A study of the climate of Egypt with special reference to agriculture

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A STUDY OF THE CLIMATE OF EGYPT WITH SPECIAL REFERENCE TO AGRICULTURE

by

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To

Dr. Peter Beaumont

with grateful thanks

for his guidance and encouragement

ABSTRACT

This thesis contains a study of the climate of Egypt with special reference to agriculture. It is organised in three main sections. The main body of the thesis, beginning with Chapter 3 (Temperatures in Egypt), deals with surface, earth and water temperatures in detail. Analysis of daily maximum temperatures at selected stations during the 15 year period (1960 - 1974) showed that spring is the period during which the frequency and severity of hot spells is greatest.

Analysis of precipitation over Egypt showed that the rainy season in Egypt occurs between October and May and the maximum rainfall over the coastal Mediterranean region occurs in January, but in Middle and Upper Egypt this maximum occurs in October and May.

Evaporation and evapotranspiration was estimated using the Penman equation and the Thornthwaite formula for selected stations in Egypt. These indicated that the evaporation and evapotranspiration values for each month are very high at Aswan, Kharga and Dakhla stations, in comparison to Alexandria and Tanta.

The main weather features which are sufficient to specify what is called Khamsin weather have been analysed. These are excessively high surface temperatures and extremely low humidities, associated with the invasion of south and south-east winds which produce rising dust and duststorms. It is also seen that there are two types of Khamsin depressions. The first originates over the Atlantic and the second forms to the south of the Atlas mountains.

Factor analysis techniques have been used to classify the climate of Egypt. The results showed that the climate of Egypt can basically be divided into two climatic zones. The first comprises the Mediterranean Coastal area, including the Delta. The second zone covers the rest of the country south of Cairo.

Multiple regression equations have been used to explain the relationships between the crop yields and selected climatic variables. The results derived show that the multiple regression equations analysing climatic data have good predictive qualities in terms of annual yields.

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ABBREVIATIONS

Agr. or Agric.	Agriculture
Alex.	Alexandria
A.R.E.	Arab Republic of Egypt
Ass.	Association
Aust.	Australia
Bull.	Bulletin
Climatol.	Climatology
Cott. Gr. Rev.	Cotton Growing Review
Econ.	Economics
Ed.	Editor or Edition
Fed.	Feddan
Geog. Jour.	Geographical Journal
Geog. Rev.	Geographical Review
Geogr.	Geography
Geol.	Geology
Gov.	Government
Ha.	Hectare
Inter.	International
J. Exp. Agr.	Journal of Experimental Agriculture
J. Soil Sci.	Journal of Soil Science
Mag.	Magazine
Meteorol. Dept.	Meteorological Department
Publ.	Publication
Res.	Research
Rev.	Review
Roy. or R.	Royal

Sci. or Sc.	Science
Soc.	Society
Std. Dev.	Standard Deviation
Trans.	Transactions
Trop.	Tropical
N.	North
U.A.R.	United Arab Republic
U.N.	United Nations
U.S.	United States
Wld.	World

CHAPTER 1

INTRODUCTION

"The Physical Environment of Egypt"

"The Physical Environment of Egypt"

Egypt forms the north-eastern corner of Africa and occupies nearly one-thirtieth of the total area of that continent. It is bounded to the north by the Mediterranean Sea, to the south by the Republic of the Sudan, to the west by Libya and to the east by Israel, the Gulf of Aqaba, and the Red Sea. It measures 1073 Km in length from north to south and 1226 Km in breadth from west to east. It embraces a total area of almost one million square kilometres (386,110 sq. miles).

Egypt's territory extends over about ten degrees of latitude, from 22° N to 32° N with the southern portion of the country lying south of the Tropic of Cancer. In consequence most of Egypt comes within Africa's dry desert region, apart from a narrow strip in the far north which experiences a Mediterranean climate (Damagnez, 1973). Barren desert covers more than 96% of the country. The only inhabited part of Egypt is a longitudinal oasis corresponding to the Lower Nile Valley. This locale is where Egypt's inhabitants have concentrated since the dawn of history (Ball, 1939).

The Nile enters Egypt, flowing from the south, at Wadi Halfa on the Egyptian-Sudanese frontier. The river flows across Egypt for a distance exceeding 1530 Km, until finally discharging its waters into the Mediterranean Sea. The Nile in its lower section in Egypt has no tributaries to supply it with water other than a few dry wadis entering from both banks. These wadis are rarely filled with water. The Nile in this respect is similar to all rivers which run through deserts in their lower courses, such as the Colorado River in the United States, the Loa River in Chile, the Indus River in Pakistan, and the Tigris and Euphrates Rivers in Iraq (Abu Al-Izz, 1971).

The Nile divides Egypt into two distinct morphological regions. The region to the east consists of a dissected plateau draining to the river, while the region to the west consists of a series of unconnected depressions. Although the land to the east of the Nile forms one geomorphological region, it is divided geographically into the Eastern Desert and the Peninsula of Sinai separated by the Gulf of Suez (Fig. 1.1).

According to Said (1962), Egypt consists of four regions, namely :-

1.1 - The Nile Valley and the Delta.
1.2 - The Western Desert.
1.3 - The Eastern Desert
1.4 - The Sinai Peninsula.

Some of the main geographical features of each of these provinces are given in the following paragraphs.

1.1 - The Nile Valley and Delta :-

The Nile Valley and the Delta occupy the alluvial tract along the lower 1530 Km of the River Nile within

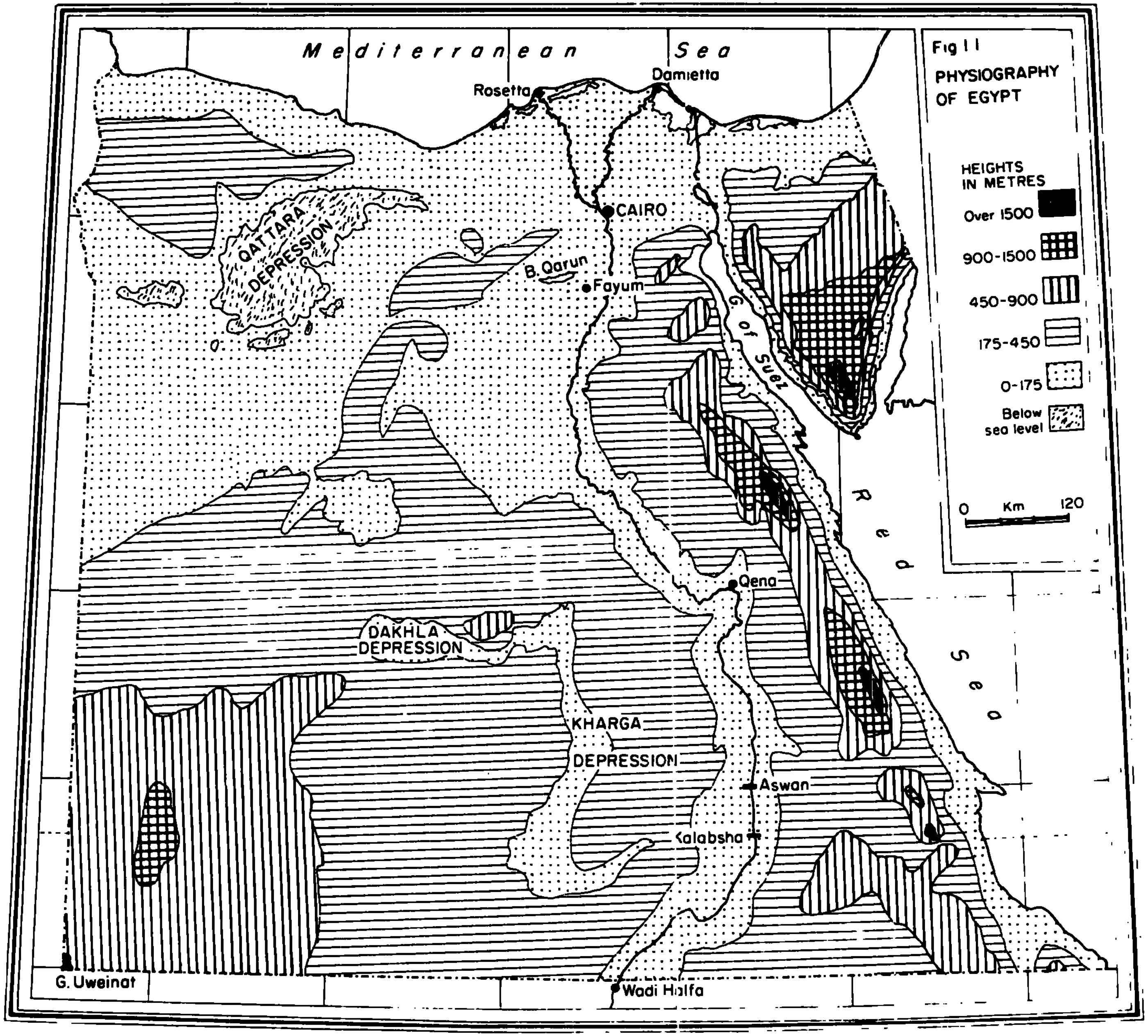


Fig 11
PHYSIOGRAPHY
OF EGYPT

the borders of Egypt. Along this section the Nile receives no tributaries. After entering Egypt at Wadi Halfa it passes for more than 300 Km through a narrow valley with cliffs of sandstone and granite on both its eastern and western sides until it reaches the first cataract which commences about 7 Km south of Aswan. The construction of the Aswan Dam at the beginning of this century drowned the strips of cultivable land along this stretch, while the construction of the Aswan High Dam rendered large tracts of the Nubian Desert a vast reservoir of water. At Kalabsha the river flows through a rocky gorge, then at the first cataract its course is much obstructed by rocky islands.

At flood time the slope of the water surface in thisstretch is from 125 m above sea level at Wadi Halfa to 92 m above sea level at Aswan; an average gradient of about 1 m in 11 Km. This figure exceeds only slightly the average slope of the river in the remaining 1200 Km of its course to the Mediterranean. North of Aswan, the Nile Valley broadens and the flat strips of cultivable land, extending between the river and the cliffs that bound its valley on either side, gradually increase in width northward. About 260 Km north of Qena, the cliffs on the western side of the valley become much lower than those on the eastern side and continue so for more than 400 Km to Cairo, where the valley opens out to the Delta. The average width of the flat alluvial floor of the Nile Valley between Aswan and Cairo is about 10 Km, and that of the river itself about 0.75 Km. Throughout its entire course, the Nile tends to occupy the eastern side of its valley, so that the cultivable lands on the west of the river are generally much wider than those on the east. In fact, in some places, the stream almost washes the eastern boundary cliffs. In many parts of the valley marginal terraces containing flint implements can be traced at heights considerably above the cultivation level indicating that the river must have flowed in prehistoric times at higher levels than it does at the present (see Ball, 1939; Awad, 1947; Said, 1962; Wendorf et al., 1977).

After passing Cairo, the river flows in a northwestward direction for a distance of 20 Km, after which the branching of the Delta begins. The Delta has two distributaries, the Rosetta and Damietta branches. The first has a length of 239 Km, and the second is six kilometres longer (Abu Al-Izz, 1971).

The Fayum depression, lying a short distance to the west of the Nile Valley, is connected with the River Nile by a narrow channel through the desert hills. The lowest part of the depression is occupied by a shallow lake called Birket Qarun which is about 45 m below sea level and about 200 Km^2 in area, the soils of the depression are formed from the Nile's silt, and are, therefore, similar to the soils of the valley and the delta. The area of the Fayum depression is 1700 Km^2 (For more details, see Beadnell, 1905; Said, 1962; Abu Al-Izz, 1971).

