The extent of irrigation lands particularly salt-affected soils in Egypt

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SUMMARY - Extent of irrigated lands in the Near East region are identified. Salt-affected soils are widely spread in semi-arid and arid areas such as Egypt. Nature and distribution of salt-affected soils in Egypt are identified. Formation of salt-affected soils in Egypt is discussed. Crop management on salt-affected soils expressing Egyptian experience are presented. Major Land Improvements Projects in Egypt are mentioned. Water composition and availability including characteristics of Egypt's Nile irrigation system, status of water quality of the main Nile irrigation system, canal and drains and Nile aquifer are described.

Key words: Salinity, crop management, water quality.

RESUME - Les étendues de terres irriguées des régions du Proche Orient ont été identifiées. Les "sols affectés par la salinité" sont largement répandus dans les surfaces arides et semi-arides de l'Egypte. La nature et la distribution des "sols affectés par la salinité" en Egypte ont été identifiée. La formation des "sols affectés par la salinité" en Egypte a été discutée. Les données concernant les récoltes dans les "sols affectés par la salinité", selon des expériences égyptiennes, sont présentées. La plupart des projets d'amélioration des terres en Egypte sont mentionnés. La composition et l'efficacité de l'eau, comprenant les caractéristiques du système égyptien d'irrigation du Nil, l'état de la qualité de l'eau des principaux systèmes d'irrigation, les canaux, les rigoles de drainage, et les nappes aquifères du Nil sont décrits.

***Mots-clés**: Salinité, exploitations des récoltes, qualité de l'eau.*

Introduction

Egyptian agriculture is wholly dependent on irrigation from the Nile River. One exception is the small area of irrigation land in several depression in the Western Desert where fossil groundwater supplies water for irrigation. Rainfall is so negligible that it is excluded as a source of water for agriculture except for a small area along the Mediterranean Coast in the Western Desert and Sinai, with less than 200 mm rainfall. Outside the Nile Valley and Delta and the Mediterranean Coast, the bulk of Egypt (almost 97%, of the total area) is arid desert.

In semi-arid and arid areas, as it is the case with almost all the Middle East countries the provision of irrigation water is one of the most important factors for the expansion of agricultural production in the direction of intensification as well as of expansion of cultivated land. According to FAO's Indicative Word Plan the total irrigated areas in 1962 in the Near East countries amounted to about 27.2 million ha, which is equivalent to 36.5% of the total arable area. The irrigated areas will have to be increased to about 40.7 million ha by 1985 if agriculture is not to fall behind the expected economic growth of the region, and this increase will be equivalent to about 51% of the total arable areas of the region (Table 1).

The effect of irrigation on the substantial increase of agricultural production in volume as well as in value as compared to rain-fed farming is a well accepted fact. The 36% of the total arable land of the region which is irrigated produces about 70% of the total crop value.

Irrigated agriculture seems to be specifically important for countries such as the ARE, West Pakistan, Iraq and Saudi Arabia. In many of the countries of the region, surface water is the main source for irrigation, and in areas where this source is scare or unavailable ground water is used. The success of any agricultural development in the region will, therefore, depend on the wise use of the available water resources. However, irrigated agriculture may be faced with and/or develop new problems that need special consideration, such as natural salinity of soils and ground water, waterlogging, secondary salinization, and shortage of irrigation water (Khatib, 1971).

Nature of salt-affected soils

The majority of salt affected soils in the ARE are located in the Northern-Central part of the Nile Delta and on its Eastern and Western sides. Other areas are found in Wadi El-Natroun, El-Kebeir, the Oases, many parts of the Nile Delta and valley and El-Fayoum province (Fig. 1).

Soils of primary salinity are mainly those of marine and lacustrine origin, such as brackish lake beds or salt marshes along the northern coast. Soils of Edko, Maruit and Burullos are examples of this type. These soils are saline or saline-alkali with sodium chloride and sulphate as dominant salts. The sea water affects both soils and groundwater to the extent that the groundwater salinity in such areas is often higher than that of the sea water. The dominant salts in the groundwater are generally sodium chloride, sodium sulphate and, to a lesser extent, magnesium sulphate. In Fayoum, the salinization took place as a result of the deposition of the migrating salts during the soil formation.

The salinity in El-Wadi Gedid and Kattara Depression lands is generally connected with the evaporation of deep salty groundwater wedged up to the soil surface through tectonic fractures, and the accumulation of salts on the soil surface, under extremely desert-arid conditions.

