NILE VALLEY REGIONAL PROGRAM
PHASE II

Resource Management Series

Volume 12

INVENTORY STUDIES

Rainfed Areas of Egypt

North Sinai

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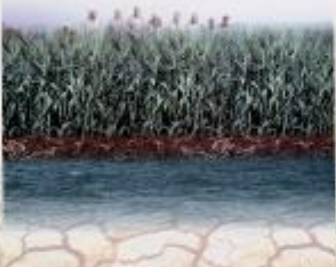

Volume 12

Resource Management in the Rainfed Areas of Egypt: North Sinai

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Foreword

Limited soil and water resources and threatened sustainability of agricultural production call for an effective resource management strategy and farming systems approach in agricultural research. Implementing a long-term research program where more emphasis would be on systems-oriented rather than commodity-oriented agricultural research would represent such a strategy. Therefore, the Resource Management Component of the Nile Valley Regional Program (NVRP) of the International Center for Agricultural Research in the Dry Areas (ICARDA) was developed. The Component, which started in 1994 in one of the Nile Valley countries, Egypt, and is expected to be extended to the others, aims at achieving sustainable production at a high level, based upon the need to protect the resource base (land and water) through good management. This would be achieved through basic intensive technical research (long-term on-station trials) and on-farm extensive monitoring of resources in farmers' fields and farmers' decision making logic.

Preparatory studies were carried out prior to conducting the trials and monitoring activities. The objectives of these studies were to define and characterize the major farming systems of the main agroecological environments; to identify and prioritize—with respect to the natural resources—the constraints to optimum utilization and the threats to sustainable production; and to provide an outline for the strategy, design and implementation of the long-term research activities.

The preparatory studies involved three procedures for information collection: **Inventory Studies**, in which existing information and details of the ongoing research and development, related to soil and water management, agronomy and cropping systems, and socioeconomics were collected; **Rapid Rural Appraisals**, which included qualitative sampling of farmers and extension views concerning current limitations, constraints, dangers, and opportunities in the utilization of soil, water, and inputs; and **Multidisciplinary Surveys**, which employed short-focused questionnaires to fill some important information gaps. In general, information collected in the preparatory studies dealt with resource description, resource utilization and management, productivity, and threats to sustainability. This knowledge was used in planning the long-term research activities at selected locations by identifying high-priority researchable resource management problems, in the context of realistic cropping sequences and farm level economics.

The outcome of these studies is hence presented in what is called the ***Resource Management* Series**. The series includes a total of 18 volumes on Inventory Studies, Rapid Rural Appraisals, and Multidisciplinary Surveys in the Old Irrigated Lands, New Lands, and Rainfed Areas. In the Inventory Studies, five volumes on the research and development activities and findings in each of the Old and New Lands were compiled. These volumes were on Agronomy, Soil Fertility and Management, Water Management, Socioeconomic Studies, and a Synthesis of all the latter. The Inventory Studies of the Rainfed Areas included two volumes, one on the Northwest Coast and the other on North Sinai.

These studies were conducted in Egypt with the involvement of the Agricultural Research Center (ARC), Desert Research Center (DRC), National Water Research Center (NWRC), National Research Center (NRC), Ain Shams University and ICARDA within the NVRP with financial support from the European Commission. Appreciation is expressed to all those who contributed to these important reviews and studies.

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Weights and Measures

1 feddan (fed) = 0.42 hectare = 1.037 acres
1 hectare (ha) = 2.38 feddans
1 ardab wheat = 150 kg
1 ardab barley = 120 kg
1 ardab lentil = 160 kg

Acronyms

AERI = Agricultural Economics Research Institute
ARC = Agricultural Research Center
CAPMAS = Central Agency for Public Mobilization and Statistics
CEC = Cation Exchange Capacity
DRC = Desert Research Center
EU = European Union
FAO = Food and Agriculture Organization
FCRI = Field Crops Research Institute
GARPAD = General Authority for Reclamation Projects and Agricultural Development
GTZ = Gesellschaft für technische Zusammenarbeit (German Agency for Technical Cooperation)
ICARDA = International Center for Agricultural Research in the Dry Areas
JICA = Japan International Cooperation Agency
MALR = Ministry of Agriculture and Land Reclamation
NVRP = Nile Valley Regional Program
SWERI = Soil, Water and Environment Research Institute
TDS = Total Dissolved Salts
USBR = United States Bureau of Reclamation
USDA = United States Department of Agriculture

Introduction

The rainfed areas in North Sinai are located in the northern part of North Sinai Governorate, which is located between 32° 10' and 34° 33' east longitude and between 29° 36' and 31° 10' north latitude. It extends over an area of 27,564 km^2.

The rainfed areas in North Sinai have been the subject of several studies. Since the early Fifties, the Desert Institute (now the Desert Research Center) has played a major role in the assessment and management of soil, water, plant, and animal resources. The Desert Institute has had an affiliated research station in Al Arish since the Fifties. It has cooperated with other institutes and scientists in carrying out many studies (El Gabaly, 1954). Several theses have been prepared, especially based on the investigations of Wadi Al Arish (Sabet, 1958).

Investigations were interrupted by the occupation of the Sinai in 1967, to resume promptly after liberation in the late Seventies. Theses were once again prepared by research staff (El Nennah *et al.*, 1981; Elwan *et al.*, 1983), as well as several special studies (El Bagouri *et al.*, 1982). Research projects, sponsored by the Academy of Scientific Research and Technology (1983–1993), the Ministry of Development and New Communities, Dames and Moore (1983), the German Agency for Technical Cooperation (1993), and others, were carried out as part of R&D activities to build the database needed for development of all the regions of the Sinai, a top priority of the Government of Egypt.

Climate

General Description

The climate in the area is known as the Mediterranean type, characterized by relatively rainy, cool winters and dry, hot summers. A description of the climate of Egypt and the Sinai is given in Griffith (1972). The author reports that the climate of the Sinai is determined by the following factors:

- In each season there is a semi-permanent pressure system, such as the cold Siberian anticyclone in winter, the heat lows of Africa in spring and summer, and the huge low over southwest Asia in summer. These systems are air mass source regions in their respective seasons.
- Traveling depressions and associated weather occur in winter and the transitional seasons.
- The Mediterranean Sea, as a source of water vapor, has a pronounced influence on North Sinai.
- Orography plays a small role in the general climate but has local effects.

During winter, the climate of the Sinai is mild, with some rain showers, mainly in the coastal area. The Siberian anticyclone is the source of cold air masses. The coldest spells in Egypt occur with the arrival of these air masses. The synoptic conditions that favor the invasion of this air occur when a deep depression with a tight pressure gradient covers the Mediterranean when the Siberian anticyclone extends westwards.

The main feature in the spring is the southward shift of the depression tracks. The centers of the depressions move either along the coastline of North Africa or further south, where they are known as desert or *khamsin* depressions. The average frequency of these depressions is 3–4 per month, but may vary between 2 to 6 per month. The difference between *khamsin* depressions and *khamsin* conditions should be made clear: the latter are the warm, dry, dust-laden, southerly winds that usually occur in front of the *khamsin* depressions.

The summer climate is generally hot, dry and rainless; clear skies prevail. In this season, depressions cease to move across Egypt and the weather becomes settled. The steady Etesian winds (north or northwest) blow persistently, for they are part of the circulation around the huge Asiatic low centered over northwestern India.

The autumn climate is similar to that in spring, for autumn is another transitional season. *Khamsin*-like depressions begin to cross Egypt during late October and cause a breakdown of the settled summer regime. The depressions at this time are much less vigorous than in spring and are slower in their eastward movement. The higher humidity in this season favors greater frequency of thunderstorms and heavier precipitation, especially in November.

Rainfall

Rainfall in the Sinai decreases from the northeast to the southwest, and is highest south of 30° north latitude. Even above this line the average annual rainfall varies: El Quosayma, 97.1 mm, Bir El Hassana, 30.6 and Abo Egila, 57.8. Fig. 1 presents the rainfall isohyets in the Sinai. The greatest amount of rain is found in Rafah (304 mm/yr) in the northeast. The annual average along the Mediterranean coast is 120 mm/yr. Rainfall decreases in the uplands to the south to about 32 mm/yr. On average, the annual rainfall in the entire Sinai peninsula is 40 mm, of which 27 mm are estimated to come from individual storms that provide 10 mm each.

Rainfall recording stations are located in Ismailia, Al Arish and Nakhel. These are the only stations that have made meteorological observations for 30 years.

Rainfall occurs in Sinai mainly during the winter season (November to March) and during spring or autumn. Rainfall decreases markedly or is completely non-existent from May to October. Along the Mediterranean Coast, 60% of the rain occurs in winter, while 40% falls during the transitional seasons. Due to differences in water availability, growing seasons differ in the different parts of North Sinai Governorate.

In general, rainfall decreases from northeast to southwest.

The rainfall characteristics and distribution (Arcon, 1992) are presented in Fig. 2 for three locations in North Sinai Governorate, namely Rafah, Al Arish and Abo Egilah. These variations not only cover average annual rainfall but also monthly distribution. Rafah receives the highest average monthly rainfall between mid October and mid December, with considerably lower rainfall in the following months, until April. Al Arish has an even distribution of rainfall from mid October through mid February, then rainfall tapers off until May. At Abo Egilah, the much lower rainfall has an even distribution from October till mid January, with a significant rise in March and May.

The maximum one-day rainfall is the same between November and February. At Rafah, the maximum one-day rainfall is 25–30 mm. Al Arish shows a similar trend, with the exception of early storms in October. At Abo Egilah, the maximum one-day rainfall occurs in November, December, January, and March.

Temperature and Relative Humidity

The air temperature in the Sinai is subject to large diurnal, seasonal and geographic variations. Along the Mediterranean and Gulf of Suez coasts, similar maximum winter temperatures are observed. Maximum temperatures in summer vary considerably. Table 1 shows the temperature and average relative humidity in Al Arish. It is interesting to note that the average relative humidity is more or less within the same order of magnitude throughout the year, with a slight decrease in May and June.

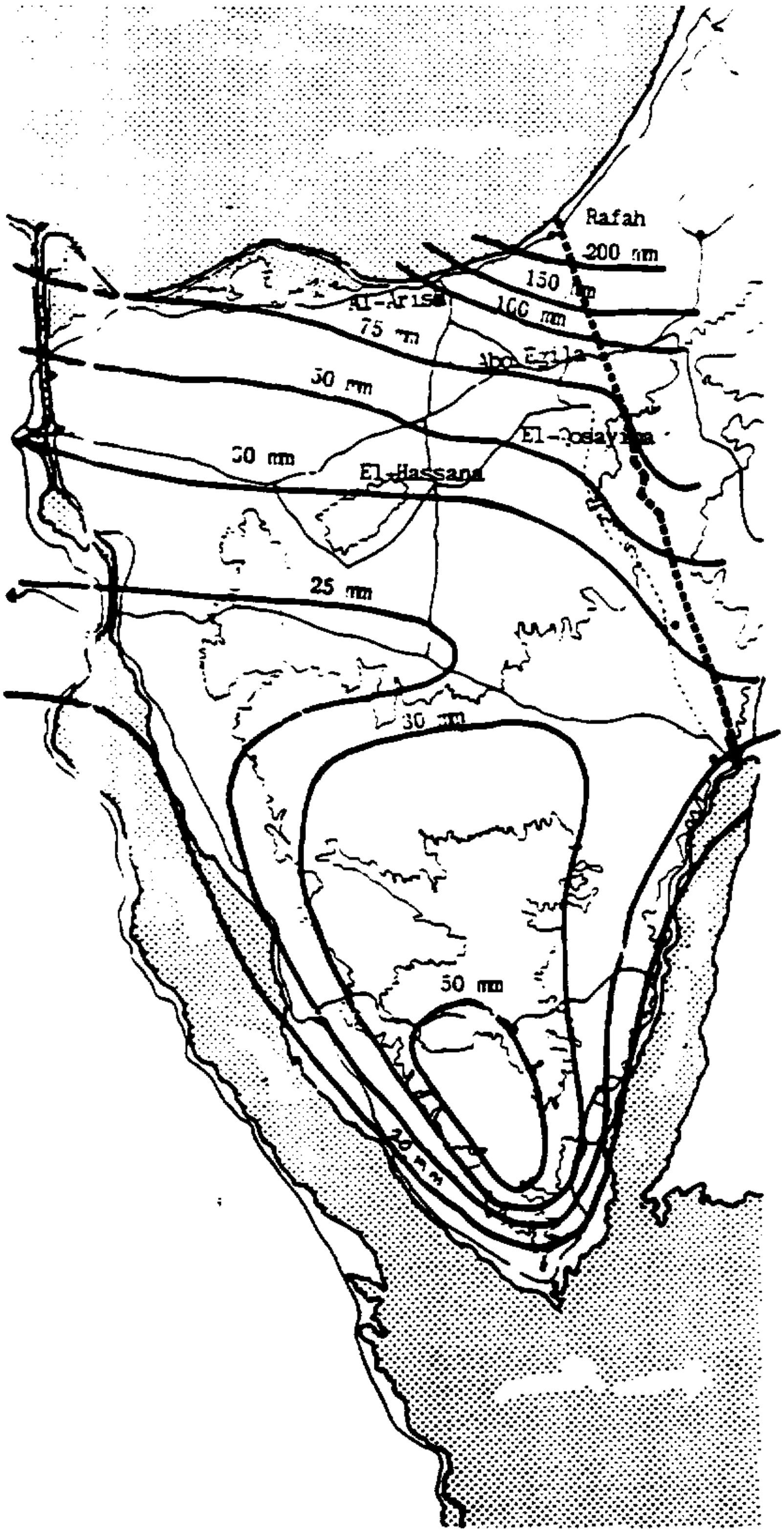

Fig. 1. Average annual rainfall in Sinai (mm/year).

