830	264,120
Wadi Tharthar		2,980	3,715	17,775	24,470
Wadi Hawan				16,770	16,770

The length of the Tigris is 1,718 km; that of the Euphrates is 2,333 km. not including the Kora Sou (450 km) and the Murat Sou (650 km). The average flow of the Tigris near Baghdad between 1906 and 1952 was estimated at 38.8 billion m^3/year and of the Euphrates near Hit (1924-1952) 26.4 billion m^3/year.

As soon as the rivers enter the Mosopotamian Plain they are meandering rivers which become more irregular in the lower reaches. A fundamental fact is that most of the water from the twin rivers does not reach the sea. It is partly used for irrigation, a part evaporates, and a large part just disappears in the marsh region (Ahwar) in the southern part of the plain. Water in both rivers is of good quality for irrigation and domestic purposes although it contains some soluble salts (0,2 - 0,4 g/liter) and a rather high amount of silt (1 - 4 gr/l). Nearly all salt and silt are deposited in the Lower Mesopotamian Plain.

In ancient Mesopotamia, people diverted most of their irrigation water from the Euphrates River. In the area the remains of ancient irrigation canals, two of them among the largest canals of all time, demonstrate the great irrigation skills of these early civilizations. Today, large areas are extremely saline and in all areas the banks of the canals are built high with silt, showing that much labour was required to keep them open.

There is no general agreement on the reasons for the decline of irrigation agriculture in Mesopotamia. Some authors favour the theory of increasing aridity; others conclude that the whole valley between the Tigris and the Euphrates was never under irrigation at one time and the the present water supply is sufficient to irrigate as much land as was ever irrigated at once. But much can also be explained by historical facts. The country was often overrun by warlike nations and the invasion of the Mongols in 1258 destroyed much of the ancient irrigation systems, many of which were never rebuilt.

The Indus Basin. The catchment area of the Indus Basin covers approximately 710,000 km^2, of which 528,000 km^2 is in Pakistan, and the rest in Kashmir, India, Tibet and Afghanistan. The headwaters of the Indus and its 5 main tributaries are in relatively cool, high rainfall areas. The main irrigated area, the Punjab, has a total area of 200,000 km^2 and is situated in an arid and semi-arid region. The length of the Indus River is nearly 3,220 km from its headwaters in Tibet to the sea near Karachi.

The water supply in the irrigated area comes from precipitation, well water, and river water. The river supplies an estimated $1.7 \times 10^{11} m^3$/year. The salt content of the river water, collected at the rim stations, is commonly in the range of 150 - 250 ppm.

The Indus Plain had some irrigation before the Christian Era. But the great projects for which the Punjab is famous have been constructed during the past hundred years. Famines have been greatly reduced through increased crop production by irrigation and provision has been made for the support of a greatly increased population. However, soil depletion, canal seepage, waterlogging and salinization have already become major problems, and large areas of once productive soils go out of production each year. Views on the cause of these problems all point to factors such as drainage and water management, and an integrated approach to basin planning is felt as the only way to a solution.

The Nile Basin. The Nile is the dominating feature of the north-east quarter of Africa. Its basin has a total area of about 2,847,750 km^2 and the distance from its remote source near Lake Tanzania to the Mediterranean Sea is about 6,690 km. The Nile waters affect all of Egypt, the Sudan and Uganda, one-third of Ethiopia and parts of Kenya, Tanzania and Zaire. Its sources and tributary streams and rivers are located in high mountain tropical areas where there is considerable rainfall. In the Bahr-el-Ghazal Plain, the climate is subhumid to subarid. North of Khartoum, rainfall becomes negligable, and the river enters an area of arid climate until it reaches the Mediterranean sea.

The Nile rises and floods over about the same time each year. These flood-waters come mainly from the Blue Nile, one of the two major tributaries. Outside the flood season, the Blue Nile shrinks to a small river but fortunately the other tributary, the White Nile, has a more steady stream thereby preventing the level of the Main Nile from falling too much. The regularity of flow in the White Nile is due to the fact that its sources, the great Lakes Victoria and Albert, do not vary greatly with the seasons. Another important tributary, in terms of flooding, is the Atbara River coming from Northern Ethiopia.

From the mouth of the Atbara to the sea, a distance of 2.700 km, the Nile has no more tributaries. It decreases in volume due slightly to evaporation, but chiefly to the considerable amounts of water used for irrigation in the Sudan and Egypt. (The total irrigated area in the Nile Basin is approximately 8 million ha). The annual discharge of the Nile near the Egyptian border (Wadi Halfa) amounts in average to about 84 billion cubic meters. Dams and reservoirs in the Sudan and Egypt contribute to a further regulation of the flow of the Nile. In order to solve difficulties in basin management which may occur when two different nations share one river basin, the two countries established in 1959 the Nile Water Agreement.

The history of irrigated agriculture in the Nile Basin is a long one. Nile water was being used for irrigation 6,000 years ago. Unlike the Mesopotamian Plain, the Nile Valley has sustained irrigated agriculture for a period of some 4,000 years without major problems, mainly because the basin irrigation method allows sufficient leaching of salts to prevent accumulation. Salinity problems, however, have started to occur following the introduction of modern perennial irrigation, which has apparently disturbed the delicate hydrological balance prevailing before.

1.4 Integrated river basin planning

The three major river basins in the region, briefly described above, have a long history as regards irrigation and development. Several others like the Helmand Valley in Afghanistan and the Mahabad Valley in Iran are less well known, but here also irrigation was already practiced long ago, as is true of so many smaller sites in the region.

All river basins, large and small, in arid and semi-arid regions, have in common a history of problems due to the disturbance of the original ecological, including the hydrological balance. These complex problems cannot be solved without an integrated approach. The main objective should be a complete coordination of all uses of water, and therefore the geographical unit of each water management project, whether it be solely for irrigation or a multipurpose project has to be *the drainage basin*. Although some apparently simple relations exist within the drainage basin system as a whole, the system is a complex one, composed of many different biotic and abiotic elements and in which many different processes occur. Any interference by man with one of these, whether it be deliberate or accidental, can set in motion a sequence of events that may extend throughout the whole syste. As regards irrigation, it is important to establish a water supply budget within a basin; its evaluation will show if additional water is needed. New water resources may be sought in adjacent basins.

Many countries in the region are actively engaged in integrated basin planning, because the basin is a geographical unit and very often also an ecological and sometimes even an economic unit. Many projects, however, are planned with little attention to watershed boundaries, economic planning regions seldom being tidy physical units. In such cases the context of a drainage basin as a planning unit may become rather irrelevant, except at the execution level of site evaluation and site control.

Ecosystems in the natural environment are extremely difficult to comprehend as so many exchanges are taking place at the same time. In an assessment of the inputs and outputs of an ecosystem, the possibility of using the drainage basin as a suitable evaluation unit was considered by Bormann and Likens.[1] This argument was based on the fact that nutrient cycles are strongly related to the hydrological well for other cycles, i.e. climatic, economic and human.

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1. *Bormann, F.H.; Likens, G.E. (1969). The Watershed Ecosystem Concept and Studies of Nutrient Cycles. In: The Ecosystem Concept in Natural Resource Management. G.M. Van Dyke (Ed.), p. 49-76. The Academy Press, New York.*

1.5 Relation of MAB Project 4 with other MAB projects

MAB Project 4 has as its theme "the impact of human activities on the dynamics of arid and semi-arid zones' ecosystems, with particular attention to the effects of irrigation". Obviously this project has many links with other MAB projects, the closest being with Project 3: "the impact of human activities and land use practices on grazing lands: savannah, grassland, from temperate to arid areas, tundra". The subjects of Projects 3 and 4 actually overlap in the arid and semi-arid regions; this is why Project 4 is to concentrate on the impact of irrigation. But even in this case the relation remains close because the irrigation of certain areas, affects the grazing lands adjacent to them.

Other MAB projects which have links with Project 4 are:

MAB Project 5. This project is concerned with "ecological effects of human activities on the value and resources of lakes, marshes, rivers, deltas, estuaries and coastal zones. The activities of Project 4, especially in large river basins, will have strong relations with Project 5. Irrigation in river basins does not only affect the river itself, by taking its water; it also upsets the original hydrological balance and all waterbodies of the river system - deltas, estuaries, coastal zones etc. are affected as well.

MAB Project 9. This project deals with "ecological assessment of pest management and fertilizer use on terrestrial and aquatic ecosystems." In modern irrigation schemes the use of herbicides, insecticides and fertilizers is common practice. It is clearly within the scope of an integrated approach to the effects of irrigated agriculture to include the ecological effects of pest management and fertilizers, both on the soil (terrestrial) as on the rivers, irrigation and drainage canals, and connected waterbodies (aquatic ecosystems).

MAB Project 10. This project is focussed on the "effects on man and his environment of major engineering works". Irrigation of large river basins involves the construction of large dams, big and small irrigation canals, pumping stations etc. Project 4 also takes into account the impact of such major works.

MAB Project 12. This project relates to "interactions between environmental transformations and genetic and demographic changes". This project concerns the migrations of populations. Migration may be followed by a marked effect on both the migrant population and on the new environment. This exactly is the case in the resettlement schemes of many large, new reclamation projects in arid and semi-arid areas. Failures of such schemes are often caused by a misunderstanding of the effect of migration and ignorance as regards population-environment relations.

<u>MAB Project 13</u>. This project is entitled "perception of environmental quality" and is related to Projects 12 and 4 especially as regards the settlement of pastoral nomads in irrigation schemes. A greater change of "environmental quality" is hardly possible; man can tolerate a wide but not unlimited change in environmental conditions.

2. AN INTEGRATED APPROACH TO PROBLEM-ORIENTED RESEARCH ON IRRIGATION SCHEMES

2.1 Introduction

Ancient civilizations developed irrigation gradually and slowly. Remedial measures to counteract undesirable effects probably were introduced almost simultaneously; in any case no large areas were involved when land was reclaimed for irrigation.

With the introduction of mechanical power, however, it became technically feasible to carry out major irrigation projects. Especially in the first part of this century large areas of arid and semi-arid land were reclaimed by the introduction of irrigation. The usual history of a modern, new irrigation scheme is in general one of a successful increase of agricultural production in the first 5 - 10 years of its life followed by a slow or sometimes sudden decline until rehabilitation works are undertaken.

Distinction between new and rehabilitation schemes. New irrigation reclamation projects are being implemented in the countries of the region at an ever increasing rate. Also, many irrigated areas are being repeatedly extended; often there is no sharp demarcation between a new programme and the rehabilitation of an old one in difficulty. In order to simplify discussion, however, the meeting made the following distinction: the new scheme starts from an opportunity (dry land and available water), while rehabilitation starts from a problem (there is already something which has gone wrong). The new project poses much wider research problems; the old one sets a more precise question to be answered. Many actual sites have components of both situations. A scheme can still be considered new when human settlement has not yet started; old schemes are those that are in full operation and where settlement has taken place.

Characteristics of the integrated approach to research. There is now wide appreciation of the pitfalls likely to be encountered when the knowledge of a single discipline is applied to solve a complex problem. If a public health specialist designed an irrigation network it might present no hazard to health but be impossibly expensive. If, as has commonly been the case, an irrigation engineer draws up by himself the plans for the canals and villages, they may be an unpleasant place for people to live. If geologists, engineers, agronomists, geographers, soil scientists, and other related workers are called on separately to report on an area it remains unlikely that the complex irrigation system will be understood. This is not an integrated approach, as decisions made on one aspect may cause problems with another. The hydrologist may assume the crop rotation or the watering schedule to be fixed, while the agronomist may assume that nothing can be done to change the flow rate in canals. Only when they begin to discuss each other's findings before making their own definite conclusions can any integration be said to occur. Integrated research thus is far more demanding than just multidisciplinary work. It requires a willingness to listen to those knowledgeable in other fields, to sacrifice some of ones' solutions which are optimal in isolation but not when considered as part of the whole plan. The meeting stressed that it is necessary to combine disciplines as early as possible in the project planning stage and that a close working contact be maintained among all those involved.

The meeting strongly felt the necessity to avoid concentration of efforts mainly on long-term research and limit research to those activities which are a basis for further planning and mangement and which can induce quick action where most nee needed. Poorly planned research on a broad front tends to become vague and over-diffuse and there is a danger of trying to "measure everything" that could be relevant. This generates much data but few conclusions.

A useful basis for integrated research is the attempt to answer operational questions. Below are some examples formulated by the SCOPE workshop, key questions that require multidisciplinary answers:

(1) Has adequate provision been made for drainage and leaching so as to permanently maintain the quality of soil and water in the root-zone?

(2) Has the full range of alternative measures for achieving efficiency in water use been appraised?

(3) Have the probable effects upon aquatic and adjoining terrestrial ecosystems been examined?

(4) Have costs been assigned to the social health and economic measures which would be required to ensure that anticipated benefits from crop growth and social stability be realized?

Effective integrated research is best conducted when a whole project is not launched at one time but rather when a pilot irrigation project (often still large) or a part of the irrigation scheme or rehabilitation programme is begun before the rest, or when the programme proceeds in stages, each of which can provide data useful for planning the following stages.

Demonstration projects. The meeting considered it desirable that the MAB Project 4 integrated demonstration projects be situated in both new and rehabilitation projects within the region. It is clear, however, that in new irrigation areas the demonstration projects will focus on permanent monitoring of the overall system and its subsystems whereas in rehabilitation areas emphasis will be on a historical case study approach to find out how and why things have gone satisfactorily or unsatisfactorily. The demonstration sites proposed by the countries of the region are described in Section 3.

2.2 New irrigation programmes

The objects of new irrigation programmes are in most cases economic development, providing food for a growing population, or resettling a landless community. Research may aim at finding out if any programme can also help fill other national needs. Once a substantive proposal has been made and objectives set out, the next step is a reconnaissance of available resources.

The resources available to any irrigation programme are land, water, people and finance. All are finite and limited both in quantity and quality. The reconnaissance, as is generally now appreciated, will include work by geologists, hydrologists, agronomists, irrigation engineers, chemists and climatologists. Less often included but equally important at this stage are studies by social scientists, geographers, health workers and anthropologists on both the resident population of the area proposed for irrigation and the people who are considered likely to migrate into the area later. Environmental studies of potential pollution should be made early if procedures to avoid this are to be incorporated into the execution plan.

The results of the reconnaissance form the basis for making the major decisions concerning the irrigation programme. The biggest decision concerns whether to proceed, though this may have been taken already at a higher level, well before the scientists became involved. But there follows a whole series of decisions concerning the nature of the scheme, the mode of irrigation, the type of socio-economic structure, the provision of public health services and related topics. The appropriateness of the solution adopted will depend on the adequacy of the reconnaissance and the extent of discussions and consultations having taken place among the specialists in the various disciplines concerned before the proposals are set out.

Monitoring. In demonstration projects, there should be ample opportunities to follow the course of change, to evaluate the processes leading to the ultimately desired situation. The meeting emphasized that provision should be made on the site for long-term monitoring of the physical, ecological, social-economical and other processes which will be taking place when the original balances are disturbed. Assessment of the results should be made at specific intervals in order to trace quantitively the evolution of these processes and to check possible ill-effects well before damage is irrepairable.

2.3 Rehabilitation programmes

A rehabilitation project starts from one or more problems resulting from defective initial planning, from unforeseen, structural developments or from a combination of both. The main objective is to restore and/or improve soil productivity. There may be other objectives similar to those mentioned in the previous section on new schemes: feeding a growing population or resettling a landless population.

The meeting sought to establish some guidelines for developing a methodology of rehabilitation. The first step is the identification of possible problems, among which it is useful to distinguish between physical, chemical and biological problems.

Among the physical problems, waterlogging and salinity, soil erosion and sedimentation, loss of water through seepage, soil compaction and detioration of soil structure were considered to be widespread and serious and therefore of major importance. Especially waterlogging and salinity have caused an extremely serious decline, and sometimes even a complete stop, in the agricultural production of many irrigation projects in arid regions. The lack of proper provisions for drainage, and the usually low efficiency of irrigation water use, are the major reasons for these problems. The chemical quality of irrigation water from different sources was identified as one of the major constraints of a chemical nature. Nutrient deficiency and reduced bacterial activity in irrigated soils seem to be important biological problems, another of which is the growth of weeds and water plants which clog canals, pumping stations, etc.

It was pointed out that many of the above problems may occur very soon after the completion of new irrigation projects as a result of poor design, planning decisions not having been based on the results of research conducted beforehand in pilot schemes. In the case of new projects, the lessons to be learned from mistakes in the older projects may be very helpful.

Health problems. The widespread occurrence of waterborne diseases, such as malaria, bilharziasis (schistosomiasis),and intestinal parasites was recognized as the major health problem in existing irrigated areas. They attack the farmer and as a result agricultural production suffers. Also, nutritional diseases may occur. Health problems may not always easily be foreseen; diseases can spread unexpectedly. Poor hygenic conditions and pollution of irrigation water are, however, the main causes of existing diseases.

Other human problems. Health problems are one type of human problem, but other conditions prevailing in irrigated areas also affect the inhabitants directly or indirectly. Some of the problems below are faced by the inhabitants of new projects as well:

(1) difficulty in adapting physically and psychologically to a new environment;

(2) difficulties in social integration;

(3) lack of education and technical knowledge;

(4) seasonal migration of population from settled irrigation areas to industrial urban areas in order to supplement their revenue;

(5) permanent migration of rural populations in irrigation areas to urban agglomerations.

The meeting cited obsolete legislation for water rights and land-ownership and changes in the pattern of rural society which affect leadership and family conditions (children refusing to help) as other human problems.

Most of these problems can rarely be foreseen, as they are the result of a gradual change in social conditions, often linked with changes in the standard of living, education, and the economy of a developing nation. These problems may often make rehabilitation extremely difficult, as the success of other efforts (physical or medical) to improve a declining project sometimes depends entirely on success in solving human problems.

Economic problems. In the better designed older irrigation projects, production factors such as size of plots, size of holdings, degree of mechanization, type of irrigation, were adapted to the economic conditions prevailing at the time of design. Many such factors have gradually or suddenly changed since, as a result of a changing world or national economy, economic and technical developments in agriculture (input/output ratio) and improved standards of living. The meeting recognized that the following economic problems prevail throughout the region; the holdings are too small for efficient management; farm and irrigation practices are outmoded; and there is a lack of sufficient credit facilities. As a result the per capita net income of the farmer has become too low in many older irrigation projects and this alone is enough to affect agricultural production seriously.

In the face of these problems, rehabilitation, although essential, will prove to be extremely difficult and intricate as it may require an entirely new design of the irrigation system and/or a reallocation of holdings.

In irrigated areas requiring rehabilitation, *land* is not considered a limited basic resource, except in a few existing cases where land is lost forever as a result of salinity or alkalinity. But *water*, in terms of both quality and quantity, was identified by the meeting as the major constraint in efforts to rehabilitate spoiled land in all areas. It is therefore important to focus research on the improvement of irrigation efficiency, indeed one of the key factors in the solution to most physical and chemical problems.

With regard to *human resources*, trained manpower appears almost nowhere sufficient to meet the requirements. The meeting considered that people with adequate knowledge and experience in agriculture, scientists and technologists, and skilled labour were lacking in most of the settled irrigated areas (and to a lesser extent also in the new projects). The major impediment, however, was considered the often existing lack of an active experienced and authoritive project manager! (See also section 5).

Financial resources were also considered as a basic prerequisite for agricultural development in irrigated areas, including rehabilitation areas; their scarcity everywhere was recognized.

Case studies. The meeting agreed that the methodological approach in demonstration projects in areas to be rehabilitated should be developed on the basis of case studies. Such studies, integrating the contributions of several disciplines, would trace the history of existing irrigation schemes in various countries in the region and environmental conditions, so as to make clear the train of events that led to a decline in agricultural production.

