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of so-called 'virgin soils' will be important for generations to come. ISM has therefore reacted positively to Unesco's suggestion that it become involved in the soil studies for the MAB Biosphere Reserves, especially those that are established or planned in the tropics and sub-tropics.

It is hoped by all those engaged in the operation and development of the museum that the programme as outlined above will make a worthwhile contribution to the study of the soil, with the ultimate aim of assisting mankind to reach a better standard of living, particularly in the developing countries.

Coastal protection of the Nile Delta

A. Khafagy and M. Manohar

Coastal erosion has been the bane of the Nile Delta coast for a long time. The Government of Egypt has undertaken a number of coastal studies in local areas of erosion and carried out the necessary coastal protection works; but these limited solutions were found to be inadequate, and in some cases damaging to adjacent areas. A comprehensive study of the whole coast from Alexandria to Port Said was considered essential. Such an undertaking was beyond the resources of the Egyptian Government, however, and United Nations assistance was sought. As a result, a Coastal Erosion Project for 1971 to 1977 was developed in Alexandria, with the Government of Egypt represented by the Academy of Scientific Research and Technology, and Unesco acting as technical executive agency for the United Nations Development Programme. This article is a summary of the salient features of the project during that period.

OBJECTIVES AND ORGANIZATION

Coastal processes involve wind, weather, waves, tides, currents, sediments, coastal features, etc. The initial objectives of the project, therefore, were to initiate and establish an interdisciplinary field-oriented research, data procurement and processing programme, and to coordinate the activities of the various disciplines with the ultimate objective of providing engineering recommendations for protection of the coast. Coastal processes are best studied statistically because of their ever-changing character, and many years' carefully monitored data are necessary. It is therefore fundamentally important that a permanent organization with qualified staff—senior, semi-senior, and suporting (technical and non-technical) in the various specializations (geology, geomorphology, oceanography, meteorology, engineering, computer technology, etc.)—be established, with the requisite equipment, laboratories and field-transport facilities.

The short-term ultimate objective was to deal immediately with near-shore erosion, which causes or may cause damage to the shore or coastal structures in the near future. The long-term objective was to predict the natural evolution of the coastal areas and the protective measures which could be pre-planned for immediate (or later) implementation.

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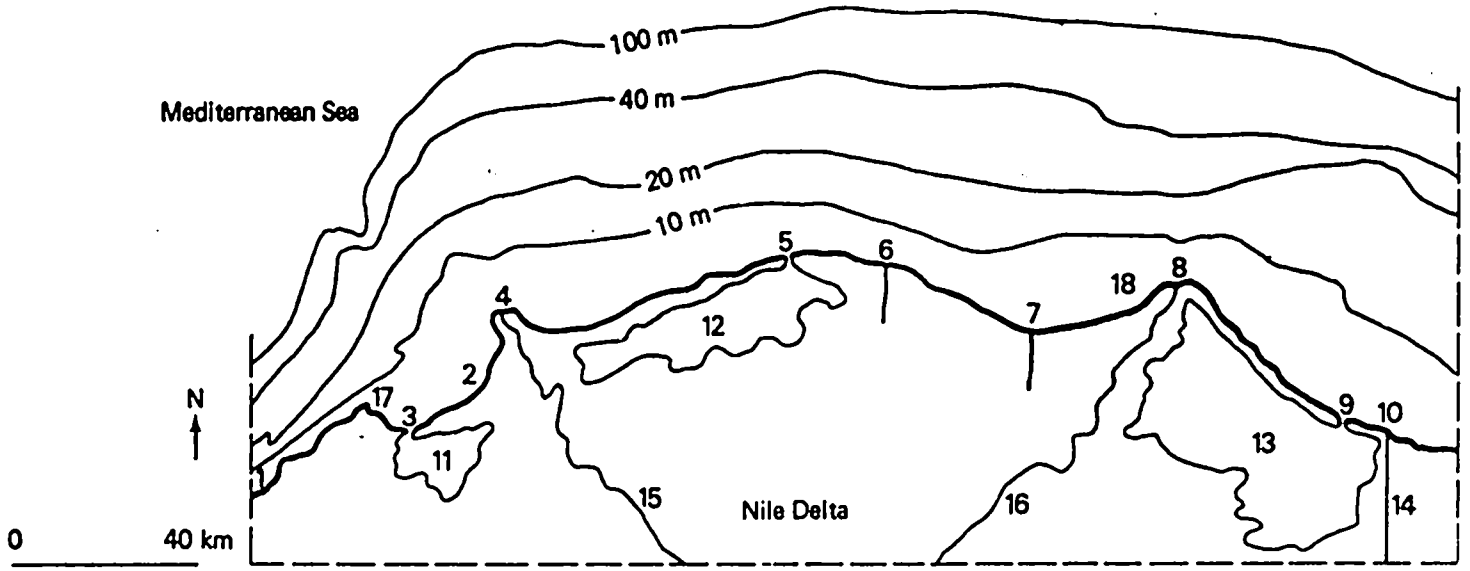