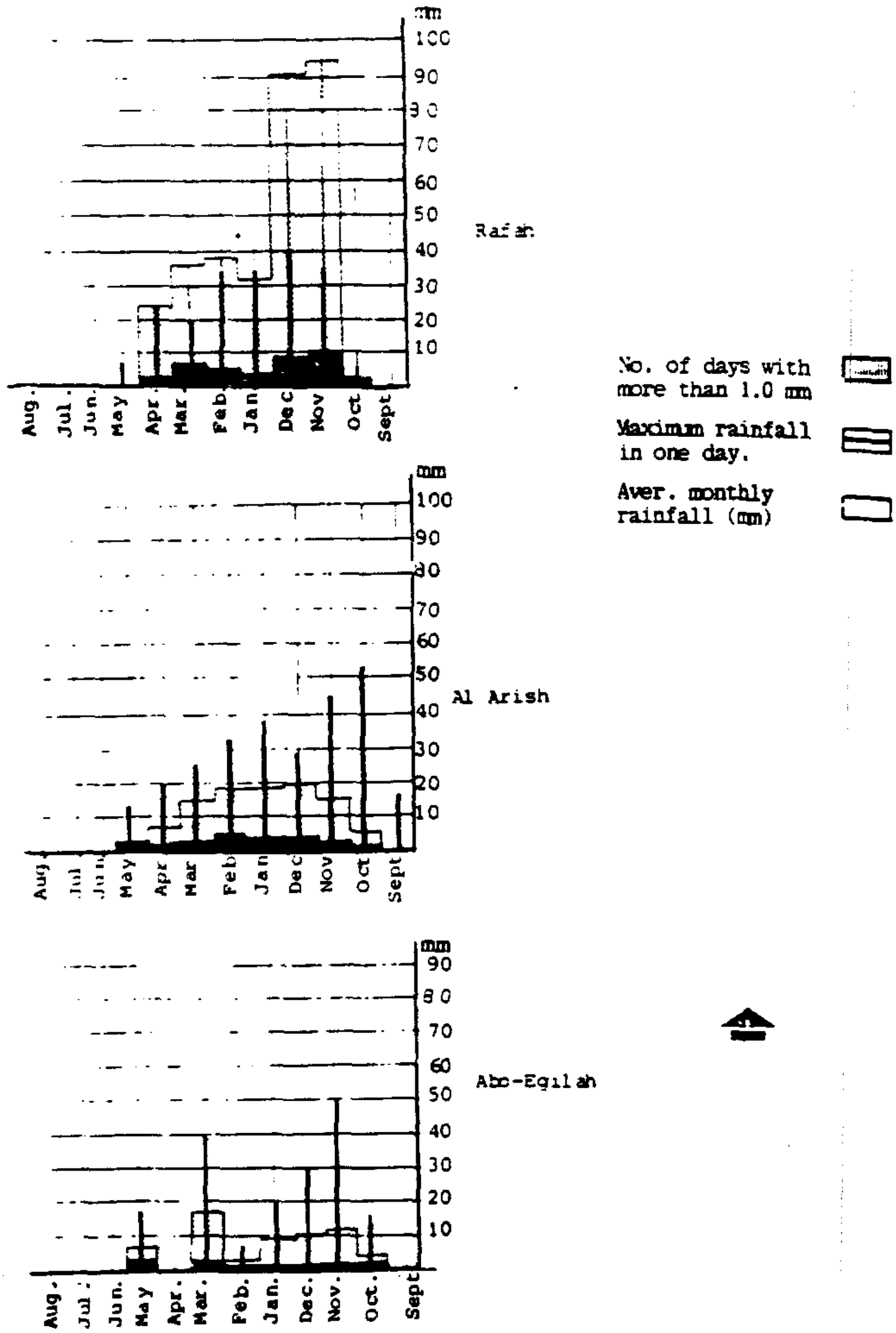

Fig. 2. Distribution of rainfall in the northern cities.

Table 1. Temperature variation and relative humidity in Al Arish.

	Ave. air temp (°C) 1988	Ave. max. temp. (°C) 1989	Ave. min. temp. (°C) 1989	Ave. rel. hum. (%) 1989
January	10.6	16.0	6.4	77
February	11.6	18.0	6.0	72
March	14.6	20.8	9.1	69
April	19.5	28.2	12.1	66
May	21.7	28.2	15.0	65
June	24.0	30.1	17.5	64
July	25.9	31.5	20.6	70
August	26.3	32.1	30.7	72
September	24.8	30.8	19.2	74
October	21.4	38.2	15.5	71
November	18.2	25.4	12.2	73
December	13.8	20.6	8.4	73

Wind

The annual average wind speed is around 14 km/hr, and the prevailing wind directions are northwest and north. Figs 3 and 4 illustrate the wind direction and average wind speed at Al Arish.

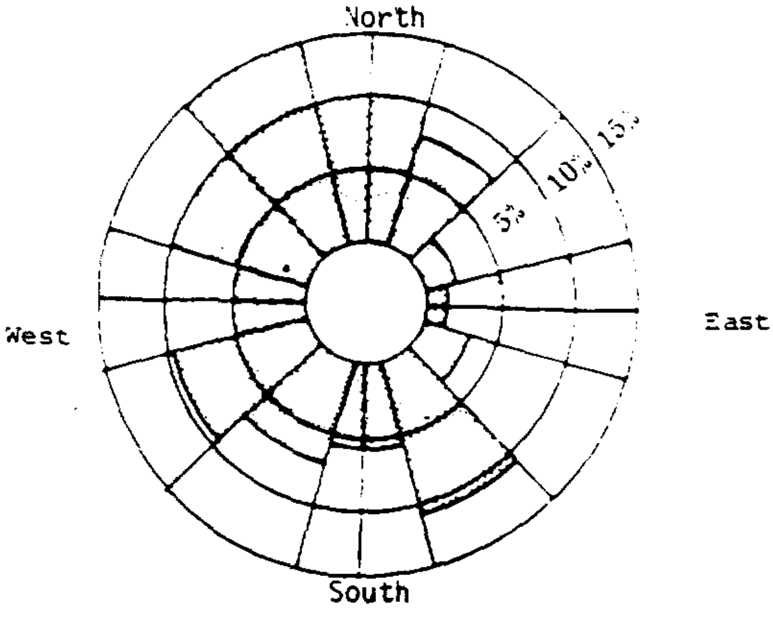

Fig. 3. Annual wind direction in Al Arish (Arcon, 1992).

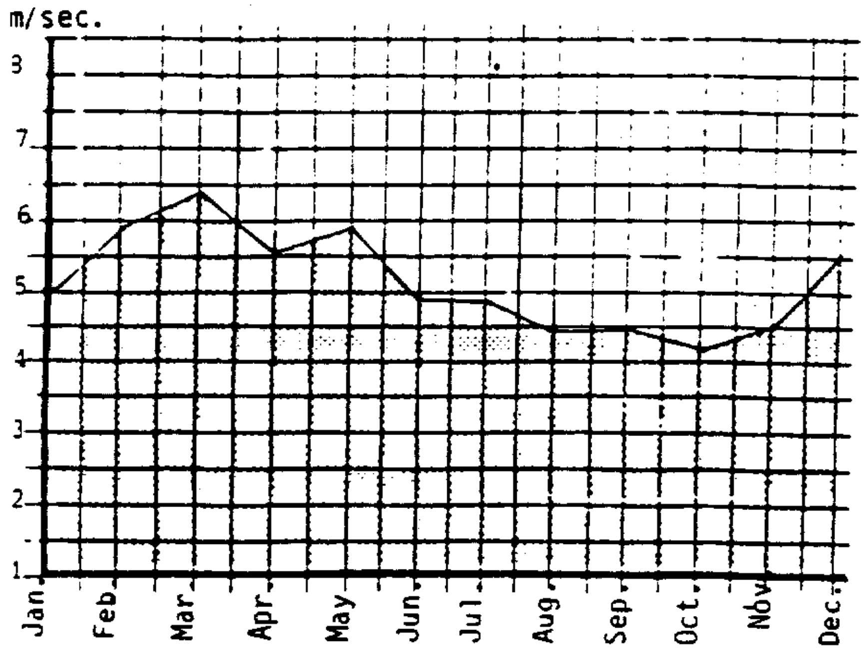

Fig. 4. Monthly average wind speed in Al Arish.

The Etesians, a wind system formed in the Aegais and the western part of Turkey, is the reason for the predominant summer winds, which blow from the north and northwest. The air masses absorb humidity from the Mediterranean Sea as they blow towards northeast Africa. The wind temperatures above the water surface are lower, and the winds heat up when they reach the coastline. Air is able to hold a certain amount of water, depending on the temperature. When the wind reaches the land, the air masses are heated up, which increases the water-holding capacity. This is why the Sinai peninsula has a dry summer. When the temperatures decrease in autumn, many days with heavy fog occur along the coastline. This is caused by the lower air temperatures, due to lower solar radiation. This fog precipitation has an effect on plant growth that should not be underestimated. Exact figures on the amount of precipitation are not available.

Sand or dust storms occur on three to five days each winter, or, in the northern region, in the transitional seasons. These storms affect many activities in the Sinai, including agriculture, as the sand may cover wide areas in a relatively short time.

Evaporation

The amount of evaporation is highly dependent upon location. Values for a town will differ from those only a few kilometers away. The difference is mainly due to a variation in wind speed. Table 2 presents the mean daily evaporation data for Al Arish and Port Said.

Table 2. Mean daily evaporation (mm).

Month	Al Arish	Port Said
January	3.5	4.7
February	4.0	5.4
March	4.4	6.5
April	4.6	6.4
May	4.9	6.8
June	4.9	7.4
July	4.8	7.5
August	4.9	7.3
September	5.2	7.8
October	4.8	6.9
November	4.0	5.9
December	3.6	4.5

Taken from Griffith (1972).

Soil Resources

Topography and Geology

The topography is depicted in Fig. 5. The northernmost strip—about 5 km inland from the shoreline—has a very gentle slope (S_1), reaching about 20 m asl. Further inland a medium slope (S_3) develops, reaching elevations of 90 m asl.

In North Sinai Governorate, the lowest areas of calcareous rock belong to the Cretaceous SUDR-formations (uniform marine chalk with shale intercalations at the top; local flint concentrations). Old tertiary (Paleocene), ESNA-formations, including greenish-gray open marine shales, extend northward into shallow facies with gray to yellowish-green shale and sandy shale. These sediments are overlain by the middle tertiary (Eocene) EGMA-formations, which are described as moderately-bedded marine chalky-limestone with chert bands. Only in the far southeastern region of North Sinai Governorate are there volcanic outcrops (rhyolitic to alkali feldspar-rhyolitic rock).

The physiography and geology of the two pilot areas (Al Arish/Lehfin and South El Bardawil) were studied in detail by the Desert Institute (Dames and Moore, 1983). Geologic descriptions of both areas are presented below.

Al Arish/Lehfin

Al Arish/Lehfin stretches from north to south for about 20 km. To the north, this area is bounded by the Mediterranean Sea, to the east and west, by complex sand dune belts. To the south, it emerges gradually into an elevated gravelly plain stretching between Gebel El Halal and Risan Ineiza.

Land forms: Fluvial agents under wet paleo-climates carved out Wadi Al Arish and deposited a thick alluvial fill. As a result of the drop in the level of the Mediterranean Sea in the Late Quaternary period, Wadi Al Arish was subjected to several phases of deepening. Thus, several terraces were created.

Wadi Al Arish runs between Lehfin and the Mediterranean Sea in a NNW–SSE direction. Its alluvial plain is 2 km wide at Lehfin, and its alluvial fan is 4 km wide near the Mediterranean Sea. At its delta, Wadi Al Arish is joined by Wadi El Maazar. The latter is a narrow tributary that drains the highlands to the east. Its channel is characterized by several meanders. Sand dunes skirt both sides of this wadi. The present Wadi Al Arish channel is narrow, ranging from 30 m at Lehfin to about 500 m near the Mediterranean Sea. Between Lehfin and El Henwa, some 6 km to the north, Wadi Al Arish is characterized by several meanders.

At Bir Lehfin, Wadi Al Arish is bounded on the west by a terrace rising 5 m above the Wadi floor. This terrace is steep, influenced by shifting sands from the west, which form a sand shadow 2 m thick. Higher terraces are covered with shifting sands. The Wadi is bounded on the east by terraces (discontinuous remnants of different levels). These remnants, sometimes rising 15 m above the Wadi floor, are dissected by numerous minute wadis, flowing towards Wadi Al Arish. Where Wadi El Maazar and Wadi Al Arish meet, at least two terraces have been formed, rising 2 m and 10 m from the Wadi floor.