2.4 Aspects of design in new and rehabilitation projects

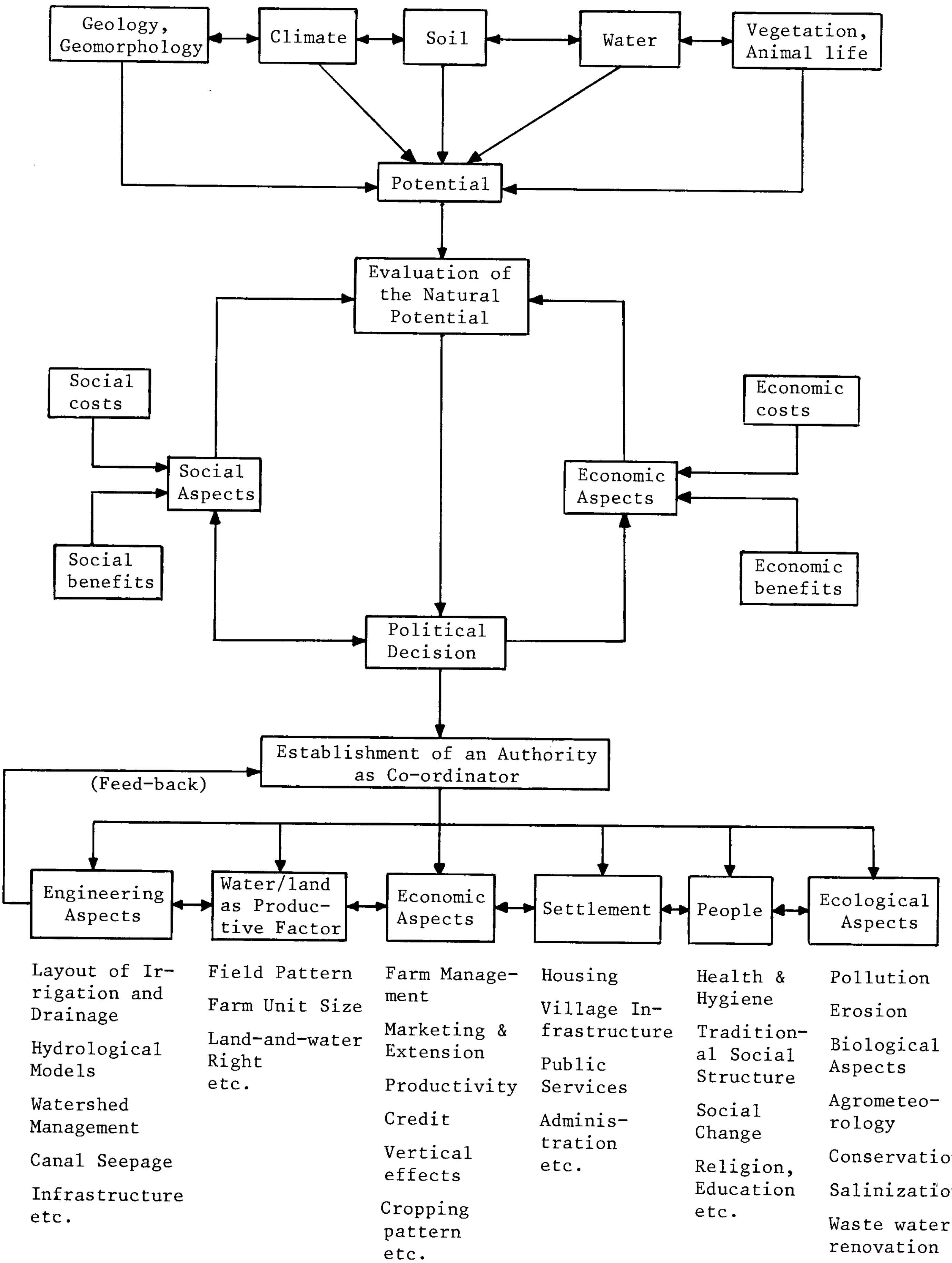
With the initiation of a new or a rehabilitation scheme, an opportunity is created to develop rational land and water management in harmony with the needs and aspirations of the local people. The meeting stressed that the success of the scheme depends largely on the quality of the design, or plan, elaborated at the outset. A satisfactory plan must necessarily be based on research findings and conceived through co-operative efforts among research wrokers, planners, decision-makers, and the population concerned. In a given locality, it is probable that there will be certain crucial factors requiring particular study and attention. Nevertheless it is possible to identify, in general terms, the various components of a comprehensive irrigation scheme plan. In Figure 2 these are indicated so as to show their interrelationships; it will be noted that irrigation itself is just one of many aspects. Viewing an irrigation scheme as a system, the meeting delineated areas for interdisciplinary research, each area representing one of the subsystems. They are described below:

The land-water interface subsystem. A key subject for interdisciplinary research is the field area at the end of the tertiary or final canal. Here there are problems of water requirements, water allocation among fields and among farmers, crop rotation, and land tenure. All should be the object of integrated study. Too often the solution to one of these problems has been decided upon beforehand, the solutions to the others thus being indirectly determined simply in function of the first aspect. A suitable study team would include: irrigation engineer, agronomist, soil scientist, sociologist and legal expert at the very least if water is to be used as efficiently and if all possible alternatives are to be properly considered.

The canal subsystem (engineering aspects). This topic usually dominates all others in an irrigation planning operation; it is deliberately placed after consideration of the small scale field-level decisions, as they can sometimes make suggestions concerning the engineering arrangements. These arrangements certainly have a large part in making the farmers' lives more or less pleasant. Several disciplines in addition to water engineering have a role to play. The rates of flow will determine whether the snails which transmit schistosomiasis can live there. If a system of rather large minor canals acting also as reservoirs is adopted, linear flow rates are low and snails flourish in those canals which are most in contact with man. Canal linings require attention because of the large water losses in many places through them; here again is a field for integrated study. Many of the large-scale land planning aspects of a new irrigated area are best considered here.

The economic interface. Too often the economics of irrigation are confined to an analysis of capital cost, obvious expenditures, and the financial benefits from sale of crops. But an adequate study will extend to the social costs of disease, the benefits and costs of resettlement and the wider economic changes brought about by the irrigation, not omitting the downstream effects on the river which provides the

Figure 2. *Diagram of the processes in irrigation planning.*



water. There are also numerous indirect links between the irrigation programme and other geographical and economic considerations, for example intensity of traffic and the need for new roads, the flow of goods, secondary and tertiary employment needs and the marketing of crops. The market structure will influence both cropping patterns and the credit needs of the small farmer. Studies need to involve not just the economist but also agriculturalists, sociologists and others.

The socio-cultural subsystem. Participants pointed out that it is too often forgotten that those who live on irrigation schemes are real people with a culture, with family ties and a pre-established way of life. This is rarely considered in the lay-out of communities and the work patterns expected of their new inhabitants. An extreme example is the settlement of nomads who change from livestock rearing to arable farming.

Human health depends not only on health care facilities but also on contact with water (given the threat of schistosomiasis and leptospirosis) and on the existence of mosquitoes breeding in standing pools and flooded rice fields. A five-fold increase on mosquito populations followed irrigation in Kenya; moreover the species composition moved towards the more efficient malaria vectors. There is a tendency to populate irrigation schemes with nuclear families having a few young children and this may overburden those left behind with the elderly and may lead to incomplete family structures in the irrigated areas in societies where the elderly traditionally play an important role as advice-givers and child-minders. Here again sociologists, geographers, physicians and agriculturalists are needed if research is to be effective.

Almost every irrigated area, old or new, contains human settlements. Too often these have been located and built with little thought for human comfort and health. When different ministries are responsible for irrigation and for housing, there are dangers of village sites being located close to major canals, regardless of the risk of schistosomiasis. The houses themselves are often built by a contractor in a style unfamiliar to those who will live in them (who should have been consulted). Suitably inexpensive methods for supplying domestic water of adequate quality and for disposing of excreta have yet to be found. Some farmers previously lived in dispersed rather than aggregated settlements; the possibility of similarly dispersed living patterns on irrigated areas is, as yet, rarely even contemplated. The architect, rural sociologist, public health engineer and landscape architect should join their skills in studies preparatory to planning settlements.

Any irrigation scheme has profound effects on the terrestrial and aquatic ecosystems in its vicinity. Fertilizers and pesticides will pollute waste waters; the major hazard of waterlogging salinization must be prevented; specific vegetation and wild animals may need conservation. Studies of these processes, involving most of the specialists referred to already, also must be undertaken at the planning stage.

2.5 Examples of integrated studies concerning specific problem areas

To illustrate in more detail some of the specific areas to which MAB Project 4 demonstration projects might direct their attention, some problems are described below which needed to be solved at the planning stage in the case of several new and rehabilitation programmes.

The re-use of irrigation water. In several irrigated areas, the re-utilization of water collected in drains from the primary site has been contemplated. Such water differs from raw water: it contains a greater amount of fertilizers and salts; it may also contain pesticide residues. The latter may gain access to groundwater and build up there. If organic matter and sewage has reached the drainage, water health hazards are added. Re-utilization of water raises many problems, the solution to which is poorly understood; sometimes the use of pipes instead of canals is the answer. In any case they can be solved only through the combined skills of a soil chemist, a biologist, a toxicologist and public health and irrigation engineers.

Drainage. Irrigation and drainage are complementary activities. If land is irrigated without proper provisions for natural or artificial drainage, the groundwater table will rise, causing waterlogging and salinity, in old as well as in new projects. Lowering of the water table by means of canals, tubewells or other structures in one area, may, however, cause a rise in adjacent areas. Much work has been done on this topic, as in Egypt and Pakistan for example, by drainage engineers, very often following a sectorial approach. The problems relating to drainage clearly very much call for a multidisciplinary approach, involving the knowledge and skills not only of engineers, but also of soil scientists, agriculturists, hydrologists and ecologists.

Sedentarization of nomads. An aim of several new irrigation programmes, including one in the Sudan, has been the sedentarization of nomads. Such people, when obliged to settle in one place, face a complete dislocation of their lives: they are put in houses instead of tents; their herds are restricted or even done away with. They have to undertake agriculture of a particularly rigid and demanding type and their whole culture must change. How many of the changes are essential? What form of dwelling is best suited both to their new life and to their previous customs?. To what extent can they continue to keep livestock on the irrigated fields and in what way does this fit in with their arable farming? All these questions have been too often ignored by administrations which tend to adopt a sectorial approach and forget the origin of the people concerned. Being physically moved is in itself a shock; as a result populations are less rather than more able to cope with other changes. This is both an interesting and urgent topic requiring the combined efforts of the sociologist, geographer, veterinary surgeon, agronomist and anthropologist.

Displacement of people. When a primary aim of irrigation is to produce a highly mechanized high yielding crop to boost the economy or provide food for urban areas, the existing population under dry farming or in old irrigated areas may be greater than the new system can employ and a process of resettlement in reverse may occur, with another problem which requires the attention of scientists from a range of disciplines if a solution is to be found that will not leave the former inhabitants in worse straits than they were originally.

Education of farmers. Provisions for the education and training of those who are to live and work in the irrigation project, especially if they are unfamiliar with modern irrigated agriculture, are extremely important. Little work has been done on this topic. The services of adult educationists, agricultural extension workers and agronomists, irrigation engineers, and sociologists will be necessary.

Use of human wastes. In irrigated areas human excreta raises problems which require an integrated approach. The high water table and likelihood of connection between pit latrines and water increase the risk of rapid *Culex fatigans* breeding and pollution of water which may be used for drinking. Indiscriminate defecation causes the proliferation of many diseases, while schistosomiasis is a specific consequence of poor sanitary facilities or failure to use them. The normally advised means of processing human wastes in warm countries, by oxidation ponds, may be too demanding of land; also, pathogens may escape through seepage. This is clearly a problem that the sanitary engineer, biologist, agronomist, social scientist and hydrologist need to tackle together.

3. MAB DEMONSTRATION SITES

Each delegation brought to the meeting information concerning sites where MAB demonstration projects - related both to new and rehabilitation schemes - might be created in its country. It was understood that in these projects research design would be in keeping with the integrated, problem-solving approach described in Section 2.

3.1 Criteria for the selection of MAB integrated demonstration sites

The meeting accepted the following criteria for selecting sites for MAB demonstration projects. It should be reasonably certain that new irrigation works, or rehabilitation works, will actually be undertaken in the area in which the demonstration project is located; plans for these works, however, should not be so advanced that research cannot assist in their preparation. Also, the site should be representative of environmental conditions and of the problems likely to arise in other irrigation schemes in the country and the region.

In the case of rehabilitation schemes, the problems encountered should be characteristic of older irrigated areas in arid regions. In order to prepare a case study of past experiences with irrigation in the area to be rehabilitated, the history of the area should be well known and the information about the physical, chemical and other changes which have caused the deterioration of soil productivity should be readily available.

The site should be accessible, secure against disruption of research facilities and activities, and near institutions of research and higher learning.

Objectives of the research project should be set out sufficiently clearly to allow for subsequent evaluation of the research and to make it possible for other countries in the region to see how the research project is relevant to their needs.

3.2 Demonstration sites proposed by participating countries

Delegates submitted to the meeting the following proposals for integrated demonstration projects:

Afghanistan

New irrigation scheme: The Kunduz Khan Abad Scheme
Rehabilitation scheme: The Helmand Project

The *Kunduz Khan Abad Scheme* is located in the Kunduz district in North Afghanistan. The area is part of the basins of the Khan Abad and Ali Abad rivers; it measures about 30,000 ha. Altitude is 700 m and the water source is the Khan Abad River. The soils of the area are deep, fertile alluvial and loessial loams. The climate is dry-continental: total annual precipitation is 250 mm and average temperatures in winter and summer are respectively about -15°C and 39°C. There is much wind in summer. The natural vegetation is annual grasses and perennial bush. Land use is dryland farming of wheat and barley. In the irrigated parts cotton, rice, wheat, corn etc. are cultivated. The project area itself is not populated at the moment, but people in the already irrigated areas live by subsistence farming and livestock raising.

The proposed irrigation scheme will be completed within 3 years. Irrigation will be of the basin and farrow type; crops will be wheat, barley, corn and cotton. There is no other big irrigation project in the vicinity.

There are research institutes in the district but not in the area. Facilities for housing are available. Maps are not yet ready, but preliminary studies have been undertaken and construction activities will start soon. Research on irrigation has not been undertaken yet, but the Research Institute of the Ministry of Agriculture and the Faculty of Agriculture of Kabul University are prepared to do so.

The *Helmand Project* is located in the western part of Afghanistan. The Helmand Valley has an area of 260,000 km^2; the project area is 60,000 ha in size. Altitude is partly above 1,000 m, and soils are of alluvial and loessial origin. The climate is favorable for crop cultivation, average temperatures being 91°F (33°C) and 46°F (8°C) for July and January respectively. Annual precipitation is not more than 125 mm and the majority falls in winter. The Helmand project is the biggest irrigation project in the country.

The inhabitants of the project area are from many different parts of Afghanistan. Settlement and land allocation are still in progress.

The area is quite accessible. Housing facilities are excellent. There are agricultural schools and a number of agricultural research stations. Research reports related to the various aspects of the project are available.

The problems encountered are mainly waterlogging, salinization and those related to the common occurrence of impermeable subsoil. For this and possibly other reasons agricultural productivity has so far been disappointing.

Egypt

New irrigation scheme: West Nubareya Project
Rehabilitation scheme: West Nubareya Project

The *West Nubareya Project* is situated in northern Egypt, west of the Nile Delta. Its area is approximately 120,000 ha; irrigation is by water from the Nile. The climate is arid and semi-arid near the Mediterranean coast with annual precipitation between 150 and 200 mm. The yearly average temperature is 20.6°C, varying between 14.0°C in January and 26.9°C in August. Soils are mainly loams, underlain by lagoonal and deltaic deposits.

Land is reclaimed by the Government of Egypt and cultivated for a number of years by the Organization of Reclamation and Cultivation. The land is then rented to farmers.

Irrigation is by the borderstrip and long furrow system. The water is conveyed to the fields via open ditches. The major crops are field crops, forage crops and fruit (mainly grapes).

Reclamation activities started about 15 years ago. Still further extensions of the area are planned. The oldest parts of the Nubareya Project are in need of rehabilitation work. The current extensions may serve as the object of research related to newly irrigated land. (See also the summary of a case study of this area in Annex 6).

Research in the areas planned for irrigation should be directed towards increased irrigation efficiency and control of groundwater level. The problems which call for rehabilitation in the older areas are mainly waterlogging, salinization, spread of diseases and other human problems. The area is quite accessible and housing facilities are no problem. Maps, in various scales, and background research reports as well as case studies of the reclamation history of the area are available.

An agricultural research station with laboratory and field facilities exists in the area. The following scientific institutes are either in the area itself or in nearby Alexandria or in Cairo: faculties of agriculture of the University of Alexandria and of three universities in Cairo, the National Research Centre (Soils Dep't), the Desert Institute (Alexandria and Cairo), the Ministry of Irrigation (Cairo), the Academy of Science and Technology, the Human Settlement Institute, and the faculties of Medicine of the Universities of Alexandria and Cairo.

Iran

New irrigation scheme: Mahabad Project
Rehabilitation scheme: Mahabad Project

The *Mahabad Project* is located in north-west Iran, near Mahabad City in the West Azarbayejan Province. The area is 21,500 ha and its elevation is about 1,500 m above sea level. The main source of irrigation water is a reservoir in the Mahabad River (300 million m^3). Water is also derived from deep and shallow wells and springs. The climate is semi-arid with an average annual precipitation of 423 mm and an average monthly temperature of 24.1^{o}C in the hottest month (July) and 0.1^{o}C in the coldest (January). The soils are mainly of alluvial origin with small areas of residual soil. The crops traditionally grown in the area are wheat, sugarbeets, alfalfa, sunflower and potatoes.

The present inhabitants, about 23,000 in number, live in 24 villages located in the project area. The population is expected to double, however, after completion of the scheme. These people make their living from agriculture and animal husbandry.

The proposed area is suitable for research both on reclamation of new land and on rehabilitation of existing irrigated areas because the new scheme is to be introduced in an area where irrigated agriculture was traditionally practiced for many years.

Major aims of this project are the efficient use of land and water resources and the increase of crop and dairy production. The direct socio-economic aim is to provide more employment in the area by establishing agro-industries. This may also reduce migration of rural population to the cities. Major problems encountered so far are water pollution, salinity and human diseases. They obviously call for an integrated approach.

The project area is well accessible. Maps of varying types and scales are available, as well as a soil survey and other research reports.

The Rezaieh Agricultural College of Resaieh City (150 km northwest of Mahabad) is the educational and research institute nearest the project area.

Iraq

New irrigation scheme: Thartar Project
Rehabilitation scheme: Dujaila Project

The *Thartar Project* is situated about 65 km northwest of Baghdad. Average altitude is 65 m above sea level. The climate is arid. The project area is in the Thartar Basin, which is a depression partly covered with shallow water (Thartar Lake), and saline marshes. Part of this basin, about 6,000 km^2, will be reclaimed with water drawn from the Tigris River and brought to the project area via a canal 50 km long.

The natural vegetation is reeds and halophyts. The soils are highly gypsiferous. The local population live on fishing, grazing and nomadic dry-farming. The area, which has some housing facilities, is linked by road to the town of Abu Ghraib, 90 km away. In Abu Ghraib are found an agricultural college and various research institutes.

The main problem is the occurrence of salinity in an irrigated area without natural drainage (depression). Background studies have been carried out in the field of vegetation dynamics, fish and fauna, as well as geology. The area is a physical unit which would lend itself well to integrated research (soil, hydrology, health, biology, agriculture).

The *Dujaila Project* is on the right bank of the Tigris River near the town of Kut. Its area is 100 ha. The climate is arid with very high temperatures in the summer. (Mean temperatures in July and August are respectively 35.7 and 35.0^{o}C). The average temperature in January is 11.4^{o}C. Rainfall is about 138 mm yearly, falling in the winter only.