FIG. 1. Nile Delta coast: 1, Alexandria; 2, Abu Qir Bay; 3, Maadia outlet; 4, Rosetta promontory; 5, Burullus outlet; 6, Kitchener drain; 7, Gamasa drain; 8, Damietta outlet; 9, El Gamil outlet; 10, Port Said; 11, Edku Lake; 12, Burullus Lake; 13, Manzala Lake; 14, Suez Canal; 15, Rosetta branch; 16, Damietta branch; 17, Abu Qir; 18, Ras El Bar.

As a result of many unforeseen local problems, heightened by the explosive Middle East political situation and a war in October 1973, the first phase of the project concentrated on the protection of badly eroded areas, namely Burullus and Ras El Bar (Fig. 1), leaving the remaining objectives to be implemented in the second phase which was to take place from 1975 to 1977.

Apart from the administrative staff, the project recruited and trained field and design teams, with the help of Unesco experts capable of conducting oceanographic, hydrographic and geological surveys, measuring waves, currents and tides, maintaining and repairing equipment, evaluating and analysing field data hydrodynamically, geologically and statistically with or without computerization, processing and storing data systematically, and constructing simple mathematical models in line with their limitations. Most of the technical staff received part of their training abroad on Unesco fellowships.

ANALYSIS OF COASTAL PROCESSES

The most important information in the study of coastal processes pertains to the mechanism of these processes within the breaker, nearshore and offshore zones; assessment of erosion and accretion areas; and analysis of sediment motion in the various zones with the resulting sediment budget and demarcation of the coast into physiographic units, i.e. coastal stretches which behave independently of adjacent stretches. A proper coastal protection design is not possible unless these are known.

Since short-term coastal protective measures could be based on breaker and nearshore zone processes, and since the offshore processes are comparatively smaller, the major part of the project study was concentrated on the former, the main exercises being the following:

Study of coastal morphology and coastal changes drawn from surveys made since the last century.

Preparation of a near sediment distribution map up to the continental shelf.

Computation of sediment distribution off the Nile Delta coast as a flow indicator.

Analysis of wind and wave climatology based on past and present synoptic charts of the Mediterranean Sea, and examination of Nile discharges including sediment load since the beginning of the century.

Flood patterns in the Nile basin.

Bore holes drilled in the past and during the project period in the Nile Delta.

Annual and semi-annual hydrographic surveys of the coast taken during the project period.

Coastal currents (wave induced and others) in the breaker and nearshore zones measured from time to time.

Coastal changes, coastal cusps, changes at and around existing coastal structures, etc., made during frequent trips along the coast.

Monthly pre-storm and after-storm hydrographic surveys taken at outlets and heavily eroded areas.