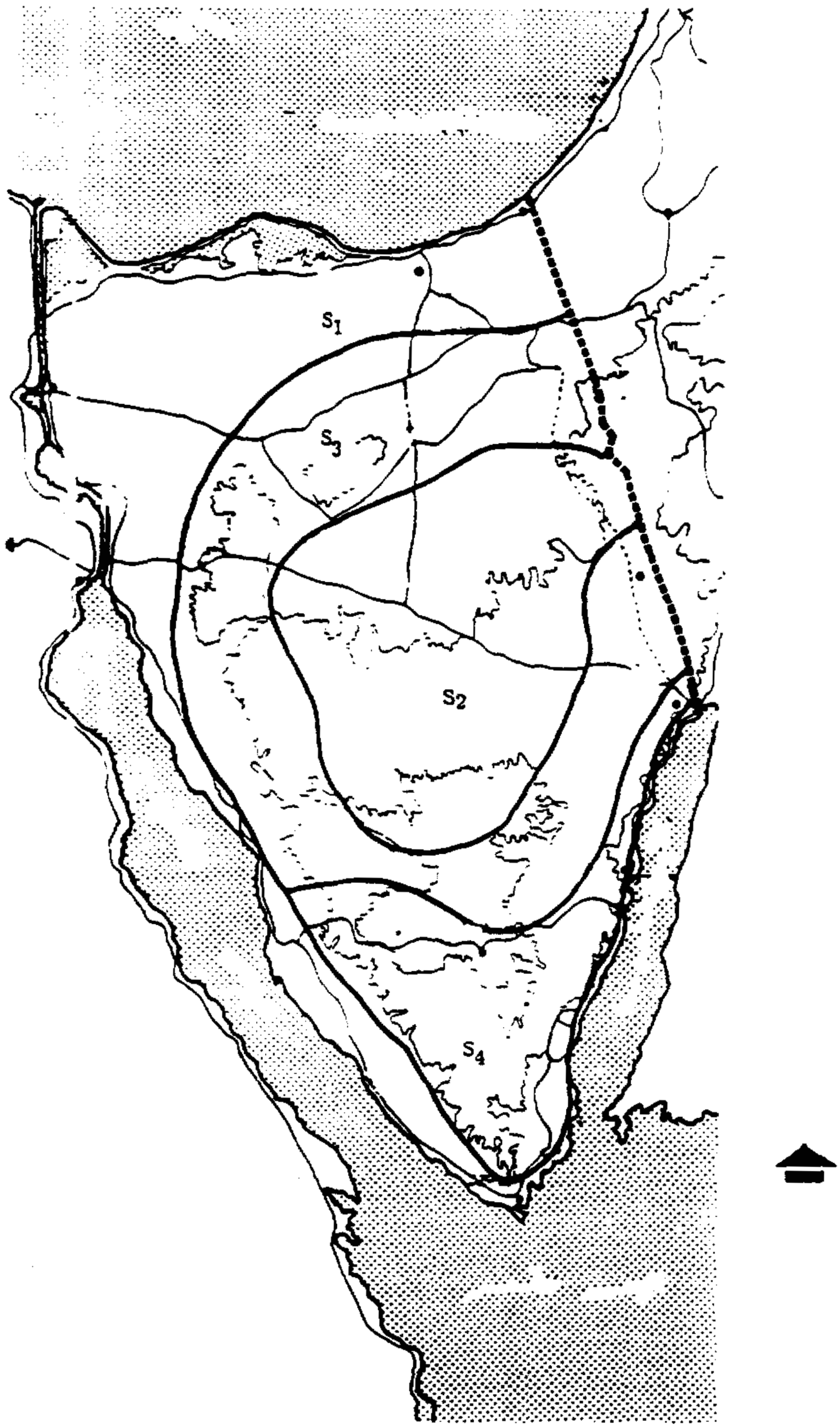

Fig. 5. Slopes in the Sinai.
S_1 = Very slight slope; S_2 = Slight slope; S_3 = Medium slope; S_4 = Severe slope.

Aeolian processes under the present arid to semi-arid climate have resulted in the development of mobile sand dune belts bounding Wadi Al Arish on both the east and the west (Fig. 6). These dunes reflect the convergence of winds from the southwest, northeast, northwest and occasionally from the west and north. The sand dunes to the west of Wadi Al Arish have a direct influence on the cultivated lands of the Wadi and its delta. Sands from these dunes are continuously shifted towards the Wadi. The dunes to the west of Wadi Al Arish constitute a complex belt, with height increasing towards the west. At their lower reaches, e.g. the portion skirting Wadi Al Arish, the dunes are what are called burchans, which tend to coalesce and join. The height of burchans is between 5 and 10 m. The majority advance 30° N–45° E, with a few to the south (Fig. 6)

The sand dunes to the east of Wadi Al Arish, near the airport and at Wadi El Maazar, have different trends. Dunes advance to the northeast (under the influence of southwest winds), southeast (under the influence of northeast winds) and east (under the influence of western winds).

Isolated burchans have recently accumulated on the floor of Wadi Al Arish, e.g. 4 km to the south of the Mediterranean Sea (west of the Wadi El Maazar outlet). The height of these burchans varies between 1 and 3 m. They advance 30° N–75° E.

South El Bardawil

South El Bardawil constitutes a portion of the Mediterranean coastal zone. It is bounded on the south by a complex sand dune belt, on the north by the Mediterranean Sea, on the west by El Tina plain and on the east by Al Arish coastal plain. The area is about 90 km long, with a width ranging from 10 km at Nigila to about 1 km at Feleifil, west of Al Arish.

Land forms: In South El Bardawil, *the following land features are found:*

- Sand dunes
- El Bardawil Lake

Sand dunes: The sand dunes in South El Bardawil form the northern extremity of a huge sand sea. Migration of these dunes forms one of the main problems in the eastern Mediterranean coastal zone. Shifting sands block the main roads, and encroach upon wells, railway lines and other vital areas.

The sand dunes are dominated by burchans, which tend to coalescence and join, forming long lines. The height of these dunes increases towards the south. Palm groves and natural plants are found in the interdunal hollows.

The sand dunes at South El Bardawil are differentiated into the following:

- Sand dunes of the central portion (El Maazar–Nigila).
- Sand dunes of the western and eastern fringes.

The morphological features of the sand dunes of the central portion have been investigated at Misfaq, Bir Salmana, Bir El Abd, Bir El Afein, El Khirba, and Nigila. Generally, these dunes advance towards the northeast under the influence of southwest winds (Fig. 7). At Bir El Abd, there is a reverse movement of sand towards the southwest, due to northwest and northeast winds.

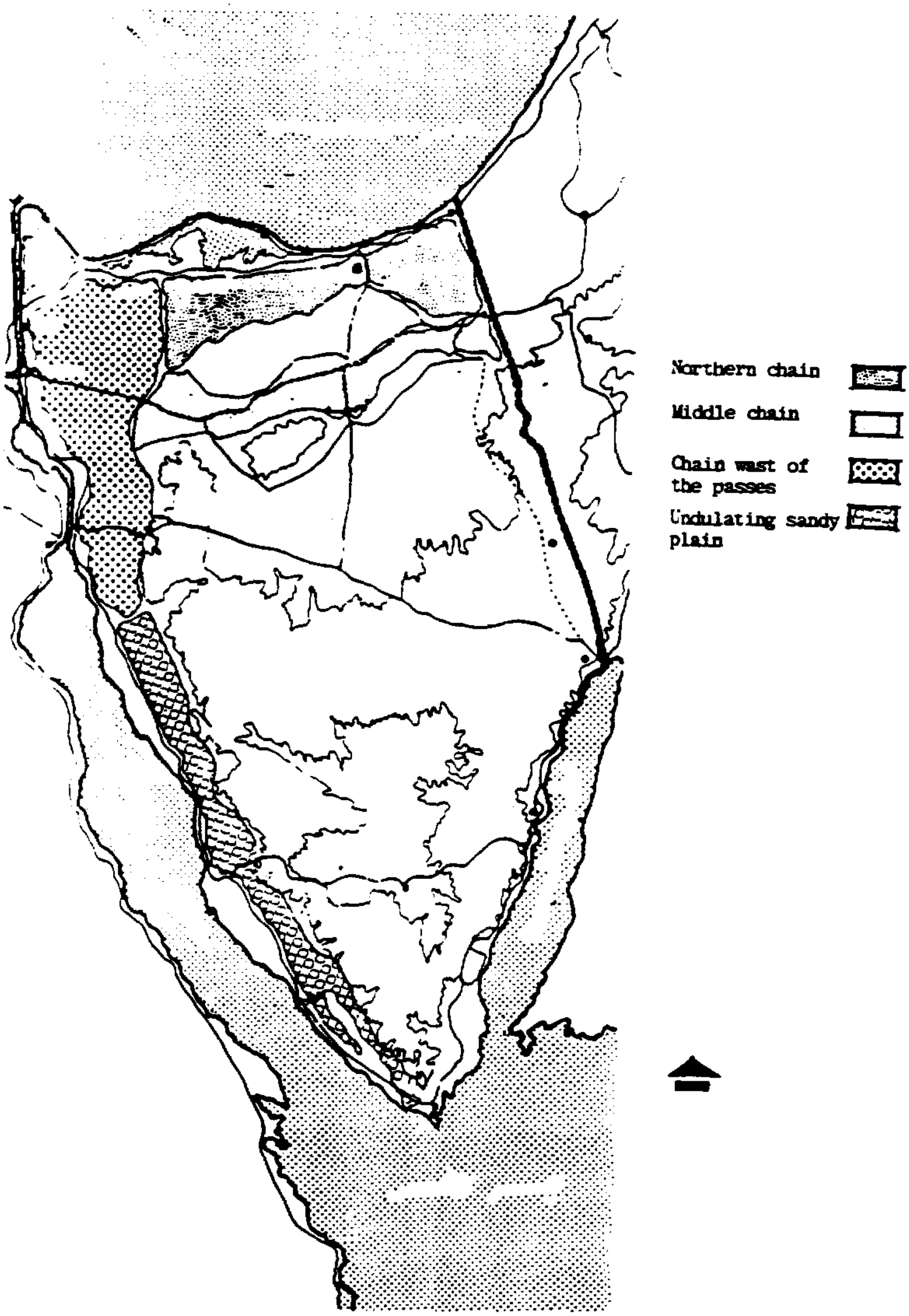

Fig. 6. Distribution of windblown deposits.

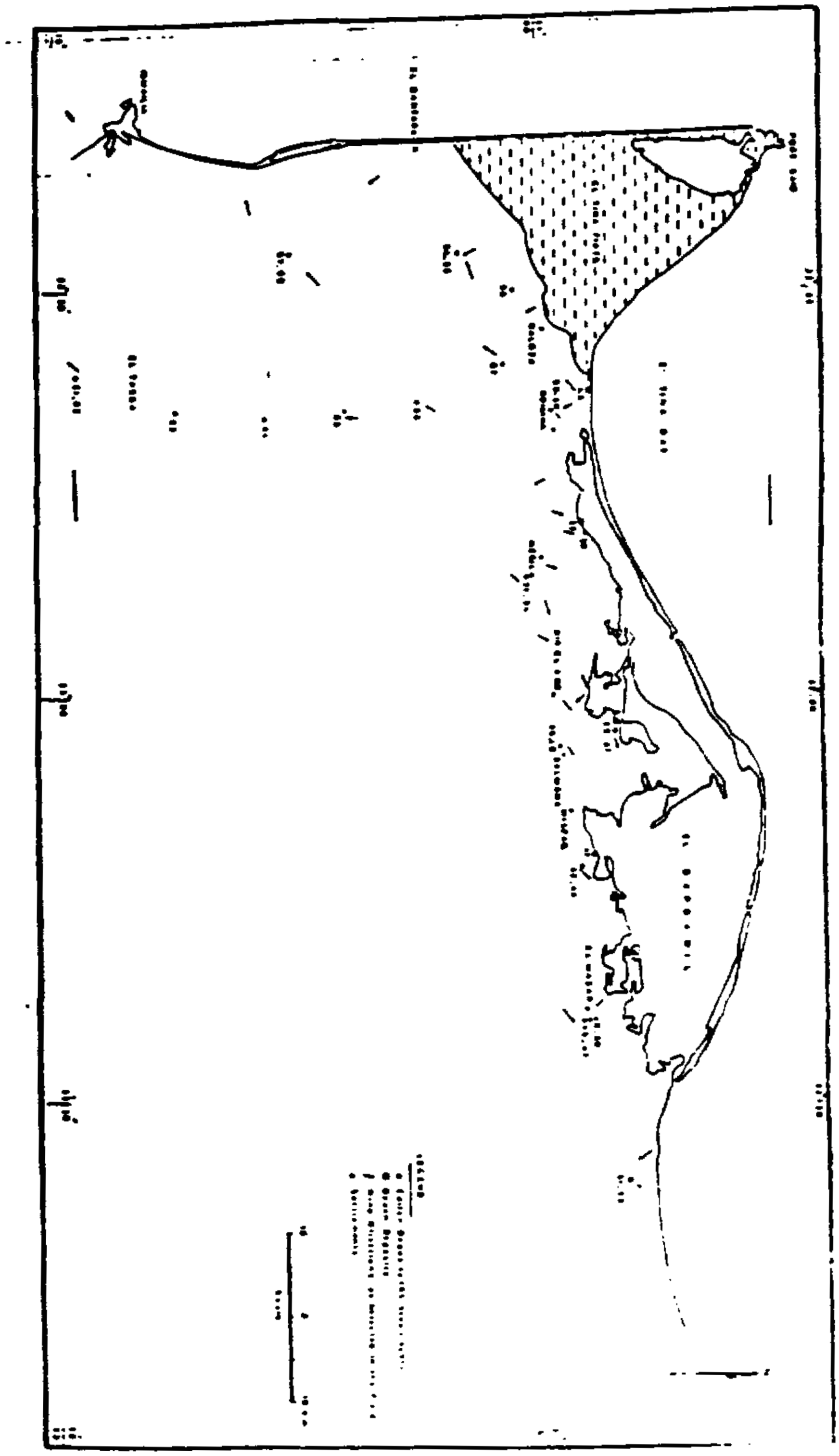

Fig. 7. Study locations in South El Bardawil and El Tina (East Ismailia).