The soils of the area are of alluvial origin. The soil profile is stratified with alternating layers of compact heavy clay which reduce the permeability. The major part of the soil is medium to strongly salt affected.

The project area was reclaimed between 1937 and 1949. The irrigation system was adequate, but drainage had not been provided from the start. A drainage system constructed later had only open drains and no field drainage. The result was a continuous increase in the salt content of the soil as well as of the groundwater. The farmers had to leave the land, and moved into towns.

The present government had started a big agricultural development project in the area; ample funds have been allocated for it in the present Five Year Plan (1976-1980). The Dujaila Project is conceived as an agro-industrial project; the effects of industrial waste on soil and water will therefore need attention as well. There is also a social problem of resettlement. The former agricultural systems will have to be changed. This project is a geniune rehabilitation scheme which will greatly benefit an integrated, scientific approach.

Pakistan

New irrigation scheme: Tarbela Project
Rehabilitation scheme: Mona Project

The *Tarbela Project* is located in the Northwest Frontier Province of Pakistan. The area is part of the Indus Basin. Water for irrigation will be obtained from a large reservoir formed by the Tarbela Dams. The area on the whole is not densely populated. The farmers make their living from rainfed agriculture or livestock raising. There is no irrigation as yet.

The major object of the project is to irrigate a large area in which displaced persons affected by the construction of another nearby dam, the Mangla dam, can be resettled. These people were originally resettled in the Punjab, far from their traditional socio-economic environment, and many have left. It is expected that they will feel more at home near Tarbela.

Nearby universities and research institutes are in Peshawar (Peshawar University and the Pakistan Academy for Rural Development). In Tarnab is an Agricultural Research Institute.

There is ample background information available concerning the Tarbela Dam Project.

The *Mona Project*. The Mona Project is situated in the north central part of the Salinity Control and Reclamation Project lying in the Chaj Doab (area between the rivers Chenab and Thelum) in the Indus Plain. Under the command of the Mona Distributory this project covers an area of about 55,000 ha. It has been selected for pilot studies in the field of drainage and reclamation. The object of this project is to derive from operational research information making it possible to identify and apply the agricultural and groundwater hydrology techniques most adaptable to areas being developed in the country. Investigation and research are being conducted on the following aspects:

(1) Developing methods and procedures to achieve effective use of water and land; the reclamation of saline land for agricultural development.

(2) Detailed hydrologic studies to determine the effect of groundwater management, changes in water quality and tubewell performance.

(3) Tubewell operation, maintenance, rehabilitation and replacement.

(4) Management of water supplies.

(5) Determination of optimum cropping input-output relationships; and

(6) Transferring knowledge to farmers and inducing its application; extending research results to the project areas.

Recently the Salinity Control and Reclamation Project started a programme of studies which aims at improvement of water management practices (to obtain substantial economic returns from the limited water resources). The University of Agriculture at Lyallpur is closely associated with this project and is cooperating in the studies relating to socio-economic aspects, agronomy, soil, irrigation, extension services, etc. This project, which is well equipped for laboratory and field research, may serve as a nucleus for a demonstration project and in due course be expanded and developed. The area of activity can be extended to the bigger area in the Chaj Doab covered by the Upper Thelum and Lower Thelum Canal Systems serving a cultivable area of one-half to one million ha, and also for the purposes of comparison, 35,000 ha of rainfed fields in Gujrat Plain. The area has a good communication system. Bench mark data and reports concerning various aspects are available.

Sudan

New irrigation scheme: The Rahad Project
Rehabilitation scheme: Khashm el Girba Scheme

The *Rahad Project* is located along the eastern bank of the Rahad River (tributary of the Blue Nile) south east of the city of Wad Wedani. It is about 250 km from Khartoum. The area is flat with an altitude not exceeding 500 m; it falls within the Nile basin and will be irrigated with water from the Blue Nile. The project area will cover 150,000 ha when completed after three years.

The soils are black cracking clays with a high clay content (Vertisol-group). The climate is semi-arid with about 400 mm rainfall per year, high summer temperatures and a mild climate in winter. Natural vegetation is acacia scrub with grasses and herbs.

At present the area is sparsely populated except close to the river where permanent agriculture has permitted higher densities. It is proposed that the project have some 14,000 tenancy holders. If families are added the permanent population will approach 100,000 persons. This means a massive resettlement programme.

Present agriculture is rainfed and traditionally irrigated. There is also pastoral nomadism and season labour in cotton schemes. Proposed agriculture in the Project is irrigated cotton, groundnuts, vegetables and the commercial production of livestock. Cropping intensity will be 84%. The major aims of the project area are to produce export crops and to stabilize and improve the welfare of the local population. The following major problems are expected:

(1) Settlement efforts will not produce good farmers from the start.

(2) Pastoral nomads given tenancies will keep their animals.

(3) The borders of the project area will be subject to the continuous invasion of pastoral nomads.

(4) There will be malaria and bilharzia.

(5) Long furrow irrigation may produce new ecological problems.

(6) The project will affect and possibly eliminate the migration of wild game.

The access to the project area is by paved road; it is only 4 to 5 hours by car from Khartoum. There is a government resthouse in the area. An extensive collection of maps is available. Not far from the area are the University of Khartoum, the Agricultural Research Farm of Wad Medani and the National Council for Research. The project area has been studied and reports are available on its agriculture, economics, and soils. Newly completed studies include a social survey and a study of how to integrate livestock raising in the scheme.

· It is proposed that in tne future research be directed towards developing a concept and a procedure for the integration of pastoral nomads in a massive irrigation project. If successful, such a concept may affect the future of pastoral nomads in the Sudan and elsewhere. A team appropriate for integrated research in this field is needed; it would include anthropologists, veterinarians, agronomists, economists, geographers, regional planners, local government representatives and taxation experts.

The *Khashm El Girba Scheme* lies on the esttern side of the Atbara River. The scheme has a gross area of approximately 200,000 ha which are gravity irrigated from Khashm El Girba dam. It is characterized by its very flat land and gentle slope, well suited to irrigation. Soils are formed in back-swamp deposits of the River Atbara which flows from the basic rocks of the Ethiopian Plateau. There are deep cracking clays with high fertility. Like the Gezira clays they have no limitations for irrigation and problems of salinity are not expected to arise.

The scheme started to function in 1964, the aim being to resettle Nubians displaced from areas affected by the Aswan High Dam as well as the nomadic tribes of the Butana plain. The intention was to bring about change from subsistence farming to a modern cash economy through intensive use of land and water resources, new techniques, better seeds, fertilizers, crop protection facilities, mechanization, provision of credit and marketing facilities. However, eleven years in the life of the scheme showed that a lot is needed to achieve good production levels and to satisfy the farmers as well as the nomadic tribes grazing in the area.

The general low production in the scheme is attributed to human as well as physical factors. A lot is also to be learned if we review the priorities which are respected when planning irrigation schemes for settlement such as Khashm El Girba. Obsession with economic development and transformation has resulted in a general negligence of the traditional patterns of people involved. A boundary is drawn between old institutions and new modern forms. As a result people become less supportive of development efforts. In the Khashm El Girba Scheme, plans were drawn up without sufficient information about religions or peoples involved. Research will be needed to evaluate in an integrated manner the present efforts being made in the scheme. Also necessary is an investigation of obstacles to increasing crop production; emphasis would best be put on problems of water management: crops requirements, means to ensure the efficient use of water, control of needs, and the role of water in spreading endemic diseases.

Syria

New irrigation scheme: The Euphrates Project
Rehabilitation scheme: The Ghab Project

The *Euphrates Project.* No description is available.

The *Ghab Project* is situated in the west of Syria. About 12,000 ha of swamp have been drained of which thrity-five ha are devoted to the cultivation of cotton and sugar beets. The recovery of this land is the first Syrian pilot project in the rehabilitation of such areas through irrigation and drainage.

The land in Ghab is very productive and has the largest network of irrigation canals in the country. The soil is rich in calcium and salts. The climate is semi-arid. Average yearly rainfall is 374 mm. The temperature ranges between 30°C in summer and 5°C in winter.

The population density of the Ghab area is slowly increasing because the government is encouraging people to come cultivate the reclaimed land.

The region is easily accessible by roads and railroads. Housing is available in nearby villages erected by the government. There is a veterinary college in the city of Hama, located in the Ghab area; in Homs, in the periphery of the Ghab, is the Institute of Petrochemistry. There are some agricultural research centres in the area.

Studies of the Ghab area have been made with the cooperation of international organizations. There are also studies of the problems that emerged as a result of flooding due to the insufficient capacity of the main drainage canal, which in turn caused the water table to rise. The factors that cause these floods are very complex. The main reason is defective design of irrigation and drainage canals which does not take into account differences in the level of the land and variations in soil fertility. Other reasons seem to be the silting up of drainage canals, as well as the growth of waterweeds and poor maintenance. To summarize, the major problems calling for rehabilitation are salinity and waterlogging, which have in turn led to economical, sociological and health problems.

4. INFORMATION AND DOCUMENTATION

Access to existing information and knowledge on irrigation, irrigated areas and problems related to irrigation (through documentation facilities) is an important prerequisite for effective research development and training action. Participants noted that although a considerable amount of research on many aspects of irrigation has been carried out in the region - this can be seen in the country reports presented to the meeting - documentation concerning this research and the information about the institutions and persons involved is highly dispersed. The meeting judged that efforts were needed at both the national and regional level to bring together information relevant to research and training activities in the context of MAB Project 4.

Action in three specific areas was recommended: (1) the compilation of an inventory of national research and training institutions in the field of irrigation and drainage; (2) the compilation of national bibliographies and the establishment of a regional documentation network so as to improve the accessibility of scientific and technical information on integrated research activities in irrigation and drainage projects; and (3) improvement of the diffusion of information relevant to MAB Project 4 and to MAB Programme activities in general.

4.1 Inventory of national research and training institutions

The meeting recommended the preparation of an inventory of the research and training resources of the region as regards the disciplines involved in an integrated approach to irrigation and drainage projects. The inventory should be based on information provided by the MAB National Committees of the countries of the region and should focus on institutional and manpower resources. It might be prepared in collaboration with FAO, which is carrying out similar inventories in this field, in order to avoid duplication. The collaboration of UNEP should also be sought. The meeting also considered it desirable to prepare a report on present institutional and manpower requirements in the disciplines involved in integrated irrigation and drainage research in the region. Both of these tasks might be carried out by the *ad hoc* regional coordinating committee (see Section 6).

4.2 Documentation facilities

As regards scientific and technical documentation and information, the meeting made a distinction between national and regional activities. It was proposed that at the national level the MAB National Committee of each country in the region elaborate a bibliography (if possible with synthetic abstracts of each reference listed) of all investigations completed or underway which are important for the implementation and coordination of future MAB Project 4 activities. This bibliography must be distributed as widely as possible among all institutions and research workers involved in this MAB Project.

For use at the regional level, one of the tasks of the proposed regional coordination committee (see Section 6) should be to encourage participating countries to establish scientific and technical documentation and information centres capable of dealing with all research fields and disciplines concerned with the ecological impact of irrigation in large river basins of the region. In the meantime it would be useful to designate existing national documentation institutions to take over certain documentation services for the region in their particular fields. Respective sections could be: irrigation and drainage, socio-economics, soils, agriculture, flora and fauna, public health, anthropology etc. Another task of the documentation centre could be the identification of practical problems and of gaps in knowledge as regards the ecological impact of irrigation.

4.3 Diffusion of information on MAB activities

In order to facilitate regional cooperation, it was suggested that MAB National Committees publish national newsletters and that a regional newsletter, in English and Arabic be published. The MAB National Committee of Egypt offered to take the responsibility for this publication if assisted by the Unesco Regional Office for Science and Technology for the Arab States and the Unesco/MAB Secretariat. Therefore, any useful information regarding MAB programme activities in general and MAB Project 4 in particular should be communicated to the MAB National Committee of Egypt. Also the team leaders of research activities undertaken by specialists from countries outside the region should be specifically instructed to report the commencement, progress and results of their work to the president of the MAB National Committee of the host country. This reporting should be done on a regular basis, at least every six months.

Finally, the regional meeting recommended that international organizations, governments, research councils and institutions participating in MAB Project 4 activities in the region unify their efforts in order to improve the existing channels of information exchange on subjects related to this project and in particular to intensify their bibliographic work.

5. TRAINING

The meeting emphasized that in order to be fully effective, MAB Project 4 work must be supported by training activities at different levels. Rather than taking place in a classroom, training should be concentrated in or near the MAB Demonstration Sites where practical problems can be closely viewed and experienced.

Attention should also be given to the introduction of environmental education in the curricula of the different educational systems in the countries involved.

There was general agreement that training is needed at the following levels:

(1) *Graduate training through interdisciplinary courses, located on the demonstration site, for graduate scientists. The theme should relate to the ecological impact of irrigation.*

(2) *Technician training by training courses, again on the demonstration project site itself, for technicians of various levels. The integrated approach in irrigation and drainage management should be emphasized. Courses intended to upgrade specific technical skills (modern irrigation techniques, agricultural aspects, water economy, tropical hygeine, etc) are, however, highly desirable, provided the multidisciplinary aspects are sufficiently brought out.*

(3) *Farmers programmes, organized at the demonstration site, to show farmers the results of good irrigation management at farm level. Here the importance of the "land-water interface" at the end of the final canal should be emphasized. The interrelationship of the various other subsystems should be shown, including the disasters that are likely to occur as the result of poor maintenance of irrigation and drainage canals.*

(4) *Seminars for directors and decision-makers on the interdisciplinary approach to various problems encountered in large reclamation and rehabilitation projects. The meeting postulated that failure of large projects is often caused by incompetent directorship. Irrigation projects in particular can be operated successfully only under excellent management.*

(5) *Training courses for graduates and technicians in data collection, processing, and analysis.*

The training activities described above should be encouraged and facilitated by the proposed *ad hoc* regional coordinating committee for MAB Project 4 (see Section 6).

The meeting also suggested the organization of regional seminars on various important topics such as salinity and its control, water and soil management, water needs and their control, health problems and vector control, water pollution and its control, etc. These seminars should preferably be held near MAB Demonstration Sites and participation should be limited to those scientists and technicians who are involved in demonstration project activities. It was agreed that each country should choose one or two demonstration sites where training facilities would be provided to other member countries facing similar problems.

6. MECHANISMS FOR IMPLEMENTATION AND COORDINATION

As described in the preceding sections of this report, the meeting identified priorities for research and training action in countries of North East Africa and in the Near and Middle East where there are projects of large scale river basin development based on irrigation. The meeting made a start in dertermining the specific sites where research and training activities of interest to the region could be carried out and in describing the major features of these activities. In considering the implementation of such a programme, questions of regional frameworks for cooperation and mechanisms for coordination and implementation at both national and regional level are of prime importance.

6.1 A regional network of complementary demonstration projects

The basic framework proposed for MAB activities in the region comprises a limited number (1 or 2 per country) of integrated demonstration projects. While mainly of a national character in purely administrative terms, it is intended that each demonstration project fulfill, in effect, a regional function. Sites are to be selected according to their representativity of environmental conditions and of the problems likely to arise in irrigation sites elsewhere in the region. The exchange within the region of personnel and information, as well as various regional training measures, will be a basic part of demonstration project activities.

6.2 Coordination at national level

Linking integrated research and development planning. In respect to the whole process of elaboration of research and training programmes, it is important to involve resource managers and decision-makers in the various key stages of the conception and implementation of field projects in order to ensure that activities relate to real development needs and that mechanisms are developed for the rapid and efficient insertion of results of research into the planning process. MAB National Committees should encourage the establishment of procedures for closely linking the functions of integrated research with the needs of practical management and development planning. This will greatly facilitate the inclusion of environmental criteria and of alternative options for management in the development process, and as such, are important to the whole development process of the countries of the region.

As traditional administrative structures often adopt a sectorial approach resulting in various aspects of an irrigation project being dealt with by different administrative services, the meeting recommended that countries consider establishing, for every irrigation scheme, a coordinating body with decision-making powers composed of representatives of the various ministries and agencies concerned. Such a body should be set up at the early planning stage, before research is underway.

MAB National Committees. MAB National Committees can play a valuable rôle in facilitating regional and international cooperation; they are intended to define and organize research activities on national problems relating to similar problems occurring elsewhere. The meeting noted that in a few countries of the region, however, MAB National Committees were in an embryonic state and were not yet equipped to play this rôle. The meeting called on Unesco to give particular assistance in getting these Committees established in every country.

6.3 Coordination at regional level: the *ad hoc* regional coordinating Committee for MAB Project 4

In order to strengthen MAB National Committees in the region and to encourage cooperation among the countries of the region and between the MAB Secretariat and these countries the meeting considered it most acceptable to create an *ad hoc* coordinating committee for the region with one representative from each of the seven participating countries.

The functions of the coordinating committee would be as follows:

(1) to urge countries to establish MAB National Committees and give them the financial support they need to work effectively;

(2) to activate and maintain cooperation among the MAB National Committees of the region;

(3) to prepare scientific inventories and help build up documentation and information centres as indicated in Section 4;

(4) to develop and maintain links among research workers and institutions involved in MAB Project 4 research activities in the region;

(5) to facilitate cooperation on the international and inter-regional aspects of MAB Project 4 and to examine the ways and means of ensuring exchange of information and personnel at all levels;

(6) to recommend methodologies to ensure comparability of research results;

(7) to coordinate the diffusion of interim and final reports relating to MAB Project 4;

(8) to encourage and facilitate the training of scientists, technicians,

farmers, managers and decision-makers, as described in Section 5 (Training);

(9) to encourage and facilitate the organization of seminars and training courses on special topics as specified in Section 5 (Training);

(10) to encourage and facilitate study visits by specialists to member countries for tackling of special problems.

The meeting suggested that the structure and mode of operation of the regional coordinating committee be as follows:

(1) The committee shall consist of seven full members, one from each of the seven participating countries of the region, appointed by the MAB National Committee. In addition, *ad hoc* members or an extra-regional expert can be invited from countries outside the region participating in MAB Project 4 research in the region. These members shall also be appointed by their relevant MAB National Committee.

(2) The members of the committee shall elect from among themselves a chair person whose term of office shall be one year, subject to renewal. The chair person shall be a member of the international panel of consultants for MAB Project 4 and shall be responsible for reporting, whenever appropriate, to the MAB International Coordinating Council on progress and problems of the work conducted in the regional framework.

(3) The coordinating committee shall meet if possible once a year. The place of the meeting will rotate among the seven member countries when possible and appropriate.

(4) Subgroups shall be appointed to ensure progress in specific areas as required. Practicability and flexibility must be guiding principles if a high degree of regional and international collaboration is to be achieved.

In summary, the main functions of the coordinating committee would be to supervise the overall development and cohesion of the MAB Project 4 activities in the region, subject to instructions and advice of the International Coordinating Council. An important corollary function would be to maintain contacts with other regional efforts and with other activities within the broad scope of the MAB Programme. Certain other specific tasks could be mentioned, such as making sure that copies of documents providing basic research data and preliminary and final scientific papers originating elsewhere in the world be processed and made available within the region.

6.4 Support from Unesco

The responsibility for development of firm proposals for research projects, including funding requirements, evidently depends on the countries themselves. The meeting agreed that in carrying out MAB related activities, countries of the region would welcome support from the MAB Secretariat. It called on the Secretariat to: (1) assist the National MAB Committees with the organization of regional meetings on specific topics and visits of scientists and consultants from within and outside the region; (2) consider the appointment of a Unesco regional officer responsible primarily for MAB Project 4, but also for other MAB projects; and (3) explore with UNEP the possibility of providing financial support for helping to get integrated research and demonstration projects and related training and information activities underway in the region.