The alkali soils of Wadi El-Natroun are the result of the microbiologic activity of sulphate reducing bacteria under anaerobic conditions. The salt affected soils of secondary origin in the ARE are mostly in the old cultivated area, and are more pronounced in low lying lands adjacent to the irrigation canals. The deterioration of these soils is mainly attributed to shallow saline groundwater and misuse of irrigation water over the years as a result of the introduction of the perennial irrigation system, unaccompanied by adequate drainage.

In addition to saline and saline-alkali soils, two other types of deteriorated soils were identified:

Alkali soils which are characterized by their adverse physical properties, their dispersed condition and impermeability to water, are to be directly connected with sodium as the dominant exchangeable base and the presence of magnesium silicate precipitated during the process of soil alkalinization. The gypsum-veined soils are characterized by their low permeability to water, presence of Ca, Mg and Na salts in varying amounts.

In addition, an impermeable layer underlaid by a horizon veined with gypsum at variable depths is always present. Upon wetting, the impermeable layer in such soils becomes highly dispersed while it becomes hard when dry. This may be due to the presence of magnesium silicate.

Such deteriorated soils are connected with the depth, duration, regularity and fluctuation of groundwater. The gypsum-veined type is found under conditions of deeper water tables whereas the alkali type is found on the low-lying areas where the water tables is high. Moreover, the formation of these four types of salt affected soils in the irrigated area is largely related to the degree of concentrations, chlorides, sulphates and bicarbonates dominate following the same order. Saline, saline-alkali, gypsum-veined and alkali soils are formed respectively (El-Mowelhi, 1972).

Distribution of salt-affected soils

A salt affected soil is simply defined as a soil that has been adversely modified for the growth of most crop plants by the presence of soluble salts, exchangeable sodium, or both. Saline or solonchak soils refer to those showing a high concentration of soluble salts which result in lowering the soil moisture potential due to osmotic effects. Under this condition, plants suffer from osmotic drought and hinderance to normal water and nutrient uptake. Sodic (alkali or solonetz) soils refer to those characterized by the presence of sufficient exchangeable sodium and high pH to interfere with the growth of most crop plants. The decisive limiting factors in such soils are the poor physical conditions, the unfavourable internal drainage and the unavailability to plants of micro-elements (U.S.S.L., 1954).

Although this brief description of salt affected soils gives the impression that they have serious limitations for agriculture production, yet generally these soils are potentially productive. They cannot be brought under the plough until suitable technology for their amelioration and management is evolved. Moreover, the economic implications involved in reclaiming salt affected soils are a major consideration to increasing production. The problem is really a pressing one in many countries, particularly in arid and semi-arid regions, as well as in a number of river Delta, plains with poor outflow and closed basins.

It is known that salt affected soils are found in every continent (Table 2). Information on the exact degraded areas and in particular their degree of deterioration is not available for all of the countries affected by salinity sodicity. Szabolcs (1971) estimates that roughly over 20 million ha of the European salt affected soils are solonetz and about 7 million ha are solonchak. Vast amounts of these solonetz soil are found in Bulgaria, Czechoslovakia, France, Hungary, Rumania, U.S.S.R. and Yugoslavia, while in Austria, Greece, Italy and Portugal they are spotted about.

The present and potential salt affected areas in the Near East Region are estimated at 30 million ha, the bulk of which is distributed as follows: Iran 7.3, Pakistan 6.4, Somalia 3.0, Turkey 2.3, Egypt 2.0, Iraq 1.8 and Syria 0.2 million ha (FAO, 1971).

In Africa salt affected soils are known in Nigeria, Chad, Mali, Algeria, Morocco and Tanzania.

Information on the global distribution of salt affected soils has been obtained from the FAO/Unesco soil Map of the World by countries (Massoud, 1974).

It should be borne in mind that the areas given in the tables are not necessarily arable but mainly salt affected lands.

The salt affected soils of the world amount to about 970 million ha of which 250 million ha are solonchak and solonetz soils and approximately 650 million ha are saline and sodic phases that mark present or potential degradation. In general about 7 percent of the total soil surface area of the world is covered by salt affected lands: Australia 42.3%, Asia 21%, South America 7.6%, Africa 3.5%, North America 0.9%, Central America 0.7% and Europe 4.6%.

Formation of salt-affected soils in Egypt

Soils affected by sea-water and salty lakes intrusion

Table 1. Percent and potential land use in the Near East region areas in 1000 ha (Khatib, 1971).