The sand dunes of the western fringes, which extend westwards from Nigila to near Romana, and the eastern fringes, which extend from El Maazar to near Al Arish, are characterized by dunes resulting from the constant blowing of northerly winds. These dunes exist simultaneously alongside dunes migrating from the southwest.

El Bardawil Lake. El Bardawil Lake fronts the Mediterranean Sea, from which it is separated by a narrow coastal strip, covered by sand dunes. This lake has a direct connection with the Mediterranean Sea via several tidal inlets.

El Bardawil Lake consists of a main body about 30 km in length, extending from Misfaq to El Maazar, alongside El Qantara–Al Arish road. The width of the lake ranges between 22 km (to the west) and about 10 km (to the east). Two arms extend from this central body, the western arm extending in a southwesterly direction, reaching Abu Feleifil, some 20 km to the west of Al Arish.

The inland margin of El Bardawil Lake is irregular, exhibiting numerous finger-like water bodies separated by land indentations, where narrow crescent-shaped beaches have developed. In the area opposite Nigila, this beach is 100 m in width, reaching about 1 km opposite Misfaz. This beach is sometimes backed by sand ripples and low burchans. At Mallahet El Marqab, the burchans attain a height of 3 m.

To the south of El Bardawil Lake, numerous scrub-covered salt flats and ponds are found. Ephemeral ponds develop in winter, degenerating in summer.

General Description of Soil Resources

The soils of North Sinai have been studied before by various local institutions. However, none of the previous studies covered the entire governorate. The studies performed by the General Authority for Reclamation Projects and Agricultural Development (GARPAD) of the Ministry of Agriculture and Land Reclamation (MALR) in 1981 dealt with the northwestern part of the peninsula. This survey only considered soil texture. No international classification system was applied. A land capability classification was made with reference to the United States Department of Agriculture (USDA) and the United States Bureau of Reclamation (USBR). These surveys formed the background for a study by the Japan International Cooperation Agency (1992). The land master plan proposes a reclamation area of 254,700 fed (107,016 ha). The core of that report is a feasibility study of 53,400 fed (22,436 ha), mainly in the Tina Plain and the sandy terrain in the Rabaa/Qatia area.

To gain more detailed information about the area, JICA conducted a soil survey, investigating 27 soil profile pits (maximum depth, 3 m), 230 auger borings (2 m) in a 1 km grid, and analyzing 100 soil samples taken from soil profiles representing various mechanical and chemical parameters. Soils were classified according to the USDA Soil Taxonomy and related to land forms.

In 1981 the Desert Institute carried out a study of the soil resources in the area. A soil classification was made according to the USDA Soil Taxonomy. Soils in North Sinai Governorate were investigated according to region. The report consists of four volumes: Wadi Al Arish/Lehfin (Vol. I), South El Bardawil (Vol. II), El Bruk and Gifgafa (Vol. III), and El Giddi and Qalat El Nakhl (Vol. IV).

These studies were performed for Dames and Moore (1983) and form the background of pedological considerations in the Sinai Development Study, Part I.

Within the framework of the Sinai Water Resources Project, the Ministry of Irrigation performed a detailed soil study of El Maghara. The study region is located in the transitional area between the inland dunes and the plateau, approximately 50 km south of Al Arish. The field work for the soil investigation was performed on 5,000 fed (2,100 ha) located at Wadi El Maghara, North Sinai.

Soil Composition

The soils are of three different origins: Aeolian, alluvial, and soil formed in situ. The latter is related to the land form in which the soil concerned is located. Soils formed in situ are found on the Wadi Al Arish plateau, of either calcareous or volcanic parent material. If the soil depth is less than 30 cm, and if the soil was recently formed from the parent rock, it is called leptosol. This applies for calcareous and for volcanic parent material as well. Other soils created in situ are those of the gravel plain. These soils may have been created under paleo-climatic conditions and therefore rather old. The soils of the gravel plain could have been built under alluvial conditions, with the yermi phases covering older layers with alluvial properties and lacking signs of calcareous parent material, which is proof of periods of higher precipitation. No investigations have been made to separate the alluvial soils from the in situ soils of the gravel plain.

The majority of alluvial soils were formed under recent climatic conditions. They constitute the present wadi beds, and are characterized by a granulometric differentiation according to flood intensity and sedimentation. As a consequence, soils upstream from the wadis are coarser in texture than downstream.

Among the dunes, the soil is generally different than in the gravel plain. The area of the dunes is dominated by arenosols, with almost no sign of soil-forming processes. Saline soils are found exclusively in the coastal zone. Haplic calciosols dominate the desert region in the gravel plain. These soils show more signs of development. Calcaric fluvisols are the typical soils in the wadis. The shallow soils of the mountainous regions are lithic leptosols.

In the soil development and formation of morphological features, a gradient of increasing aridity is recognizable towards the south, but the typical desert soil features, such as surface horizons with vesicular pores, a desert pavement, or accumulation of blown sand on the surface, are found only in the gravel plain.

In the dune area to the north there is a significant difference between haplic and calcaric arenosols. The former consists of blown sand that is up to 98% quartz, the latter of Aeolian material such as desert loess with a much higher calcium carbonate content. Haplic arenosols often function as the basic material for soil development because of the dynamic process of wind deposition and surface erosion. Nevertheless, they have a role as a habitat for plants. Calcaric arenosols are more stable and show soil forming processes such as lime-accumulation and carbonization.

The organic matter content is very low (< 0.1%) throughout the governorate, and it cannot be used to distinguish between semi-desert and desert. It is better to make this distinction using a precipitation value of 50 mm or less.

Soils are mainly medium alkaline; those with low salt content are also strongly alkaline. The maximum pH was recorded in a calcaric arenosol near Rafah. In general, soil salinity in the study area is quite low. Higher values are characteristic for solonchaks (salic properties) and older calcisols. This is a consequence of coarse soil texture with low water-holding capacity and presumed high permeability. High values of electrical conductivity correlate with soluble salt content—chloride and magnesium—and gypsum.

The exchange capacity correlates with clay content, but is also related to the silt fraction. In general, cation exchange capacity (CEC) is low. FAO (1976) quotes CEC values of 8–10 meq/100 g soil in the top 30 cm as the minimum value for satisfactory production under irrigation, provided that other factors are favorable. Any CEC value < 4 meq/100 g soil indicates a degree of infertility normally unsuitable for irrigated agriculture. CEC is essentially a property of the colloidal fraction of the soil, derived mainly from the clay and organic matter fractions, although silt-sized particles sometimes contribute significantly. No detailed data concerning clay mineralogy in the study area were available. Thus, there is no further assessment of the clay/CEC relationship.

The soils in the study area are—with the exception of the haplic arenosols—already strongly to extremely calcareous. A maximum calcium carbonate content of 93.99% was found in fluvisols in desert composed of calcareous sediments. Lime-solution displacement and accumulation as soft powdery lime are the most important soil-forming processes in the calcaric arenosols in the northeast. This is basically due to precipitation levels above 100 mm. As a proof, the accumulation of soft powdery lime in fluvisols is found exclusively in Wadi Al Arish in the vicinity of the settlement. It is well-distributed throughout the Rafah area. Calcrete development in the soil of the gravel plain is proof of an old surface and a long period of formation.

Soil development can be seen in different regions of the study area. As mentioned above, soil in the northeast shows properties of formation in terms of lime accumulation in the lower horizons. Other features such as clay illuviation, loamification or weathering to stronger chroma and redder hue are representative of older soils of the gravel plain. The fluvisols of the wadis do not show any sign of soil formation. Among these sediments, it is impossible to differentiate between different soil horizons. Consequently, delivery of fresh material prevents the creation of desert pan.

Land Suitability

A Land Suitability Classification was carried out on North Sinai Governorate according to USBR guidelines. USBR terminology distinguishes between "arable" and "irrigable" land. The former is land that is mapped as suitable for irrigation, while the latter is land actually selected for development, which means that land without access and small, isolated or odd-shaped tracts is excluded. In the US system, land classes are based on production economics. Six land classes are recognized: four basic classes are used to identify arable land according to its suitability for irrigation agriculture, plus one provisional class, and one class for non-arable lands. Brief descriptions of the six classes follow:

- Class 1—Arable: Land that is highly suitable for irrigated farming, capable of producing sustained and relatively high yields of climatically adapted crops at reasonable cost. This land has a high potential payment capacity.

- Class 2—Arable: Land that is moderately suitable for irrigation. This land is usually either adaptable to a narrower range of crops, more expensive to develop for irrigation, or less productive than Class 1. This land has an intermediate potential payment capacity.
- Class 3—Arable: Land that is marginally suitable for irrigation. It is less suitable than Class 2 land and usually has either a serious single deficiency or a combination of several moderate deficiencies in soil, topography or drainage properties. Although greater risk may be involved in farming such land, under proper management it is expected to have an adequate payment capacity.
- Class 4—Limited Arable or Special Use: Land that is adaptable to only a very limited range of crops. For example, land suited only to single crops such as fruit is categorized as Class 4. Class 4 land has a payment range greater than that for associated arable land.
- Class 5—Non Arable: This land is temporarily considered as non-arable because of specific deficiencies such as excessive salinity, questionable drainage, flooding, or other problems which require further study to resolve. These deficiencies are of such a nature and magnitude that special agronomic, economic or engineering studies are required to make the land usable. The Class 5 designation is tentative and can be changed to either Class 6 or an arable classification upon formulation of a recommended plan of development.
- Class 6—Non Arable: Land that is non-arable under existing or projected economic conditions associated with proposed project development. Generally, Class 6 comprises steep, rough, broken, rocky, or badly eroded land, or land with inadequate drainage or other deficiencies. In some instances land considered to be Class 6 in one area may be arable in another because of different economic conditions.

Land suitability classification requires assessment criteria based on expected utilization. The main characteristics taken into consideration in this survey were pedological features such as texture, soil depth, salinity and fertility. Since the USBR classification is an international standard, it was essential to judge the results on a worldwide scale. This led to the exclusion of Class 1 in the project region. There are no parts of the governorate that can be reclaimed without high cost. More than 85% of the area fits into Classes 3, 4, and 6:

- Class 2s: 1.96%
- Class 3s: 4.63%
- Class 3std: 0.72%
- Class 4sp: 0.78%
- Class 4sdp: 2.60%
- Class 6st: 32.75%
- Class 6std: 45.45%
- Mountains, settlements: 7.61%

Class 2 land represents less than 2% of the area. It is found solely in two minor areas in the northeastern region of North Sinai: Wadi Al Arish and Rafah. The former is located around the city of Al Arish, between Bir Lehfin and the mouth of the Wadi, as well as the area west of the settlement towards Bir Masaid.

The soils in the Wadi meet Class 2 standards as to depth, salinity and nutrient content. Another factor is the average annual precipitation of 100 mm and the resulting water availability. The flood risk in the Wadi is comparatively low. Major floods are controlled by the Ruweifa Dam, and smaller floods and rains contribute to the recharge of the shallow water aquifer. At present, the variety of crops includes vegetables such as tomato, cucumber, capsicum and red beet. Irrigated plantations of olive trees and other tree crops are already quite common.

The area west of the settlement of Al Arish is also Class 2, even though there are some minor disadvantages regarding cultivation. Most soils are of Aeolian origin and are of coarse texture and low fertility. The reason this area is Class 2 is the water availability and the variety of crops that can be cultivated. In addition, the already existing plantations of palm trees illustrate the possibility of using brackish water. Traditional agriculture is being supplanted by modern methods for economic benefit.

The other Class 2 region in the northeast portion of the Governorate is Rafah. The main reason to designate this land as Class 2 is that the soils (calcaric arenosols) are of medium to coarse texture, derived from Aeolian material such as desert loess—with higher calcium carbonate and nutrient contents than other soils from Aeolian material—and with comparatively good water-holding capacity and permeability. The existing land-use systems provide an example of high suitability, possibility for diversify and opportunity for intense cultivation.

Class 2 soils must avoid salt accumulation by controlled leaching. Crop selection should take salt tolerance into account, since salt has a major influence on yield potential.

Class 3 is subdivided into the subclasses 3s and 3std. The former is found in the northeastern part of North Sinai, in Wadi Al Arish between Bir Lehfin and the piedmont zone of Gebel Halal, as well as Wadi Hareidin and Rizan Aneiza. One reason to put these areas into Class 3 is the low precipitation, low water availability and high salinity risk. Soils of this mapping unit are similar to the alluvial deposits in Class 2. Other limiting factors are restricted crop varieties and lower yield potential.