7. SUMMARY RECOMMENDATIONS

In conclusion, the "Regional meeting on integrated research and training needs in North East Africa and in the Near and Middle East related to the ecological effects of irrigation derived from large river basins" formulated the following recommendations for review and action by MAB National Committees, by the International Coordinating Council for the MAB Programme and by collaborating international organizations:

(1) *Research and demonstration projects, and training activities, related to large scale river basin development based on irrigation should be developed in countries of North East Africa and the Near and Middle East.*

(2) *New efforts should be made to apply an integrated multi-disciplinary approach to studies and research on irrigation.*

(3) *Two MAB demonstration projects should be established in each country of the region, one related to a new irrigation scheme and the other to a scheme in operation but in need of rehabilitation. These projects should be situated in areas where it is reasonably certain that work will be undertaken but where plans are not so advanced that research cannot assist in the design. The site should be representative of the environmental conditions and the problems likely to occur in other irrigation schemes in the region.*

(4) *In order to function effectively, MAB National Committees should receive adequate support from their Governments.*

(5) *An* ad hoc *regional coordinating committee for MAB Project 4 should be established to supervise the overall development and cohesion of MAB Project 4 work in the region. In particular, it should support MAB National Committees and maintain regional cooperation among them; develop and maintain links among research workers and institutions involved in MAB Project 4 documentation and research activities; facilitate international and interregional cooperation; encourage and facilitate the organization of seminars and training courses for various target groups; coordinate the diffusion of reports relating to Project 4; and recommend methodologies to ensure comparability of research results.*

(6) *MAB National Committees should encourage the establishment of procedures for close linking the functions of integrated research with the needs of practical management and development planning.*

(7) *The MAB National Committees of each country should elaborate a bibliography of all investigations carried out or under execution which are essential for the implementation and coordination of future MAB Project 4 activities.*

(8) *The MAB National Committees should assist the* ad hoc *regional coordinating committee in preparing an inventory of research and training institutions in the region in which the accent will be put on institutional and manpower resources for research related to irrigation and drainage projects. Collaboration with FAO and UNEP should be sought.*

(9) *A regional newsletter, in Arabic and English, should be published. The Unesco Regional Office or the MAB National Committee of Egypt might undertake this task. When feasible, MAB National Committees might also publish national newsletters.*

(10) *International organizations, governments, research councils, and institutions participating in MAB Project 4 in the region should unify their efforts in order to improve the existing channels of information exchange.*

(11) *Scientific and technical documentation and information centres integrating all research fields and disciplines concerned with the ecological impact of irrigation in large river basins of the region should be established. Until that time, existing research institutions should provide documentation and information services for the region in their particular area of competence; for example: irrigation and drainage, socio-economics, soils, agriculture, flora and fauna, medicine, anthropology ...*

(12) *Training activities should be organized, preferably in or near the demonstration sites, for different target groups: graduate scientists, technicians of various levels, farmers, and directors and decision-makers. Countries should open certain training facilities to other Member States facing similar problems.*

(13) *Regional seminars should be organized on various important topics such as salinity and its control, health problems and vector control, water pollution and its control, etc.*

(14) *The Unesco/MAB Secretariat should support countries in their MAB work by assisting with the organization of regional meetings and with visits of scientists and consultants from within and outside the region. The Secretariat should consider the appointment of a Unesco regional officer responsible primarily for MAB Project 4. Moreover, it should explore with UNEP the possibility of providing financial support for helping to get Project 4 activities underway in the region.*

ANNEX 1

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ANNEX 2

OPENING ADDRESS BY H.E. DR. MOHAMED HAFEZ GHANEM,

Deputy Prime Minister and Minister of Higher Education, Chairman of the Egyptian National Commission for Unesco

Mr. Representative of the Director-General of Unesco,
Delegates,
Representatives of international organizations,
Ladies and Gentlemen.

It gives me pleasure to welcome you on behalf of the Egyptian Government to the first regional meeting to be held in Egypt as part of the Programme on Man and the Biosphere to study the environmental effects of irrigation in arid and semi-arid zones.

This meeting affords an opportunity for experts from seven countries in the region - countries through which major rivers flow and which depend on these rivers for the irrigation of their land and in which problems and side-effects have arisen as a result of irrigation schemes - to exchange information and expertise in an attempt to find the best solutions to problems connected with man's relations with his environment and with the dynamic relationships which stem therefrom.

Taking part in this meeting with us are representatives of the specialized agencies of the United Nations, the United Nations Environmental Programme and non-governmental organizations. There is no doubt that the presence of these international bodies concerned with the same problems greatly enhances the scientific and practical importance of our meeting.

Ladies and Gentlemen,

In recent years the developing countries have been engaged in a fierce struggle to catch up with the level of civilization which has been attained by the world community in the latter part of the twentieth century. This struggle is all the more remorseless and violent because of the rapid and impressive advances which have taken place in the fields of education and modern technology. The balance of environmental systems in the arid and semi-arid zones would not have been capable of supporting the continuation of human life on such a scale and at such an advanced level unless man had had recourse to new methods of using the rivers which have granted life and enabled them to develop to those zones. For life in the countries situated in the arid and semi-arid zones is closely bound up with irrigation and land reclamation schemes. The aim of human thinking and of using it in the service of modern science and advanced technology is to increase agricultural output in order to satisfy the growing demand for food and industrial commodities through a horizontal expansion of land reclamation and through a vertical expansion of the agricultural yield of land. To this end, dams and reservoirs have been constructed and control has been established over the water and rivers so as to make optimum use of it.

It is undeniable that the result of human intervention and the launching of such schemes are not a one-way process but are a two-sided relationship and a mutual interaction between man and the environment, either for good or for ill. The question now is how to achieve human intervention and to launch various projects which take account of environmental relationships thereby making possible the optimum use of land and water so that they will continue to be of benefit to man, both now and in the future.

The launching of such schemes and the benefit or harm to which they give rise, of course, are the product of human thinking and its evolution. Land use for man's agricultural requirements may be at odds with his requirements for settlement or for industrial schemes. Similarly agricultural methods themselves and the application of various means of irrigation are of decisive importance with regard to both land yield and the side-effects of agricultural operations; this is shown by irrigation schemes which have in some cases resulted in a rise in the water table or the salinization of the soil. Moreover, the implementation of such schemes may expose man to infection by certain diseases, the most important of which in our own region are bilharzis and malaria. Our own experience in Egypt indicates that the reclamation of new areas requires careful study, not only of the relationship between alluvial flood water, the soil and reserves of sub-surface water, but also of the human settlements which will be established in these areas and of the new relationships which will arise as a result of schemes entailing the emigration and resettlement of populations.

There are some examples of the interrelationships arising from irrigation as a result of which man, by virtue of the power of creative thought with which God has endowed him, is the originator of problems and is alone capable of solving them.

Our meeting today affords a valuable opportunity to study the problems arising from the programmes and projects being carried out by individual countries in agricultural regions which are dependent on irrigation and many questions arise in this connection. How is the water of rivers controlled? How should one study the soil and its utilization and are the problems which arise in connection with man, his health and sickness, his housing, life and relationships, his education and training? How can one achieve co-operation for the implementation of joint projects?

I hope you will succeed in finding answers to these questions, thereby enabling man to exercise better control over land, water and agriculture for the benefit of present and future generations. It is certainly vital for the participating countries to continue the positive effort the beginning of which is marked by this meeting.

In conclusion, I wish you an agreeable stay in Egypt, the gift of the great River Nile, and I wish every success to your Conference and thank Unesco, the Scientific Research Academy and the Egyptian National Commission for having organized this meeting.

May Peace and the Mercy of God be upon you.

ANNEX 3

SUMMARIES OF THE NATIONAL REPORTS OF PARTICIPATING DELEGATIONS

The participating delegations all submitted to the meeting reports on the particular situation in their country. All reports were discussed at the meeting. These national reports were to be compiled according to guidelines given to the MAB National Committees beforehand and discussed with a visiting Unesco consultant some months before the meeting.

AFGHANISTAN

Afghanistan's economy is primarily agricultural; about 85 per cent of the population is engaged in agriculture. The potential cultivable area is estimated at 14 million hectares (22 per cent of the total area) of which 5.3 million hectares are potentially under irrigation. However only 2.0 million hectares are irrigated every year. The climate of the country ranges from cool and moist in the high mountain areas to very arid in the southwest.

Irrigation projects. Among the various development projects undertaken by the Government the Helmand Valley Project is most important. Its object is to develop new land as well as to rehabilitate old cultivated land. The Helmand River extends from the Hindu Kush Mountains to the Chakmansur-Siestan sinks, a distance of about 600 km. About half of the watershed has an altitude of more than 1,000 m. Great outwash plains with a gently rolling to hilly topography extend from the mountains towards the southwest. The Helmand Valley has an area of 260,000 km^2. Most of the irrigable soils are valley fillsoil which is predominantly deep, moderately light brown silt loam to fine sandy loam. Other areas are desert plain soils, which are predominantly shallow, reddish loams and sandy loams, highly impregnated with calcium carbonate, over outwash gravel. Subsoils are often slowly permeable and irrigation may here be the cause of salinization due to the formation of a perched water table.

Drainage. Due to poor irrigation practices, poor drainage or a combination, high water tables, salinization and excessive exchangeable sodium levels have developed locally and therefore large areas of the Helmand Valley have been abandoned. In order to maintain irrigated agriculture, adequate provision for drainage must be part of any new or rehabilitation programme.

Research. In the light of the mentioned facts a number of research projects have been undertaken in the framework of the Helmand Valley Project, but also in other project areas such as the Kunduz and the Khanabed Irrigation Project in the Kunduz District (North Afghanistan).

In the opinion of the MAB National Committee of Afghanistan, the following research topics should receive priority:

(1) determination of the water consumption of crops and the moisture holding characteristics of the soils;

(2) irrigation efficiency;

(3) evaluation of various cropping systems and their impact on the chemical and physical properties of the soil;

(4) efficient use of fertilizers;

(5) evaluation of salt affected soils;

(6) determination of chemical and mineralogical properties of the soil.

ARAB REPUBLIC OF EGYPT

The Nile Basin and the impact of irrigation. About 4 per cent or 3.3 million ha of the territory of the Arab Republic of Egypt is cultivated by means of irrigation. The major part of this area is situated in the basin of the River Nile; irrigation is therefore almost entirely dependent on the water supplied by this great river. The annual discharge of the Nile after entering Egyptian territory ranges from 45 billion m^3 (in which case there is serious drought) to 150 billion m^3 (in which case life and property is exposed to destruction). The average annual discharge in this century is 84 billion m^3, showing a peak in the summer months.

Until 1902 agriculture during the summer season relied almost entirely on the natural supply of the river. But to use the Nile water more efficiently, a great number of water control schemes have been carried out, beginning with the old Aswan Dam in 1902 and culminating in the erection of the High Aswan Dam in 1963. The Aswan High Dam has increased the guaranteed water supply by 22 billion m^3. Ultimately the quota for Egypt will be 55.5 billion m^3 and for Sudan 18.5 billion m^3 while 10 billion m^3 will be left to compensate for evaporation and seepage losses in the reservoir zone.

Simultaneous with the steady increase in water storage capacity, thousands of kilometers of irrigation canals have been constructed, gradually transforming the traditional basin irrigation system into a perennial one. Much salty marsh land in the Northern Delta and also desert land on the fringes of the Delta have been reclaimed and cultivated. The crop index has increased from about 1.0 in the beginning of the century to 1.67 at present. But due to the increase in population, one man in Egypt may now have only 4 m^3 water per day at his disposal, against 25 formerly.

At present all the Nile water is used by man and practically all water discharged by pumps into the Mediterranean is drainage water drawn off the irrigated land.

The above changes, all caused by human activities, have had a tremendous impact on the ecology of the Nile Basin in Egypt. The silt load has decreased dramatically. The average total weight of silt passing the Aswan Dam during the period 1929-1955 was 134 million tons per year. In 1972 only 2.72 million tons passed the Aswan Dam and 4.40 million tons the Delta Barrage, near Cairo. Sediments are a key factor in determining the character of the ecosystem and as sites of intensive microbiological activity they plan an important rôle in recycling nutrients.

Another major change has been the increase of salt affected areas. Although much salty land could be reclaimed as a result of perennial irrigation, cultivated land elsewhere in the Nile Basin became saline, mainly due to an excess of irrigation water, insufficient drainage, and a high rate of evaporation in the summer season.

Improvement of this situation and prevention of further soil deterioration can be achieved by reducing the amount of water applied to the land and improving of field drainage. Investigations have shown that tile drainage is more suitable and economical than an open system and therefore an area of about 500,000 hectares is being provided with tile drains as a first stage in further improvement.

Among the most pervasive problems is the spread of aquatic plants. The floating hyacinth (*Eichhornia crassipes*), the most common, can build up quickly by vegetative reproduction. Before 1958 the hyacinth was not seen in the Delta, but in 1965 the infestation had reached a dangerous point and many irrigation canals and drains were blocked, threatening land productivity. Other ill-effects of aquatic weeds are: fishery losses, blockage of pump intakes, water losses (because leaf transpiration can exceed evaporation from a free surface, health losses weeds provide a good habitat for malaria mosquitoes), and disruption of navigation, fishing and recreation. Aquatic weeds may be controlled by mechanical, biological and chemical means. One of the sources of contamination after treatment are the private field drains of the farmers who do not clean their ditches. Most of the aquatic weeds have been under control in Egypt since early 1976.

Seawater intrusion. With the changing river system and the prevailing irrigation and drainage conditions after the construction of the High Dam, new static pressures of no recharge happened with considerable head differences between fresh and salt water. Also the lowering of the water table by one meter in the coastal zones of the Nile Delta has upset the naturally and critically balanced equilibrium between salt and fresh water. The effect has been an inland migration of salty water along the coastal areas of the Nile Delta, where the partially permeable underlying rocks are hydraulically connected with the sea. As a result fresh groundwater becomes saline and the soil productivity decreases. The electric conductivity of the groundwater is being monitored in deep test boreholes at many sites in the Delta. It has been discovered that salty water has reached through coastal aquifers inland a line of more than 15 km from the coast.

Water management and various irrigation methods in Egypt. Nile water in Egypt is now being used to the last drop; even a shortage is expected soon. It is imperative to economize this water and to look for new sources of water. Possible measures are the minimization of water losses; the construction of new storage and conveyance systems; rational water use and management with a judicious choice of crops (sugar beet crops require less water than sugar cane, for example); exploitation of deep groundwater; extension of rainfed agriculture (limited possibilities along the north coast of Egypt); and exploitation of non-traditional techniques such as desalinization of sea water by means of nuclear energy.

The obvious starting point is minimization of water losses and efficient management. Investigations revealed that the widely used traditional irrigation system with short furrows and border checks causes much water loss; this type of system wastes 10 to 20 per cent of the land by its many borders, levees and ditches and prevents the passing of modern agricultural machinery. A comparative study of various water distribution systems such as short and long furrow irrigation, sprinkler irrigation and trickle irrigation showed that long furrow irrigation is least expensive, but when cost is assumed for water, sprinkler and trickle irrigation are more advantageous. The trickle system requires less expenditure for labour; with the sprinkler method, however, energy costs are higher.

Development of natural resources in desert areas and ecological changes in newly reclaimed areas. The green and cultivated Nile Valley and its delta is surrounded by barren desert. A fringe of varying width is part of the river basin and the processes of water and wind erosion in the desert fringes affect the ecological balance in irrigated areas. In Upper Egypt windblown loess of desert origin is being deposited on fertile land, obstructing irrigation canals and levelled fields. Not less than 218 wadi's (dry river beds) with catchment areas varying from 1 km^2 to 240 km^2 empty into the Nile Valley and torrential rains may occasionally bring down large masses of sand and boulders into the irrigated fields. In the North the delta is surrounded by areas with shifting sand dunes which here and there encroach upon the irrigated area. Many investigations concerning the problems of soil and water conservation in the desert fringe areas of the Nile Valley have been conducted. It is recommended that soil conservation measures be established in the beds of the wadi's, the lower slopes of the valley escarpment, and on the coastal plains, in order to avoid obstructing the passage of water needed for irrigation. In other desert fringe areas, water conservation works should be established to help the development of the local population.

Impact of irrigation on range land and fodder plants. Egypt's growing population requires that land and water resources be used more efficiently than they are today. Efforts to make better use of natural precipitation and irrigation water from deep wells have resulted in improved pastures and fodder crops. Precipitation, however, is significant only in the littoral belt (some 200 mm annually) and well water often contains soluble salts. Studies in various project areas have produced valuable findings:

(1) Higher yields of Berseem (*Trifolium alexandrinum*) were initially obtained by adding either salinized (4,000 ppm soluble salty) or Na-carbonate (375 ppm) water to fresh irrigation water. In later years, however, yields gradually decreased due to the deteriorating effect of saline and alkaline water on the soil (sandy soil and clay loam). Comparable results were obtained in experiments with alfalfa (*Medicago sativa*).

(2) Cultivation of newly reclaimed saline-alkali soil with both alfalfa and barley (*Hordeum vulgare*) caused a marked increase in total microbial flora. Also, in the soils of another area (*Wadi Natrum*), levels of the microbial flora, and also of total nitrogen, tended to increase as cultivation progressed.

(3) Saline water of drains can be used for the irrigation of light textured soils, provided that special measures be taken for salinity

control and sufficient drainage. Mixing with fresh Nile water is recommended. Moreover crops with a high salt tolerance (i.e. range plants) are recommended.

(4) When irrigating pasture and fodder plants in newly reclaimed areas it is recommended not to over-irrigate to prevent leaching of nutrients and not to irrigate too long at a time so as to avoid encouraging moisture loving plants such as sedges; moreover, not to irrigate little and frequently as this would foster the development of shallow root systems. It is preferable to grow tall plants responding vigorously to irrigation such as alfalfa, ladina clover, tall fescue, sorghum grass, napier grass, and Panicum species, and to provide enough water to keep the plants growing and to apply a sufficient amount of fertilizers given the increased demand of nutrients.

(5) Many range crops are salt tolerant and therefore highly suitable for cultivation of saline land or when using saline irrigation water. In the drier regions, drought resistant crops are recommended as a means to increase production.

(6) The natural vegetation of range land, pastures, and fodder crops has a positive effect on the soil, especially on newly reclaimed land, because soil nitrogen as well as organic matter are increased or maintained, because soil conservation is improved through greater plant cover, and because aeration, infiltration capacity, and soil structure are improved.

(7) Natural range land can in general be improved by better grazing management (fencing!), reseeding (natural and artificial), installation of water-spreading systems (diversion dams, cisterns), development of water resources (wells), and supplemental feed to animals.

Ecological changes in newly reclaimed areas. The agrosystem in the newly reclaimed lands is an artificial one. The traditional crops, which are particularly adapted to the fertile conditions in the Nile Valley and Delta, adapt more poorly to the ecological conditions in these new areas where the soils are less fertile. Thus the natural balance is upset, causing the chain of undesirable reactions mentioned before. Under the new conditions of inbalance, severe pest infestations are common.

To avoid running the risk of poor crop yields and pest infestation in newly reclaimed areas, traditional crops should be grown on an experimental basis before they are introduced on an expanded scale. Research programmes in expansion areas should include comprehensive analyses of the natural ecosystem in all its complexity which existed before land reclamation began, with soils, plant cover, fauna, water resources, etc. being taken into consideration. The rôle of the existing insects, bacteria, fungi, and nematodes under the new conditions of cultivation should be evaluated. If some of these may turn into pests or pathogens, the means to control them should be sought. Experiments related to the improvement of soil structure and fertility should be conducted, as should breeding experiments to test and select adaptable varieties and strains. Preference should be given to varieties which are fast and dense growing in order to compete successfully with weeds. Selection of a suitable crop rotation system in harmony with the ecological conditions in reclaimed lands is important. Studies should also be made of the ecological behaviour of the most disastrous weeds and pests in view of finding the best methods to bring them under control.