1.2 - The Western Desert :-

West of the Nile, the Western Desert extends over a vast area occupying more than two-thirds of the total area of Egypt (681,000 Km^2). It is essentially a plateau with vast flat expanses of rocky ground and numerous extensive and deep depressions (see for example, Said, 1960; Ball, 1939; Beadnell, 1909). It attains its greatest altitude in the extreme south-western corner of the country, where the general plateau character is disturbed by the great mountain mass of Gebel Oweinat lying just outside Egypt, (Fig. 1.2). The north-eastern flanks of the mountain are, however, within the borders of Egypt.

To the north of the great Gilf Plateau lies another plateau with arms extending in several directions. This plateau is composed of limestone and is lower in elevation than the Great Gilf Plateau, its average elevation being less than 500 m above sea level. The limestone plateau forms the main landform feature west of the Nile Valley, as it extends from south to north for more than 700 Km. This means that it covers over two-thirds of the length of Egypt. The high ridged plateau slopes towards the Nile Valley in the east; towards the Kharga and Dakhla Oases in the south; and towards the Qattara-Siwa Depression in the north. Hollowed out of the plateau surface are two great depressions, those of Farafra and Bahariya. The area of the former is more than 3000 Km^2 and the second has an area of about 1800 Km^2, slightly more than that of

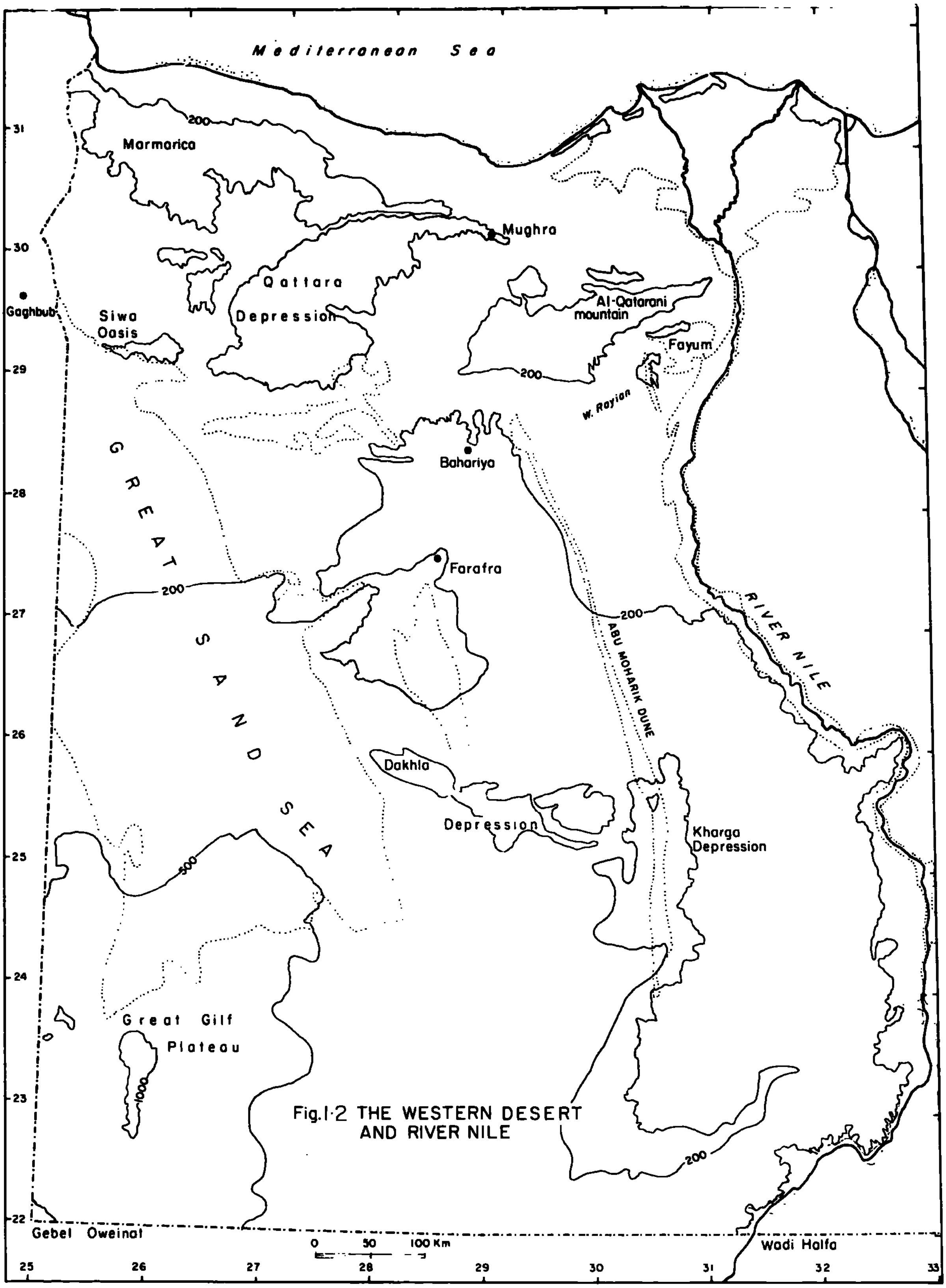


Fig.1·2 THE WESTERN DESERT AND RIVER NILE the Fayum Depression (Said, 1962; Abu Al-Izz, 1971).

A Miocene limestone plateau lies to the north of the Qattara-Siwa Depression. It is triangular in shape, with its apex lying west of the Nile Delta and its base running along the frontier between Egypt and Libya. This plateau is known by the name of Marmarica. Its elevation is about 200 m above sea level, and its surface slopes toward the Qattara-Siwa Depression where a high ridge stands like a wall between the plateau and the depression. The Miocene plateau is very close to the sea in the far western part of the Western Desert (Fig. 1.2) and is only separated from the sea by a narrow coastal plain produced by several wadis which flow from the plateau into the Mediterranean.

A pronounced feature of the Western Desert, obviously due to its arid climate, is the almost complete absence of well-marked drainage lines (Murray, 1951; Butzer, 1959; Himida, 1970). There are a few gullies draining from its northern edge to the sea, and a few others draining into the Nile Valley along its eastern border, but none of these extend far back into the rocky platform. Over the vast interior of the desert, such scanty rainfall as occurs is lost mostly through evaporation and partly through drainage over broad stony plains into the various internal depressions.

Another feature of the Western Desert is the nature and distribution of its water sources. Along the narrow belt of the Mediterranean littoral there are wells and cisterns fed by local rainfall. At the foot of

Gebel Oweinat there are springs fed by the occasional rains which fall on the mountain mass, but the land in between is practically rainless. The Oases of Siwa, Bahariya, Kharga and Dakhla owe their habitability to artesian supplies. All the Oases, as well as the scattered wells to the south of Kharga, are situated in great depressions where the ground water supplies can rise to the surface, but the vast intervening areas of high plateaus are waterless (For more details, see Hammad, 1970; Himida, 1970).

The Western Desert is also characterized by parallel belts of sand dunes, of immense length and comparatively small breadth, running generally in a south-south-easterly direction. One of the most noteworthy of these is the Abu Moharik dune belt which extends for a distance of over 300 Km in length and only a few kilometres in width. This chain extends from the west of the Bahariya oasis to the north of Kharga and continues, with minor breaks in the same direction, for another 150 Km within the Kharga depression (Beadnell, 1910). Besides these dunes there are extensive flat expanses of drifted sand especially in the south and west. The total area covered by sand is in fact less than that occupied by bare rock (see, for example, Ball, 1939; Said, 1962).

1.3 - The Eastern Desert :-

Between the Nile Valley and the Gulf of Suez - Red Sea coastline is the Eastern Desert. It consists of a backbone of high rugged mountains running parallel to, and at a relatively short distance from, the coast. These mountains are flanked to the north and west by sedimentry plateaus. The Eastern Desert occupies a substantial portion of Egypt, with an area greater than 223,000 Km^2, or about 21% of the total area of the country.

The backbone of the Eastern Desert is a mountain chain known as the Red Sea mountains, running parallel to the Red Sea, and separated from it by a narrow coastal plain. Neighbouring the Red Sea mountains on the north and west are dissected plateaus formed from sedimentary rocks. Examples of these plateaus are Al-Galala Al-Qibliya (1464 m), Al-Galala Al-Bahariya (1274 m), and Mount Ataqa (871 m). These are blocks separated from one another by broad Wadis terminating in The Red Sea and the Gulf of Suez, (Fig. 1.3). The Red Sea mountains themselves are composed of igneous rocks. These rocks are first seen at latitudes 28° N, near Mount Um Tanasib, and from there they extend in a narrow triangle to a base paralleling the Egyptian-Sudanese border at latitude 22° N. This igneous triangle protrudes into the eastern Sudan.

The Red Sea mountains are not a single chain, but several groups of mountains chains lying in lines parallel to the Red Sea Coast. These mountains are intruded by igneous blocks. The highest of the peaks is Mount Al-Shayib (2184 m) at latitude 27° N. The peak known as Gabal Ilba is in the far south-eastern corner

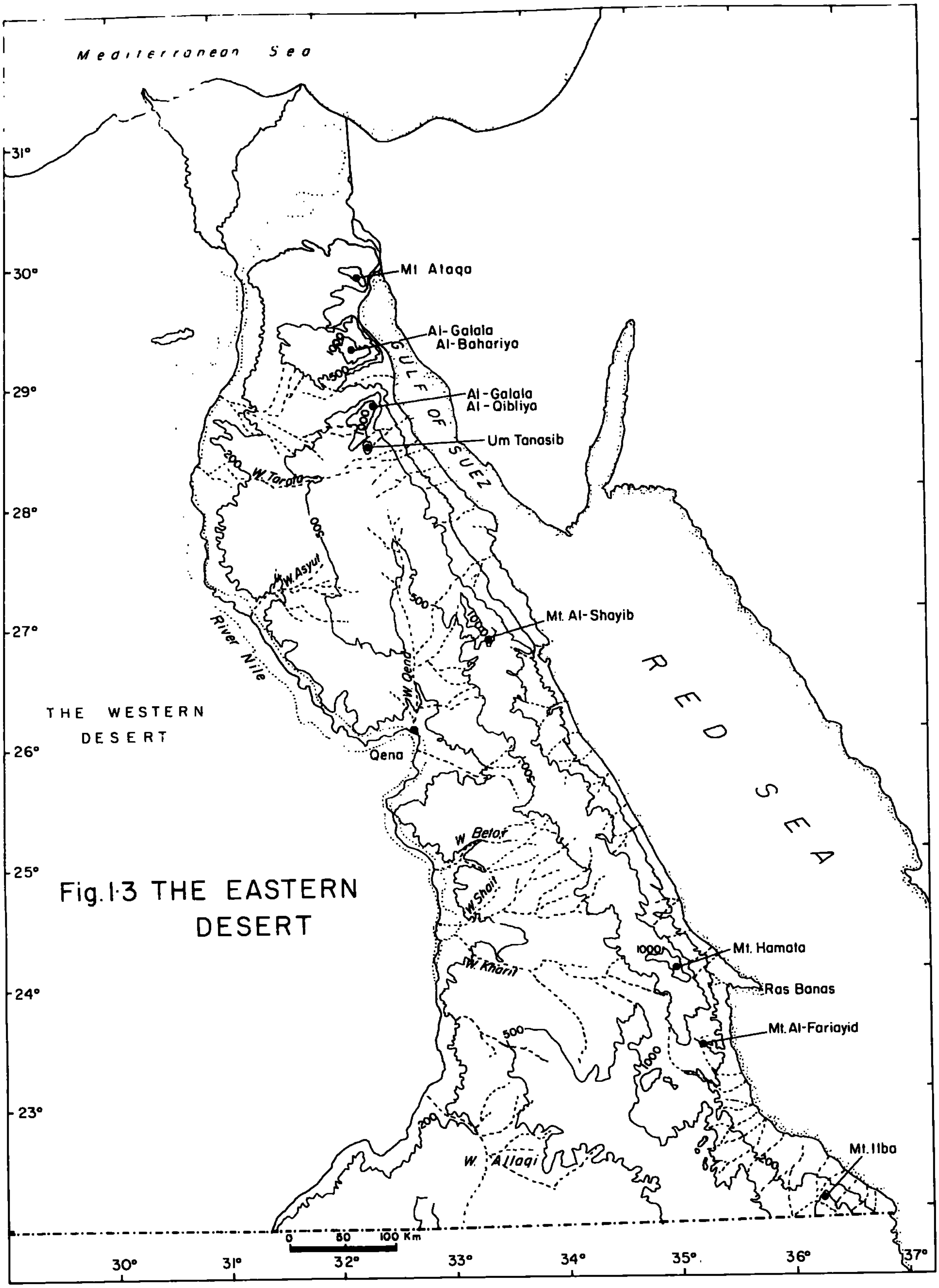


Fig.1·3 THE EASTERN DESERT

of Egypt. It has an elevation of 1437 m, and is an igneous block with a square shape. Located close to the Red Sea Coast, its slope has a differentiated vegetation cover varying in vertical zones according to altitude. Other major peaks are Mount Al-Fariayid (1366 m) and Mount Hamata (1978 m), (Fig. 1.3).