Country	1962			1985		
	Total arable land	Total irrigated land	Irrigated as % of total	Total arable land	Total irrigated land	Irrigated as % of total
Afghanistan	9,017	2,885	32.0	11,070	3,007	27.0
Fed. Republic South Yemen	400	68	17.0	400	153	38.0
Iran	16,850	3,150	18.7	19,599	4,894	25.0
Iraq	6,747	3,559	52.7	6,329	3,798	60.0
Jordan	1,726	55	3.2	1,246	66	5.3
Kuwait	20	2	10.0	20	7	35.0
Lebanon	270	60	22.2	363	117	32.0
Libya	3,645	132	3.6	-	-	-
West Pakistan	19,700	11,400	58.0	30,400	24,400	80.0
Saudi Arabia	341	240	70.0	357	255	73.0
Somalia	1,917	17	0.9	-	-	-
Sudan	6,166	2,566	41.6	-	-	-
Syria	6,645	500	7.5	6,875	830	12.0
UAR	2,595	2,595	100.0	3,156	3,156	100.0
Total	76,039	27,229	36.0	79,815	40,683	51.0

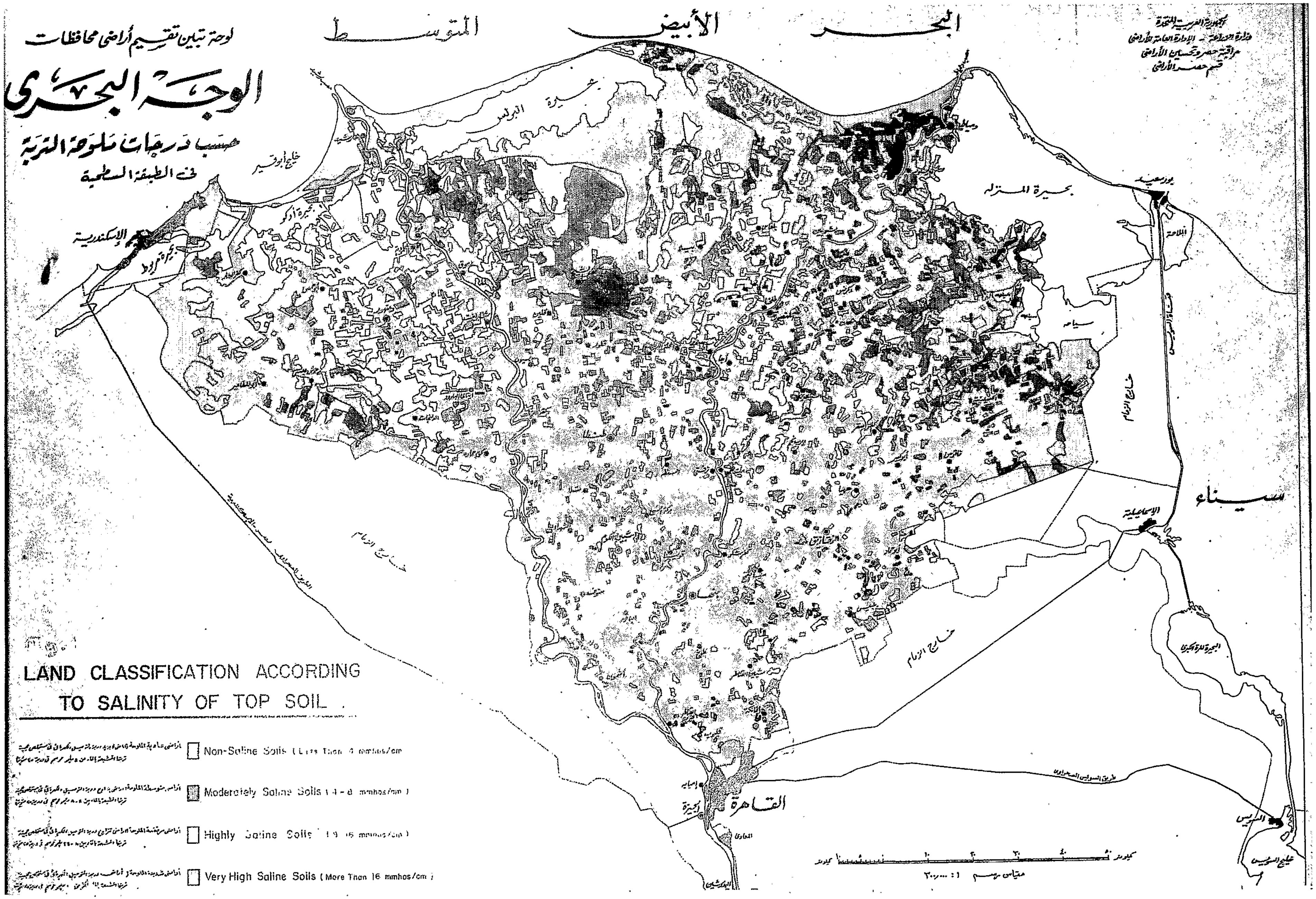

Fig. 1. Land classification according to salinity of top soil.