Fish culture in paddy soils. In Egypt, fish culture in paddy (wet rice) soils is of great significance to the national economy because it provides the population with relatively cheap protein, it may produce additional national income, it helps in reclaiming saline soils, and it may improve rice production due to fish excreta, a decrease in harmful insects, and increased aeration. Not all paddy soils, however, are suitable. If the total area cultivated with paddy in Egypt (1 million ha) were also properly used for fish production, the minimum yield of fish per year would be in the order of 60,000 tons.

Socio-economic problems of reclamation and settlement. The objectives of the Egyptian Project for Land Reclamation and Settlement (RAS) can be summarized as follows: (1) to extend the area under cultivation and alleviate population pressure; (2) to create new stable communities in the reclaimed areas which serve as models of improvement of the old rural communities in economic and social terms.

The RAS aims at reclaiming 0.65 million hectares of non-cultivated desert and lake land and at building a suitable modern physical and human environment. The areas selected for reclamation have been divided into zones and each zone into settlement areas of an average of 2,500 hectares each. These areas are scattered all over Egypt. The activities of RAS comprise engineering, agricultural, and socio-economic operations.

The socio-economic operations are conducted in accordance with the Government's land tenure policy. Land is classified according to its productivity level. If it is submarginal it remains government owned, but if it exceeds the minimum productivity level, it may be distributed as family farms to settlers selected from the local nomads and to settlers from old communities, according to certain criteria. After being rented for a few years, the land is transferred to ownership. When several years of investment are required before returns come in, as in the case of nurseries, experimental areas, etc., land may be kept as state farms.

To date, about 400,000 ha have been transformed from desert to irrigated land and more than 400 communities have been created in the reclaimed areas, providing an adequate livelihood for approximately half a million people. There have been negative results too. Waterlogging and salinization have damaged land and crops in several of the reclaimed areas (West Nubareya in particular); water pollution, diseases, and invasions of weeds in the cultivated areas are also problems.

IRAN

The Plateau of Iran has an area of 1.64 million km^2. Two-thirds of this has arid or semi-arid climatic conditions. The arid zone can be divided into a southern part and a central part.

The southern part extends from Gouter to Khouzestan. This part is situated below the 500 meter contour and temperatures here in summer are extremely high (average summer temperature is 26.2 °C) and the winters are mild. Diurnal variation is low. Rainfall is mainly in winter and very irregular (average 180 mm annually). The central part is also desert and known as the Kavir Plain. This is a very large area which extends from Teheran to the Afghanistan and Pakistan borders. Climate data are scarce here, but diurnal variation is high. The semi-arid zone occupies part of the Plateau of Iran and also the plains of Moghan and Gorgan. There are also mountainous areas in this zone with altitudes between 1,000 and 1,500 meters; these have little rain but have lower average temperatures.

Soil types in arid and semi-arid zones. The soils have a typical desert morphology: profile development is limited to the upper part of the soil. In large areas there is a hard surface crust and secondary calcium carbonade may accumulate at various depths in the profile as a result of variable amounts of precipitation, i.e. leaching of the surface soil. As in most arid and semi-arid soils, base saturation is high and consequently the pH is usually above 7. Salinity and alkalinity occur locally.

Irrigation. Agricultural surveys have shown that some 33 million hectares in Iran are potentially suitable for agricultural production. The rest is mountains, improductive desert or lake. Only 26.2 per cent of the cultivable area is permanently productive. 33.2 per cent is dry-farmed and 39.4 per cent is not used because of poor drainage, water shortage, salinity, or socio-economic reasons. Some 1.2 per cent is used for horticulture.

A special feature in Iran is water supply by means of the old Quanat system using spring-canals, and, by modern deep and shallow artesian wells. A recent survey shows that these underground water resources of Iran are considerable. In addition a number of large hydroelectric and irrigation schemes have been initiated. The total area of land brought under cultivation recently is 648,600 hectares and the target is another 212,800 hectares before 1982.

IRAQ

Iraq can be divided into 5 physiographic zones: the mountains, the low hill area, the desert, the "Gezira" and the Mesopotamian plain. The latter is an alluvial plain deposited by the twin rivers Euphrates and Tigris. It extends in one direction for more than 500 km; its area is about 25 per cent of the total arable land in Iraq. Irrigation has been practised there for about 6,000 years and still depends today mainly on water from the "twin rivers".

The climate of Iraq is arid, with dry hot summers and winters. There is some rainfall in central and southern Iraq (100-150 mm annually) and more rainfall in the northern part of the country (up to 1,000 mm). The greater part of the country has a real desert climate with high diurnal temperature variations. Evaporation in summer varies between 15-25 mm per day. It is estimated that over 50 per cent of the alluvial land is affected by salinity and alkalinity.

Land and soil. The cultivable area in the Mesopotamian plain is estimated at 8 million hectares. About 3.3 million hectares are annually irrigated. The rainfed zone is estimated at 4 million hectares and about half of it is dry-farmed.

The soils of the Mesopotamian plain have textures ranging from heavy clay in the basin lowlands to coarse sandy loam in the levee soils. They contain high amounts in lime and gypsum (pH is high), but natural fertility is low. About 3.7 per cent of the total area of arable land in Iraq is strongly salt affected. Some 48.3 per cent is moderately and 18.8 per cent is slightly salt affected. The rest, about 30 per cent, which is not affected, is situated in the north mainly.

Erosion and land management. The watershed of the Euphrates, the Tigris and its tributaries extends to the mountainous land where rainfall may reach high intensities. The resulting erosion causes a heavy and damaging sediment transport in rivers, irrigation canals and reservoirs. Protective measures are now being taken by the government to reduce erosion in the watersheds through afforestation and mechanical structures (terraces, dams) and by improving land management according to scientific methods.

Irrigation and drainage projects. Traditional agriculture, even in the Mesopotamian plain, has been in the form of a fallow system. Annual cropping occupied 60 per cent of the irrigable land (85 per cent in winter, 11 per cent in summer and 5 per cent perennial). Water shortage in the summer was the main reason for this. This practice, however, has an adverse effect on the land that is left fallow, because, due to insufficient drainage, water tables tend to rise causing severe salinization in the lowest areas. Strong efforts have been made to modernize the irrigation system by the following measures:

(1) improvement of traditional irrigation systems by installing a drainage system;

(2) construction of entirely new irrigation and drainage projects inducing the improvement of agricultural practices (the total improved area now is 3.2 million hectares);

(3) organization of integrated projects comprising a completely new development of land and community. Much emphasis has been laid on the importance of such projects.

Groundwater. To satisfy the need for additional irrigation water in periods of riverwater shortage, for the reclamation of new land, and for animal and human consumption, a great many tube-wells have been dug to bring up underground water.

Irrigation research. Research in the field of water use and irrigation management has only recently started in Iraq. Experiments started in 1961. Many investigations on crop-water requirements were carried out, applying modern methods such as the radiation technique. Also research on evapotranspiration and on irrigation methods has been conducted (the Greater Mussayeh Project).

Future activities. The problem of a growing water shortage will in the future be tackled by two major undertakings: the lining of irrigation canals to decrease the high losses by deep percolation (causing waterlogging elsewhere); and the construction of water storage reservoirs. The present water storage capacity is some 13.25 billion m^3 and there are future plans to increase this with a total capacity of 42.55 billion m^3.

Another big plan is to construct a drainage canal from Baghdad to the sea. This canal, called "the third river", will discharge into the sea all saline drainage water which is collected from the irrigated areas in the central and southern parts of Iraq. This project is expected to be completed within the next 5 years, if God permits.

PAKISTAN

The economy of Pakistan, which is basically agrarian, is almost wholly dependent on irrigation. Out of the total cultivated area, about 70 per cent lies within the canal-irrigated areas of the Indus System. The majority of the soils have good textures and a high productivity potential. The climate, moreover, is favourable for year round cultivation. Irrigation has made a big impact on socio-economic conditions. Despite the blessing of irrigation, however, unscientific land and water management practices have resulted in a number of problems which have handicapped agricultural production. Waterlogging and salinity are among the major problems.

The Indus Plain, which lies south of the Himalayas and the Salt Range, comprises the main irrigated areas of the country. It forms an important physiographic unit. It is divided into two parts. The Northern Zone, comprising the Upper Indus Plain, covers an area of about 34 million acres (13.8 million hectares) and the Southern Zone, comprising the Lower Indus Plain, covers an area of about 14 million acres (5.7 million hectares).

Precipitation. The mean annual precipitation in Pakistan ranges from less than 4 inches (100 mm) in the Southern Zone to more than 30 inches (760 mm) at the foot-hills of the mountains in the North. Evaporation is a significant factor with respect to crop water requirements and to losses from reservoirs and barrage ponds. Humidity tends to increase after the relatively dry winter months through spring; it reaches high values during the monsoon period and then drops rapidly in late September or early October.

Soils. There are great variations in the soils of Pakistan. Soil surveys have been completed over 90,000 square miles. Silt loams are dominant and silty clays are second in extent; this sequence is followed by loams, silty clay and loamy sands. With respect to fertility, the soils are characteristically deficient in nitrogen, organic matter and phosphorus. There are some pockets of potash deficiency as well, especially in the rice tract and the submountainous areas. The soils are, generally, adequately provided with micronutrients, but in some areas the deficiency of copper and zinc has been recognized. Where the rainfall is 20 inches (510 mm) or above, deficiency in available Boron has also been noticed.

As regards land use, out of the total area of 187 million acres (79.8 million hectares), only 75 million acres (30.4 million hectares) or about 38 per cent can be used for cultivation. Only 48 million acres (19.4 million hectares) or 24 per cent, however, is currently cultivated. Of the cultivated area two-thirds is irrigated and one-third depends wholly on rain.

Crop yields. There are two main cropping seasons: summer and winter. Important crops sown in the irrigated areas in summer are rice, maize, cotton and sugarcane. The winter crops are wheat, grains, tobacco and barley. Agricultural production is largely subsistence oriented. In rainfed areas the main crops in summer are maize, millet and groundnut; and in winter wheat, barley and grain. The crop yields in Pakistan are among the lowest in the world. Shortage of irrigation water in general and in particular at critical times of crop growth; saline and alkaline soils, lack of drainage, and unsatisfactory agricultural and irrigation practices are considered to be the main reasons for the low yields. The cropping intensities range between 90 and 100 per cent.

Irrigation and drainage. Water for agriculture within the Indus Basin is supplied by three sources: rainfall, surface water and usable groundwater. The effective rainfall forms a useful and fairly reliable supplement to the irrigation supply. It ranges from 1 inch (25 mm) to 17 inches (432 mm). The present contribution of rain to crops in the irrigated areas is estimated at about 6 million acre feet (MAF) (0.07×10^{11} m^3).

The surface water from the River Indus and its major tributaries (the Jhelum, Chenab, Ravi and Sutlej rivers) is the principal source of irrigation. The Indus, one of the major rivers of the world, with a total length of nearly 2,000 statute miles (3,220 km) from the headwater in the distant high lands of Tibet to the sea. The total area of the Basin is about 364,700 sq. miles (710,000 km^2) of which about 204,000 sq. miles (528,000 km^2) lie in the Indus Plain. The Chenab, Ravi and Beas rivers all rise in India and Jhelum in Kashmir before flowing into Pakistan. With the implementation of the Indus Waters Treaty in 1960, only the Indus and its western tributaries - the Jhelum and Chenab rivers - are involved in the future development of Pakistan. The total supply for future use in these rivers is now limited to about 139 MAF (1.7×10^{11} m^3). Presently about 100 MAF (1.23×10^{11} m^3) of the annual river flows are diverted in a canal system. Out of this water a considerable amount is lost by way of evaporation and seepage.

The net water supplies, consequently, are inadequate to meet the crop water requirements. In order to supplement surface water supplies, the development and use of groundwater has increased with time. It has an additional advantage in that groundwater supplies can be regulated to conform to the crop calendar. Groundwater development has also become a necessity to check and control waterlogging caused by high recharge to the groundwater storage from the irrigation activities in the Indus Plain. The use of groundwater is being developed on a large scale both in the Northern and Southern Zone of the Indus Plain by means of tubewells. The gross area commanded by the irrigation system totals about 33.5 million acres (15.4 million hectares) of which the CCA (Commanded Cultivated Area) is about 33.5 million acres (13.6 million hectares). Some 22.3 million acres (9.0 million hectares) of this area are authorized for perennial supply while the remaining 13.2 million acres (5.3 million hectares) receive a non-perennial supply usually from mid-April to mid-October.

According to the Soil Survey Project of Pakistan the CCA can be divided into four classes for irrigated agriculture: Class I (very good) land is estimated to occupy about 38 per cent of the area; Class II (good) 51 per cent; Class III (moderate) 6.2 per cent; and Class IV (poor) 5 per cent. It is considered that the Class I land has no limitation for agricultural use and has very high potential for crop production, the Class II land has only minor limitations of various kinds and high potentials, and Classes III and IV have increasingly severe limitations.

Drainage. Surface drainage works became necessary to protect the agricultural lands from the effects of excess storm water run-off and flooding. As the need arose, individual surface drains were therefore constructed. At present there exists a large network of surface drains in the irrigated areas of the Upper Indus Plain and to a lesser extent in the Lower Indus Plain. Recently, an effective surface draining system has also become necessary for the disposal of the brackish water pumped from the saline areas with high water table conditions and which cannot be used for irrigation purposes.

The need for subsurface drainage in the country was recognized after large scale diversion works were constructed for irrigation. As was expected, the water table, in the absence of any natural subsurface drainage, started to rise, creating waterlogging and salinity problems.

Waterlogging and salinity. Before the introduction of a weir-controlled irrigation system in the Indus Plain, there was a dynamic equilibrium between groundwater recharge and discharge. As soon as the perennial canal system was introduced, this equilibrium was disturbed. The deep percolation water from canal-irrigated lands formed a new increment of recharge which was greater than the rate at which water could be discharged from the aquifer. As a result, water tables rose in the canal-irrigated areas. Over large areas of the Upper Indus Plain water tables rose at rates varying from about one-half foot (15 cm) up to 2 feet (60 cm) or more per year. In the Lower Indus Plain, the rate of rise was not as rapid; the previous water tables were shallower, however, because of the low altitude and nearness to the sea. In areas where the water table came very close to the surface, creating waterlogged conditions, the drainage capacity of the soils decreased, affecting the agricultural productivity of the soils. Further, greater evaporation from the high water tables, which resulted in a steady accumulation of salts from the soils in the irrigation water in the root zone of crops, aggravated the problem. In those areas where application of irrigation water was insufficient to leach down salts, an environment was created which accelerated the salinization of the land surface. As the water table continued to rise in the irrigated areas more and more lands became adversely affected and went out of production.

According to recent appraisals about 8.2 million acres (3.3 million hectares) in the Upper Indus Plain are affected by waterlogging while an area of about 6.7 million acres (2.7 million hectares) is moderately salt affected. In the Lower Indus Plain an area of 8.0 million acres (3.2 million hectares) is affected by waterlogging while an area of 4.8 million acres (1.9 million hectares) is severely salt affected and about 8.3 million acres (3.4 million hectares) are moderately salt affected. The tremendous extent of the problem required comprehensive investigations on an extensive scale. These were started in 1954 in the Upper Indus Plain and were later extended to cover the entire canal-irrigated area in the country so as to evaluate the problem in an overall context and to elaborate feasible means and methods for the ultimate solution of the problem. The programme of investigation included soil and salinity surveys; compilation and analysis of groundwater data; drilling of test holes and electric logging to study subsurface geologic conditions; pumping tests for determining the aquifer characteristics; collection of groundwater samples from varying depths and their chemical analyses; seepage studies from rivers and canals, etc.

The planning of the first major Salinity Control and Reclamation Project (SCARP) was completed in 1958. A ten-year programme of Waterlogging and Salinity Control was formulated in 1957, which recognized the need for development of groundwater to provide subsurface drainage and to supplement irrigation in order to increase the agricultural production. Waterlogging and Salinity Control got new impetus in 1973 when, on the directive of the present Government, an Accelerated Programme of Waterlogging and Salinity Control was prepared (SCARP). This programme more or less follows the recommendations contained in the Action Programme proposed by a World Bank Study Group earlier.

Upon the implementation of the programme it would be possible to cover a CCA of about 14.2 million acres (5.7 million hectares) during the period 1974 to 1985. This would still leave an area of about 13.0 million acres (5.3 million hectares) from which the menace would be eradicated over a further period of 15 to 20 years after 1985. The Accelerated Programme is being reviewed to change the relative priorities of some projects in the light of the latest conditions of waterlogging and salinity and to update the cost estimates in view of recent monetary inflation. According to the present proposals, the whole of the remaining area of over 22 million acres (8.9 million hectares) which has not been tackled so far is scheduled to be covered in a period of 21 years. It is estimated that the programme would involve the construction of about 38,000 new tubewells, replacement or rehabilitation of 21,000 tubewells, construction of 10,500 miles (16,900 km) surface drains, 37,000 miles (59,500 km) of tile drains, and remodelling of 650 miles (1,050 km) of existing surface drains. The results of the implementation of the SCARP programme are quite promising particularly with respect to drainage aspects in spite of the problems of corrosion and incrustation in tubewells. In SCARP-I, which has been in operation for the last 13 years, the water table has declined to safe limits due to pumpage by tubewells and is now fairly well under control. The water table is now averaging about 8.6 feet (262 cm) below land surface, thus eliminating waterlogged conditions in the project area. As regards land reclamation, the results were very encouraging in the initial years of project operation. About 45 per cent of the affected area was reclaimed in the first nine years. Subsequently, however, the progress has been rather slow; this has been attributed to the sodicity of the soils.

As a result of land drainage, reclamation of considerably salt affected areas, and availability of more water for irrigation through groundwater pumpage by tubewells, together with additional agricultural inputs such as fertilizers, good quality seeds, better agronomic practices, etc., irrigation intensities have gradually increased and crop yields have improved. Consequently, the gross value of agricultural produce (crops and livestock) has increased. But groundwater pumpage and its use has, however, also created some problems. It has been reported that the use of tubewell water has caused adverse changes in chemical and physical characteristics of the soils in some areas. In such areas the farmers have changed the pattern of agriculture. The sensitive cash crops have been given up and in their place less remunerative, hardier crops are being grown. In certain cases the damage to land was of such magnitude that even salt resistant crops would not be grown there. The soil deterioration hazard is considered to be due to the liberal standards of irrigation water quality that have been adopted.

Water management. The watersheds of the Indus Basin rivers are extremely vast and varied. These suffer from excessive and widespread removal of woody vegetation and heavy overgrazing. The damage to the vegetal cover of the watersheds has led to an acceleration of soil erosion and the rivers carry heavy loads of sediment, especially during floods. It has been reported that soil at the rate of 4 to 7 thousand tons per square mile (1.6 to 2.7 thousand tons per km^2) is carried away annually by the rivers Chenab and Jhelum. In the Indus this leads to one of the highest sediment loads in the world. It is because of this fact that the reservoirs of Mangla and Tarbela are given the short storage lives of only 100 and 55 years respectively! In the sandy areas in the Indus Plain wind erosion is very serious, as blowing sand creates difficult operation and maintenance problems in the irrigation system. This is particularly true in the Thal Daab area in the Northern Zone.

In view of the above, scientific management of the watersheds is very essential for the safety and extended useful life of the existing and new water storage reservoirs, barrages, canals and hydro-electric installations. Recent studies carried out on the irrigation system losses have shown that the losses from the canal head source to the outlet head are about 25 per cent of the canal head discharge and in the water courses about 15 per cent of the discharge at the head of water course. So far no economic and efficient way of lining the main canals has been devised which could satisfactorily reduce the seepage losses. For bigger canals lining has been done in some reaches at huge cost but this has not solved the problem. Water losses at the field level are also colossal. Recent studies in the Mona Reclamation Experimental Project have shown that the irrigation application efficiencies (the ratio between the amount of water stored in the root zone and the water applied to the field) measured on farmers' fields range from zero to 100 per cent. Of 64 individual observations the median application efficiency measured was nearly 20 per cent.