The southern region is known as the Al-Ababada plateau, borrowing its name from a local tribe. This plateau is sandstone and has a higher elevation than the limestone plateau. It is characterized by increasing width toward the south, reaching its broadest part at the frontier between Egypt and the Sudan.

There are several differences between the Eastern and Western Deserts :-

1) The Eastern Desert is highly dissected by numerous wadis and their tributaries. These cut it into several small plateaus which lie between the Red Sea mountains and Nile Valley, (Fig. 1.3). In contrast, the Western Desert is dominated by vast rocky surfaces devoid of any drainage lines.

2) The Eastern Desert has external drainage, in comparison to the predominantly internal drainage of the Western Desert. Its wadis fall into two drainage systems, whose base levels are the Red Sea and the Mediterranean Sea, and which are separated from each other by a drainage divide following the Red Sea mountains. The Red Sea system consists of a large number of steep, short wadis, while the Mediterranean (or Nile Valley) system is composed

of a relatively small number of trunk channels such as the Wadi Tarafa, the Wadi Asyut, the Wadi Al-Betor, the Wadi Shait, the Wadi Kharit, and the Wadi Al-Allaqi (Fig. 1.3). The basins of these wadis cover an area of several thousands of square kilometres. For instance, the Wadi Al-Allaqi's basin alone covers more than 44,000 Km^2. All of these wadis follow an east-west direction except Wadi Qena, which runs from north to south.

3) Both deserts are poor in water resources. The Eastern Desert's main source of water is the sporadic desert rains which fall on the Red Sea mountains and flow in torrents eastward to the Red Sea or westward to the Nile. This water immediately percolates through the gravel and sand deposits which fill the wadi beds. The most common watering places in the Eastern Desert are wells dug in the wadi beds, tapping these natural underground reservoirs. Most of the wells in the Eastern Desert are so shallow that their water can be drawn from a depth of between eight and ten metres, (see for example, Hume, 1907; Said, 1962; Abu Al-Izz, 1971).

4) Unlike the Western Desert the Eastern Desert has no sand sheets. There are, however, heaps of sand along the Red Sea Coast south of Ras Banas. The reason for the accumulation of sand in this area is the convergence there of the north-west and south-east winds, producing a condition of calm in which sand is laid down. These heaps of sand, though, are not in any way similar to the great sand sea in the Western Desert.

1.4 - Sinai Peninsula :-

Sinai covers an area of 61,000 Km^2. It is separated geographically from Egypt by the Suez Canal and the Gulf of Suez. It is triangular in shape and continuous with the Asiatic continent for a distance of over 200 Km from the head of the Gulf of Aqaba to Rafah on the Mediterranean. The core of the peninsula, situated near its southern end, consists of an intricate complex of high and very rugged igneous and metamorphic mountains. The northern two-thirds of the peninsula is occupied by a great northward-draining limestone plateau, which rises inland from the Mediterranean coast. This extends southwards, and terminates in a high escarpment on the northern flanks of the great igneous core, (Fig. 1.4).

Sinai's igneous core contains the greatest mountains in Egypt. The highest peak, Gebel Katherina, attains an altitude of 2632 m above sea level. Many other peaks and crests rise above the 2000 m contour, including the Gebel Um Shomer (2586 m) and the Gebel El-Thpet (2439 m). The core of the peninsula is highly dissected; its gaunt mountain and deep rocky gorges form one of the most rugged tracts on the earth's surface.

To the north of the igneous core lies the Gebel El-Tih the highest part of the limestone plateau. At its southern end is the Al-Ugma plateau, rising to 1620 m above sea level. The central portion of the plateau surface forms a fairly open country draining to the Mediterranean by numerous tributaries of the Wadi

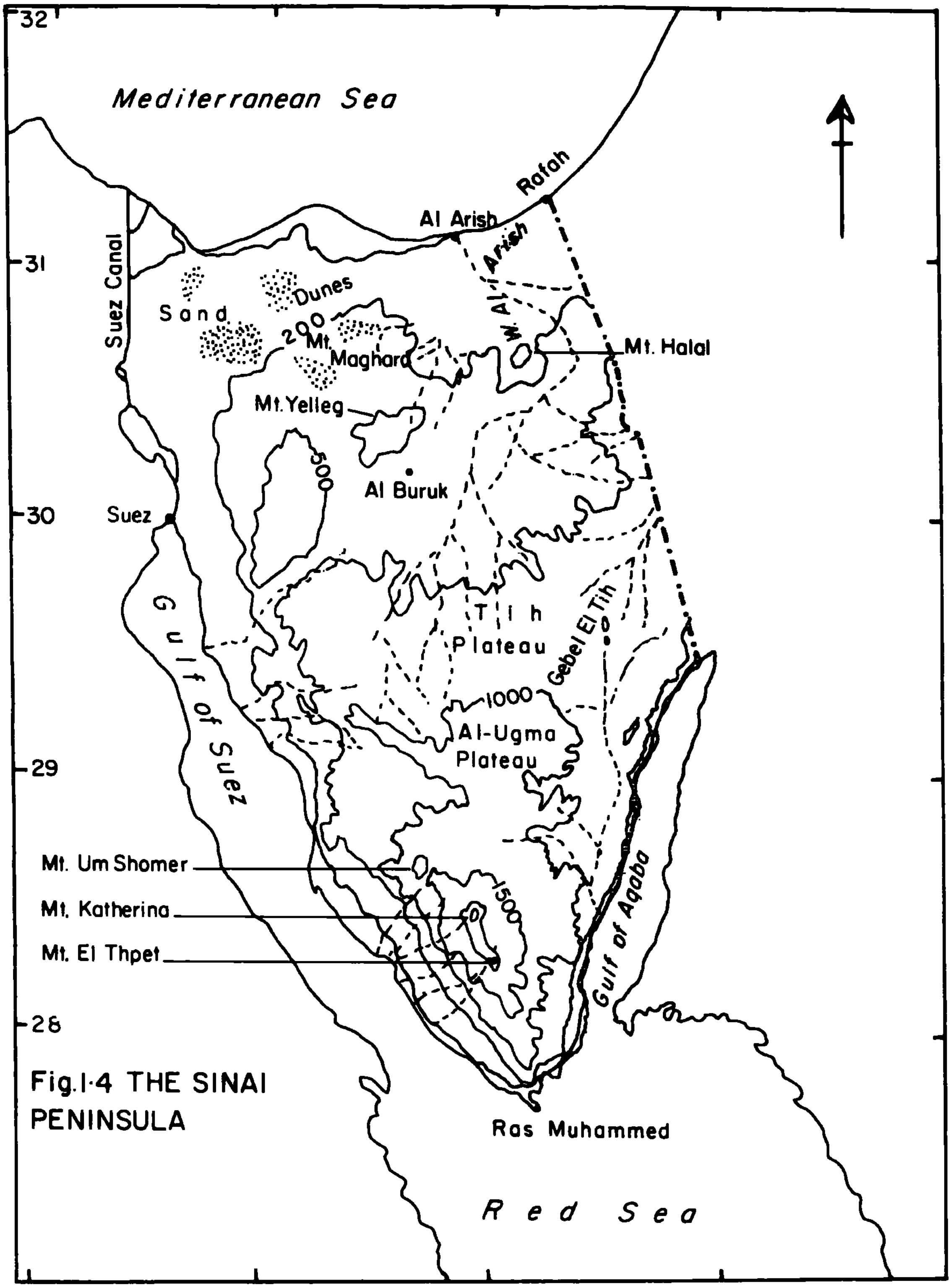


Fig.1·4 THE SINAI PENINSULA

Al-Arish. The eastern and western edges of this plateau are dissected by numerous narrow and deep rocky valleys draining to the Gulfs of Aqaba and Suez (Beadnell, 1926).

To some geologists the Sinai plateau is a geological extension of Asia, separated from the rest of Egypt by the Gulf of Suez (Said, 1962). If true, Egypt's eastern boundary, which extends for a distance of 200 Km between Rafah and the Gulf of Aqaba, forms an artificial line cutting through a single geological and physiographic formation. The Tih plateau which occupies the central part of Sinai is considered to be an extension of the plateaus of Samarra and Yahudiya in central Israel.

In northern Sinai, the northward dip of the plateau is broken by hills of considerable size, the principal of which are the Gebels Yelleg (1090 m), Halal (890 m) and Maghara (735 m). Beyond these, and extending nearly to the Mediterranean coast, is a broad tract of sand dunes some of which attain heights of over 100 m above sea level.

1.5 - Drainage patterns in Egypt :-

The influence of regional slope is clearly noticed when we compare the Eastern and Western Deserts. The drainage systems in the first are distinct and numerous; and believed to be the product of a number of uplifts which have made the Eastern Desert higher and steeper than the Western Desert.