Table 2. Regional distribution of salt-affected soils in 1,000 ha (Massoud, 1974).

Regions	Solonchak	Saline phase	Solonetz	Sodic phase	Total
Europe	-	-	-	-	50,804
North America	-	6,191	9,564	-	15,755
Mexico & Central America	242	1,723	-	-	1,965
South America	10,461	58,949	14,790	44,963	129,163
Africa	43,579	47,705	1,881	5,356	98,521
South Asia	47,233	36,077	-	1,798	85,108
North & Central Asia	22,465	69,156	30,062	90,003	211,686
South East Asia	-	19,983	-	-	19,983
Austral Asia	16,567	792	38,111	301,860	357,330
Total	140,547	240,576	94,408	443,980	970,315

Sodium chloride is the dominant salt and it is the main source of salinization. Inundating the soils with sea and lake salty water a long time is the most important factor for salinization in the mentioned soils, beside the tidal affect and the salty soil solution. Shalma and El-Hamoul South Borulus lake represent this type.

Soils affected by salty ground at South Manzala lake East and at Abees West

Magnesium chloride and magnesium sulphate are the dominant salts and the main source of salinity in the Manzala Lake area, while sodium chloride is the dominant salt and the main source of salinization in the area representing Abees South Maryot Lake.

Soils affected by seepage (areas at Maryot Lake West and Tal-El-Kabeer East)

Sodium chloride and sodium sulphate is the dominant salt in Maryout and Tal-El-Kabeer areas respectively. The main factor responsible for the deterioration of these soils is seepage from irrigation canals in Maryot and from Ismailia canal in Tal-El-Kabeer.

Soil affected by biological sulphate reduction. Ferhash area (Behaira Governorate North West Part of the Nile Delta)

Sodium carbonate, bicarbonate and sodium sulphate are the dominant salts in Ferhash area. The main factor for alkalinization is the effect of biological sulphate reduction.

Soils affected by irrigation water quality (Wadi El-Natrun area)

Sodium chloride is the dominant salt and sodium saline irrigation water (~5000 ppm) is the main factor for salinity formation in this area.

Crop management on salt-affected soils

The cropping pattern in Egypt is somewhat adjusted to soil condition. In the Northern Delta where soil salinity is somewhat higher than normal, crop rotation includes rice and cotton as the main summer crops and wheat and clover as the main winter crops. All these crops have proven to be tolerant or semi-tolerant to salinity. Sugar beet which is known to be tolerant to salinity has been recently grown in the Northern Delta. Its area increased from 16,000 *feddan* in 1982 to 42,000 *feddan* in 1988 and is now supporting a big sugar factory. Further expansion in sugar beet production is planned in the new reclaimed land west of the Delta.

However basic crop management on salt-affected soils could be presented as follows:

Crops during reclamation

The reclamation of virgin saline soils is usually divided into the following stages:

i. The preparatory stage of the project including field surveys, field and laboratory research work, design of irrigation and drainage system.

ii. The constructional stage during which all constructional work including levelling, construction of irrigation and drainage system, roads, building, is completed.

iii. The leaching stage during which the excess salts are leached to a level and depth that permits the start of cropping.

iv. The leaching-cropping stage during which the growth of crops combined with leaching affects further reclamation; during this stage the input from the land is less than the output.

v. The normal cropping stage during which a variety of crops can be grown with output from land exceeding input.

In many virgin saline areas in the region, i.e., ARE, the salinity of the soil is too high to permit the growing of crops from the beginning. Under such conditions, the leaching stage must precede the leaching-cropping stage to lower the initial salinity to a level that permits the growth of salt tolerant crops, i.e., where the total soluble salt is < 0.63 or E.C. < 15 mmhos. If this is achieved before the month of November a salt tolerant winter crop such as barley, rye grass, berseem clover, can be tried. If the salt concentration is above 0.65% on the surface foot the growth of these crops will be spotted. The liberal use of water combined with drainage will help reduce salinity level and increase depth of desalinized zone by the end of the growing season.

On the other hand if the leaching is completed before the month of May a summer crop such as *nuseila* (*Echinochloa stagnina*) and rice can be grown. The former is salt tolerant and requires liberal use of water. By the end of the growing season of rice, the salt level is greatly reduced to allow more varied cropping during the winter season of the second year.

Salinity tests should be made every six months following the leaching and before the sowing of next crop. On the basis of the level and depth of salinity a better crop selection during reclamation can be made.

Such a selection should be based on:

i. Tolerance to salts.

ii. Tolerance to waterlogging.

iii. Liberal water requirements.

iv. Economic value.