Discharge measurements at outlets and drains along the coast.
Isolated measurements of bottom currents and surveys of offshore areas.
Continental shelf changes found by other ship surveys such as CHAIN (United States) during the project period.
Aerial photographs of the coast taken earlier.
ERTS imagery.
Papers and discussions from two seminars (sedimentology and hydrodynamic aspects of the Nile Delta coast) organized by the project.
Data, papers, notes, correspondence, etc., from other studies of the Nile Delta coast or similar coasts.
Reports and discussions resulting from visits by short-term Unesco consultants, and Advisory Panel Board meetings held from time to time during the project period.
The principal features of the final analysis are described below.

Wave climate

Wave action along the coast is seasonal in nature, with storm waves (winter) starting from the fourth week of October or the first week of November and continuing to the end of March; the summer (swell) season covers the months of July and August, April and May being transitional months and September and October characterized by a relatively calm sea. In general, there are sixteen storms per year, of which seven are fairly strong, with high winds and heavy rain, and the stormy season is out of phase with the Nile flood season.

Statistical analysis of the waves recorded along the coast coincided closely with theory. Though the most frequently occurring waves had significant wave heights of 130 cm (period 7-8 sec.), probability analysis showed that a significant height of 2.36 m can be expected to occur once in fifty days with a maximum height of 3.33 m occurring at least once during the stormy season. During the swell season, wave heights vary from 40 to 75 cm (period 8-9 sec.). Frequency distribution analysis showed that 50 per cent of the time, waves are higher than 76 cm and 80 per cent of the time higher than 55 cm.

Wave steepness, a major factor in the sediment transport direction, was found to vary from a maximum during the stormy season of 0.035 (average: 0.016) to a maximum during the swell season of 0.004 (average: 0.003). As regards direction of waves, those predominant during the stormy season at Burullus and Abu Qir (Fig. 1) were NW. and NNW, and waves from N., NNE., NE. were not uncommon at Burullus, especially in December and March. Swells, however, were generally from NNW. or NW. At Ras El Bar, storm waves often came from WNW. or NW. The predominant direction of wave energy flux, which is primarily responsible for nearshore coastal changes, was more or less the same as that of the waves.

Comparison of the various wave climates at the same instant showed that waves starting at Abu Qir took about eight hours to get to Ras El Bar, and waves from Burullus took about four.

Currents

Wave-induced current systems play a dominant role in the coastal processes of the nearshore zone. In general, there are two such current systems in addition to the oscillatory orbital wave motions and the resulting mass transport. They are the currents beyond the breaker zone and alongshore currents within the breaker zone. There is only a limited exchange of water (through rip currents, cusps, etc.) between them.

The Nile Delta coast continously changes in orientation therefore, and although waves may have a predominant direction, longshore currents in the breaker zone do not have a single predominant direction, because of refraction effects. In fact, for the predominant NW., NNW., N. and NNE. wave directions alone, the coast has to be divided into twelve stretches, in each of which alongshore currents work independently, having nodal points where currents reverse direction or become negligible. One significant fact emerges from the analysis and measurements, namely that even for wave heights of 50 cm (period 7-9 sec.), the magnitude of currents is in excess of 20 cm/sec. more than what is necessary to move the Nile Delta coast sediments (D_{50} varies from 0.025 mm to 0.20 mm in most areas). In some areas such as Burullus and Ras El Bar, storm waves generate currents in excess of 1.25 m/sec. Average velocities in these areas vary from 45 to 55 cm/sec. even in moderate weather. Thus alongshore transport in the breaker zone exists throughout the year, but significantly, it is compartmentalized instead of having one predominant direction when one considers the whole coast.