Figure 1.5 shows the distribution of drainage

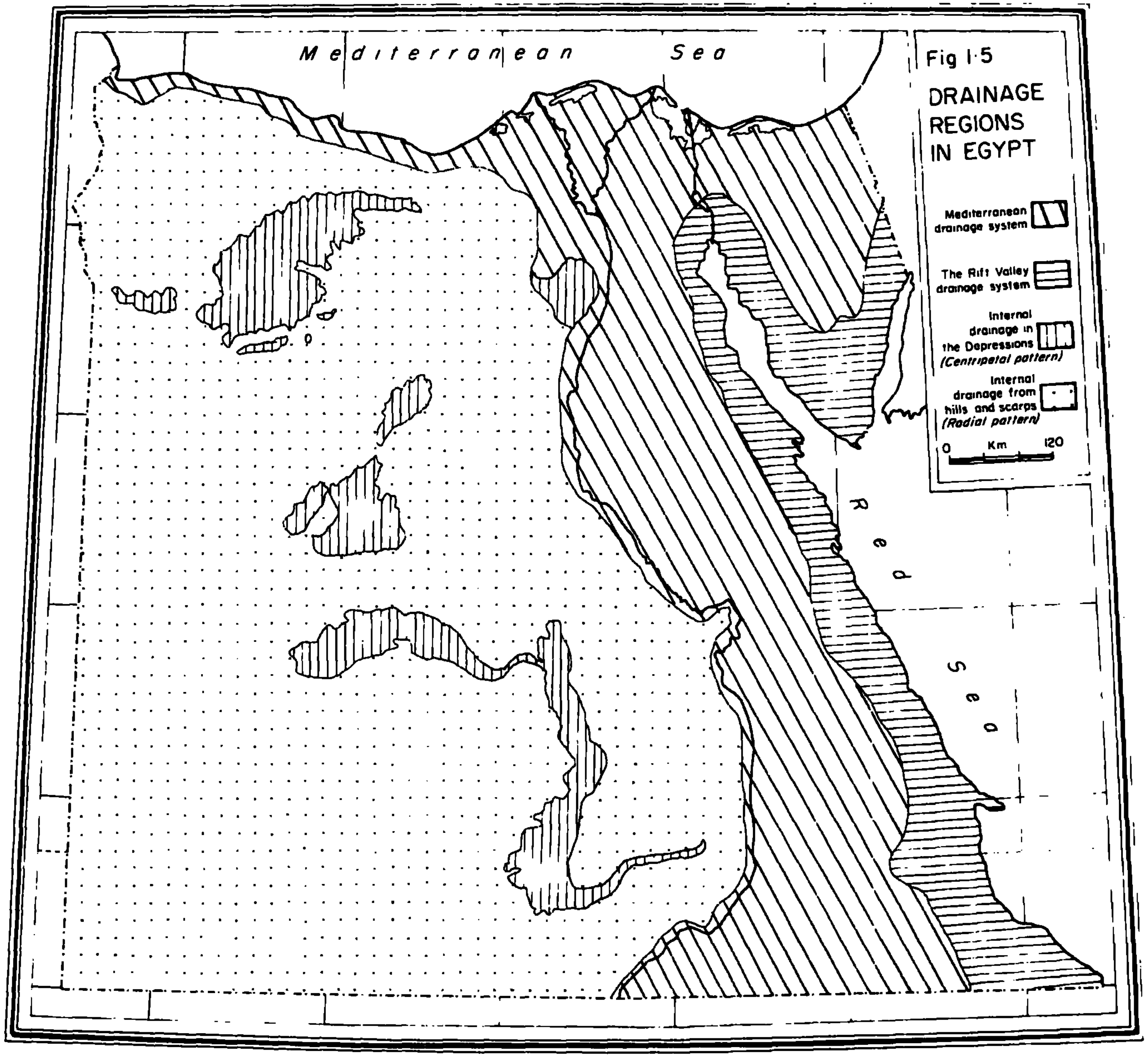


Fig 1·5
DRAINAGE REGIONS IN EGYPT

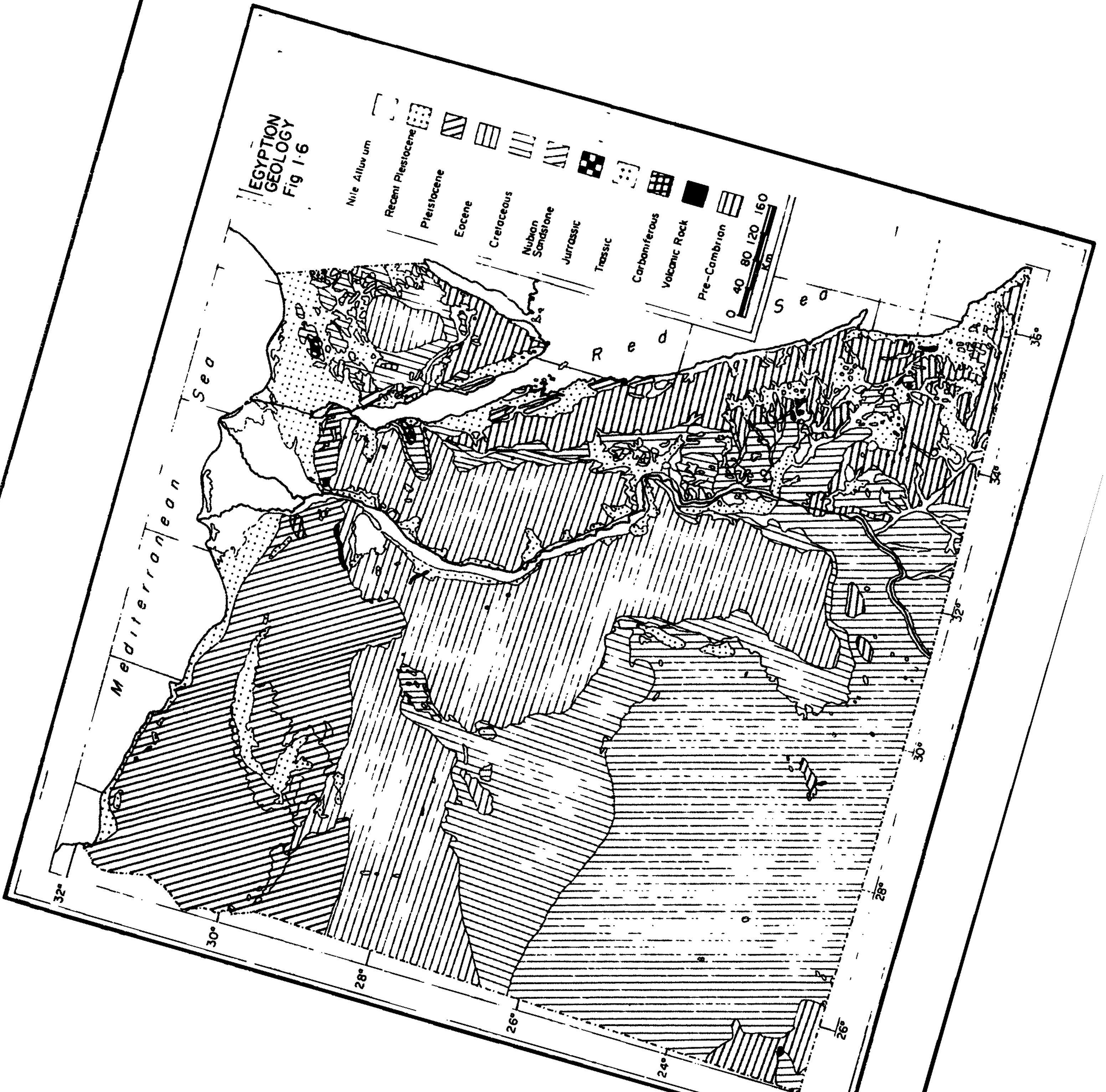
patterns in Egypt. The Red Sea mountains can be considered as the eastern boundary of the Nile basin, since from their eastern slopes steep wadis flow into the Red Sea, and from their western slopes water flows toward the Nile. The water divide between the Red Sea and the Nile basins runs in a north-south direction, sometimes close to the Red Sea and sometimes distant from it according to the characteristics of the rocks and the regional slope.

The drainage regions in Egypt can be classified as follows :-

1) The Mediterranean drainage area covers 245,000 Km^2,
2) The rift valley drainage system covers 99,000 Km^2.
3) The remaining two-thirds of Egypt (664,000 Km^2) has an internal drainage system, all of which is located in the Western Desert (Nuttonson, 1961; Abu Al-Izz, 1965 and 1971).

1.6 - The geological map of Egypt :-

The geological map of Egypt shows the general geology of the country in as much as its scale permits (Fig. 1.6). The geology of Egypt has been studied by a large number of geologists, including, Krenkel (1925); Hume (1929); Yallouze and Kenetsch (1955); Abu Al-Izz (1953); Shata (1959); Said (1962); Barakat and Miland (1966); Philip and Fakhry (1969); McKenzie et al (1970); McKenzie (1970); Takin (1972) and others. These studies have proved that Egypt, as well as other countries of North Africa, was invaded several times by the Sea of


EGYPTION GEOLOGY
Fig 1·6
Nile Alluvium
Recent Pleistocene
Pleistocene
Eocene
Cretaceous
Nubian Sandstone
Jurrassic
Trassic
Carboniferous
Volcanic Rock
Pre-Cambrian
0 40 80 120 160
Km
Mediterranean Sea
Red Sea
32°
30°
28°
26°
24°
22°
36°

Tethys. This old geologic sea probably began to form in the Pre-Cambrian Era. The Sea of Tethys is the antecedent of the Mediterranean Sea, and has always encroached upon the land of Egypt from the north. This means that Egypt's past land-sea distribution has not always been the same as that of today. Indications are that the sea has invaded parts of Egypt several times, retreating northward with a rise in the land surface. This alternation has been repeated often during Egypt's long geologic history.

The following table shows the distribution of geological formations from different geologic periods in Egypt (see Said, 1962 and Abu Al-Izz, 1971).

Table 1.a

"Areal distribution of the formations of the different geologic periods in Egypt"

Geologic period	Area (Km^2)	%
Pleistocene and Holocene	165,000	16.18
Pliocene	7,000	0.69
Miocene	113,000	11.08
Oligocene	16,000	1.57
Eocene	203,900	20.00
Cretaceous (Limestone)	130,000	12.75
Cretaceous (Sandstone)	290,000	28.44
Jurassic	450	0.04
Triassic	50	0.01
Carboniferous	1,200	0.12
Pre-Carboniferous	93,000	9.12
Total	1,019,600	100.00

This thesis is concerned with three main sections :-

The first section is a study of the major climatic elements and is divided into six chapters. The first chapter is a general explanation of the effect of the main climatic factors and air masses on the climate of Egypt. The second chapter is a study of the temperatures (surface, earth and water temperatures). Precipitation and evapotranspiration are discussed in the third and fourth chapters in this section respectively. The fifth chapter analyses Khamsin weather conditions. The last chapter is an attempt to classify the climate of Egypt using factor analysis techniques.

In section two, the agriculture of Egypt is studied in three chapters. The first is an introduction to the agriculture of Egypt and its soils. The second discusses the major crops and the expansion of agriculture lands in Egypt. The irrigation and drainage systems are studied in the third chapter.

Section three analyses the relationships between climatic elements and crop yields in Egypt. Four chapters are involved. The first is an introduction to the relationships between crop yields and climatic conditions. The second and the third chapters analyse the effects of climatic elements on cotton and wheat yields in Egypt respectively. The actual and predicted maize, rice and sugar cane yields are studied in the fourth chapter.

-:-:-:-:-:-:-

(SECTION ONE)

"The Main Climatic Elements in Egypt"

- Introduction
- Temperatures in Egypt
- Precipitation in Egypt
- Evapotranspiration in Egypt
- Khamsin Conditions in Egypt
- Climatic Classifications in Egypt

CHAPTER 2

Introduction to the Climate of Egypt

To understand the climate of Egypt, it is necessary to examine the major factors and the main air masses that prevail over adjacent areas, as well as their characteristics, and the modifications they undergo prior to their arrival in Egypt.

The climate of Egypt is influenced by the following basic factors :-

1) The semi-permanent pressure systems in each season; such as the cold Siberian anticyclone in winter, the heat lows of Africa in spring and autumn, and the huge low pressure system over southwest Asia in summer.

2) The trajectory of the depressions and associated weather systems in autumn, winter and spring.

3) The Mediterranean and, too a much lesser extent, the Red Sea as sources of water vapour, in addition to their role as positive or negative thermal sources. The Mediterranean has a pronounced influence on the northern area (Lower Egypt) but the effect of the sea greatly diminishes towards Upper Egypt.