Soil erosion and conservation. Erosion is a process that destroys the essential productivity of the soil. Other factors being equal, its adverse effects on agricultural economy are reflected usually in the progressive deterioration of productive land and in lower farm returns. In extreme cases it has led eventually to submarginality, abandonment, rural migration, community disintegration and similar maladjustments of an economic and social nature.

More than 25 per cent of the Indus Basin is subject to some form of erosion when the land is exposed to the effects of wind and rain. Water erosion is mostly active in the northern regions of the country, while wind erosion presents a problem of equal gravity in the arid areas of the Southern Zone and the Thal area in the Northern Zone. Early attempts to control erosion tended to lean on a single method of control. For example, terracing was regarded as a complete measure against erosion. However, where it was done improperly it has caused more harm than good. The same is true of other control methods used alone under conditions which required a combination of measures. The present approach to erosion control involves a planned system of land use and the co-ordinated application of a variety of control measures. Within two or three years time, this approach has very largely controlled erosion in demonstration areas of the Soil Conservation and Watershed Management Departments. There is ample evidence that in many demonstration areas as well as in farmers' fields, measures have been adopted to control erosion and to improve lands whose quality for agriculture sometime ago were declining steadily. As a result of erosion control work, many of these farms are moving in the direction of increased yields.

Flora and fauna. Before the massive development of canal irrigation, there were four major biotic associations: the hydric river and floodplain complex, the xeric tropical thorn plain, the xeric sandhills, and the village complex. With the development of a widespread system of irrigation canals, a number of habitat changes took place. Most of the tropical thorn plain was converted to irrigated agricultural land, linked to the riparian habitat by the canal system. Villages became more numerous and more complex, linked by a system of roads and railroads. The extensive sandhills, although not physically modified, became more heavily grazed. Along with these changes, the spread of human settlement led naturally to a greater amount of contact between man and the larger mammals. This resulted in an increase of hunting pressure on both the original game species and the predators. Most of these developments have probably been taking place in a slow and irregular way in these regions for a long time; the peculiarity of the last century is their acceleration. Several large mammals, which were probably not abundant in any event, have apparently been completely eliminated from the region by hunting and trapping. These include caracal, tiger, striped hyena, fishing cat, nilgai, blackbuck, and chinkara.

The remaining fauna of the tropical thorn plain have suffered severe reduction due to habitat destruction. A few relict areas support small populations of the little Indian field mouse, Wagner's gerbil, desert gerbil, and Bengal fox. These relict areas, with their fauna, may be expected to disappear as more irrigation water and more land levelling machinery become available. The Indian crested porcupine, the Indian hare, and possibly the long-eared hedgehog have managed to survive widely along the periphery of cultivated land.

In contrast, some surviving members of the river and floodplain fauna have apparently benefited from a great increase in available habitat. This new habitat includes the well-watered canal-banks, cropland, irrigated plantation forest, and newly-developed marshy areas. The species which have apparently increased or spread westward include Asiatic jackal, jungle cat, wild boar, short-tailed bandicoot-rat, and Indian gerbil.

Land tenure and land reforms. Land in Pakistan can be divided into four broad types: State Land, Government Land, Provisionally-owned Land, and Privately-owned Land. State land is land which has never been cultivated. It may be used from time to time but no title to it has been recognized or registered. Government land is either State land which has been taken over for development and sale by the Government or privately-owned land which has been resumed by the Government. The land granted to an individual on a provisional basis on terms and conditions laid down by the Government is known as Provisionally-owned Land. Privately-owned land is land which has been permanently alienated by the Government (on payment of an annual land revenue), or land the title to which has been recognized by the Government as belonging to a private individual, family, village or company. In 1972 a new land reform law was introduced. It aimed at reducing income disparities by redistributing the land wealth lying in the hands of big landowners, to increase agricultural production and to create a relationship of mutual benefit between the landowner and the tenant. The water rate and all agricultural taxes are now being paid by landowners who are also responsible for providing and paying for seed. The cost of remaining inputs is shared equally between landowners and tenants. Land Commissions are taking steps to ensure that the landowners fulfil their obligation in regard to supply of seeds to the tenants and payment of 50 per cent of the cost of fertilizers and pesticides.

Human settlement and irrigation. The Indus Plain has been the scene for successive developments in irrigation techniques and organization. Since 1859, several irrigation projects have been completed in the area, involving irrigation on a gross area of 38 million acres (15.4 million hectares). These projects are exemplary of changing concepts and procedures in regional planning and development in dry areas. Associated with regional needs and technology, each of these changes has profoundly influenced the nature of subsequent occupance.

As a result of perennial irrigation in the Indus Plain an increase in the relative proportions and values of the summer crops was experienced. The increased acreage under summer crops changed the economy of the Plain from a subsistance to a commercial type, in which the export of cotton played an important rôle. The extension of irrigated agriculture in the Plain meant a marked change in regional settlement pattern. The planned colonization of the newly irrigated lands with pioneer settlers and establishment of new farms and villages became new elements of the existing settlement structure.

A process of redevelopment and colonization followed in the Thal, where the integrated development of agriculture and industry under the planned supervision of a single agency represents an important conceptual change in government irrigation policy. The newly developing agricultural organization and the rapidly emerging industries in the recently irrigated lands are adding few features in the morphology of settlements in the Plain.

Following the implementation of the Indus Water Treaty, the construction of Mangla Dam on the Thelum was undertaken. This necessitated the evacuation of the old city of Mirpur and 282 villages to create a 100 square mile (259 km^2) reservoir. Most of the affected landowners have resettled by now in colony areas of Pakistan. In the place of Mirpur Town, a new city known as New Mirpur Town has been constructed for a population of 15,000, complete with all facilities and amendities such as roads, electricity, water supply, sewerage, hospital, mosques, schools, colleges, district headquarter buildings, residential buildings and shopping centres, etc. In addition, seven hamlets have been established for the displaced population of the surrounding village. Almost the entire work planned under this scheme has been completed. A similar organization, known as Tarbela Dam Resettlement Organization, is now working in the Tarbela Area. It is entrusted with the stupendous and difficult task of assessing and acquiring some 85,000 acres of land containing houses, trees, etc. which fall in the settled districts, tribal areas, etc. of the Tarbela Dam Project area. From 1967 to 1972 adequate space was available in the settled districts of Lyallpur Jhang and Multan for allotment of alternate lands to effectees of Tarbela Dam Project. But the effectees were not generally interested in settling in these areas and received compensation payment. However, the resettlement of effectees in hamlets and townships in the periphery of the reservoir continued with the result that these towns are now humming with life.

Impact of irrigation on health. Irrigation and drainage development has affected environmental health conditions over a large part of the Indus Plain. Monsoon rains leave many shallow pools of water, which, in combination with a warm climate, provide excellent breeding habitats for malaria carrying mosquitoes. Swamps and marshy areas, high water tables, and standing pools of surface waste from irrigation provide additional breeding areas. Provision of new storage reservoirs, link canals, and increased irrigation water have added to the mosquito breeding habitats. With malaria already a serious menace, measures are being taken to prevent establishment of factors suitable to an increase of the mosquito population. There is a need, however, for giving serious consideration in global irrigation and drainage studies to research concerned with the eradication or control of disease carriers.

Institutions conducting research. There are several institutions in the country which are interested in research in the fields of irrigation, drainage and reclamation, and water management practices. The Irrigation Research Institute of the Government of the Punjab, located at Lahore, has been conducting research since 1924 in hydraulics, irrigation, drainage and reclamation, etc. It has contributed enormously to the understanding of the problem of waterlogging and salinity and to finding suitable solutions. The subjects on which work is being carried out in the Institute at present include: canal seepage and lining, evaporation and evapotranspiration and exploitation of groundwater by tubewells.

Research on problems relating to the suitability of water for irrigation, techniques for reclamation of saline and sodic soils, consumptive use of water, drainage of land, irrigation practices, effect of salinity on crop yields, and fixing standards for deteriorated and reclaimed soils is being carried out in the Directorate of Land Reclamation, Government of the Punjab, also located at Lahore.

The work on Mona Reclamation Experimental Project (MREP) includes research on the effective use of water and land, the reclamation of saline lands and agricultural development.

The Irrigation, Drainage and Flood Control Research Council (IDFCR) organizes, promotes, co-ordinates and conducts research in the fields of irrigation, drainage, hydraulics, tubewells, reclamation, and flood control, etc. Since its establishment, the Council has given highest priority to studies on waterlogging and salinity. A monograph with a bibliography, *Waterlogging and Salinity Problems in Pakistan* has been compiled; several research schemes relating to the subject sponsored by the Council in various laboratories of the Punjab and Sind are in progress; recently a national institute called Drainage and Reclamation Institute of Pakistan (DRIP) has been set up at Hyderabad for conducting research in the fields of drainage of agricultural lands, salinity control and land reclamation, water use and management, and the economic and technical evaluation of drainage and reclamation methods.

The Irrigation and Drainage Department of the University of Agriculture, Lyallpur, is conducting research on watercourse losses, irrigation practices for traditional and precision levelled fields in Pakistan, irrigation application efficiency, surface irrigation systems using brackish water, economic analysis for selecting the most efficient method of irrigation, determination of consumptive use of wheat crop, relationship of farm water management practices to waterlogging and salinity, etc. Research on topics related to irrigation, hydrology and hydraulics has also been started recently in the University of Engineering and Technology, Lahore. The Agricultural Institutes established at Lyallpur, Tando Jam and Tarnab undertake research on purely agricultural subjects. Some work on irrigation water requirements of crops and farm water arrangement is also being undertaken by these institutes.

Extension. It has been realized that an extension service, the connecting link between the research worker and the farmer, the ultimate user, is one of the "musts" for the success of a project aiming at land development. Through the efforts of extension workers, the research findings on the soil water relationship are being conveyed to the cultivators. To produce trained extension workers from the public and private sectors, the Agricultural University at Lyallpur has started a programme called the farm guide movement. It is a voluntary movement in which persons from all walks of life interested in social work are participating. All participants undergo pre-enrollment training for one to two months. During the past one and a half year about 200 guides and guide-leaders have been trained and are now operating in the field. The movement is now being extended to rural schools.

Problems for investigation and research. The large scale irrigation activity in the Indus Plain has created both pleasant and unpleasant effects on the ecosystem. Commendable research efforts have been made in the country in the past to understand and solve the ecological problems arising from large scale irrigation. Some of the problems which require consideration and which may also be of common interest to the countries in the Middle Eastern region are:

(1) Conventional canal lining methods are expensive, and in many cases impracticable.

(2) Sedimentation of streams resulting from soil erosion in watersheds is a serious problem. Added to this is the wind erosion problem in the sandy areas of the Indus Plain.

(3) Tubewells are the central features of the groundwater development and drainage and reclamation programme in Pakistan. The design of the wells and the material employed in the construction of tubewells have become a controversial topic because of the poor performance of the wells due to corrosion and incrustation. Considerable work has been done on the development of a suitable design and material to be used in these wells but satisfactory solutions have not yet been evolved. There is thus a need for concerted research on this subject.

(4) In areas where the layer of usable water overlying brackish water is relatively shallow, the brackish water moves upwards in the fresh water aquifer with pumpage. In these conditions pumping should be limited to the drainage surplus and the tubewell designed to as to prevent the saline water from being pumped with upper good quality water. Two separate discharge streams should be maintained, the main one for water of good quality and the other one for the saline water from below.

(5) In some areas the use of tubewell water has caused adverse changes in the chemical and physical characteristics of the soils. This is considered to be due to the liberal standards of irrigation water quality that have been adopted.

(6) Attention is needed to the study of plants with a short growing season that can be used to take advantage of the highly seasonal character of the water supply. For example, it should be possible to develop high yielding sorghums to replace maize where water is in short supply.

(7) The soils are characteristically deficient in nitrogen, organic matter and phosphorous but the degree of deficiency varies in different soils. To make up the deficiencies of the nutrients in the root zone fertilizers are being used without taking into consideration soil types. Detailed investigation of the effect of fertilizers in different soil types and other crop conditions is therefore necessary.

(8) Due to poor irrigation and agricultural practices the water losses are colossal at

the farm level. The irrigation application efficiencies are very low. To increase the water supplies for crops, there is a great need for the improvement of 'farm water management'.

(9) The present extension services are limited to agricultural crops and, to some extent, cultural practices. As regards the irrigation practices and the water use, extension services must fully cover both land and the water use and their interaction.

(10) Scientific research regarding the social and economic problems of different geographical areas of the Indus Plain region is lacking; it is needed to be able to make rational plans for the development of this region.

SUDAN

A major feature of the Sudan is the Nile River. Of the four countries that share the Nile Basin, Sudan has the larger portion. The White Nile and the Blue Nile and their tributaries flow across a vast clay plain in part of southern and central Sudan. Half of the Nile's course is across Sudan's northern desert into Egypt. The Nile is the main communication line between the centre and the south. It provides water for almost all irrigated land as well as water in the dry season for nomadic herders.

Over most of the country a tropical continental climate prevails. In the south it merges into equatorial rainy climate and in the north into desert. The variation in climatic and geological features has led to variation in soil types and zonation in vegetation. The vegetation types range from desert (less than 50 mm annual rain) to modified tropical rainforest (with more than 1,250 mm annual rain).

The soil types of the Sudan are influenced by climate, nature of parent rock, relief, drainage and vegetation. Most of the land that has been irrigated and selected for development lies in the central clay plain with annual rainfall between 300 and 800 mm, and along the Nile and its major tributaries. The entire area is characterized by the occurrence of dark strongly swelling (and cracking) clays with a high clay content and low permeability (Vertisol-group). These soils are in general fertile except for lack of nitrogen. The Sudan is rich in land resources, but only about 12.5 million hectares, which is 1/8th of the possible cultivable area, are under cultivation. Chiefly nomads live in the desert and semi-desert to the North; in the central part (semi-desert and mixed woodland savannah) a mixed type of land use combining animal raising and traditional rainfed shifting cultivation prevails. In the South, on the more humid clay plain, rainfed cultivation is more dependable than to the North but animal raising is still the major occupation.

As regards land tenure according to a 1905 Act all waste lands, forests, and unoccupied lands are to be considered Government property. However, the present land laws are not always satisfactory. Inheritance laws have produced uneconomic working units and officially recognized multiply owned holdings.

The productivity of the vast clay plain under natural rainfall and traditional agriculture is very low. Therefore, the presence of extensive, fertile soil resources and irrigation water from the Nile and its tributaries makes irrigation the only logical answer for the agricultural development of the country. The soil resources in the Sudan, i.e. the land suitable for further agricultural development, are estimated at approximately 117,000 million hectares or some 55 per cent of Sudan's territory. At present a little over 1.5 million hectares are irrigated which is only 0.54 per cent of the country and 13 per cent of the cultivable land. Vy 1980 the irrigated area is expected to increase to about 2.25 million hectares, which will still be a fraction of the area irrigable. As regards water resources, the Nile River and its tributaries are the major water source for perennial irrigation. Sudan's share of the Nile water is fixed by agreement with Egypt at 20.3 billion m^3 at Sennar. Out of the Sudan's share of the Nile water, only 2 billion m^3 is yet to be allocated but it is expected that after completion of a number of new agricultural schemes in the framework of the Ten Year Plan the water requirement will be over 9 billion m^3. Sudan's present share of water has therefore to be supplemented. This extra water is to be obtained as a result of water conservation works planned in the upper reaches of the Nile Basin.

As agriculture contributes about 89 per cent of the total exports of Sudan, expansion of agriculture is of paramount importance. Such a development implies the expansion of irrigated areas, intensification of cropping in the already irrigated areas and diversification of crops to avoid the hazards of a one-crop economy.

The impact of irrigation on crops and soils is obvious and has been studied intensively in the past and present. Evidence so far has confirmed that salinity hazards associated with irrigation in so many countries in the Near and Middle East are not encountered in the irrigated heavy clays of the Sudan.

The experience of the Sudan with irrigation. In the Sudan the practice of irrigation dates back to pre-historic times when ancient Nubians developed and adopted irrigation techniques such as controlled or uncontrolled basin irrigation. These were replaced in later times by the shaduf (a hand operated level with a weight attached to one end and a bucket on the other for raising water) and the sagia (an ox-drawn water wheel). The Nile River is the home of all these techniques, which gradually diffused to the Nile tributaries and other streams in the eastern and western Sudan.

Sophisticated and modern large scale irrigation techniques were not applied until the beginning of the 20th century. In 1925, the construction of the Sennar Dam was completed; as a result the gross irrigated area in the Gezira exceeded 1 million hectares. Since 1925, the irrigated areas in the Sudan have increased to almost 2 million hectares. Such expansion was made possible by the development of numerous pump schemes of various sizes and the construction of three dams: Jebel Awlia, El Roseires and Khashm el Girba dams.

The following types of irrigation systems are common in the Sudan: gravity irrigation, pump irrigation, flush irrigation, and traditional systems. Gravity irrigation is commonly used in the two major irrigation schemes of the Sudan: the Gezira Scheme and the Khashm Girba Scheme. The Gezira Scheme is located in the Gezira plain south of Khartoum between the Blue and the White Niles. The Scheme has a gross area of 1 million hectares including the Guneid Scheme which lies east of the Blue Nile and is irrigated by pumps. The Scheme was originally created to produce cotton for world markets but in the nineteen sixties ambitious crop diversification policies were introduced and as a result wheat and groundnuts are progressively playing important rôles in the Gezira regional economy. The areas devoted to wheat and groundnuts are increasing, the target being 300,000 hectares for wheat and 225,000 for groundnuts and vegetables in 1974/ 75. Iubia, vegetables, philipesara, and rice are the additional crops produced in the Gezira. Besides the cash returns to Government and tenants who number 96,018 and their families, the Scheme has also furnished about 24,000 permanent jobs and 500,000 seasonal jobs. There is no doubt that the Gezira Scheme is a big success and has had a profound impact on the national economy. Furthermore, its development has resulted in the complete metamorphosis of previous economic patterns because it has introduced the inhabitants of the area to new realities and higher standards of living.

The Khashm el Girba Scheme lies on western side of the Atbara River 200 miles east of Khartoum. The Scheme has a gross area of slightly less than 250,000 million hectares which are gravity irrigated (except at certain low periods) from Khashm el Girba Dam. This Scheme is relatively recent and owes its development to the need for settling the Nubian population of the Northern Province which lost its homelands as a result of the construction of the Aswan High Dam. The 1959 Nile Water Agreement between Sudan and Egypt allowed the Sudan to undertake this massive development. In addition to the settlement of the Nubians, another object of the Khashm el Girba Scheme is to produce two important crops: wheat and sugar cane, in addition to cotton and groundnuts. Furthermore, the Scheme represents a serious attempt at helping the pastoral nomads in and around the Scheme to improve their well-being. Unfortunately these attempts are not entirely successful.

Pump irrigation is quite common in the Sudan and is practiced along the main Nile, the Blue Nile, the White Nile and on the banks of a few other seasonal streams. The crops grown under such irrigation include cotton, groundnuts, sugar cane, dura, kenaf, vegetables and fruit. Pump irrigation areas are the Suki Scheme, the Northern and Nile Provinces Pump Schemes, the Blue Nile and the White Nile Pump Schemes, the Kenaf Scheme, and several sugar irrigated plantations (Guneid and Khashm el Girba Sugar Plantation). In the Suki Scheme, as part of the agricultural development plan, a massive resettlement programme is underway.