Measurements of currents beyond the breaker zone show that the current pattern is different from that within the breaker zone and that circulation cell systems exist. For NW./NNW. waves of 50-100 cm in height (period 7-9 sec.), it was found that the whole coast, 245 km in length, could be divided into twenty-five

stretches based on circulation cells and negligible velocity zones. The most interesting aspect about them was that they were significantly high (25-30 cm/sec.), and reversed in directions on both sides of the outlets and drains. Also areas such as an 18-25 km stretch midway between Rosetta and Burullus, a short stretch 8 km east of Burullus, and an area 15 km east of Damietta promontory showed negligible currents. The magnitude of the measured currents in most places compared well with the calculated values of horizontal bottom velocities using small amplitude theory.

Volumetric changes and trends in erosion and accretion

Coastal processes depend greatly on motion of sediment and its volumetric displacement in the breaker zone and beyond. Because of practical difficulties, actual measurements beyond 6-m depths could not be taken except in a few places (ship surveys), but changes up to 6-m depths from the shore represent major variations, which one can expect in that stretch, especially when currents other than those induced by waves have been found by measurement to be negligible.

With the type of current systems existing within the breaker zone and circulation cells beyond, with no major littoral barriers along the coast except at Port Said, which receives sediment only from a short stretch to the west, and with no accurate depth surveys beyond 6-m depths, theoretical methods to find the alongshore transport rates were found to be unreliable; therefore volumetric changes based on profile surveys and *X-T* diagrams were used to interpret the changes and types of coastal stretches.

Dividing the coast into various stretches, salient features of the changes can be described.

Abu Qir Bay is a separate physiographic unit extending up to but excluding the Rosetta promontory. Alongshore movement is towards the Rosetta outlet from Maadia and vice versa from the Rosetta outlet terminating in a nodal zone in a mid-stretch. Beyond the breaker zone, there is universal erosion twelve times greater than in the breaker zone, with sediment moving offshore (offshore current measurements also show seaward drift). The whole area, with the exception of a small breaker zone stretch in the middle, is undernourished. Any land development too near the coast should be viewed with caution. Left to itself without interference, the area may become stable after a number of years of instability.

Because of its protruding position, with respect to other parts of the coast and consequent wave refraction effects, Rosetta promontory acts independently. Although there has been a decrease in the erosion rate since 1977, it is one of the worst areas of erosion. The current pattern and circulation cells induce sediment motion partly offshore, partly to the west and partly to the east. With no Nile sediment through the Rosetta branch, promontory erosion will continue (although its rate may decrease) until the outer part of the promontory head disappears. This is one area where short-term protection may not work and long-term works should be undertaken as early as possible. The area is excessively undernourished.

The Rosetta-Kitchener drain physiographic stretch may be considered to start 10.5 km east of the Rosetta outlet, terminating 18 km east of the Burullus outlet. In the breaker zone, easterly sediment movement predominates, although the Burullus outlet blocks such movement, and the drift at Kitchener drain is almost negligible. The transport rate itself is very small in this stretch, and erosion and accretion have balanced for a period of four years. Beyond the breaker zone, coastal changes with net erosion behave in a fascinating way. There is no set pattern either in the behaviour of the profile shapes or in erosion or accretion. On a specific location, the erosion of one year becomes accretion the next. It is totally uncertain what may happen the following year. But the net effect is a shifting of the sediment back and forth. Left to itself, this area is not a problem area either on a short- or a long-term basis.

With the exception of two small stretches, one near the Kitchener drain and one near the Damietta promontory (at Ras El Bar), the Kitchener drain-Ras El Bar stretch is stable. Breaker zone erosion balances with accretion annually, whereas beyond the breaker zone, they balance once in four years. As in other stretches, the sediment movement beyond the breaker zone is offshore and onshore over the submarine bars which exist under-water along the entire coast in the form of a break-point bar at the point of wave breaking and one or two storm bars in 3.5 and 5 m depths.

The Damietta promontory behaves in the same way as the Rosetta promontory, with progressive erosion beyond the breaker zone, most of the eroded material moving eastwards. Recession of the promontory itself has been stopped temporarily by means of a jetty constructed on the western flank of the Damietta estuary, although signs of offshore erosion encroaching at an increasing rate in the breaker zone are already appearing. Protecting this area from erosion is possible and will be dealt with later.