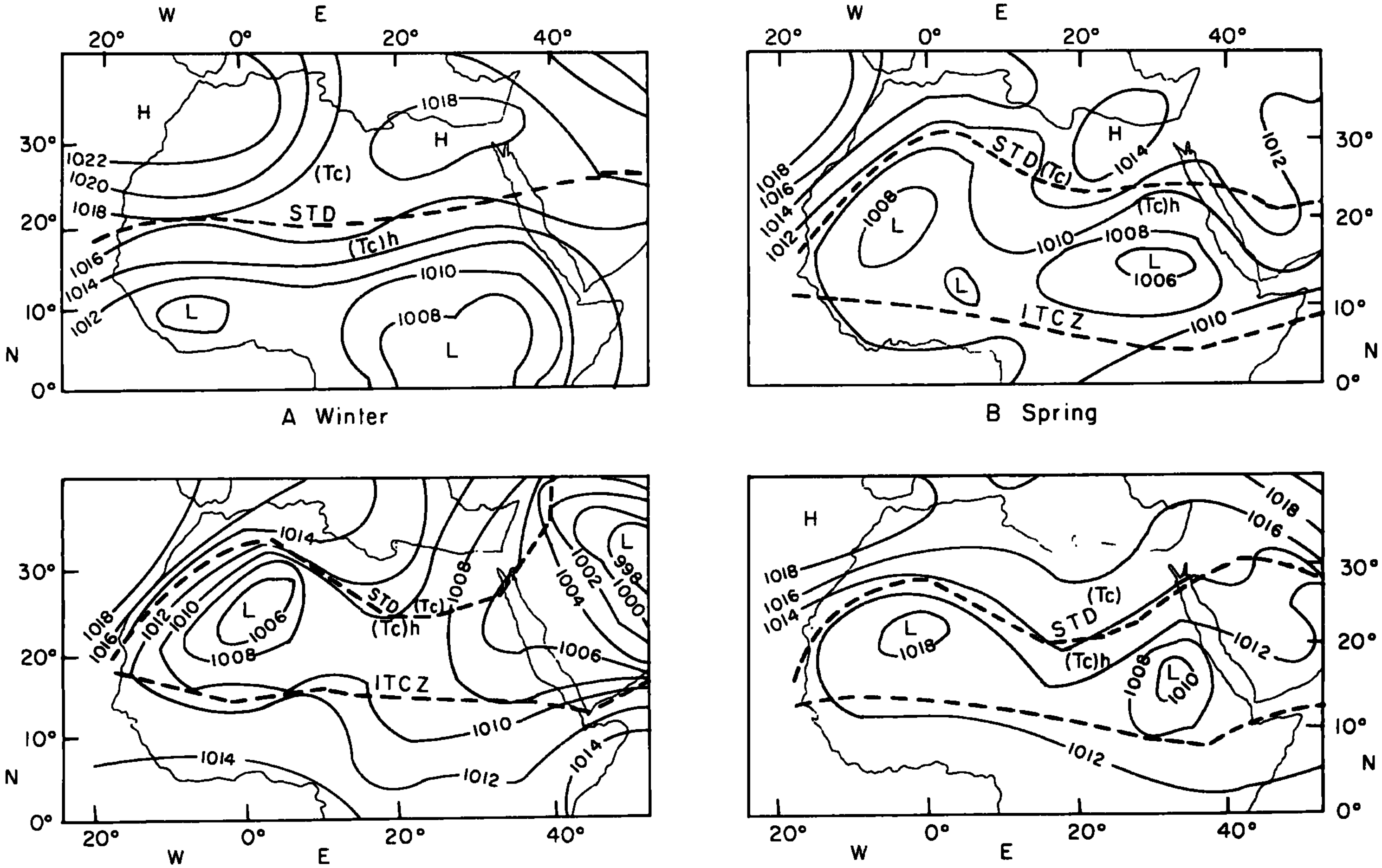
4) Orographic influences play a small role in the general climate but have important local effects.

The main air masses in each season are summarized hereafter :-

In winter the Mediterranean becomes the theatre for the consecutive passage of depressions, some being single centred and others complex. They are the main cause of weather change in this season. Mediterranean depressions mainly affect Lower Egypt with Upper Egypt remaining practically untouched by them. However, the cold northwesterly winds in the rear of depressions over the eastern Mediterranean reach southwards to Upper Egypt and cause both a reduction in temperature and the occurrence of sand-storms. They are not usually associated with any precipitation. The coldest winter spells experienced in Egypt result from the arrival of such air masses. The Pc air occurs when a deep depression with a strong pressure gradient (usually centred over Cyprus) covers the Mediterranean at a time when the Siberian anticyclone extends to cover the Balkans. The Pc air reaches Egypt as a cold northwesterly wind. In this season the air mass $(Tc)_h$ is much warmer than the (Tc) air above North Africa. The two air masses are separated by a quasi-Stationary Surface of Discontinuity, the Sub-Tropical Discontinuity (STD). In winter, however, the $(Tc)_h$ air is too far south to be drawn northwards by Mediterranean depressions and therefore rarely affects Egypt in winter (Fig. 2.1A).

In spring the Sudan trough sometimes extends northwards to cover Egypt and consequently, the hot southerly current of air from Arabia flows over the country, causing moderate or severe hot spells. This air is hot and dry except in the Mediterranean coastal strip where it picks up moisture from the sea. This sometimes leads to the formation of early morning radiation fog over Lower Egypt. In this season the STD is located north of its winter position (Fig. 2.1B) and comes within the field of interaction of the Khamsin

Fig. 2·1 MEAN SEASONAL PRESSURE PATTERNS (millibars)



A Winter

B Spring

C Summer

D Autumn

depressions. After the formation of the depressions the STD experiences north-ward movement so that the very hot $(Tc)_h$ air forms the warm sector of the depressions.

In summer, there are frequent temperature oscillations as a result of the northerly winds which can prevail over Egypt at this time. These winds have two different sources :-

a) Asiatic origin, arriving in Egypt as NE winds causing hot spells.

b) European origin arriving in Egypt as NW winds bringing cooler spells.

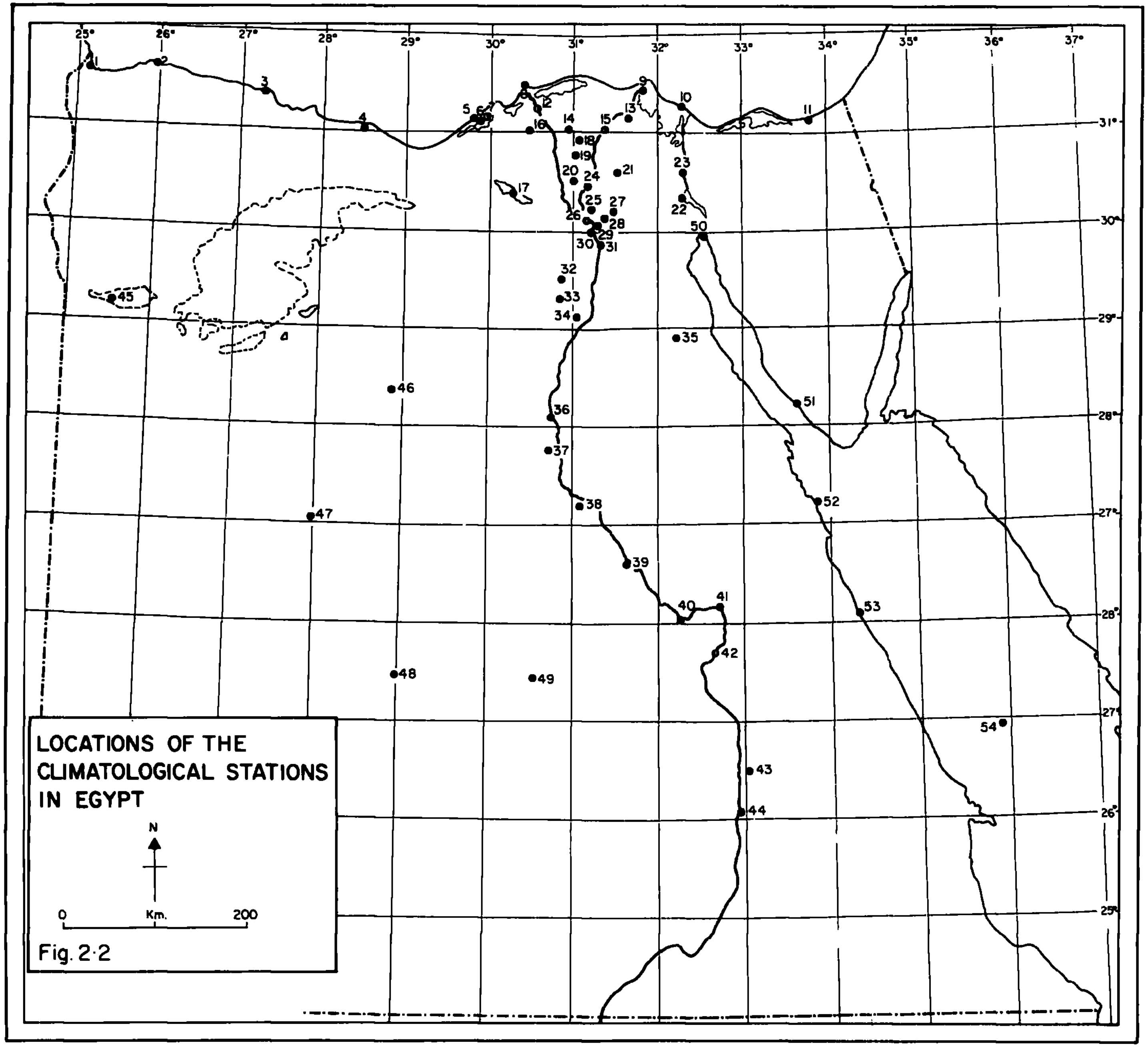
In summer the climate of Lower and Middle Egypt, being affected by the cool Mediterranean waters, is warm during the daytime and rather cool by night. The maximum effect is obviously felt in coastal areas where the weather is pleasant. As the STD moves further northward in summer, Upper Egypt lies to the south of it and experiences a hot, very dry climate (Fig. 2.1C).

The climate in the autumn season is similar to that in spring, for it is another transitional period. Khamsin-like depressions begin to cross Egypt during October and cause a break down of the settled summer regime. On the other hand, the higher humidity in this season favours greater frequency of thunderstorms and heavier precipitation; especially in November. In this season heat waves are less common and less severe than in spring. This is because the depressions are weaker and since the STD is further south, $(Tc)_h$ air is not easily drawn northwards to affect Egypt (Fig. 2.1D).

Climatological data used in this work were taken from 54 climatological stations (Fig. 2.2). Average daily, monthly and annual values registered at the long-term base stations were used.

All the maps of the various climatic elements included in this thesis have been objectively drawn using a computer program - the SYMAP - method which was originally written by the Laboratory for Computer Graphics at Harvard University, U.S.A. This programme works on the basis of given co-ordinates of data points and the values associated with them. Continuous variation is assumed between two contour lines and the interpolation algorithm is based on a weighted average of slopes and values of nearby data points. The spatial units are defined by the nearest neighbour technique from point information, so that each character location on the output map is allocated the value of the nearest data point. Boundaries are assumed along the line where the values change and choropleth is then applied. The SYMAP program also has been used to draw the choropleth maps for the major agriculture crops in the agricultural section in the present thesis (For other instances of computer drawn climatic maps see, Brown and Rosenbery, 1969; Williams, 1970; Maine, 1967; Bleasdale and Farrar, 1965; Herbst, 1966 and Muxworthy, 1972).

The present section considers temperatures, pre-



LOCATIONS OF THE CLIMATOLOGICAL STATIONS IN EGYPT

Fig. 2·2

1 - SALLUM
2 - SIDI BARRANI
3 - MERSA MATRUH
4 - DABAA
5 - KOM EL-NADURA
6 - DEKHEILA
7 - ALEXANDRIA
8 - ROSETTA
9 - DAMIETTA
10 - PORT SAID
11 - EL-ARISH
12 - EDFINA
13 - EL-SIRW
14 - SAKHA
15 - MANSURA
16 - DAMANHOUR
17 - WADI EL-NATRUN
18 - GEMMEIZA
19 - TANTA
20 - SHEBIN EL-KOM
21 - ZAGAZIG
22 - FAYED
23 - ISMAILIA
24 - BANHA
25 - KHANKA
26 - DELTA BARRAGE
27 - ALMAZA
28 - CAIRO
29 - EZBEKIA
30 - GIZA
31 - HELWAN
32 - SHAKSHUK
33 - FAYUM
34 - BENI SUEF
35 - SAINT ANTONY
36 - MINYA
37 - MALLAWI
38 - ASYUT
39 - SHANDWEEL
40 - NAG HAMMADI
41 - QENA
42 - LUXOR
43 - KOMOMBO
44 - ASWAN
45 - SIWA
46 - BAHARIYA
47 - FARAFRA
48 - DAKHLA
49 - KHARGA
50 - SUEZ
51 - EL-TOR
52 - HURGHADA
53 - QUSEIR
54 - ABU EL-KIZAN

cipitation, evapotranspiration, Khamsin weather conditions and a classification of Egypt's climate using factor analysis techniques.