Class 3 land is found in the wadis of the plateau. Limiting factors are coarse soil texture, low fertility, and a high risk of salinity. The subclasses 3t and 3d refer to soils with a depth of less than 150 cm. Areas in the west of the governorate, with higher salinity risks, average even less than 30 mm of rain annually. In addition, evaporation values are above 2,000 mm/yr. This means that, even if the amount of irrigation water is sufficient for agricultural production, the quantity of water used for irrigation must meet the leaching requirement to avoid salt accumulation. This reason, among others, explains the high cost of reclaiming these areas. In Class 3 land, lower benefit can be expected because of lower yield due to higher salinity. Soil properties such as high gravel content and low fertility are taken into account when designating this class. The high calcium carbonate content, with corresponding high pH and soil consistency, has a negative effect on root penetration. Other limiting factors are the enormous logistics necessary to reclaim these areas.

Irrigated agriculture in these areas would be restricted to water from shallow groundwater aquifers. Shallow groundwater is limited in quantity and is of comparatively high salinity. As a consequence, agriculture would be on a small scale, using only trickle irrigation, and limited to small parcels.

Class 4 land is found in two different physiographic units in North Sinai. Subclass 4sdp land includes the wadis and their tributaries in the plateau. The classification is based on certain pedological assumptions. The soils are coarse in texture, low in depth and fertility, and subject to flooding. Thus, irrigated agriculture cannot be recommended. Since there is natural vegetation, these areas are classified as suitable only for grazing; there can be no improvement of the pasture because of the very low rainfall. The tendency of the Bedouins to place dikes further and further up the courses of the wadis, in order to use the water for rainfed agriculture, goes against the suitability of the land. The very coarse texture and high gravel content cause a low water-holding capacity, so that yield is definitely lower than it would be if the water could flow to the lower parts of the wadis.

Subclass 4sp land is found in the coastal zone between Bir Masaid and the western border of the Governorate. It is composed of solonchak and arenosol soils. The arenosols are almost sterile and subject to wind erosion; the solonchaks are characterized by a sodic phase which reflects the salt content of the soil. Reclamation costs would be enormous and the benefits, compared to Class 2, would be very low. The land-use pattern of palm tree plantation and camel breeding testifies to the suitability of this district. Irrigated agriculture would be small-scale, based on the use of groundwater. The supply of water by large-scale canals will never bring economic returns that would justify the cost of reclamation. Some areas are more suitable for salt harvesting than for agriculture.

Class 6 land is by definition not suitable for any kind of agriculture. The inland dune area with shifting sands is classified as subclass 6st. The dunes are almost sterile and more a basic material for soil genetic processes than a location for agricultural development. Slopes of up to 30 degrees among the dunes made the terrain very unsuitable. Soils of the gravel plain have limiting factors, including high salt content, coarse soil texture, up to 90% stones, and, in some parts, slopes that make irrigated agriculture impossible.

Land Use

A description of agricultural systems is found in Tasoar and Zohar (1985), wherein it is written that the coastal desert sand dunes in the northern Sinai have been used for agriculture for hundreds of years according to the *mawasi* system. In North Sinai Governorate, the *mawasi* system was employed in the northwestern region between Al Arish and Rafah. The main reason for this distribution is the amount of rainfall in the area.

Mawasi means "suction" in Arabic and refers to water that has been sucked up to the surface. The principle of *mawasi* is based on the fact that sand is a good substratum for infiltration of rainwater. Near the coastline, the water table is elevated above sea level. This means that a reservoir of freshwater bulges into the sea water through an intermediate freshwater–salt water interface slightly offshore. The dunes along the desert coast are usually transverse, so that the low interdunal areas close to the beach are a few decimeters above the water table.

The agricultural parcels are situated in the interdunal area and, by clearing out the sand down to the water table, the problem of water availability is solved. Animal excrement and green manure are used to fertilize sand that is very poor in nutrients. The protective wall of the surrounding sand dunes acts as a windbreak. Sand cleared out in the preparation of the farming area can be used in the construction of dikes around the area, thus contributing to the protection of plants and foliage from wind and salt. Because of the high water table, the area is rich in palm and tamarix trees, which reduce sand movement.

Mawasi is being used today, along the coastal sand dunes of the Sinai, in combination with modern techniques such as trickle irrigation and mulches. There are two main problems related to *mawasi*. One results from over-pumping of freshwater, whereby the water table drops below the reach of plant roots causing the drying up of the field. The other is the opposite extreme: during a very wet year, with precipitation well above average, the agricultural parcels are usually flooded by groundwater that cannot be drained out. This is because runoff is nil and recharge of sand dunes to groundwater is very high, causing the water table to overflow. The recent extensive pumping of wells in the coastal plain is causing saltwater intrusion to the wells, because the decrease in the pressure of freshwater on the bulge causes the sea water to flow in. This mishap does not affect the *mawasi*, as it is maintained by the thin upper layer of freshwater that exists above the interface, starting at the shore line.

Apart from the *mawasi* areas, there are palm strips parallel to the coastline. On the interdunal areas or the northward flanks of the inland linear dunes of the Sinai, away from the high coastal water table, the Bedouins grow castor bean, almond, peach, barley, wheat and watermelon, which feed the camels during the summer dry season. This non-intensive and non-irrigated agriculture is dependent on winter rains and is not as profitable as modern agriculture.

Proper management of the sand dunes between Al Arish and Rafah, with restricted grazing, prevents the sand from shifting and ameliorates the soil by retaining and increasing the amount of vegetation. In that way, sand dunes in semi-arid and arid regions can serve as producers of firewood, which is still one of the main sources of energy in the region. The agricultural systems around Al Arish—westwards up to Bir Masaid and southwards to Bir Lehfin—were designed for different conditions than those found in Rafah.

Intensive agriculture on soils of pure dune sand has been developed. However, as in other modern methods of agriculture, the techniques used require considerable capital input and are therefore economical only when compensatory crops with a high market value are produced.

All the disadvantages of sand as a soil are exploited in this technique. Dune sand is known as a poor substratum for essential elements such as plant nutrients. Therefore, any agricultural activity on sand requires, as a precondition, effective fertilization with effective irrigation.

Deserts have a climatic advantage. The thermal properties of sand create a very high temperature on the surface and a few centimeters above it. It is known that water has the highest thermal capacity of any substance. Heavy soils with a high field capacity contain more water and, therefore, have a higher thermal capacity. Hence, wet, heavy soils will not display the extreme temperatures a sandy soil does because of its very low field capacity. For this reason, sandy soils are warmer during the day and more suitable for off-season crops; tropical plants like mango are forced to ripen.

There is already a variety of tree crops and vegetables in Rafah, grown according to this system. Peach trees, the main crop of the area, are usually in mixed culture with almond trees. The latter have a better root development in the early periods of growth but the economic benefit is not as high as with peaches. The suitability of this area demands improvement in the management of non-irrigated agriculture. One measure to intensify cultivation would be to promote mixed cropping and intercropping. This means that vegetables would be cultivated in combination with tree crops. Nutrients would be introduced by fertilizer application.

Water Resources

Rainfall and Runoff

Data on water resources are cited from Dames and Moore (1983). When precipitation occurs in the Sinai, it is generally less than 8–10 mm. Accordingly, there is very little runoff of rainwater; most of the water either evaporates or percolates into the subsoil. When rainfall amounts to more than 10 mm, runoff may occur, and wadi beds will begin to carry water, depending on the amount and the duration of rainfall, the intake capacity of the basin soil, and the moisture content.

It is estimated that 60% of the annual rainfall in the Sinai is lost to evapotranspiration, 5% runs off to the sea, and 35% percolates deep into the rocks and unconsolidated deposits. Much of the deep percolation constitutes groundwater recharge. Recharge values have been estimated for the major aquifers of the peninsula. Northern Al Arish is estimated to receive 66,000 m^3/day.

Groundwater Resources

Generally, groundwater in the Sinai is classified into two main types:

- Shallow groundwater, occurring mainly within weathered layers of igneous and metamorphic rock, Quaternary rock, and recent deposits such as wadi fills or sediments, and sand dunes.
- Deep groundwater, mainly occurring in semi-confined aquifers of pre-Quaternary formation.

Hydrological Structure

According to an investigation conducted by the Japan International Cooperation Agency (1992), a thick Quaternary formation extends from Wadi Al Arish to the international border with Israel, covering approximately 800 km^2 along the Mediterranean coast. There is heavy groundwater extraction from aquifers within this Quaternary formation at Al Arish, and from Sheikh Zuwayid to Rafah (Fig. 8).

The main prospecting Quaternary aquifer is a kurkar aquifer, underlain by pre-Quaternary shale, sandstone and limestone.

At Test Well JNO9, there is a pre-Quaternary sandstone and gravel bed underlain by shale. These beds form an aquifer which is assumed to be in contact with the Quaternary aquifer at the boundary between these two formations (Fig. 8). Similar circumstances are observed in other sections in the area, where the pre-Quaternary limestone may contact with the Quaternary aquifer.

The thickness of the kurkar varies from 10 to 40 m, thinning out in some places such as Wells No. 211-11 and 11-20 on the coastal sand dune near Rafah. The kurkar is replaced by other Quaternary deposits such as gravel, sand, and sandstone in the southern end of the kurkar aquifer.

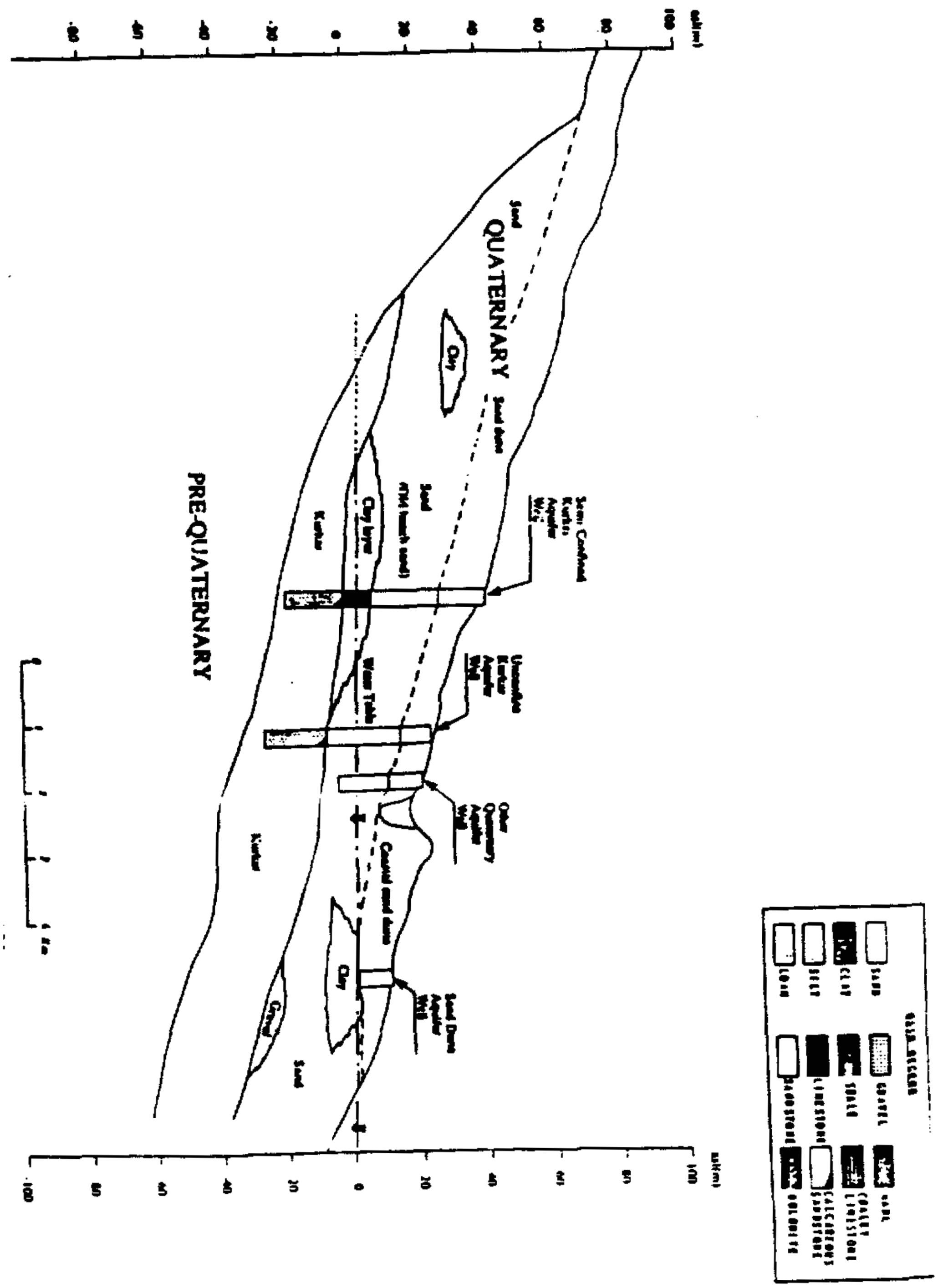

Fig. 8. Schematic geological section of Quaternary formation in the coastal plain.

The kurkar is overlain by old beach sand which underlies the dune sand. The boundary between the old beach sand and the dune sand is unknown in many cases. Clayey beds and gravel are interbedded with each other in different thicknesses. Wherever a thick clayey material overlies the kurkar, a confined aquifer is formed.

The groundwater level along the Mediterranean coast remains at 1–2 m asl, estimated at 4–5 m asl at the southern end of the kurkar aquifer. The southern end of the kurkar is dry.