The Ras El Bar-Port Said stretch is the most unstable

stretch along the Nile Delta coast. The first 10.5-km length has been eroding at a fast rate, especially in the breaker zone, and the vertical type coastal structures built as emergency works by the government to protect the main highway between Damietta and Port Said contribute a good deal to this erosion. The next 7-km stretch is an accretional area with a spit growing steadily seaward of the main coast. Lately, its growth has slowed down. The next 10 km has no set pattern of erosion or accretion. The remaining 19 km to Port Said has accretion in the breaker zone and erosion beyond. Project studies indicate that much of the siltation at the Port Said breakwater and entrance channel is only from this 19 km stretch, contrary to earlier assumptions of a predominant easterly drift along the whole coast reaching Port Said.

Physiographic nearshore units

One of the most important conclusions derived from the project study has been that the Nile Delta coast does not behave as one single unit but as a series of units, some of them independent and some acting as sources for the adjoining areas, even though they themselves are eroding. Many years of data collection and analysis are necessary to determine any set pattern of the physiographic units, but preliminary study gives the following indications:

The Abu Qir area is a separate unit, although its northern end acts as a drain for part of the Rosetta promontory.

The Rosetta promontory acts as a unit as far as erosion is concerned, and as a source for the adjoining areas on both sides.

The 70.5-km stretch from the Rosetta to the Kitchener drain appears to be a physiographic unit with the sediment shifting back and forth within the stretch.

The 66-km stretch from the Kitchener drain to Ras El Bar is a stable unit, although there are stretches of erosion and accretion balancing each other.

The Damietta promontory stretch behaves in a fashion similar to the Rosetta unit except that it acts mostly as a source for an eastern drain.

The coastal stretch, 15 km east of the promontory unit, is greatly influenced by a spit formation at its eastern end. It acts as a drain for the promontory erosion and to some extent as a source for the 10-km stretch located immediately eastwards

The remaining 19-km stretch appears to be an independent unit and acts as the major source for the Port Said breakwater and its entrance channel.

COASTAL PROTECTION WORKS

At the start of the project, there existed already or were under construction certain coastal structures built on the basis of purely local studies. Some of them, such as the breakwaters projecting seaward from the coast at the Burullus, Damietta and Maadia outlets, were built to improve outlet navigation. They were effective immediately after their construction, but became inefficient as their updrift side became silted and sediment moved into the navigational channels. Other structures, such as the vertical structures protecting the Damietta-Port Said highway, contributed more to damaging the coastal area than to stabilizing it. A wealth of information derived from project analysis indicates that the above designs could have been altered for better utility —above all for the least interference with the coastal processes.

The first task of the project, therefore, was to improve, maintain and add to the existing works at Burullus and Ras El Bar by designs which were less costly and which at the same time contributed to their efficiency. Four coastal protection design reports, one for the Burullus outlet, one for the Burullus sea-wall and its eroding easterly stretch, one for the Ras El Bar jetty and one for the Damietta estuary were prepared and submitted to the government for immediate implementation. By the end of the project, most of them were executed or under construction.

Coastal process-wave energy balance takes considerable time (many years) to become effective, and imbalance can be easily caused by interference in the form of coastal structures or improvements. The least interference with the coast is the best coastal protection.

Project studies indicate that certain areas should be left to themselves for natural restoration of their sediment-energy balances, whereas some other areas need protection to correct the imbalance, to save valuable land, or to improve navigation. The following describes the results of project studies:

Abu Qir Bay

Since breaker-zone erosion is negligible, and the erosion beyond is considerable, the success of any coastal protection measures is doubtful. The existing Mohammed Ali wall near Abu Qir, which is gradually crumbling, the deep-water erosion encroaching on the breaker zone, is an illustration. Land development, if any, should be as far inland as possible.