-:-:-:-:-:-:-

CHAPTER 3

Temperatures in Egypt

This chapter summarises temperature observations in Egypt. It includes surface temperatures; earth temperatures down to a depth of two metres at a number of stations in Egypt, and water temperatures (River Nile).

3.1 - Surface temperatures :-

A study of surface temperature data reveals the following general characteristics :-

a) The sudden change from the summer regime to the winter regime, often occuring in late October, which gives rise to a drastic alteration in mean monthly temperatures (maxima, minima and mean).

b) The change from the Mediterranean depressions of winter to the Khamsin depressions of spring which causes a sudden rise in temperature.

Mean maximum temperatures :-

The highest mean maximum temperatures occur in July or August, except in the most southerly part of the country where the combination of high sun and the arrival of hot $(Tc)_h$ air south of the STD leads to a June maximum temperature. It is noticed that the highest mean maximum temperatures occur at Aswan during June, July and August, and are 42.0, 41.9 and 42.0°C respectively. The lowest mean maximum temperatures are recorded at Alexandria and Port Said in January (18.3°C and 18.0°C respectively) (Fig. 3.1 and Table 3.a). The highest absolute maximum temperature registered at Aswan on 8th of June, 1932 was

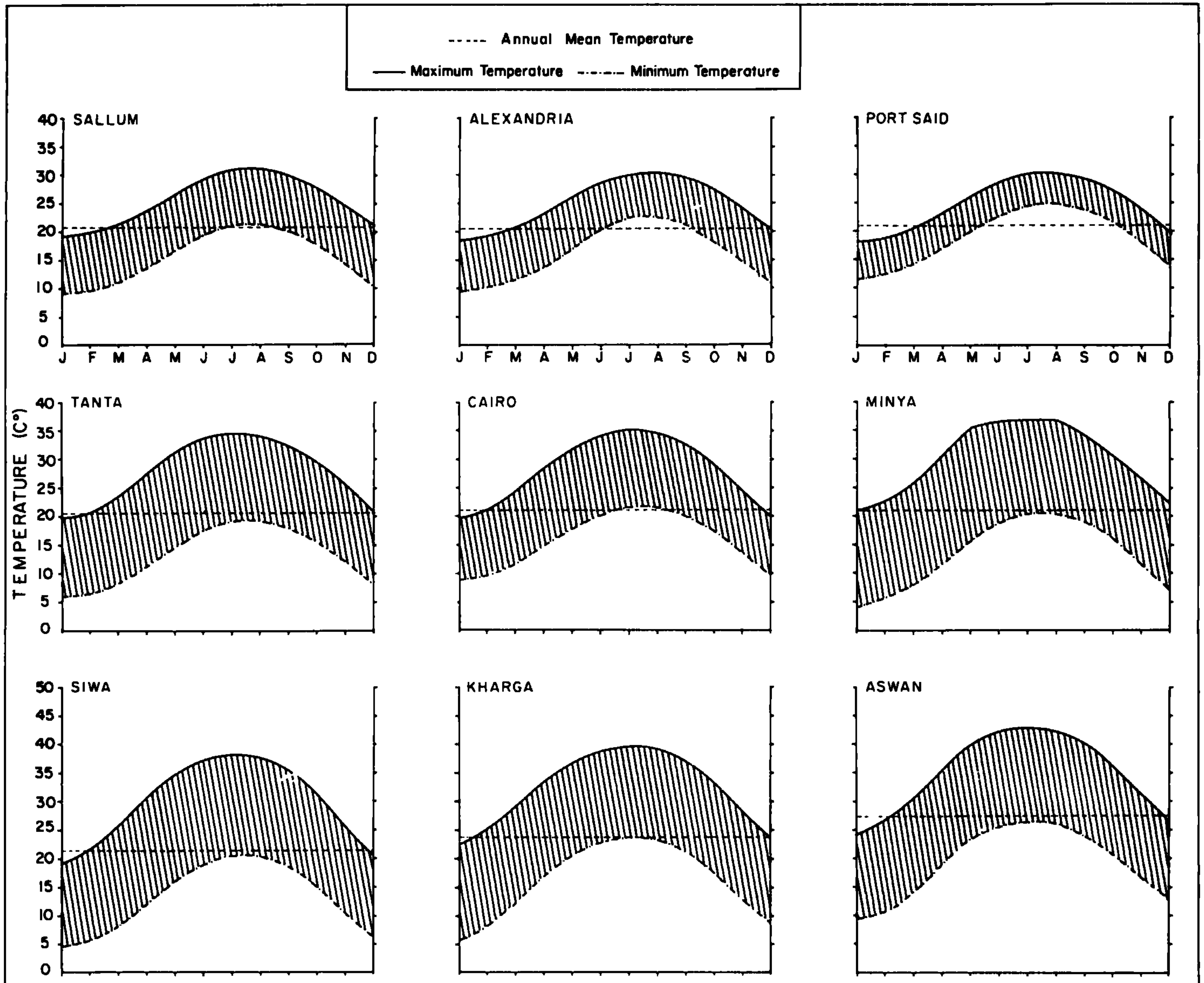


Fig.3·1 DIAGRAMS OF MEAN MAXIMUM AND MEAN MINIMUM MONTHLY TEMPERATURES (C°) FOR SELECTED STATIONS IN EGYPT.

Table 3.a

Mean Monthly Temperatures for Selected Stations in Egypt (^{o}C)

Place / Month	Sallum (1946 - 1960)					Alexandria (1942 - 1960)				
	Max.	Min.	Range	Abs. Max.	Abs. Min.	Max.	Min.	Range	Abs. Max.	Abs. Min.
January	18.9	8.9	10.0	25.7	0.0	18.3	9.3	9.0	26.3	2.4
February	20.0	9.7	10.3	33.2	3.4	19.2	9.7	9.5	36.4	2.4
March	21.2	10.8	10.4	41.1	4.1	21.0	11.2	9.8	40.4	6.2
April	23.4	13.1	10.3	41.7	6.2	23.6	13.5	10.1	41.6	7.0
May	26.1	16.4	9.7	43.2	9.5	26.5	16.7	9.8	41.8	10.5
June	29.5	19.4	10.1	44.1	14.2	28.2	20.2	8.0	42.1	11.7
July	31.0	21.0	10.0	44.1	16.2	29.6	22.7	6.9	38.1	17.5
August	31.2	21.4	9.8	43.5	18.0	30.4	22.9	7.5	39.7	17.4
September	29.5	20.2	9.3	42.1	14.2	29.4	21.3	8.1	39.9	15.7
October	27.5	17.6	9.9	39.8	11.6	27.7	17.8	9.9	39.0	11.9
November	24.9	14.7	10.2	36.0	6.7	24.4	14.8	9.6	36.5	7.4
December	20.4	10.8	9.6	31.4	5.0	20.4	11.2	9.2	28.6	4.2
Ann. Mean	25.3	15.3	10.0	-	-	24.9	15.9	9.0	-	-

Source:- Climatological normals for U.A.R. up to 1960, Meteorol. Dept. Cairo, Egypt, 1968

Table 3.a Continued

Place / Month	Port Said (1941 - 1960) Max.	Min.	Range	Abs. Max.	Abs. Min.	Tanta (1931 - 1960) Max.	Min.	Range	Abs. Max.	Abs. Min.
January	18.0	11.3	6.7	25.0	5.1	19.7	6.0	13.7	29.5	-2.0
February	18.7	12.1	6.6	32.5	2.2	21.0	6.4	14.6	35.8	-2.0
March	20.2	13.5	6.7	35.0	5.9	23.7	8.1	15.6	39.3	1.3
April	22.6	16.1	6.5	37.3	8.2	27.6	10.7	16.9	41.6	2.7
May	25.8	19.6	6.2	44.9	11.7	31.8	14.5	17.3	46.8	8.0
June	28.5	22.4	6.1	41.2	18.6	33.8	17.2	16.6	46.8	12.0
July	30.4	24.1	6.3	38.0	21.1	34.5	19.1	15.4	42.1	15.0
August	30.9	24.9	6.0	36.9	22.0	34.6	19.3	15.3	41.0	15.0
September	29.2	23.9	5.3	35.9	18.8	32.5	17.4	15.1	40.7	11.7
October	27.4	21.8	5.6	37.0	15.5	30.1	15.4	14.7	39.6	9.0
November	24.0	18.4	5.6	35.3	9.6	25.9	12.2	17.7	37.0	4.0
December	19.9	13.7	6.2	28.5	7.5	21.3	8.1	13.2	29.6	1.0
Ann. Mean	24.6	18.5	6.1	-	-	28.0	12.9	15.1	-	-

Table 3.a Continued

Place / Month	Cairo (1947 - 1960)					Minya (1941 - 1960)				
	Max.	Min.	Range	Abs. Max.	Abs. Min.	Max.	Min.	Range	Abs. Max.	Abs. Min.
January	19.1	8.6	10.5	30.2	3.0	20.6	4.0	16.6	31.4	-4.0
February	20.7	9.1	11.6	35.5	0.8	22.5	5.4	17.1	35.4	-4.0
March	23.7	11.3	12.4	39.2	4.4	25.6	7.8	17.8	40.9	-0.7
April	28.2	13.9	14.3	41.8	8.5	30.6	11.8	18.8	44.3	3.0
May	32.4	17.4	15.0	43.9	11.5	35.2	16.6	18.6	47.5	8.5
June	34.5	19.9	14.6	45.3	15.5	35.6	18.8	16.8	45.6	13.0
July	35.4	21.5	13.9	46.2	18.5	36.9	20.2	16.7	45.5	16.0
August	34.8	21.6	13.2	41.7	17.5	36.6	20.4	16.2	44.0	16.0
September	32.3	19.9	12.4	41.7	15.7	33.4	18.6	14.8	41.0	12.6
October	29.8	17.8	12.0	38.8	12.0	31.2	15.6	15.6	41.5	9.2
November	25.1	13.9	11.2	36.3	5.2	26.8	11.6	15.2	39.3	2.9
December	20.7	10.4	10.3	32.5	4.5	22.0	7.1	14.9	33.2	0.5
Ann. Mean	28.1	15.4	12.7	-	-	29.8	13.1	16.7	-	-

Table 3.a Continued

Place / Month	Siwa (1931 - 1960)					Kharga (1931 - 1960)				
	Max.	Min.	Range	Abs. Max.	Abs. Min.	Max.	Min.	Range	Abs. Max.	Abs. Min.
January	19.7	4.1	15.6	30.0	-4.5	22.3	5.9	16.4	34.0	-1.3
February	21.8	5.7	16.1	35.0	-3.0	24.4	7.4	17.0	37.7	-2.1
March	25.0	8.2	16.8	41.0	0.0	28.3	11.1	17.2	41.8	0.2
April	29.9	12.1	17.8	44.9	4.0	33.1	15.7	17.4	46.6	6.6
May	34.4	16.8	17.6	47.0	8.5	37.6	21.2	16.4	48.6	11.0
June	37.1	19.2	17.9	49.0	11.5	38.6	23.3	15.3	48.2	14.6
July	38.0	20.7	17.3	47.7	15.0	39.1	23.3	15.8	47.1	17.5
August	37.8	20.7	17.1	47.0	15.3	39.4	23.0	16.4	46.9	16.1
September	35.1	18.3	16.8	44.0	11.2	36.5	21.5	15.0	46.5	13.1
October	31.7	14.9	16.8	41.0	6.4	34.0	18.6	15.4	44.0	9.8
November	26.3	10.1	16.2	41.0	1.0	28.6	13.0	15.6	40.3	3.1
December	21.3	6.0	15.3	31.0	-2.5	23.9	8.3	15.6	38.2	0.6
Ann. Mean	29.8	13.1	16.7	-	-	32.2	16.0	16.2	-	-

Table 3.a Continued

Place / Month	Aswan (1931 - 1959)				
	Max.	Min.	Range	Abs. Max.	Abs. Min.
January	24.2	9.5	14.7	37.8	3.1
February	26.5	10.6	15.9	39.2	1.7
March	30.7	14.2	16.5	43.4	5.5
April	35.7	18.6	17.1	48.1	9.5
May	40.3	23.5	16.8	48.0	14.4
June	42.0	25.1	16.9	50.6	19.3
July	41.9	26.1	15.8	48.4	22.1
August	42.0	26.4	15.6	47.9	21.4
September	40.0	24.0	16.0	48.2	18.0
October	37.5	21.7	15 8	46.4	12.7
November	31.4	16.5	14.9	41.8	8.0
December	26.5	13.2	13.3	37.0	4.2
Ann. Mean	34.9	19.1	15.8	-	-

50.6°C, whilst the lowest absolute maximum temperature of 25.0°C was registered at Port Said on 26th of January, 1957 (Table 3.a).