Water quality of Quaternary aquifer

High salinity in groundwater is a prevailing problem in the study area. There are two possibilities which affect groundwater salinity: contamination of old saline groundwater, and sea water intrusion, because the groundwater in the pre-Quaternary aquifers has high salinity, with varying TDS levels. The well fields in the Quaternary aquifer face the Mediterranean.

In order to examine the possibility of sea water intrusion, and compare the chemical characteristics of groundwater, the ratio $(Na^{+} + K^{+})/(Ca^{++} + Mg^{++})$ is calculated. Through interpretation of these data it is concluded that the high salinity of the groundwater in the Quaternary aquifer might be caused by the high salinity of the groundwater in the kurkar aquifer, or by high salinity in the pre-Quaternary aquifers.

The age of the groundwater in the Quaternary aquifer ranges between 1,700 and 8,600 years, which may suggest that old water forms a greater part of the groundwater in the Quaternary aquifers.

It appears that there are different aquifers in the area (sand, gravel and kurkar). However, it is difficult to differentiate the characteristics of the water quality by the type of aquifer.

The range of groundwater total dissolved salts (TDS) is summarized in Table 3. The aquifer in the coastal sand dunes is the only groundwater source for potable water.

Table 3. Total dissolved salts (TDS) in the aquifers in the study area.

Type of aquifer	TDS (ppm)
Coastal sand dune	300–800
Inland sand	2,500–3,000
Old beach sand	1,300–2,700
Gravel	1,500–5,000
Kurkar, Al Arish	2,500–3,500
Kurkar, inland	3,600–5,600

Water level of the Quaternary aquifer

Since wells are densely distributed in the two well fields (the alluvial plain in the lower stretches of Wadi Al Arish and the coastal plain from Sheikh Zuwayid to Rafah) a considerable amount of water data is available. However, the recorded well fields of wells differ so much that it is difficult to construct contour lines for the well fields. Since most of the wells are productive, it was concluded that water levels had not recovered their static water level. For this reason, a one square kilometer grid was laid over the well field to determine the general features of the field by taking an average of all water levels.

In 1962, the water level of the well field in Al Arish was 2–4 m asl, although there were some areas with distinctively low water levels: grids 7–3, 7–4, and 9–2 (Fig. 9).

During the 1980s, many wells were constructed and the pump age rate was significantly increased. Accordingly, the water level in the Al Arish well field has greatly lowered, as shown in Fig. 10.

Water level recession occurred between 1962 and 1988, and was significant, especially in the well field on the western side of Al Arish. In most of the grid the water level has lowered by 1–3 m (Fig. 11).

Although there is no data to compare the difference between the water levels of the well fields from Sheikh Zuwayid to Rafah over a given time, it is assumed that the groundwater level has been greatly reduced due to heavy pump use. In the coastal belt, very close to the seashore, the water level is slightly above sea water, except at some points, where it is distinctively low.

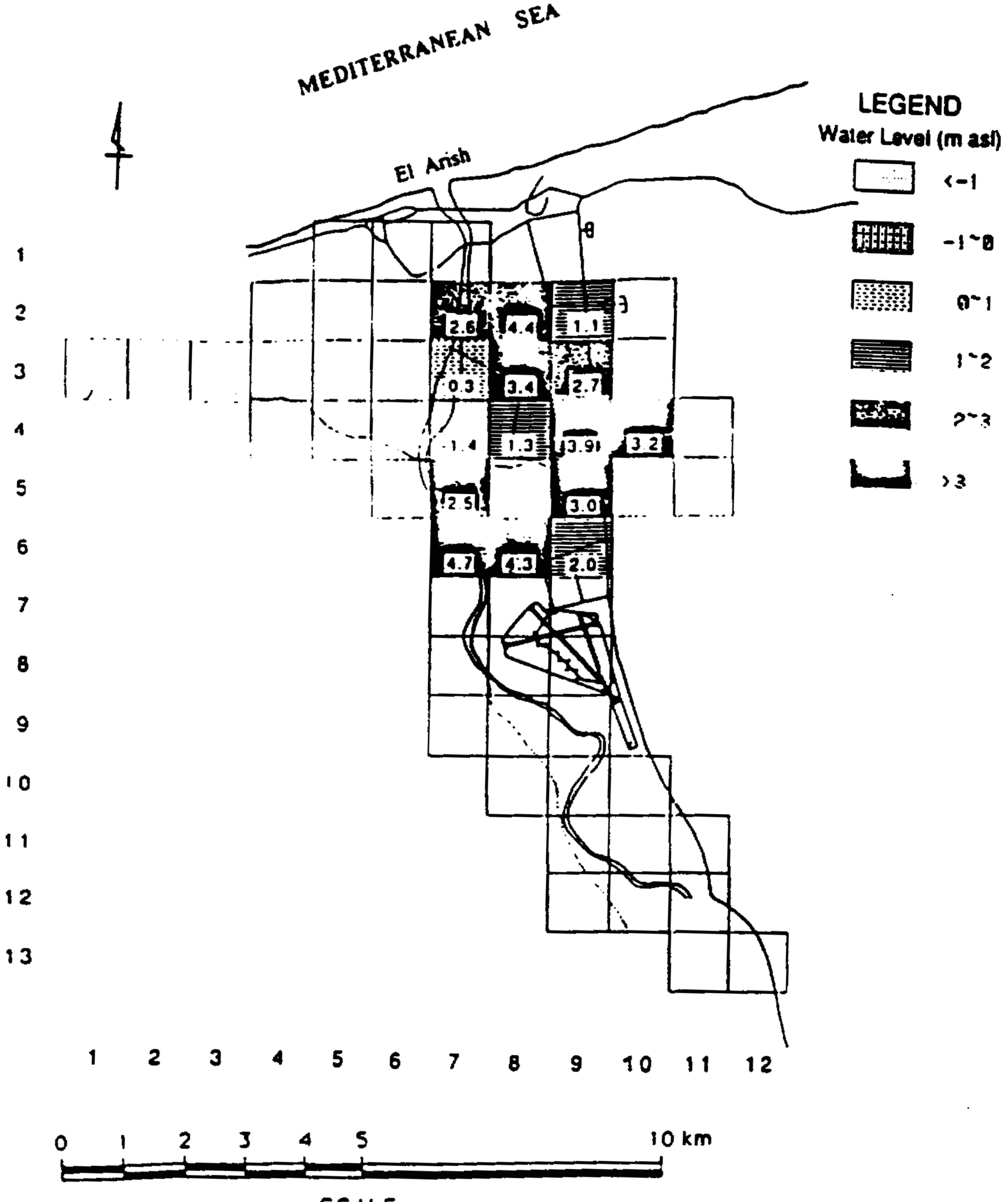

Fig. 9. Average water levels in Al Arish in 1962.

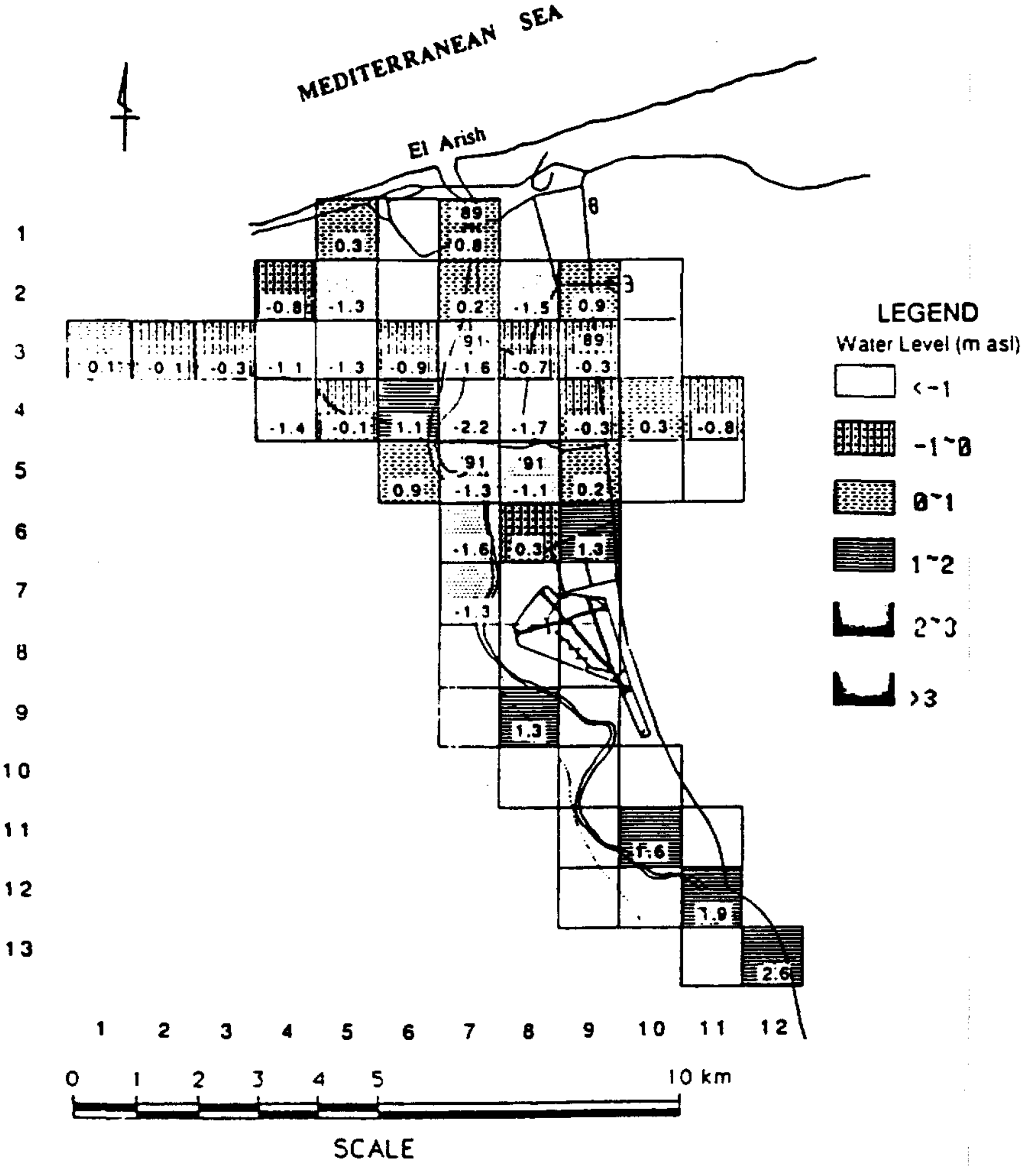

Fig. 10. Average water levels in Al Arish in 1988.

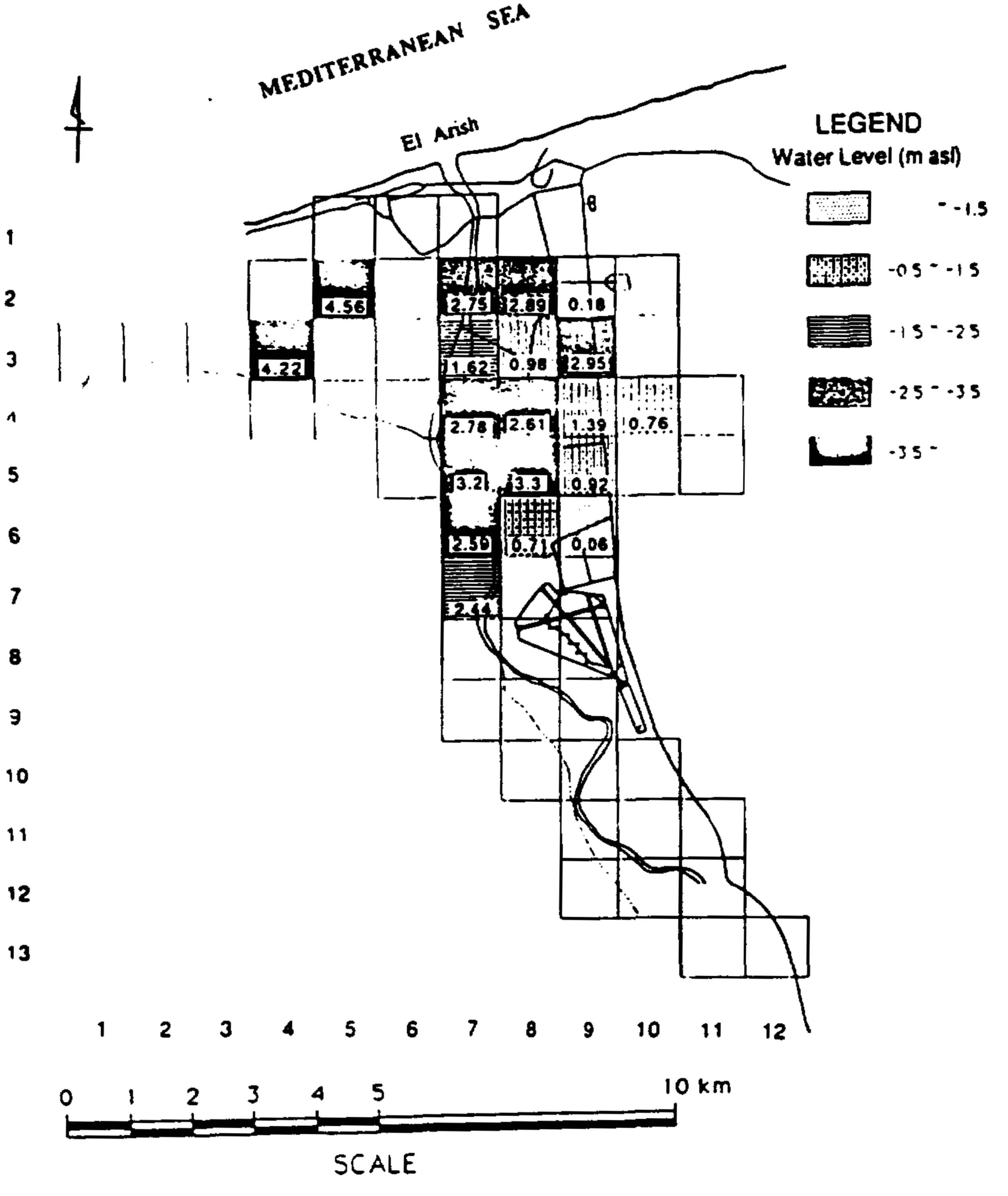

Fig. 11. Recession of water level at Al Arish, 1962 to 1988.