The following crop succession according to the level of salinity is recommended:

2nd year

Winter	Summer
Barley, rye grass, followed by	rice
Berseem clover followed by	sorghum

3rd year

Wheat followed by	rice
Clover (catch crop) followed by	cotton

4nd year

Clover (catch crop) followed by	cotton
Wheat followed by	rice

5nd year

Clover (catch) followed by	cotton
Beans followed by	corn
Wheat followed by	rice

It is supposed that after 6 years complete desalinization of the root zone and partial desalinization of groundwater will have been accomplished and normal use of the soil will be possible.

Management practices during the combined leaching cropping stage

i. Use more irrigation water than required by the consumptive use to meet the leaching requirements.

ii. Include crops in the rotation which ensure effective leaching of accumulated salts.

iii. Keep seepage losses to a minimum.

iv. Avoid-irrigation that to a rise in the water table.

v. Keep a plant cover to protect soil surface from evaporation during the summer as much as possible.

vi. Ploughing should be deep enough before leaching; if soil is left fallow surface should be ploughed.

vii. Pre-sowing heavy winter irrigation for cotton to desalinize surface layer during germination.

viii. Subsoiling and deep ploughing with deep fertilization is essential.

ix. For row crops plant on the slope of furrows below the zone of salt accumulation.

x. Re-level fields very carefully following the removal of each crop to ensure uniform distribution of water (El-Gabaly, 1971).

Major land improvements projects in Egypt

In addition to the land reclamation projects, there are two projects being started for the improvement of presently cultivated land.

Land improvement and conservation (EALIP)

In this project, low productive soils which suffer from excess alkali salts and poor physical condition or inadequate drainage are selected. Plans for their improvement are outlined according to the specific conditions of each individual case and recommendations are implemented under the supervision of specialists of the Department of the Ministry of Agriculture.

Improvement practices, generally, include the installation of open field drains, leaching of excess salts, application of required gypsum, and deep ploughing or subsoiling.

The project started in the year 1967/68 as an experiment covering an area of 2,000 *feddans*. The results obtained were greatly encouraging. In 1968/69 and 1969/70, the experiment was repeated on an area of 15,000 and 30,000 *feddans* respectively.

The increase in yield of different crops ranged between 50-150% of the initial yield. Therefore it has been planned to develop the experiment to national project to improve a total area of about 2 million *feddans*, covering all the class 3 and 4 soils, within about a 20 years period. The authority responsible is EALIP.

In 1992 almost 2.5 million *feddans* were improved. The current plan is to improve 250,000 *feddans* annually.

Drainage Projects (EPADP)

Drainage is an essential requirement for the reclamation of salt affected soils and for maintaining a good salt and water balance and good aeration for a productive soil. Therefore, artificial drainage has to be provided wherever natural drainage is inadequate.

By the end of 1988, more than 5.5 million *feddans* of cultivated land in Egypt were covered with a network of open collector drains. Of that area, more than 3.2 million *feddans* were provided with tile drains at the field level. It is planned that tile drainage will be expanded to cover a total area of 5.115 million *feddans* by the year 2000.

Water composition and availability

Characteristics of Egypt's Nile irrigation system

The present irrigation system is characterized by two dams at Aswan and 30,000 km of public canals some of which have discharged up to 1,000 m^3/sec. There are approximately 80,000 km of private *mesqa* (micro) systems and farm drains, 560 large public pumping stations, over 17,000 km of public drains and 22,000 water control structures. There are two significant areas of non-renewable groundwater located under the Western Desert and the Sinai. Estimates vary but there may be as much as 25 billion cubic meters of water laid down. The only rainfed area is a narrow strip along the north western coast where annual precipitation from only 10 to 20 centimetres. This is a very complicated system with one major river providing water to about 7 million *feddans* (3 million hectares). About 87% of the area is composed of alluvial lands along the Nile Valley and Nile Delta. There are known as "old lands" while the remaining of the irrigated area is located in recent "new old lands" or desert lands. Operationally, the major characteristics of Egypt's irrigation system are: (1) Operation and control of water primarily based on the water surface elevations downstream of intake gates; (2) Water supplied to users on a rotation system which alternates in on and off periods varying by season and cropping patterns, and (3) the fact that most Egyptian farmers, the exception of a large command in the Fayoum Governorate, have lift water on to fields from a micro-delivery systems designed below ground level. The present system of operation has created high losses of about 11 percent between canals and about 25 percent or more between *mesqa* (micro system) and field outlets. Organizationally, the Ministry of Public Works and Water Resources (MPWWR) has four departments (Irrigation, Finance, Planning, and Mechanical). There are four authorities (Drainage, High Dam, Coastal Protection, and Survey), six public companies and the Water Research Centre with 11 separate institutes. There is a total of 19 administrative directorates, 48 inspectorates, and 167 irrigation districts. The MPWWR regulates water supplies to and within each of 50 canal commands based on monthly water need estimates prepared jointly by the MPWWR and the Ministry of Agriculture (MOA).