In general the highest mean maximum temperatures usually occur in June, July and August, whilst the lowest maximum temperature data are recorded during December, January and February (Fig. 3.1 and Table 3.a). The highest range between mean maximum and mean minimum temperatures is registered at inland stations, while the smallest range is recorded at the coastal stations (Fig. 3.2).

Mean minimum temperatures :-

The lowest minimum temperatures are encountered in winter (January) in the heart of the Western Desert, approximately in the area between 25° N and 29° N, and west of 31° E. This area comprises the oases and that part of the Nile protruding into the Western Desert near Minya. The area is too far south to be affected by the warm Mediterranean air mass and too far north to be influenced by the warm east-north-west winds which form as part of the Sudan trough (Soliman, 1953Aand 1972).

It is also noticed that the lowest mean minimum temperatures were recorded at Minya and Siwa. These were 4.0°C and 4.1°C respectively (Fig. 3.1).

Seasonal temperature conditions :-

The main feature in spring (March - May) is the southward shift of the depressions tracks. Depression

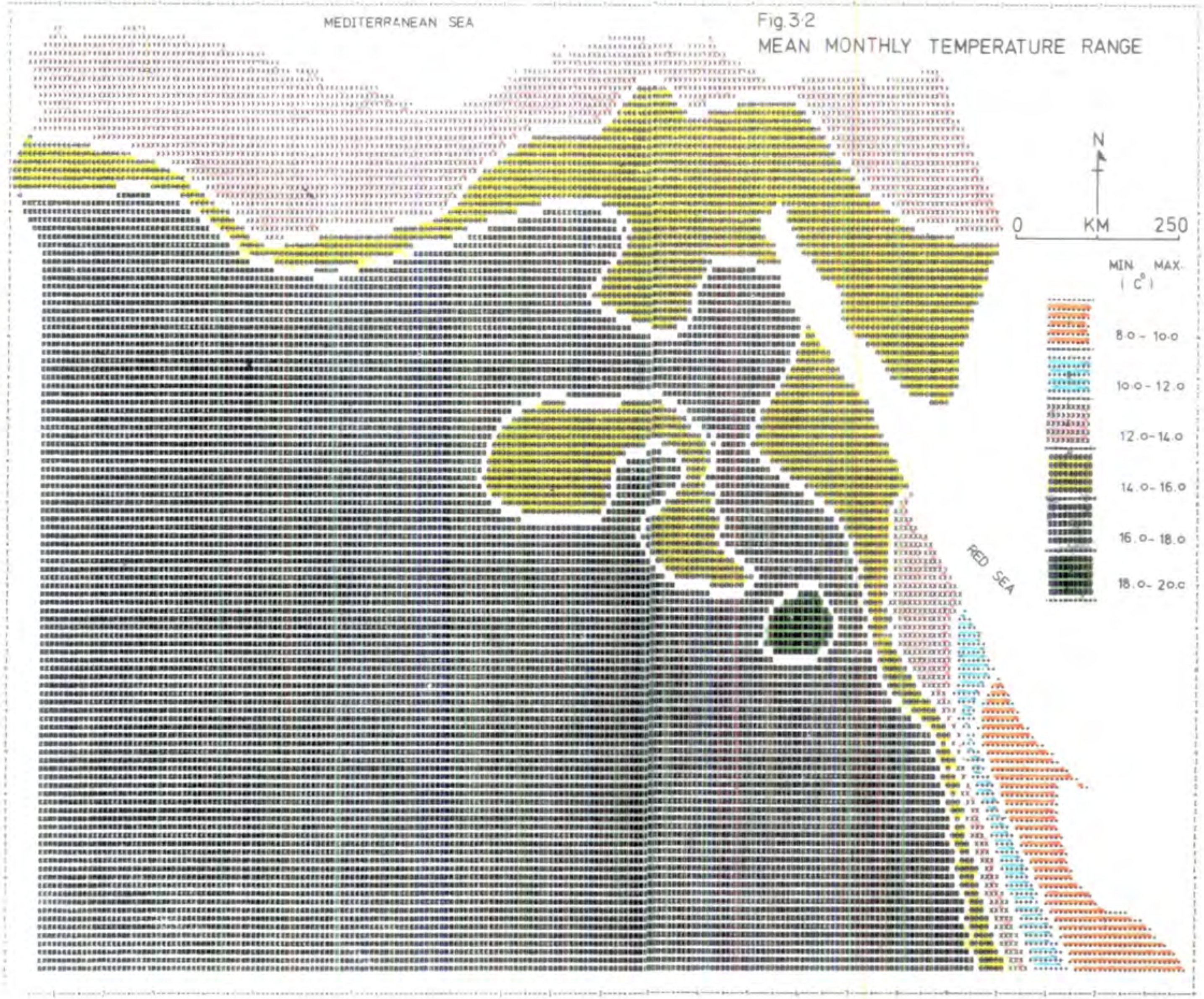


Fig. 3·2
MEAN MONTHLY TEMPERATURE RANGE

centres travel either along the coast-line of North Africa or further south, where they are known as "Khamsin depressions" (these depressions are discussed in detail in the Khamsin chapter). It can be seen that the highest mean temperature recorded in this season is found at Aswan (27.2°C). The lowest mean temperature is registered in the coastal region (i.e. 17.5°C at Sidi Barrani and Mersa Matruh stations) (Fig. 3.3.).

The general climate in summer (June - September) is hot,dry and rainless. Clear skies prevail, except for some coastal fair weather cumulus or early morning stratus clouds which form over Lower Egypt and disperse a few hours after sunrise. In this season the extreme southern part of Egypt is the hottest area in the country (Fig. 3.4). The highest record for summer mean temperature was found at Aswan (33.5°C). Mean temperatures below 28.0°C in this season are registered in the coastal region and Lower and Middle Egypt (with the exception of Fayum, Shakshuk and Ismailia stations) (Fig. 3.4).

In autumn (October, November), the highest mean temperatures are recorded at Abu El-Kizan and Aswan and these are 27.2°C and 26.8°C respectively. The lowest mean temperatures registered in this season are found in the north-western area and some other stations in the western Delta and Fayum areas (Fig. 3.5).

In winter (December - February) temperatures over the sea and in the coastal region are warm. The coastal region of Egypt is mild with some rainshowers,

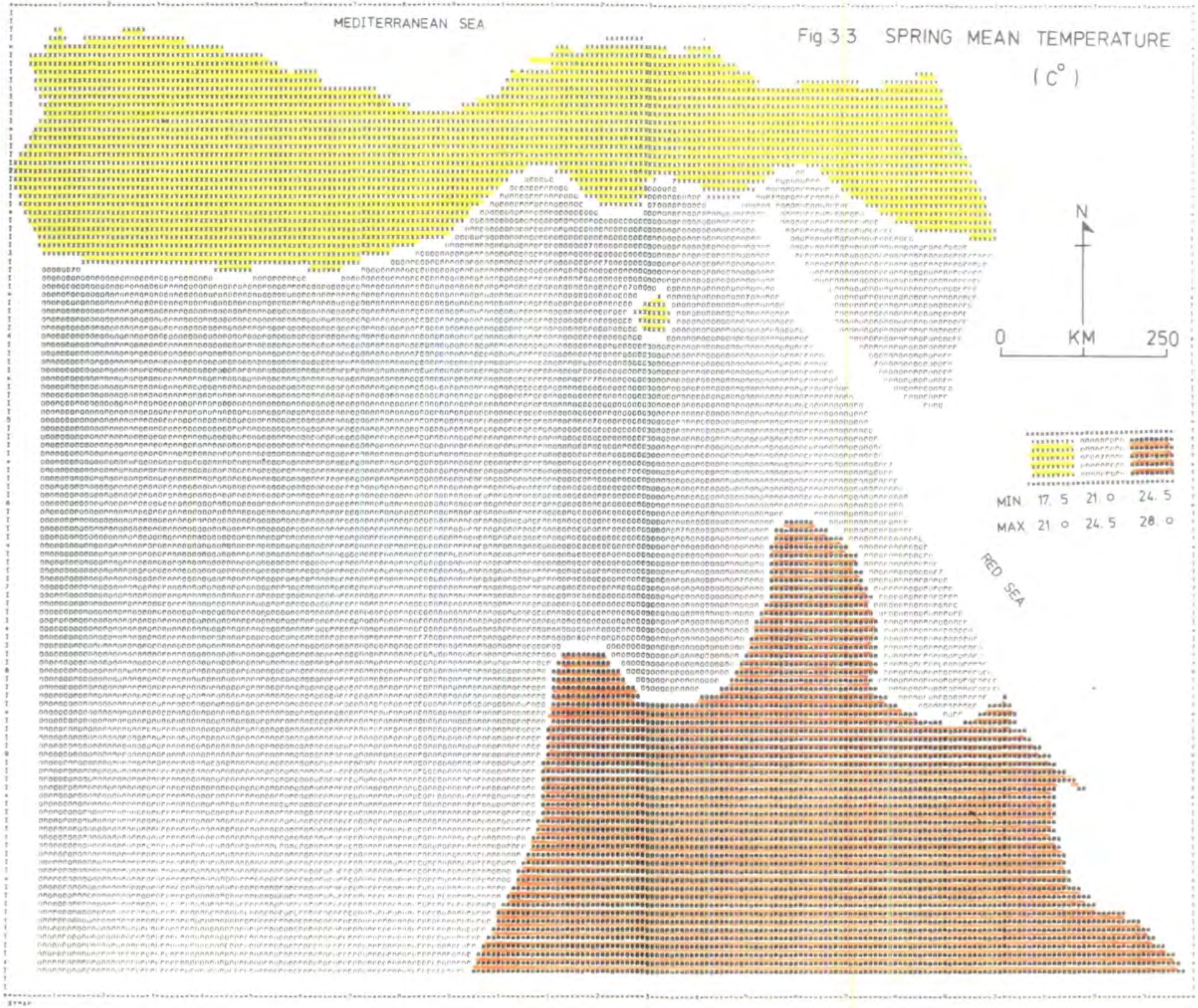


Fig 3.3 SPRING MEAN TEMPERATURE (C°)