The jetties at Maadia outlet need extension to 4-m

depths if they are to be effective in keeping the outlet open.

Rosetta promontory

If the chief source, the Nile, continues to contribute no sediment, this highly deficient promontory will disappear. The extent of loss through erosion can, however, be decelerated and reduced by building protective works at some distance inland from the existing shoreline, possibly a combination of groins, with energy-absorbing revetments between them, development of barrier dunes and vegetation landward of the present shoreline, and rerouting of the present outlet through the western arm of the promontory. Hydraulic model studies (yet to be conducted) may reveal the best location for this outlet and for the groins. The promontory must be preserved in order to avoid changes in the flow patterns to the east, an area which, at present, is not highly unstable. Relocation and improvements in the outlet will also satisfy a long-felt need for a fishing harbour in the area, since the river is sufficiently deep (10-18 m), except at the natural entrance, which is blocked by a sand-bar.

Rosetta-Kitchener drain coast

With the exception of two areas—the Burullus outlet and the township, and the Baltim Sea resort—the coastal stretch is uninhabited, and likely to stay that way for a long time. Furthermore, the coastal processes in the area are unlikely to cause major erosion. Therefore the least interference is the best protection.

The Burullus outlet area has always been unstable, however, and is at present in a critical condition. The narrow coastal strips on both sides which separate the sea from the lake are exposed to the formation of breaches between them, and the protective dunes on the eastern side have been rapidly eroding. The project has submitted detailed plans for coastal protection on both sides, involving groins, energy-absorbing sloping beaches with armour stones, dune consolidation by vegetation, and toe protection for existing walls. Since Burullus is midway between Alexandria and Port Said, its importance as a commercial fishing harbour cannot be over emphasized. Outlines for the design of an all-weather, 4-m-deep fishing harbour have been submitted by the project.

The Baltim resort coast, about 10 km east of the Burullus outlet, is subject to 'cusp formation', that is, a wave coastal configuration moving back and forth with cusp lengths ranging from 250 m to 1 km and widths up to 100 m. Through ignorance of such cusp phenomena, a resort area developed very close to the sea two decades ago, but it is disappearing fast, and a new township is being developed inland. Construction of the resort too near the coast has been one of the factors responsible for rapid erosion in the area; the Baltim lighthouse, a landmark for many years, was at a safe distance until a few years ago, but is now dangerously close (30-50 m) to the sea. Protecting a wavy coast is difficult and the best solution, again, is the least interference possible. Resort development, if any, should be far inland. Protection with groins, especially in front of the lighthouse, is a possibility suggested by the project, but it should be studied with hydraulic models before being implemented.

Kitchener drain-Ras El Bar stretch

Like the Rosetta-Kitchener drain coast, this stretch is very sparsely inhabited except at the Gamasa Sea Resort, 57 km east of Burullus, and at Ras El Bar on the western arm of the Damietta outlet. The coast being stable except near the Kitchener drain and at Ras El Bar, no coastal protection works are necessary except the precaution of keeping any development as far from the coast as possible.

Moderately high dunes just east of the Kitchener drain act as protection for that eroding area. But the Ras El Bar beach resort (3.5 m long) has been undergoing erosion at an accelerated pace ever since the Nile flows through the Damietta branch were blocked by the Foraskur Dam, located a few kilometres upstream of the outlet. As stated above, deep-water erosion has already started encroaching on the beach. Project studies indicate that an offshore breakwater to reduce wave energy, inducing consequent sedimentation of alongshore drift in the breaker zone and beach, spreading coarse sand on the beach and for some distance seaward in the breaker zone, and the prohibition of construction close to the beach, should adequately protect the beach and help the existing three groins at the eastern end to trap more sediment and widen the beach in that area.