Egypt in recent years has implemented many projects dealing with improved system performance. Only since about 1976 has solid policy and program attention been given to irrigation water management research on a large scale. Surplus water has indeed led to much over-irrigation and severe problems of return flow indicated by the fact that a large and increasing percentage of the total agricultural sector investments over the past 20 years have been allocated to drainage.

There is some debate about what the overall or global efficiency of Egypt irrigation system actually is because some estimate that there is more re-use of water by pumping from groundwater and drains than was previously thought. There are substantial data to show, however, that significant increases of rice, wheat, cotton, and other crops yields are possible with reductions of water applied. These and other environmental problems have stimulated a concern among policy makers and water uses to move towards strategies for improving total performance of the system (El-Assioti, 1992).

Status of water quality of the main Nile irrigation system

The main stem of the Nile

Lake Nasser

In general, the water quality of lake Nasser is considered good. However, some threats can be identified if the settlements around the lake and in the upstream catchment increase without taking the proper provisions to about water pollution. One of these is associated with thermal stratification in the lake resulting from its depth (up to 130 m) and seasonal variation in temperatures. This stratification reduces vertical mixing and as a consequence prevents the supply of oxygen from the surface into the deeper water layers. Hence, oxygen content in the deeper water layer is reduced and often reached anaerobic conditions. The reduction of oxygen and the chance of anaerobic conditions will increase if the reservoir is exposed to heavier loads of organic matter and nutrients. Therefore, protection of water quality in the Nile River should not be restricted to the Nile River system downstream of the high Aswan Dam; attention also should be paid to pollution threats from the upstream catchment area and from activities in and around Lake Nasser.

The Nile River

The quality of water released from Lake Nasser affects the quality of the Nile River downstream of the High Dam. The change in water quality of the river on its way down to the Delta is illustrated by the longitudinal profiles as in Fig. 2 and 3 for Total Dissolved Solids (TDS) and Dissolved Oxygen (DO). From the comparison between the profile for 1976-1978 and 1991, it can be concluded that no significant changes have occurred so far on those two parameters, but a broader index of quality shows some deterioration in the quality.

To evaluate the changes in the Nile water quality during the last decade, a summarized evaluation of changes of 10 constituents has been worked out by Nile Research Institute. In this evaluation, a water quality index is defined based on the ratio between actual concentrations and their standard deviations. The constituents used for this index include temperature, pH, dissolved oxygen, BOD, TDS, suspended solids, phosphates, nitrate, ammonia and faecal coliform bacteria. The index value for the Nile River between Aswan and Cairo is shown in Fig. 4 for both 1977 and 1986. From the comparison between 1977 and 1986 it can be concluded that some degradation of water quality has occurred since 1977. Since the quality of Nile River upstream of Cairo affects the drinking water quality for most of Egypt's population, preventive measures are essential to stop a further deterioration of the quality of this vital water source.

Rosseta and Damietta Branch

The discharge of the Rosetta branch upstream near the Delta Barrage varies between 1.000 m^3/s (during winter) and 100 m^3/s (during summer). During the summer period the discharge at the downstream Edfina Barrage is very small reducing then dilution possibilities. Accordingly, the results from recent field surveys around Kafr El-Zayat in summer months show high concentrations of faecal and total coliform bacteria and this has serious effect on the health of Egypt's population.

Status of water quality of canal and drains

Irrigation canals

The main canal system is supplied with water from the Nile River and hence the water quality in the canals depends to a large extent on the quality of Nile River water at intake. Due to wastewater discharges from both domestic, industrial and navigational activities, and uncontrolled mixing with water from polluted drains, the quality in the canals gradually deteriorates as they move downstream. Although some measurements have been carried out, there is no clear overview on the quality status of the canals, except for salinity and related constituents, which are reported on a yearly basis by the Drainage Research Institute.

Agricultural drains

Drains are mainly used as receptacles for untreated, partially treated, and treated municipal and industrial wastewater, in addition to drainage water from agricultural areas. Therefore, they contain high concentrations of various pollutants such as organic matter (BOD, COD), nutrients, faecal bacteria, heavy metals and pesticides. This situation presents serious problems as the drains are extensively used for local "informal" irrigation and for blending with Nile River water for other purposes.

The water quality of some of the drains is monitored at the discharge end. From this data, it can be concluded that some of these drains should be considered as open sewerage systems. They have strong odour (hydro-sulfide) and form a potential risk for public health since people living along the bank of the drains are exposed to high concentration of bacterial and chemical pollutants.