Agricultural Activities

Agricultural Farm Area

Table 4 summarizes the distribution of farm areas among the districts of North Sinai. It utilizes a comparative study (CAPMAS, 1992) between the areas in 1981 and 1991.

Table 4. Distribution of farm areas in North Sinai (1981 and 1991).

District	Area 1981 (fed)	Area 1991 (fed)
Al Arish	6,488	35,253
Bir Al Abd	19,514	6,920
Sheikh Zuwayid	13,185	27,593
Rafah	15,266	47,875
Rommana	-	6,208
Total	54,453	123,850

CAPMAS (1992).
1 hectare = 2.38 feddan

The data show sizable increases in farm area in all districts, with the exception of Bir Al Abd, where a considerable reduction occurred. The increase over ten years in North Sinai exceeded 200%. The largest increases were in Rafah, Al Arish and Sheikh Zuwayid, in that order. CAPMAS (1992) reports that of a total farm area of 123,850 fed (52,037 ha), 11,282 fed (4,740 ha) was irrigated with groundwater. Table 5 shows the wheat and barley areas in 1981 and 1991.

Table 5. Wheat and barley distribution in North Sinai (fed).

District	Barley		Wheat	
	1981	1991	1981	1991
Al Arish	1,681	2,863	14	6,323
Bir Al Abd	6	151	-	1,162
Sheikh Zuwayid	5,640	3,096	16	7,667
Rafah	4,779	4,808	119	9,090
Total	12,106	10,919	149	24,242

1 hectare = 2.38 feddan

The data in Table 5 show a 10% reduction in the barley area, while the wheat area sharply increased between 1981 and 1991. Barley occupied 22.2 and 8.8% of the total farm area in 1981 and 1991, respectively, while wheat occupied 0.27 and 19.6% of the total area in 1981 and 1991, respectively. The data illustrate a considerable shift towards the cultivation of wheat.

Field Crops Research

One of the major research projects of the Academy of Scientific Research and Technology (1993) was on the collection and introduction of salt-tolerant and drought-resistant cultivars of field crops and vegetables under Sinai conditions (N. Ashour, Project Manager). This was a joint project, including the National Research Center, University of Suez, and the Governorates of the Sinai.

Achievements in the Governorate of North Sinai

Project activities were conducted on private and governmental farms in the coastal zone from Al Arish to the national border at Rafah, and in Al Arish valley, upstream from the stone and earth dikes in the courses of the runoffs.

The main results and recommendations for 1984–1990 are summarized as follows:

- Maximum care is recommended in the use of groundwater resources, especially in the summer, when overuse has an adverse effect on quality and salinity levels in irrigation water.
- The integrated use of macro- and micronutrient fertilizers for optimum plant growth in desert soils that are low in most nutrients is needed.
- Leaching fractions should be applied with winter irrigation to minimize salt concentration and accumulation in the soil.
- Organic and inorganic (i.e., gypsum) amendments should be used to improve soil fertility.

Wheat

With respect to North Sinai, the following was concluded:

- It is feasible to grow wheat under rainfed conditions in the northern coastal strip. The yield of seed and straw is related to rainfall, distribution and type of soil.
- The vacant areas between the rows of peach and almond trees should be intercropped with wheat. These vacant areas represent 90% of the total cultivated area.
- Wheat could be grown as a single crop in areas upstream of earth and stone dikes, which are supplied with runoff water.
- Seven wheat cultivars were tested in the various areas of North Sinai. These cultivars are: Giza 157, Giza 162, Giza 164, Sakha 8, Israeli, Sakha 69, and Giza 160. The trials proved that the best cultivars under rainfed conditions are Giza 164 and Sakha 69, which gave the highest yield of seed and straw. Sakha 69 performed the best in the runoff courses (Table 6).
- Wheat production in North Sinai varied between 2.18 and 4.69 ardab/fed (780–1,674 kg/ha) according to location, soil type and ability to retain water.

With the intercropping of wheat with peach and almond trees, which are invariably planted in heavy soils, wheat production reached 7.0 ardab/fed (2500 kg/ha). Peach production was not affected by intercropping with wheat (13.1 t/fed).

Barley

Barley is preferred over wheat due to its greater drought resistance, especially in areas with low rainfall. The results showed that the best barley cultivars under North Sinai conditions are Composite Cross 89 and Giza 123, whether under rainfed agriculture (Table 6) or under well water irrigation with relatively high salt content (Table 7). Barley yields varied between 5.83 and 6.94 ardab/fed (1,665–1,982 kg/ha).

Table 6. Best wheat, barley, and lentil cultivars, agronomic practices, and productivity under rainfed conditions in North Sinai Governorate (Academy, 1993).

Crop/cultivar	Location	Cultivation technique	Seed (ardab/fed†)	Straw (t/fed)
Wheat		Solid or inter-cropped with fruit trees		
Giza 164	Rafah		4.20	1.04
Sakha 69	Rafah		3.66	0.74
Sakha 69	Runoff courses		4.69	1.63
Barley		Solid		
CC 89			5.83	3.91
Giza 123			6.94	3.92
Lentil		Solid. or inter-cropped with fruit trees (inoculation)		
Giza 370	Rafah		1.77	0.70
Shami	Rafah		1.59	0.57
Early (Mobaker)	Runoff courses		3.80	0.53

† 1 ardab of wheat = 150 kg; barley = 120 kg; lentil = 10 kg.

Table 7. Relative tolerance of crop varieties under irrigation with well water at various salinity levels (Academy, 1993).

Crop	Cultivar	Irrigation system	Irrigation water salinity (ppm)	Yield
Wheat	Sakha 69, Sakha 8	Flooding	1300-5900	6-12 ardab/fed†
Barley	CC 89	Flooding	1300-5900	8-10 ardab/fed
Fodder beet	Solanaca, Rota, Brzgdeir, Poly-Grontegn	Flooding	3200-5100	65-120 t/fed
Onion	Giza 20	Drip	1000-5000	6-12 t/fed
Pea	Little Marvel	Drip	1100-4100	3.5 t/fed

† 1 ardab of wheat = 150 kg; barley = 120 kg.

Legumes

The project successfully introduced the cultivation of lentil, intercropped with peach and almond trees, under rainfed conditions in North Sinai to maximize the efficiency and the use of rainwater. It was also possible to successfully cultivate lentil upstream from the earth and stone dikes in Wadi Al Arish, similar to the basin cultivation of legumes in Upper Egypt prior to the construction of the High Dam.

Results of the trials show that the best lentil cultivars in North Sinai are Giza 370 (small seed) and Shami (large seed), which mature early whether rainfed, intercropped, or in runoff courses.

Lentil, when cultivated as a single crop, gave a yield between 1.59 and 3.80 ardab/fed (Table 6). When intercropped with fruit trees (peach and almond), yield varied between 3.66–6.78 ardab/fed. Peach trees yielded 12.9 t/ha when intercropped, compared to 11.9 t/ha without intercropping.

Vegetables

Project activities included performance evaluation of many vegetable cultivars and hybrids in different locations of the coastal zone between Al Arish and the national border at Rafah. Vegetables were cultivated under rainfed conditions, drip irrigation using well water, and under plastic tunnels.

Several vegetable crops proved to be successful under field conditions with drip irrigation using well water of various salinity levels (Table 8). Pea was successfully grown under rainfed conditions in Rafah. The cultivar Little Marvel yielded 600–700 kg/fed. Seed was inoculated with rhizobia prior to cultivation.

Table 8. Relative tolerance of vegetable cultivars under irrigation with well water at varied levels of salinity (Academy, 1993).

Vegetable	Variety	Irrigation system	Irrigation water salinity (ppm)	Yield (t/fed)
Tomato	Super Marmend, El Auxor Hybrid	Drip	1000–1700	30
Cantaloupe	Polydore, Amer. Galia	Drip	2900–4100	6
Cucumber	Beta-Alfa Hyb., Amira Hyb.	Drip	1000–1700	7–9
Lettuce	Acro 8073, Great Lake	Drip	2700–3800	10-18

Rangelands of the Sinai

The natural vegetation is concentrated in the northeast part of the semi-arid land of the Sinai, as well as wadis and depressions. The poor vegetation reflects the fact that overgrazing has been rampant, and shrubs and trees have been used for fuel.

Acacia radiana and *A. tortilis* have mostly disappeared from the depressions. A very limited number of *Juniperus pheonicea* trees remains in the Halal and Maghara mountains. *Ficus sycomorus* and *Zizyphus spina-christi* trees have all but disappeared.

The fodder shrub population has been greatly reduced. The main shrubs remaining in the area are: *Atriplex halimus*, *Atriplex leucoclada*, *Calligonum comosum*, *Gymnocarpus decandrum*, *Salsola* spp., *Suaeda* spp., and *Retama raetam.*

The most palatable annual species are: *Panicum turgidum*, *Panicum dicotomum*, *Aristida pungens*, *Cynodon dactylon* and *Cyperus* spp., *Artemisia herba-alba*, *Artemisia judaica*, *Achillea fragrantissima*, *Capparis dicidua*, *Capparis spinosa*, *Anabasis articulata*, *Alhagi manurorum*, and *Helianthemum* spp.

The reduction of palatable species has resulted in an increase of unpalatable species, mainly *Pegenum harmala*, *Zilla spinosa* and *Artemisia monosperma*.

A dense community of *Medicago marina* was recently documented in the coastal sand dunes, but is now rarely seen.

Some self-seeding annual legumes are able to live and propagate because of their short life. The most important species among these annual legumes are *Trifolium* spp., *Medicago* spp. *Trigonella* spp., *Scorpiturum* spp. and *Astragalus* spp.

Present Main Range Communities

Most, if not all, of the present range species are of low palatability, especially for small ruminants, but can be grazed by camels. The most dominant range species are:

- *Artemisia monosperma.*
- *Hammada elegans.*
- *Noaea mucronata.*
- *Cornulaca monacantha.*
- *Zygophyllum album.*
- *Thymelaea hirsuta.*
- *Lygos raetam.*

Each of these communities is accompanied by other minor species which could be more palatable than the major one.

Chemical analysis of the above-mentioned species showed that CP content is very low, ranging from 1 to 7%, but TDN is approximately 50%, which is enough for animal maintenance.

Natural vegetation of the sand dune chains is very active. Cultivation of *Ricinus communis* and *Acacia* takes place in some patches. *Hammada scoparia, Zygophyllum album* and *Convolvulus lanatum* are very common. Other perennials are *Stipagrostis plumosa, Stipagrostis scoparia, Thymelaea hirsuta, Piternthus tortuosus, Launaea undicaulis, Fagonia arabica* and *Panicum turgidum*.

Some of the rocky patches are suitable for the establishment of run-off, catchment surfaces for one or more cisterns. *Panicum turgidum* is the dominant species in this area. Shrubby desert grass is highly drought-tolerant and grows in dense populations. Other associate perennials are *Moltkeopsis ciliata, Artemisia monosperma, Zygophyllum coccineum, Lygos raetam, Cornulaca monacantha, Stipagrostis scoparia, Cyperus leavigatusi* and *Monsonia niva*.

The site is covered by extensive natural vegetation. Perennial species are *Gymnocarpus decandrum, Ochradenus baccatus, Astragalus spinosus, Stachys aegyptiaca, Hammada elegans, Zilla spinosa,* and *Fagonia arabica*. The annual species are *Malva parviflora, Trigonella stellata, Euphorbia retusa, Lolium temulentum, Bromus rubens, Plantago ovata, Trigonella stellata, Iflago* species, *Lotus halopilus, Cutandia memphetica, Astragulus annularis,* and *Lotus halopllus*.

Detailed Study of Two Pilot Areas

A study of the natural vegetation of North Sinai was carried out by the DRC for Dames and Moore (1983). It included the composition and zonation of the dominant and principal natural vegetation species of the selected pilot areas as well as a general survey for the closed and connected localities as an indication of the prevailing environmental factors (climatic and edaphic), in addition to the chemical evaluation of their potential for grazing and medicinal purposes.

The ecological and vegetative features of the two pilot areas in North Sinai, namely Al Arish–Lehfin and El Bardawil, are presented below.