The high increase rate in pump irrigation schemes along the Blue and the White Niles slackened in the later 1950's and through the 1960's. Between 1958 and 1963 the irrigable area increased by only 20,170 hectares thereby raising the total area to 444,250 hectares. The decline is believed to be attributed to the poor economic performances of many pump schemes and more specifically to the low yields of 1957/58 followed by a fall in prices in the 1958/59 season. In 1968, the Government took over the management of most of the private schemes along the White and Blue Niles. This measure was initiated because of the Government's desire to improve productivity and to introduce more modern production relationships between tenants and management.

Flush irrigation refers to controlled or uncontrolled natural flooding of certain delta lands and depressions by seasonal streams or natural flooding. This type of irrigation is practiced in the Gash, the Boraka, Abu Habil and some isolated depressions in the Nile and Northern Provinces. Under such an irrigation system, annual floods determine the area of the annual cropped land. Therefore, when floods are slight the productive areas under flush irrigation shrink and the farmers are faced with economic hardship.

Some traditional methods of irrigation are still used in the Sudan, including the waterwheel or sagia and the shadaf. Areas under such irrigation are limited and a large proportion of the production consists of subsistance crops.

Future irrigation schemes include the Rahad Project (total area about 22,500 hectares) to be irrigated by pumping from the Blue Nile. A massive resettlement programme has been undertaken as part of agricultural development plans.

The Sudan has also embarked upon development of irrigated sugar cane production. It is planned that by 1985 the Sudan will produce not less than 1.5 million tons of sugar. It will come from 7 more project areas in addition to those already in operation. These projects include: the N.W. Sennar Sugar plantations, the Major Assalaya, the Kenana, the Melut, the Managalla and Renh/ Gelhah.

Recent major irrigation schemes. A brief review will be given of the main characteristics and problems of the Gezira, Khashm and Girba, the Suki and the Rahad Schemes.

1. The Gezira Scheme started in 1911 with 125 hectares of pump irrigated cotton. Its size was about 1 million hectares in 1972, irrigated by gravity from the Sennar and Rosari Dams constructed on the Blue Nile. The Scheme started with cotton as the main cash crop, the proceeds of which are shared among the 3 partners of the Scheme: Management, Government and tenant. The dura, sorghum, vegetables, groundnuts, rice, vegetables and fodder increased, whereas cotton and sorghum production decreased appreciably. Social development services were started in 1950, financed by an allocation of 2 per cent of the net proceeds from cotton. The tenants and other persons living within the scheme area benefit from them.

Although the development trends in agricultural production and processing were unprecedented, a number of problems are facing the Scheme as well. Like all big organizations, it has managerial and human problems. Major problems in this respect are the system of tenancy allotment, which needs to be revised. Holdings need consolidating. Other problems are the labour supply (all tenants depend on hired labour), the income of the tenants (which should be increased), diseases (mainly malaria and bilharzia), and the management system (more agricultural extension needed to help the tenant running his land himself). After the introduction of a new irrigated crop in an area in which only rainfed crops of sorghum and dura had grown previously a vast range of new problems of soil management, crop production and control of pests and diseases were created.

The Gezira Scheme (in itself only a very small part of the country) has received much attention from research workers. Agricultural research in irrigated environments involve the scientific definition of the environment concerned and how particular crops interact with this environment. Then, to improve crop production, environmental conditions must be adjusted by agricultural practices. In agronomic work, classic rotation experiments were conducted as early as 1926. Apart from their value in relation to cotton, these rotations have established principles to be adhered to when introducing any new crops and intensifying production in the Gezira. Using these established principles a number of rotational combinations, including crops such as wheat, groundnuts and new fodder crops, was worked out. Recently a very elaborate set of experiments were designed to include factors such as spraying, nitrogen, and sowing date in view of assessing their rôle in the seasonal fluctuations of cotton yield. Proper water use, so important in a scheme of this size, is also a subject of agronomic investigations. This becomes all the more urgent when water supplies are limited.

The soils in the Gezira are of a very heavy cracking clay character. The soil has been found to be very low in nitrogen and organic matter. Work on the composition of the soil has been in progress for many years. It has been established that soil productivity depends generally on the high clay content and low salt and sodium contents. Classification of soils for irrigated cropping has been going ahead side by side with research work including both physical and chemical parameters. With the very low content of nitrogen in these irrigated soils it became obvious that nitrogen was a critical nutrient; much early soil work was devoted to its distribution, contents, seasonality and the various cultural practices affecting it. More recently, microbiological aspects of nitrogen transformation and biological fixation have been given attention.

The effect of irrigation on the development of salinity was thoroughly investigated. It was confirmed that salinity hazards are not encountered in the clays irrigated with water from the Blue Nile. It was furthermore shown that irrigation invariably ameliorated the profiles of the Gezira clays with regard to both salt content and sodicity. Other important research findings showed that irrigation of arid and semi-arid soils intensified the overall microbial activity in the soil. Studies in the soil fauna also showed that irrigated cropping of heavy clay soil affected the three major ecological groups of plant parasite nematodes.

Irrigated forage production of some size started in settled agricultural areas in the north and central Sudan in the nineteen thirties. It was found that productivity is greatly enhanced under irrigation. Record amounts of fresh matter production of alfalfa (*Medicago sativa*) (100 tons/ha/year) could be obtained under experimental conditions. Similarly about 100 tons/ha in three cuts of "Abu Sabin" sorghum and 70 tons/ha of fresh maize yield could be achieved. However, as a result of limitations, mainly poor husbandry and finance, not more than 50 per cent of the above yields are obtained under farm conditions.

An aspect closely related to legume culture as forage crops in irrigated systems is their ability to improve the soil nitrogen status as a result of their natural ability to fix atmospheric nitrogen. Their importance as rotational crops is thus highly stressed. This conception is valid only under highly efficient nitrogen fixing systems and a crop management system which takes into account soil nitrogen conservation. Work was thus initiated in various parts of the country to discover habits of modulation of field crops and natural weeds and to assess their ability to enrich the soil. Progress in this direction will ultimately lead to Rhizobium isolate selection for high N_2 fixing potential and for reasonable stability and survival ability under the climatic and soil conditions of these semi-arid irrigated areas. This is rendered more urgent because the very low levels of soil nitrogen in arid and semi-arid soils are accentuated by the more intensive cropping recently practiced in irrigated clays.

It is important for many reasons that rhizobial inoculants used for research and ultimately in agricultural production be produced, not only in the developed countries, but also in the countries concerned (Microbial Resources Centres). If full utilization of a high photosynthetic potential of legume crops under irrigated soil conditions in the Sudan is to be realized (with stress on the limited supply of soil nitrogen) the vast resources of atmospheric N_2 should be tapped effectively.

2. The Khashm el Girba Scheme has a total area of 120,000 km² in the central part of the Butana, within the semi-arid belt of the Sudan. The area is flat and featureless and the soils are dark brown cracking clays. Both salinity and sodicity are low. Irrigation is from the Nile and the Atbara rivers. The Khashm el Girba Scheme is much younger than the Gezira Scheme. Although many of its objectives are similar (intensive cultivation under irrigation of cotton, groundnuts, wheat and sugar) a special and most important feature of this scheme is the resettlement of Wadi Halfa people and settlement of nomads, transforming them into resident farmers. In the first phase of the Scheme, 50,000 people from Wadi Halfa were distributed over some 85,000 hectares and 25 new villages and a new central township (New Halfa). From the local Butana tribes and other adjacent tribes some 12,000 people were settled during later phases of the Scheme. Apart from the major element of community settlement, Khashm el Girba differs from Gezira in having a more intensive fallow free rotation which excludes dura. A feature common to all irrigated schemes of the Sudan, which is also found in Khashm el Girba, is the lack of integration of livestock in the system. Nomads of Khashm el Girba are persuaded to part from their livestock and become full time tenants. This does seem to be working. Another major problem is serious weed infestation.

3. The Suki Scheme is another recent scheme which has embarked upon a very ambitious resettlement programme. Its area is 40,000 hectares, which are irrigated by electric pumps. The scheme produces cotton and groundnuts. The Suki Scheme is faced with several problems which are not uncommon during early years of development. There are administrative problems as well as those related to irrigation. In addition, the farmers are new to sophisticated farming techniques and therefore, as yet lack skills and probably emotional attachment to the Scheme. Also there have been resettlement problems. Before, 93 villages were within the Scheme area. As a result of development, some village locations were changed, others were grouped together, and a few new areas were contracted. As a result there are now 23

villages in the Scheme. Because they own livestock, however, most villagers live outside the scheme. Unfortunately livestock was not planned for in the rotation. This creates a very unusual situation for the recently settled tenant. It is either that he lets his livestock graze in the tenancies or that he sells them. As selling livestock is rather unpopular among traditional folks, especially semi-nomads, the villagers usually decide to remain in their old villages, which are well drained and surrounded by grazing grounds. This situation creates absenteeism and encourages reliance on hired labour which cuts on the farmer's profits. Moreover, some of the new villages are less attractive because of their ethnic diversity; Arab pastoral nomadic tribes such as the Gawasma find it rather difficult to live in the same village with western Sudanese groups. As a result most of the former group are still living in their nomadic farigs (camps) using their mobile tents.

4. The Rahad Project is a very new Scheme also aiming at the development of irrigated agriculture. Its area is 150,000 hectares on the east bank of the Rahad River. Water is pumped from the Blue Nile. The first phase will start in 1977/78. The project will take about 3 years to complete. The settlement of some 70,000 people, in an originally very sparsely populated area, is foreseen. This will call for the establishment of settlements to give equitable access to a range of facilities within varying hinterlands. These should have a population dense enough to support a minimum physical and social infrastructure, including dispensaries and schools. It is expected that a system of interdependent settlements, that may become self supporting, will evolve. The Gezira, however, was not subject to mass settlement and planning of this nature. Other social problems relate to the adaptation of an animal owner to a system predominantly oriented towards production of cotton and groundnuts. Although pre-investment studies concerning the integration of animals into the crop system were done, the picture is not yet clear. Overall changes in the ecology of the area were expected with the introduction of irrigation: the proposed gravity irrigation (canals) will interfere with the migration of wild animals in nearby Dinder National Park, not to speak of the interference caused by intensified human activity in the area (hunting for food and pleasure). Irrigation and spraying of insecticides will have a considerable impact on the spread of diseases and is likely to affect the ecological balance in the area.

Existing training and research facilities. The history of research in the Sudan dates back to 1903 when the Welcome Tropical Research Laboratories were set up. Research conducted by this organization focussed on agricultural chemistry and entomology. In 1904 the Shambat Research farm was established as part of the Department of Agriculture. In 1918 the famous Gezira Research Farm came into being; it eventually became the headquarters for agricultural research in the Sudan. At present a total of 4 regional research stations and six substations exist. All these research stations are administered by the Agricultural Research Corporation, a semi-autonomous body responsible to the Minister of Agriculture, Food and Natural Resources. Research in agriculture is also conducted by the University of Khartoum, the National Council for Research through its Agricultural Council for Research, and the Ministry of Irrigation and Hydro-electric Power which is in charge of conducting research and studies on Nile hydrology and discharge. Although research covers a wide range of activities, still several ecological conditions are not emphasized or catered for.

Agricultural training can be divided into the following categories: university and post-graduate, post-high secondary technical agricultural institutes, agricultural high secondary schools, and farming and related educational activities in junior schools. The Faculty of Agriculture as well as the Faculty of Science are increasingly offering opportunities for graduate work. Similarly, training is offered in Government research stations which are research schools approved by the University of Khartoum. The need for skilled technicians and trained field staff has been stressed by agricultural and educational planners. The Shambat Institute of Agriculture started as far back as 1954 with the aim of producing general agriculturalists having a high degree of practical training and ability to apply technical information under field conditions. Two other institutes are planned, one in Abu Huggar and the other in Abu Haraz. At present there are two operating agricultural high secondary schools. Others are planned. At the junior school level, the Government is embarking upon a farming education programme to encourage pupils to develop a farming awareness related to their environment through a combination of practical and theoretical work.

SYRIA

Syria belongs, with the exception of very small areas, to the arid and semi-arid zone. The area of arable land in this zone is limited. The soil is infertile and the climate very dry and warm with a large diurnal variation, making living conditions harsh. Shortage of water is the main factor limiting agricultural productivity.

Desertification. In regions with high rainfall the population is stable and settled; in dryer areas there is nomadism and migration to places with water and pasture. Due to the growing pressure on land, however, together with continuous cultivation and overgrazing, the desert is beginning to encroach upon inhabited regions, causing drought and a fall of the watertable. The encroachment of sand and soil erosion may eliminate the vegetation cover entirely. Consequently Syria is facing problems of soil conservation and vegetal cover. The grazing problem has received particular attention. As a result of many studies and measures by the competent authorities a number of protected areas have been created. In some of these areas, the Syrian Government has made efforts to settle the Bedouins. There are a number of settlement projects including one to introduce protected grazing land in 20 per cent of the nomadic areas. Five centres have been created for the improvement of grazing and rearing of flocks. The Government has enacted special legislation concerning projects and programmes for the conservation and protection of nomadic areas.

The Ghab irrigation project. The Aassy Basin is one of the most important, but also problematic, basins in Syria. Its average annual water input is 2,000 million m^3 and its mean annual discharge is 1,500 million m . The Aassy Basin includes areas with a dense population and fertile soil. The Ghab irrigation project is located inside this basin. The first pioneering experiment in the field of irrigation and drainage, has provided the country with valuable experience. The Ghab Project has an area of 72,000 hectares of which 25,000 hectares previously consisted of swamp covered with reeds.

One of the major constraints is the annual flooding of large areas, due to the inability of the principal drainage canals to handle the heavy volume of winter flood water. Other causes of the imperfect functioning of the drainage canals are silting up and the rapid growth of water weeds. The rising groundwater causes waterlogging of large areas for long periods as well as salinization. Waterlogging has also affected soil fertility. Alterations in the physical and chemical characteristics of the soil have affected the productivity of sugar beet and cotton crops.

The reclamation of the Ghab area has also caused biological changes affecting the environment and health. Social problems have developed as well. Solutions to such problems can be found only through integrated interdisciplinary research.

ANNEX 4

SUMMARY REPORT ON THE INTERNATIONAL SYMPOSIUM ON ARID LANDS IRRIGATION IN DEVELOPING COUNTRIES: ENVIRONMENTAL PROBLEMS AND EFFECTS

by E.B. Worthington, President
of the International Congress of Scientific Unions Committee on Water Research
(COWAR)

The main purpose of this symposium, which took place in Alexandria, was to bring together the viewpoints of engineers; physical, chemical and biological scientists; health workers; doctors; sociologists and administrators on the major environmental problems posed by irrigation. Some 250 attended, about half from outside the region. Participants spent four days in intensive discussion and had a one-day excursion to see problems in the field. The symposium reached a number of conclusions which were worked over and elaborated by a working group who stayed for another week in parallel with the MAB Project 4 Regional Meeting. This working group will produce a report to be used as a basis for a Technical Note. The full record of the symposium is intended to be published later.

In recent years there has been some tendency to emphasize the detrimental environmental effects of big irrigation schemes and to underplay the benefits which such schemes confer on mankind. The increase of diseases, reduction of fisheries, change in the erosion patterns, salinization of soils - however well predicted and taken into account - have received publicity while the main purpose of the schemes, bringing water and a better standard of life to millions of people, is apt to be taken for granted. In this symposium there was focus on how to get the best out of the potential benefits of irrigation and to ensure their permanence, as well as how to overcome the problems which it is apt to entail.

Meetings were in 8 sessions, each under a co-ordinator drawn from the appropriate international organization, which included COWAR, IAHS, ISSS, IUBS, ICID and WHO. Some 30 papers, printed beforehand by the Egyptian Government for study in advance, served as a basis for free discussion; about half of each session was therefore available for contributions from the floor.

Discussions started with the physical basis of irrigation, that is, hydrology and the supply of water in its quantitative and qualitative aspects, both before and after use. Then we considered the interaction of this water with soils of different kinds, resulting in environmental changes which have brought great agricultural productivity and prosperity to many areas, but in some countries have rendered vast tracts of formerly fertile land almost untenable through waterlogging, salinization and other alterations to soil structure and chemistry. The remedies were analysed and cases where new knowledge is needed were identified. However, there were many other cases where initial planning or subsequent management have been the cause of trouble.

From this we moved on to consider the effects of irrigation on the natural plant cover of arid lands and its animal life, including fish, snails and insects, some of which being of importance as food for mankind, others as vectors of disease. We looked also at some aspects of biological productivity, which is greatly enhanced by irrigation, enabling a much higher proportion of the sun's energy to be converted into living matter through photosynthesis. This of course is the primary object of irrigation in any of its forms, whether it be for agricultural crops or for fish ponds which supply protein. But it brings with it problems of overgrowth. Examples are algae and waterweeds which cause problems such as too rapid eutrophication (i.e. high biological productivity); an abundance of waterweeds clogs rivers, canals and reservoirs and may provide the aquatic habitat which favours snails and mosquitoes.

From this we moved to considerations of the efficiency and inefficiency of irrigation procedures, taking into account the engineers' experience from many countries, brought together at the Congress of ICID, held in Moscow in August 1975. The high wastage of water in irrigation usage, often 50 per cent or more, was recognized. Most wastage takes place in the farms themselves. Much of this experience points to the need for closer examination of the social aspects of irrigation. The emphasis has often been on economics and science; the social aspects, particularly the reactions of the individual farmer or group for whose benefit the great irrigation schemes of today are planned and carried out, have sometimes been neglected.

A session towards the end was devoted to the people actually affected by irrigation. Their health benefits from improved nutrition but is reduced by diseases associated with irrigation, especially schystosomiasis and malaria. Though not usually fatal, they cause a vast amount of distress and debility and are major environmental factors which reduce the advantages of irrigation.

The evolution of human populations, their increase in numbers and change in age structure due to the expansion of irrigation, is perhaps the greatest environmental effect of all. This subject was at the back of our minds and surfaced at intervals during the discussion. The symposium did not, and indeed had not intended, to go deeply into this overriding problem, but experience shows that it accompanies every new successful irrigation scheme or extension of an old scheme. Irrigation first attracts and concentrates people from the surrounding areas. They take time to adapt to a different way of life, and it is a rough adjustment given the health and social hazards. But as soon as prosperity is gained, the population rises, often at a phenomenal rate, up to and sometimes beyond the limits of the new resource. Taking Egypt as an example, after many centuries of using irrigation with traditional methods in balance with the environment, Egypt had a population estimated in 1800 at about 2.5 million. Then, following the development of modern technology initiated by Mohamed Ali early in the 19th century, it doubled every 50 years until about 1950 when it reached 18 million. In the last 25 years it has doubled again and must be expected to do so once more by about the end of the century. The history of the world shows few cases where this problem of over-population has yet been solved without catastrophe be it through earthquake, famine or warfare. Nevertheless, there are around the world some promising instances in which there is an effort to create a good balance between population and resources based on irrigation.

ANNEX 5

STATEMENTS FROM UNITED NATIONS ORGANIZATIONS

United Nations Environment Programme (UNEP)

Mrs. Letitia Obeng, representative of UNEP, presented the following message from Dr. Mustapha Tolba, Executive Director of UNEP:

"I have learned with considerable interest the action that MAB is taking to implement the recommendations of the Symposium on the Environmental Effects of Arid Lands Irrigation in Developing Countries and I commend the foresight of MAB in organizing this workshop to which I have the honour to send this statement. It is my understanding that participating countries will develop an interdisciplinary regional programme for identifying and evaluating the major ecological impacts of irrigation practices. It is also my particular hope that out of this exercise will emerge workable recommendations to help guide Governemnts in taking action to prevent further degradation of land through irrigation malpractices. Particularly in the North African region, a breakthrough is very much needed to improve crop production as indeed we also must have for many more regions where the problems of arid lands and deserts exist. With the present day escalation of population, useable land is a very valuable resource. The United Nations Environment Programme shares the concern of the MAB Programme and I shall await with interest the outcome of this workshop. I wish you a very successful meeting".