An example is the Bahr El-Baqar drain system, which receives untreated and/or only primary treated wastewater from East Cairo. From its upstream end, starting at the discharge point from El-Gabal, El-Asfar treatment works into the Belbeis drain, down to the confluence with the Qaliubia drain and at its discharge end into Lake Manzala (total length of about 170 km), the drainage water is under completely anaerobic condition with high of BOD values, ranging from 60 mg/l at the central section, at 32 mg/l at the discharge end, and high ammonia concentrations ranging from 5.2 to 2.8 mg/l. As the total discharge of the drain is about 1,700 Mm^3 /year, there is a serious impact on the water quality of Lake Manzala. It is reported that the drain also carries high concentrations of heavy metals (such as cadmium, copper and zinc), which partly settle and accumulate in the bottom sediments of Lake Manzala.

Nile aquifer

To date, there has been no regular water quality monitoring of the Nile Aquifer. Hence, evaluation of the quality status is based on limited observations instead of on thorough analysis. Research institute for groundwater studies indicate that:

i. In the flood plains, nearly all shallow-dug wells (less than 30 meters) show signs of pollution. However, the deeper reservoirs which are protected by the silty top-layer (50 meters), are not yet affected in most of the areas.

ii. The situation in the outer plains gives rise to concern, since there is no top-layer of silt to provide protection, while important developments are taking place in agriculture (Tahrir Project, etc.), urban expansion and industrialization (Ramadan City, Nasr City, etc.).

There are unconfirmed reports of serious groundwater pollution associated with these projects which have insufficient or no (Ramadan City) wastewater disposal systems.

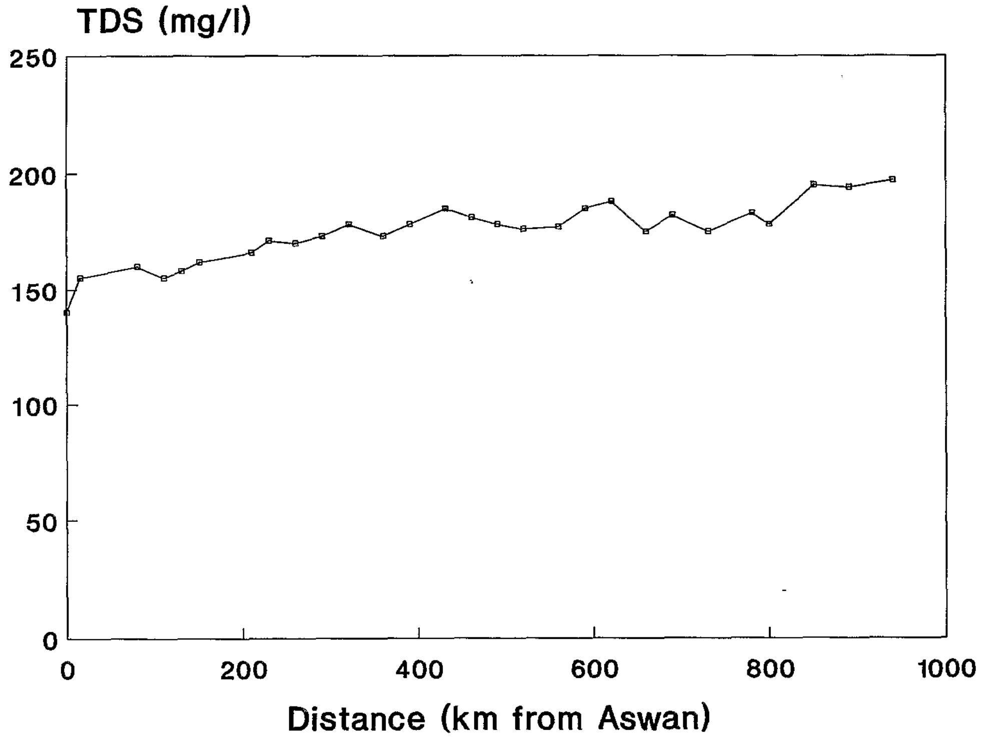

Fig. 2. Nile River (Aswan-Cairo) Total Disolved Solids concentration (TDS).