Al Arish-Lehfin

The downstream stretch of Wadi Al Arish, starting north of Al Arish and extending about 5 km down to the Mediterranean Sea, is completely barren, except for some terracing. The pilot area, about 18 km from Al Arish to Bir Lehfin, includes the following habitats:

Wadi-beds (water course): This type of habitat includes clay sandy, loose sand, and clay-sand-gravel, with the following constituents:

Achillea santolina	*Panicum turgidum*
Heliotropium arbianese	*Astragalus* sp.
Trigonella stellata	*Moricandia nitens*
Filago spathiolata	*Senecio aegyptius*
Anthemis pseudocotula	*Erodium hirtum*
Plantago albicans	*Colocynthis vulgaris*

Pancratium arabicum	*Asparagus aphyllus*
Peganum harmala	*Paituranthus tortuosus*

Elevated plains (wadi course): These clay sandy out-wash soils seem to be dominated by *Haloxylom salicornicum* (*Hammada elegans*), *Diplotaxis acris*, and *Asphodelus tenuiflolius*.

Terraces: These range in elevation between 170 cm to 5 m (compact clay, sand, gravel) and support the following species:

a)

Artemisia monosperma	*Anabasis articulata*
Cynodon dactylon	*Herniaria hemistemon*
Lycium europeum	*Moricandia nitens*
Tamarix mannifera	*Diplotaxis acris*
Tamrix nilotica	*Nitraria retusa*
Atriplex halimus	*Zilla spinosa*
Thymelaea hirsuta	*Retama raetam*
Peganum harmala	*Zygophyllum album*
Hyoscyamus nuticus	

b) Water channels cutting across the wadi terraces, include:

Plantago ovata	*Pilago spathiolata*
Centaurea aegyptiaca	*Iflago spicata*
Malva parviflora	*Trigonella stellata*

Sand dunes and sandy plains: These habitats, close to the wadi terraces and bounding their beds, support the following species:

Ricinus communis (dominant)	*Plantago cylindrica*
Pancratium maritimum	*Moltkea callosa*
Pancratium arabicum	*Heliotropium luteum*
Silene succulenta	*Pteranthus dicotomus*

The individual species of each community seem to exchange dominance according to micro-habitat conditions due to differences in soil elevation, soil moisture, soil texture and distance from the water course.

El Bardawil

The second pilot area, El Bardawil, is a coastal strip about 10 km wide between the main road and the lake, extending more than 50 km. It was found to be vegetatively poor. Close to the lake, the depression is subject to periodic saline water inundation as well as evaporation. Halophytic species are supported, dominated by *Halocnemum strobillaceum* and its co-dominant species (in salt marshes) *Arthrocnemon glaucum*. In the elevated zones (transitional zones), *Zygophyllum album* (salt-tolerant species) grows, forming a more or less pure community with increasing elevation until the sand dune habitat begins. The littoral strip includes some localities where elevated, slightly saline terraces (3–5 m asl) are dominated by *Nitraria retusa* and with some *Lycium arabicum*.

The sand dune habitat seems to be dominated in the rainy season by a *Germineae* sp. which cannot be identified because of its complete deterioration due to drought and severe grazing. In the relatively elevated slopes of this habitat (water catchment area) *Thymelaea hirsuta, Artemisia monosperma, Retama raetam* (natural and vegetatively cultivated), and *Motkea callosa* are found.

The depressions between the sand dunes and the plains resemble water catchment areas, and as such are subject to repeated water accumulation and evaporation, forming inland salt marshes that support the following characteristic species: *Juncus subulatus* (dominant), *Phragmites communis, Nitraria tridentata* (*N. retusa*), *Lycium arabicum*, and *Cynodon dactylon*.

Introduction of New Species to Improve Rangeland

The following legumes were recommended: *Lathyrus hirsutus, Pisum sativum, Vicia sativa, V. villosa, V. montana, I. dasycarpa, Medicago littoralis, M. truncatula* (annual medics), *Melilotus alba, Onobrychis sativa* (sainfoin) and *Medicago araborea* (shrub alfalfa).

The following species are also recommended: *Acacia saligna* (*A. cyanophylla*) *Victoriae*, and *Ligulata*, Cactus (*Opuntia, Ficus indica*), *Cassia sturtii* and salt bushes, *Atriplex halimus, canescens, linearis, oinerba, nummularia*, and *polycarpa*.

The amount of water required annually for each species is over 170 mm. Native species, which are better suited under difficult conditions, should be given priority on demonstration farms. Planting shrubs of the proposed species would provide year-round grazing for animals.

Improving the Rangeland in the Sinai

- Cooperatives should be established to protect the rangeland against overgrazing (controlled grazing).
- An official Department of Rangeland and Small Ruminants should be established as a department of the undersecretary of Agriculture in both South and North Sinai.
- Reseeding of annual species and transplanting of fodder shrubs should be accomplished.

For intercropping in orchards, *Trigonella* spp., *Trifolium* spp., and *Medicago* spp. are recommended.

For sand dunes, fodder shrubs and trees such as *Atriplex nummularia, A. halimus, A. leucoclada, Acacia saligna, Acacia cyanophylla*, and *Prosopis juliflora* are recommended.

Salt-tolerant, irrigated species that can be maintained by the available high salinity water resources are *Medicago marina, Lotus* spp., *Kochia scoparia, Agropyron elongatum*, and *Prosopis* spp.

Grazing is one of the most economical activities in the region. Rangeland deterioration is a result of overgrazing and fuel wood use. The carrying capacity has decreased to more than 8.4 ha/sheep. The range species affected by overgrazing are:

Trees and shrubs:

- *Acacia radiana*
- *Acacia tortilis*
- *Juniperus phoenicea*
- *Atriplex halimus*
- *Suaeda* spp.
- *Salsola* spp.

Perennial grasses:

- *Panicum turgidum*
- *Pennisetum dicotomum*
- *Aeloropus* spp.
- *Cyperus* spp.
- *Cynodon dactylon*

Legumes:

- *Medicago marina*
- *Colutea halippica*

Livestock Population and Production

Population

The number of animals on the rangeland changes continuously, following a seasonal rhythm of birth, mortality, culling, etc. The number of animals in North Sinai is summarized in Table 9. There are many more goats than sheep and camels.

Table 9. Total number of livestock in North Sinai Governorate (Census, 1990)†.

Location	Cattle	Buffalo	Sheep	Goats	Camels	Draft animals
Al Arish	716	289	25,000	45,000	884	458
Sheikh Zuwayid	377	-	13,563	30,437	2,300	939
Rafah	1,484	-	6,602	23,098	1,140	358
Bir El Abd	3	-	25,000	49,000	2,000	356
El Hassanah	-	-	10,000	30,000	2,600	1,463
Nakhel	-	-	2,073	41,57	2,680	219
Total	2,580	289	82,238	181,692	11,604	3,793

† Ministry of Agriculture, Agricultural Research Center, Agricultural Income Estimates of Governorates.

Animal ownership is relatively low, averaging 13.1 head per owner. The number of goats (68.8%) exceeds the number of sheep (31.2%), as shown in Table 9.

Production

Lambing and kidding occur once a year, in December/January. Usually, lambs and kids are born as singles. Weaning occurs at the age of 2–3 months. After weaning, goats are milked for 3-4 months, twice a day (morning and afternoon) until the next conception. The amount of milk is about 0.25–0.5 kg per day. Milk from ewes is hardly sufficient for lamb suckling. Table 10 shows milk production from goats, which exceeds that of sheep. The fat percentage in goat milk is lower than that from ewes. The protein level of ewe milk follows the same pattern as that of fat percentage. The Table also shows the total production of wool and its value in North Sinai.

Table 10. Production and value of wool and milk in North Sinai.

Governorate	Product	Production (ton)	Value (1000 LE)
North Sinai	*Crude wool*	13	33
	Milk	2,248	2,593
South Sinai	*Crude wool*	12	32
	Milk	2,775	2,215

Source: CAPMAS (1990).

Table 11 summarizes livestock fertility, which is higher for goats than for sheep, and higher in the north than in the south. This indicates that goats are more adaptable to conditions in the Sinai, and that the northern section is a more favorable environment than the south. The latter observation conforms with the live body weights recorded earlier.

Table 11. Fertility of sheep and goats in Sinai

Location	Sheep	Goats
North Sinai		
Total sampled	56	237
% females lambed or kidded	41	55.3
% females lambed and pregnant	48.2	71.3
South Sinai		
Total sampled	4	183
% females lambed or kidded	20.4	34.4
% females lambed and pregnant	22.2	47.5

Grazing Practices and Animal Feed

Movement of the flocks to the range starts at sunrise, with their return at sunset. Where palm trees are grown, animals feed on fallen dates throughout much of the year. Lambs and kids usually graze separately, closer to the settlement. After weaning they join their dams in the pasture.

Bedouins usually settle around a well, from which their animals drink once per day, after returning from the range, or every other day, depending on the season. During spring, when the range plants are succulent, animals are usually not offered water. When animals return from the range, they are offered roughage (hay) and concentrates, depending on the type of pasture they have roamed.

Table 12 summarizes feed consumption in the North and South Sinai Governorates. Animals are herded by girls and small boys. Sometimes a shepherd is hired to take the animals of the entire Bedouin group to pasture. If rams or bucks are owned, they run with the females throughout the year. The breeding season usually starts in June or July. Bucks and rams are used for the first time at the age of one and are kept for about five years. Kids and lambs are selected as future sires according to their vitality. If owners do not have their own sires, they may borrow one for 20–30 days; one sire can serve 40 females. Sires are given extra care during the breeding season, with corn, barley grain, or flour mixed with water offered along with hay and concentrates, if possible.

Table 12. Feed consumption (1000 LE) in Sinai Governorate (1991).†

Governorate	Straw	Grain	Concentrated feed	Total
North Sinai	8,677	4,865	1,729	15,271
South Sinai	-	-	629	629

† Source: CAPMAS (1991).

Threats to Sustainability

The rainfed areas in North Sinai face a number of important constraints that could pose significant threats to the sustainability of developmental activities. These threats can be summarized as follows:

- Climate changes, especially with respect to rainfall variability, pose a serious threat. More recording stations are needed. The data compiled by the three existing stations over the past 30 years should be analyzed for trends, growing seasons, and possible modeling.
- Several techniques are used to make indirect use of rainfall, including *mawasi*, and trenches. These techniques should be investigated to discover their relationship with water quality and overpumping.
- Trends show that groundwater resources are overexploited, leading to rapid deterioration of this valuable resource. More studies are needed for the conservation and development of groundwater resources that could play a major factor in agricultural development and improved productivity.
- Wind and water erosion are active in the region due to the presence of large areas of windblown deposits, lack of conservation techniques, and lack of integrated planning to combat erosion. Water erosion leads to silting of reservoirs and dams, as was the case with Al Rawafaa dam in Wadi Al Arish, which was supposed to conserve 5 million m^3 of water.
- Improvement of resource management on the farm requires concerted research and extension efforts to enhance agricultural productivity under the conditions of a fragile ecosystem.
- Rangeland deterioration requires the adoption of a range improvement policy that leads to effective and practical measures.
- Present land-use practices do not take into consideration the sustainability of resources. No policy for land use exists. Such a policy should be formulated, with the accent on the farmers' participatory role to ensure efficient policy formulation and implementation.
- Socioeconomic considerations should be the subject of more in-depth studies for research and development, including labor supply and demand, availability of credit, agro-processing, minimizing post-harvest losses, and enhancement of export opportunities.
- The quality and characteristics of the available natural resources in many areas require the adoption of innovative approaches to the use and management of these fragile resources.

References

Academy of Scientific Research and Technology. 1993. The Academy and developmental research in Sinai 1983-93, Cairo, Egypt.

Anon. 1990. Conservation and development of the natural and crop fodders in Sinai. The 3rd project report 1986-1988, DRC, Egypt.

Arcon/Ministry of Development and New Communities. 1992. Project for the integrated development of the eastern border areas in Sinai. Cairo, Egypt.

CAPMAS (Central Agency for Public Mobilization and Statistics). 1990, 1991 and 1992. Statistics Yearbook. Cairo, Egypt.

Dames and Moore/Ministry of Development and New Communities. 1983. Technical reports on soils, geology, rangeland, and livestock. Prepared by the Desert Institute, Cairo, Egypt.

El Bagouri, I.H., S. El Demerdash, A. Harga and H. El Kadi. 1982. Soils of Sinai. Academy of Scientific Research and Technology, Cairo, Egypt.

El Gabaly, M.M. 1954. The soils, water supply and agriculture in northeastern Sinai. University of Alexandria and the Desert Institute.

El Nennah, M., M.A. El Kadi, R.N. Kamh and S. El Sherif. 1981. Forms of copper and zinc in soils of Sinai. Desert Inst. Bull. 31, p. 129.

Elwan, A.A., F.H. Rabie and A.S. Sallam. 1983. Morphology and classification of North Wadi Al Arish soils. Desert Inst. Bull. 33. Cairo, Egypt.

FAO. 1976. Framework for land evaluation. Soils Bulletin No. 32, FAO, Rome.

GTZ (German Agency For Technical Cooperation). 1993. Rural development of North Sinai. Reconnaissance soil survey in North Sinai. Technical Report.

Griffith, J.F. (ed.). 1972. Climates of Africa, in: *World Survey of Climatology, Vol. 10*, Amsterdam.

JICA (Japan International Cooperation Agency). 1992. North Sinai groundwater resources study. Final Report, October 1992.

Sabet, S.A. 1958. Soils of Wadi Al Arish. Ph.D. Thesis. Cairo Univ. Cairo.

Tasoar, H. and Y. Zohar. 1985. Desert dune sand and its modern agricultural development; in: Desert Development.