Damietta promontory

After Port Said and Alexandria, the Damietta outlet is the most commercially vital, and its protection and development closely ties in with the trading centre of Damietta a few kilometres upstream. On the basis of design reports submitted by the project, protection of the existing western jetty and a new eastern breakwater to protect the entrance channel from siltation, has already been

constructed, and a 2.5-m-deep channel now enables fishing boats to use the outlet up to Damietta. The second-phase construction to extend the western and eastern breakwaters, and enlarge and deepen (to 4-m depth) the anchorage inside with necessary wharves, will begin soon, according to the project design.

Damietta-Port Said stretch

The highway connecting Damietta with Port Said gives great importance to the coastal strech here since the inland area is covered by Manzala Lake and its numerous islands. It is unstable, and the alternative, which will be decided on a primarily economic basis, are (a) taking protective measures, and (b) building another highway much further inland. The project study indicates that, except for certain vulnerable areas which could be protected by groins and high energy absorbing revetments, most of the stretch should be left alone to stabilize itself naturally. The study also suggests that Port Said be connected to Damietta by constructing a highway through the lake.

LONG-TERM MEASURES OF PROTECTION

The short-term measures described above can be expected to protect the coast for thirty to forty years, and are much more important at present than the long-term measures which, although they are felt to be necessary at present, may have to be altered later, on the basis of the behaviour of short-term measures. Therefore, they are not described in this article.

Construction and maintenance of coastal protection works require efficient, well-equipped and well-organized construction outfits. The project feels that a central construction body for execution of all coastal works and their maintenance is necessary just as the monitoring and design aspects of coastal works are taken care of by the Coastal Protection Organization established by the project.

The Nile Delta coast is, at present, under the control of various governing boards. In order to co-ordinate the various activities associated with coastal protection, a coastal zone management cell will be essential.

The comprehensive whole-coast study of the Nile Delta coastal erosion was conducted on an interdisciplinary basis. The results of the study and the consequent recommendations for the protection works were themselves major achievements, since it seems that no such comprehensive study has yet been attempted elsewhere by any organization, even in developed countries.

Research on the arid zones of the Soviet Union

Half the nations of the world have part or most of their territories in arid or semi-arid zones, regions of highly variable and sparse rainfall, which account for about a third of the vital land surface of the earth. These zones are beset by serious ecological problems which impede their development and which, climatic factors apart, are due either to over-population, over-grazing and destruction of woody vegetation or to inappropriate management including lack of suitable conservation measures, over-extension of dry-land farming, and inappropriate use of agricultural technologies involving mechanization, chemical fertilization, and irrigation.

In many instances, as the United Nations Conference on Desertification in 1977 emphasized, these factors have led to alarming acceleration of the desertification process and the loss of large areas of productive land, which have caused extreme distress to the local populations. For these reasons arid zone research and conservation have been among Unesco's major preoccupations over the past twenty-five years, a concern shared by several other international organizations such as the United Nations Environment Programme (UNEP), Food and Agriculture Organization (FAO), World Meteorological Organization (WMO), International Union for Conservation of Nature and Natural Resources (IUCN), etc.

For the USSR, within whose territories a major portion of the arid and semi-arid zones are situated, arid zone management and conservation are clearly vital.

It is therefore natural that the MAB Programme of the USSR gives high priority to MAB Project 3, 'Impact of Human Activities and Land-use Practice on Grazing Lands: Savanna, Grassland, Tundra' as well as to the implementation of the biosphere reserve concept (MAB Project 8), particularly in arid zones. These endeavours are associated with training and monitoring programmes and linked with co-operative MAB projects in developing countries, which are the main beneficiaries of the vast experience in the above fields already at hand in the USSR.

The following articles, 'The Improvement of Arid Pastures in Central Asia', by Nina Nechayeva, and 'The Repetek Biosphere Reserve', by Vladimir Sokolov and Piotr Gounine, describe some of the USSR-MAB activities in these fields.