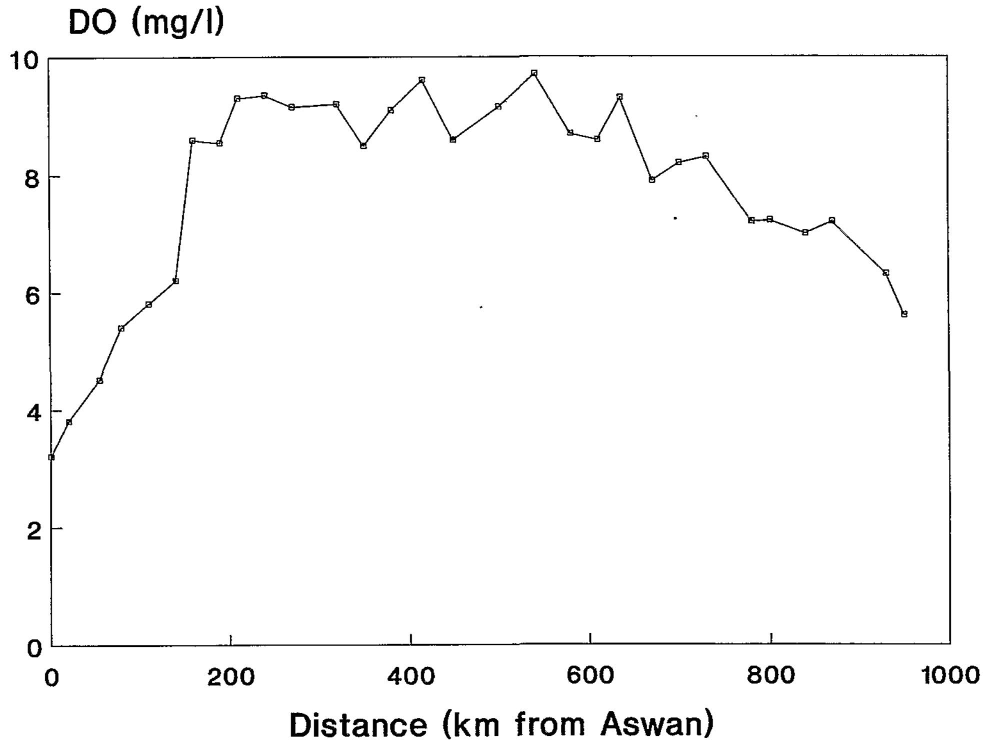

Fig. 3. Nile River (Aswan-Cairo) Disolved Oxygen concentration (DO).

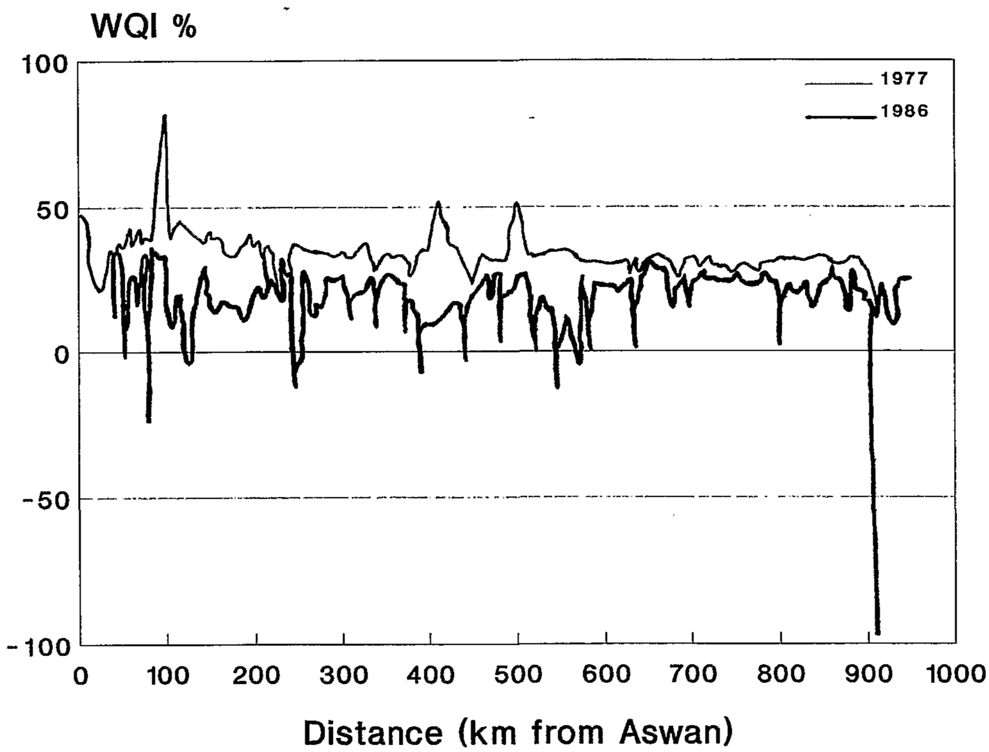

Fig. 4. Nile River (Aswan-Cairo) Water Quality Index for 1977 and 1986.

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