World Health Organization (WHO)

The World Health Organization attaches considerable importance to the development of water resources in general and to the related ecological impact in the widest sense. WHO has particular interest in irrigation development as it is concerned with the health and well-being of the populations which live in these areas and come into contact with water in irrigation schemes, with all the benefits but also ill effects that are associated with the irrigation process.

In this respect, of special importance is the irrigation of arid and semi-arid lands because of the concentration and movement of populations it causes. WHO therefore welcomes the initiative taken by the Man and Biosphere (MAB) Programme of Unesco in relation to research on the ecological effects of irrigation and related training. WHO also welcomes international cooperation in this field as it believes that progress can be achieved only through reinforced collaboration between all organizations, whether national, international or non-governmental, that are interested in the solution of the problems.

Very often, the negative effects of irrigation are not related to irrigation itself but to misuse or mismanagement. It is obvious that in order to avoid or alleviate obstacles, close collaboration between public health workers and members of other disciplines is required right from the inception of any water development project, including irrigation. WHO therefore strongly advocates an interdisciplinary approach and is confident that meetings such as the present one are doing a great deal toward integration of all available knowledge, experience and resources.

World Meteorological Organization (WMO)

WMO has been much interested in ecological studies of arid and semi-arid areas; WMO has co-operated closely with Unesco and FAO, and recently with UNEP in the important fields of ecology and environment for the benefit of mankind. The series of agroclimatological studies are a result of co-operation between Unesco and WMO. The following are some of the activities of WMO in these fields.

The Commission for Agricultural Meteorology, one of the constituent bodies of WMO, is now preparing the following reports: *Water requirements of agricultural crops under arid and semi-arid conditions; Meteorological aspects of land-use and agricultural management systems under severe climatic conditions; Meteorological factors associated with certain aspects of soil degradation and erosion; Frequency and impact of water deficiencies for selected plant-soil systems (including grasslands); Wheat and weather; Rice and weather; Weather and climate as related to world food production.*

The Commission for Special Applications for Meteorology and Climatology is now preparing the following reports: *Climatic fluctuations and man; Application of meteorology to land-use planning; Observational and network requirements for different purposes; Applications of meteorology to atmospheric pollution problems on a local and regional scale.*

With regard to training in agricultural meteorology, the following activities are going on. A rapporteur on training and education is making proposals about training facilities at universities and agricultural colleges through visiting lecturers, training programmes for different agrometeorological personnel at all WMO regional training centres, and sub-regional and workshop-type seminars on practical problems of interest.

The following symposia and training seminars are being organized: agrometeorological techniques in crop-weather analysis, water balance studies and risk analysis in agrometeorology, agrometeorology of maize, and meteorology and animal husbandry including grassland management problems.

ANNEX 6

DRAINAGE INVESTIGATIONS IN WEST NUBAREYA, ARAB REPUBLIC OF EGYPT:

HYDROLOGIC CASE STUDY OF THE GROUNDWATER RESERVOIR[1]

The construction of the Aswan Dam made it possible, in 1968, to introduce large-scale irrigated agriculture in the West Nubareya Province. About 200,000 hectares of land were involved. The ground water level rose with startling rapidity in some parts of the newly reclaimed areas. Over a two-year period in certain places the water table rose to within centimeters from the surface and even overflowed in some localities where it used to be within 10 meters from the surface. As a result, serious problems of waterlogging and drainage occurred. Before installing a drainage system, investigations were necessary to acquire a thorough understanding of the problem and to ensure that the system eventually installed would perform satisfactorily.

To investigate the acquifers and to measure water table fluctuations during different seasons, a network of piezometers (shallow and deep) and observation wells were installed over the whole Nubareya area. Routine measurements were taken for the water level in the piezometers and shallow observation wells from wells. These measurements were used to plot a piezometric map and define areas of water mounds, depressions, general pattern of the flow, anticipated flow directions and fluctuations of the water table on a yearly and monthly basis.

The area of study occupies the northwestern portion of the 300,000 feddans[2] reclamation project area. It is bounded on the east by the Nubareya Canal and on the northern side by the Burg El-Arab-Maryut coastal plain. The area extends south up to about 90 kilometers on the Cairo-Alexandria highway which crosses the area in a northwestern direction.

In the northern area, the early Pleistocene Nile deltaic deposits act as the main acquifer. They are composed of coarse sand with a varying amount of pebbles and granules and have a depth of 20 meters under the marginal deltaic deposits (late Pleistocene). The water in the area exists under leaky, artesian and water table conditions.

The Plio-Pleistocene forms the main acquifer in the southern extremities of the project area. It is composed mainly of deltaic sand and gravels deposited in the late Pliocene. These deltaic deposits contribute to the ground water supply of the Plio-Pleistocene layers.

Data from observation wells indicated a change in the water table in response to irrigation in the immediate vicinity of corresponding wells. There seems to be a general rise in water-table levels during summer months and a decline during fall and winter.

During the years since cultivation started, over-irrigation was a common practice in the investigated area. Excess water beyond water duty was maintained to leach harmful minerals elements in the soil and to maintain a suitable salt balance in the root zone of the plants. Water in excess of water duty amounted to about 60 m^3/hectare/day. The irrigation system in the area is controlled mainly by flooding. Application efficiency for this system is low as water is kept on the soil surface too long. Waste water percolates beyond the root zone to the underlying acquifer. Seepage from the unlined canals and ditches conveying irrigation water in the area also contributed to the problem. No proper drainage system was maintained. Due to the continuous rise in water level, two water mounds formed. The piezometric map for May 1970 of the area shows this clearly. The piezometric surface slope of these mounds is about 1,25 m/km where the water table rose to about 14,50 meters above sea level. The Nubareya irrigation canal in this area is no longer a source of recharge to the ground-water reservoir as it is in the upstream parts. In 1972, the water mounds enlarged and the water level increased. The northwestern mound moved further to the west as more lands were put under irrigation in the Maryut area.

This clearly suggests that excess irrigation and seepage from irrigated areas and unlined field ditches could be considered as the main source of recharge to the mound area and its consequent lateral flow, causing ponding in the lower parts.

The drainage problem in the area is not a simple one. The low permeable surface layer of loam under which lie shallow partially impermeable layers of clay which thin laterally lending interconnection between successive layers over an artesian acquifer of sand contributes to the complexity of the problem. It is doubtful that the tile drainage system alone would be successful. The laterals would have to be spaced so closely that it would not be economically feasible. In the meantime, some build-up of the water table is expected irrespective of the tile system.

A system of drainage by pumping water from wells would seem to be the most feasible and effective solution; this method has been successful in other countries in areas with similar physical and geological characteristics. In such a system the water table can easily be kept at the required depth by pumping only the irrigation losses and leaching, if necessary.

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1. *Summary of a paper prepared by Dr. M. Abaza of the Academy of Scientific Research and Technology, Cairo.*

2. *1 feddan = 42 hectares.*

ANNEX 7

IMPACT OF IRRIGATION AND DRAINAGE PRACTICES ON THE PROPAGATION OF BILHARZIASIS[1]

Schistosomiasis (or bilharziasis) is considered a major health problem in Egypt. It is the most serious endemic disease in terms of both prevalence and severity.

It is well known that the type of irrigation method used has an important bearing on the prevalence of bilharziasis. There is evidence that the change of basin irrigation into perennial irrigation increases the amount of water available to the vector (snails) and facilitates the spreading of the infection. An increase in rice-cultivated land also contributes to its propagation. Some authors have even stated that irrigation is probably the most menacing feature of the extension of the bilharzia problem in Africa. The enormous areas of barren but potentially fertile land in arid regions will certainly, after being reclaimed for irrigated agriculture, become bilharzial endemic areas unless adequate steps are taken to prevent the spread of snails into the new irrigation system and to stamp them out rapidly whenever they appear. We still know very little about several aspects of snail ecology, however, and irrigation engineers are not trained to understand and take into account the public health dimensions of irrigation schemes in spite of the fact that their objective is to improve the well-being and to raise the economic level of the whole population.

At our present state of knowledge, efforts to control bilharziasis, must comprise four simultaneous lines of attack, namely environmental sanitation, vector control, human medical treatment and health education.

Environmental sanitation. In Egypt, and generally in developing countries, canals, drains and other bodies of water are used directly or indirectly for many purposes such as drinking, bathing, washing, religious ablutions and unfortunately, often even for excreta disposal. In addition, agricultural workers, who form the great majority of the population in such countries, obligatorily come into contact, almost daily, with canal water because of the nature of their work.

Environmental sanitation conditions can be improved by (1) prevention of exposure to cercariae; (2) prevention of pollution by man (construction of suitable latrines in the village houses); (3) ensuring that new villages are fully equipped with sanitary facilities and located at a distance of at least 500 and preferably 1,000 meters from existing waterways and by locating new water courses at the same distance from existing, similarly-equipped villages.

Vector control. The growth and multiplication of snails can be discouraged by altering their habitat through: (1) irrigation by spraying (this solves the problem definitively; its cost is very high, but it allows for a 40 per cent increase in cultivated land); (2) filling in unwanted bodies of water; (3) desiccation; (4) increasing the rate of flow; and (5) changing the water level.

Irrigation systems should be planned according to the following specifications: elimination of blind ends; lining of channels; covering of channels; clearance of silt; clearance of weeds, algae and vegetation; piping of irrigation water canals and channels; applying, if possible, irrigation by lift instead of by free flow.

Molluscicide application was thought to be the best method of bilharziasis control. However, the restocking of streams by snails usually occurs in a comparatively short time, whatever the molluscicide or the method used. Therefore, much research is still needed on the various aspects of chemical snail control, especially as regards the reduction of costs and the simplification of methods of application.

Intermittent or continuous physical and chemical barriers of small doses of molluscicide help to stop or delay the restocking of streams by snails.

Human medical treatment. Research is going on successfully to discover cheap and efficient drugs to be taken in a single dose, preferably orally, and possessing a curative or at least a prolonged effect. Mass treatment should be applied in priority to children and adolescents who are most exposed to infection and to communities living under poor sanitary conditions.

Health education. Health education, which is part of "fundamental education", is a long-range measure that will undoubtedly constitute an extremely important line of attack. The development of research and training facilities in health education methods and techniques should receive high priority. The dangers of bilharziasis should be impressed upon the public using all possible methods. People should understand the basic facts of how it is contracted and how this contraction can be avoided.

Health education should form a part of the programme of study of all schools and colleges, and should be part of training courses in army camps. Success in the health education examinations should be a prerequisite for graduation. A change in the living habits of a community can bring about permanent success in controlling bilharziasis.

1. *Summary of a paper prepared by Dr. Shafika Nasser, of the Faculty of Medicine, University of Cairo.*

ANNEX 8

ECOLOGICAL AND HABITAT METHODS IN SCHISTOSOMIASIS CONTROL[1]

The transmission of schistosomiasis depends on three events taking place in the same limited aquatic environment: the presence of schistosome eggs from human (in some cases other mammalian) excreta, the presence and persistence of suitable snail intermediate hosts, and the immersion of human skin in the water once the extrinsic cycle has been completed.

The control of schistosomiasis may be achieved by breaking the cycle of transmission at any point. In practice, attention has, over the last two decades, been directed to the chemical destruction of snails and the chemotherapeutic killing of adult worms in man.

Environmental approaches to schistosome control were rare until recently. Ecological methods cover a range of habitat and consequential human behaviour alterations components of which are often not usefully evaluated. They interlock very closely and ecological changes may not reduce schistosomiasis unless combined, for example, with health education (and conversely!). The areas for primary consideration in ecological methods of control are physical alteration of snail habitats, the use of other organisms, and environmental sanitation. In other words, environmental methods may be aimed at three points in the transmission: reducing the number of intermediate hosts by habitat modification, reducing potentially infective human contacts with water, and preventing access of schistosome eggs to snail habitats.

Reduction of intermediate hosts (snail reduction) is often done with molluscicides but this is expensive. It has been estimated that the annual cost of effective application under perennial irrigation in Egypt would be at least US $ 1.35-2.25 per irrigated acre. These large recurring expenditures cannot always be justified or sustained on economic grounds. However, to change effectively the ecology of a snail habitat so as to render it unacceptable is extremely difficult because data on the ecological requirements of the snail must be available. In relation to any aquatic habitat change, the removal of water is the most effective measure. In a few places, such as Musayeb, Iraq, no snails were found in the irrigated area and this was attributed to the water management practice. In this case measured amounts of water were delivered to individual farms for five days on a 24-hour basis, and then there was no water for five days. The lining of irrigation canals is often not the complete answer to schistosomiasis control, but it tends to reduce snail breeding and minimize human contact.

In order to reduce human contact with infective water more than a basic domestic tap is needed to affect schistosomiasis propagation. It may also be necessary to fence off the infective stream or pool, forbidding children to swim and women to wash clothes. Piped water in each house is much better but expensive. When a new settlement is being contracted, dwellings should be located away from canals and drains and a safe domestic water supply provided and maintained.

Environmental methods to reduce the access of schistosome eggs to water simply represent basic sanitation practices. However, only in cultures where human faeces are a valuable resource is sanitation a really promising approach. Leak-proof storage until ammoniacal destruction of schistosome eggs has occurred seems a good method.

In general the combined use of improved agricultural methods, drainage, and the control of irrigation water has given promising results and in some such areas the snail population reduction has averaged more than 95 per cent.

One ecological approach to schistosome control is biological control: the use of other organisms to attack the snail phase of transmission. This has been done by predation, competition or parasitism. Experiments have been promising but in practical applications there has been a low specificity to the biological agents described. Relatively long-range research will be needed.

There are few pilot projects in which ecological methods have been used and evaluated in a controlled manner against other approaches and comparison communities, using schistosomiasis in man as the measure of success. The nearest to successful evaluations are the recent work in St. Lucia, and the earlier Leyte project on *Schistosoma japonicum*. Other programmes that appear to have been notably successful but for which rigorously controlled data is not available have been conducted in China, Iran, Japan, Rhodesia, South Africa and Venezuela.

<u>A framework for decisions.</u> We have not suggested numerous experimental ecological schistosomiasis control methods, as that does not appear to us the first priority. A wide view must be adopted to fit the circumstances. It would be futile to attempt a very labour-intensive self-help type of habitat modification in a country with a small but competent vector control service not comprised of local people, and conversely it would be equally unsuccessful to attempt concrete lining of irrigation canals in a very poor country with a labour surplus. The time course of expected benefits should be made clear and, unlike the early stages of disease eradication schemes, care should be taken not to 'oversell' any habitat modifications. Improvements in sanitation and water supply should arise from within the community as far as possible while snail habitat modifications should be made part of the agricultural pattern.

In general, ecological methods are the long-term hope for schistosomiasis control and should be applied steadily, and often in conjunction with other techniques of more rapid effect. Concomitant inputs of education are important and maintenance of any environmental works is crucial.

1. *Summary of a paper prepared by Dr. D.J. Bradley and Dr. G. Webbe, of the Ross Institute of Hygiene and Tropical Medicine, London School of Hygiene and Tropical Medicine.*

A note on research needs. The main research needs are:

(1) Increasing our understanding of the ecological epidemiology of schistosome transmission to the point where prediction is useful. This is rarely the case as yet: who thought that *B. truncatus rohlfsi* would invade Volta Lake? Our understanding of which introduced snails might displace or reduce schistosome hosts is very small. This work requires (a) continual increase of background knowledge but also (b) strong support of any new and penetrating ideas on molluscan ecology, as precise understanding is lacking.

(2) More empirical studies of the effect of environmental and ecological control measures - not only for their own sake, but also because the absence of such studies tends to discourage people from seriously considering them.

(3) More adequate analysis of the social circumstances under which environmental methods may be implemented and of the cultural inputs required to achieve success.

(4) Development (scarcely research) of low-cost methods for achieving environmental changes for irrigation, water supply, and sanitation, especially where local materials can be used. 'Self-help' approaches need development where the social milieu is suitable.

More important at present than research needs are training of staff and development of practical programmes in areas where environmental measures would benefit health by control of both schistosomiasis and other diseases.

ANNEX 9

SOME METEOROLOGICAL ASPECTS OF ECOLOGICAL RESEARCH AND TRAINING WITH EMPHASIS ON IRRIGATION IN ARID AND SEMI-ARID ZONES[1]

The atmosphere is an important part of any ecosystem of any size. Methods of studying ecosystems in relation to weather and climate depend on their scale.

In the case of large scale ecosystems, the macroclimate of a large area is studied by using climatic elements from station networks of national meteorological services (distances 10-100 km) in relation to general vegetational conditions, using different statistical methods. In the case of arid and semi-arid zones, the principal elements governing aridity are precipitation and evapotranspiration. The following parameters of rainfall are used: variability, seasonal occurrence and length of periods of reliable rainfall, in addition to mean amount. Mean and extreme temperatures are also useful. For studies of ecosystems on a regional scale the following are some of the investigations recommended: length of vegetation season in relation to radiation-crop development during various periods of vegetative seasons; importance of evapotranspiration and water balance during various periods. Examples of application of such investigations are found in the following studies in which WMO, Unesco and FAO participated:

1. Brichambaut and Wallén (1963). *A study of agroclimatology of semi-arid and arid zones in the Near East.* WMO Technical Note No. 56.

2. Cochemé and Franquin (1967). *An agroclimatological survey of a semi-arid area in Africa south of the Sahara.* WMO Technical Note No. 86.

In the case of small scale ecosystems, ex. a cropped field, it is possible to study the small-scale atmospheric processes which determine the microclimate of a system. The microclimate is governed by small-scale vertical and horizontal turbulent eddies which take place in the boundary layer between earth and atmosphere. An adequate picture of microclimate may be obtained by studying the diurnal, monthly and annual variation of turbulence, energy balance and water balance. Unfortunately these cannot be derived from observations of stations from networks of meteorological services. For micrometeorological purposes there is need for more sophisticated and expensive instruments. Such measurements are made in special research stations, properly equipped and staffed, for studying micro-meteorological factors in relation to biological processes. Net radiation is important as it gives the energy available to evapotranspiration. Given the radiation it is important to know how the energy available is divided between sensible heat (which heats the air) and latent heat (evapotranspiration). This requires observations of temperature and humidity at various levels, which are made at research stations as mentioned above. Wind speeds, soil temperatures and soil moisture are also important. With these observations the micro-conditions are determined using two approaches: the energy balance equation and turbulence theory. At research stations where such investigations are made, simple ecological and phenological observations are, in many cases, useful to relate micro-meteorological and vegetation conditions, but for detailed analyses physiological measurements are needed.

For meso scale or local climates, which lie between macro and micro scales of climate, there is need for special networks established for a limited period; also there is need for ecological and phenological observations to get the required relations.

There are interrelations between climatic conditions of different scales. Some investigators, including Thornthwaite and Penman, have attempted to develop approximate formulae, by which potential evapotranspiration, a key parameter of microclimate, is given in terms of simple meteorological parameters obtained from operational stations of meteorological services. The establishing of local climates and macro-climates on the basis of evapotranspiration is quite useful for application in ecological problems as evapotranspiration is very important to biological and hydrological processes. This holds as well for arid and semi-arid climates.

Considering irrigation, not only potential evapotranspiration but also actual evapotranspiration is important. As regards climatic change as a result of irrigation, the Bowen ratio (ratio of sensible heat to latent heat) has been found useful, as it changes appreciably between irrigated and non-irrigated areas.

It is clear that there is need for training observers in agrometeorological stations, agrometeorologists and micro-meteorologists who take the measurements in special agrometeorological stations, and agricultural scientists who participate in such investigations.

1. From Wallén (1974). *A Brief Survey of Meteorology as Related to the Biosphere.* WMO Special Environmental Report No. 4.