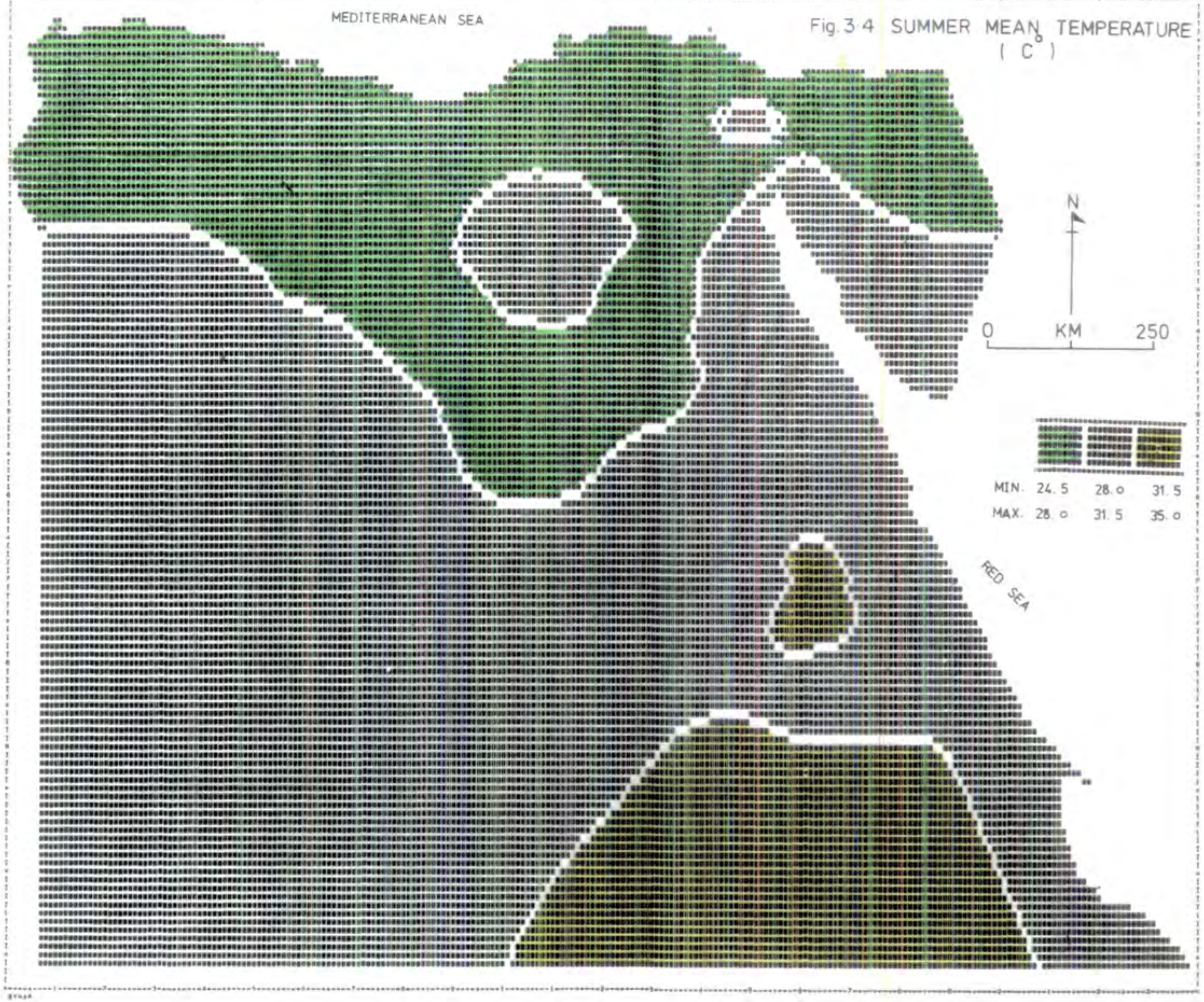


Fig. 3.4 SUMMER MEAN TEMPERATURE
(°C)

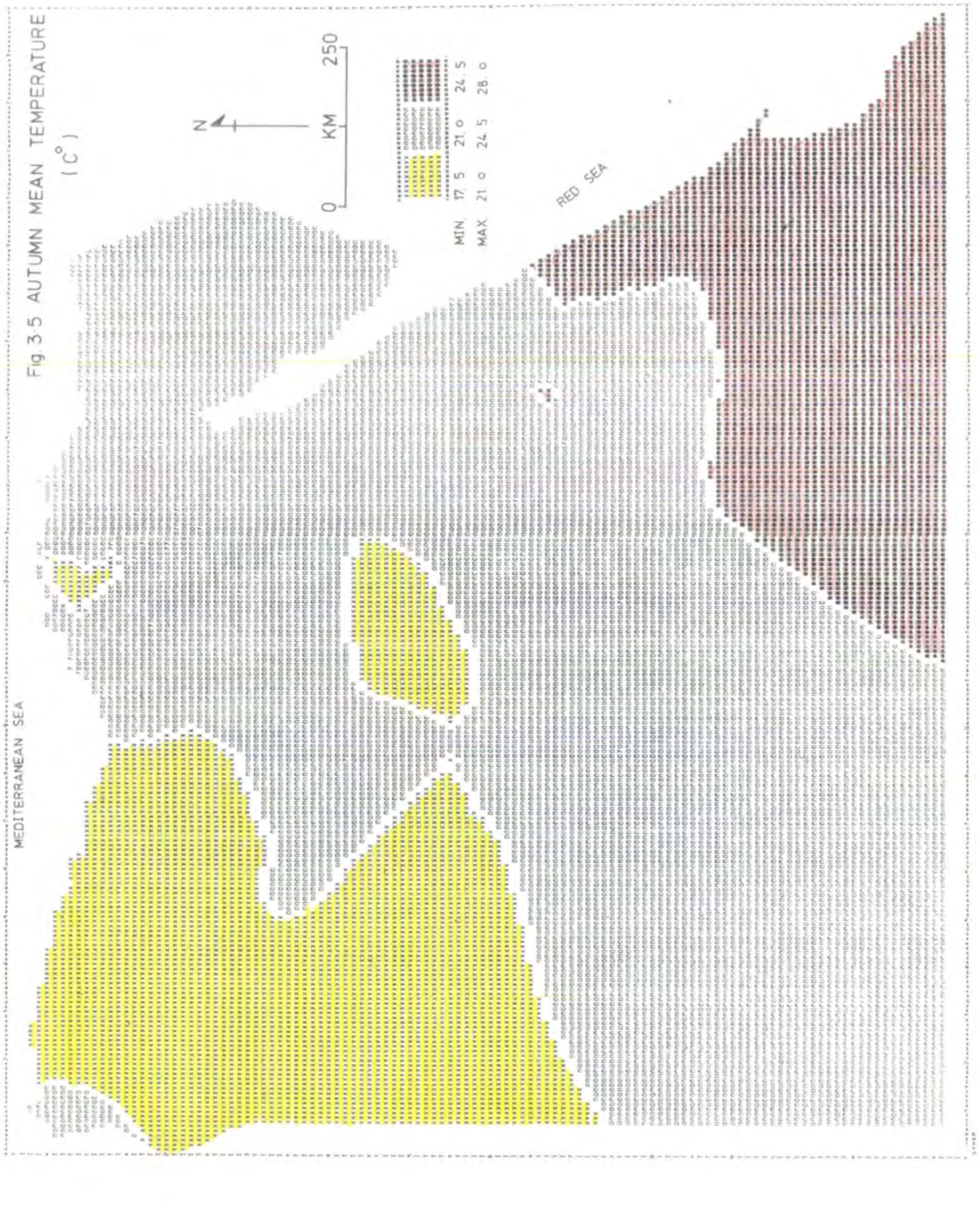


Fig. 3.5 AUTUMN MEAN TEMPERATURE (C°)

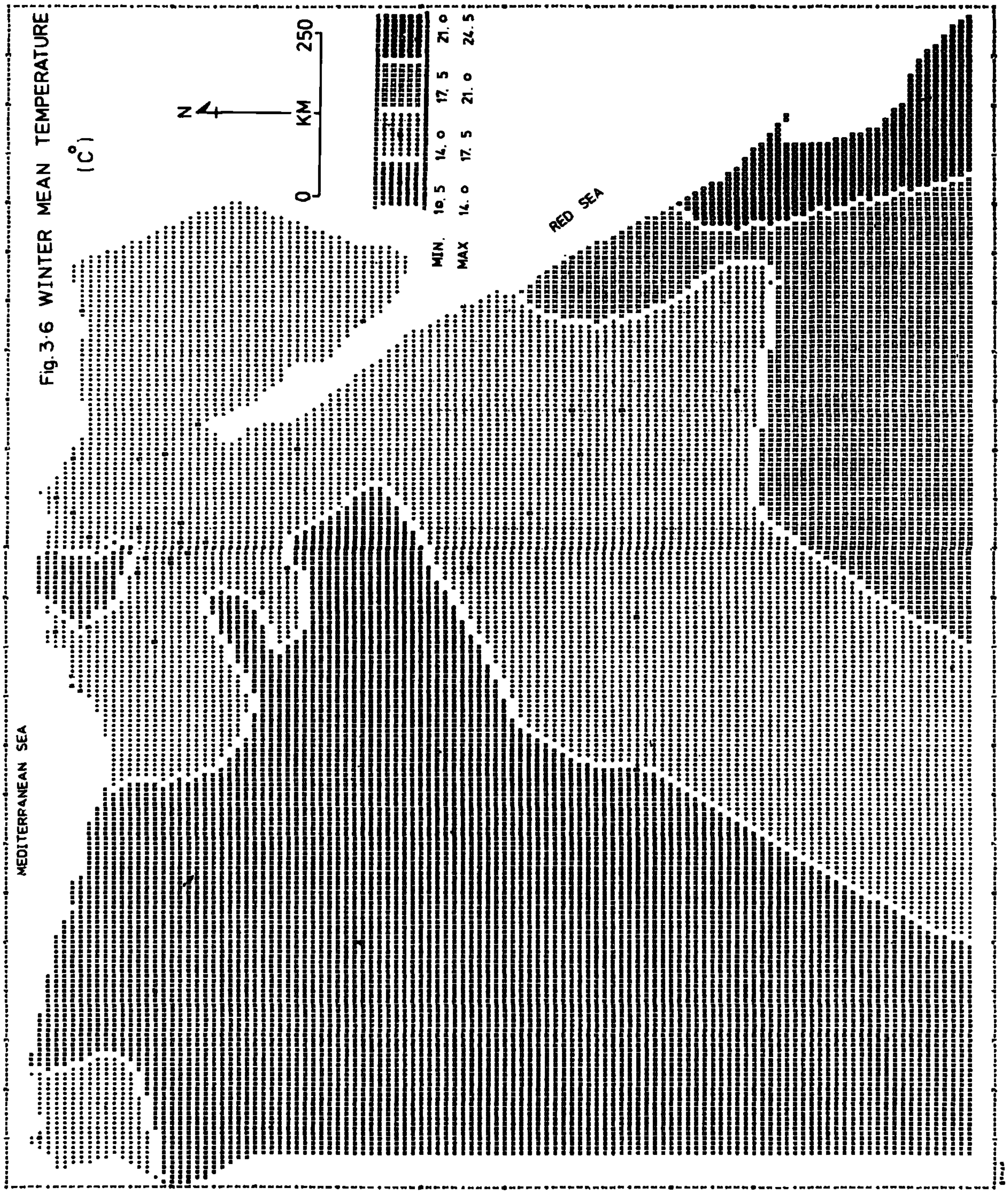


Fig. 3.6 WINTER MEAN TEMPERATURE (°C)

but Upper Egypt is rainless with warm sunny days, but rather cool nights (Conrad, 1943; Soliman, 1972). The lowest mean temperatures in the winter season are recorded at the rest of the Western Desert, whilst the highest mean temperatures are found at Abu El-Kizan (in the Red Sea), Here a value of 22.7°C is recorded (Fig. 3.6).

Daily and monthly values of temperatures :-

The daily and monthly values of temperatures are published in the Daily and Monthly Weather Reports issued by the Meteorological Department in Cairo. Figures 3.7 and 3.8 show the maximum and minimum daily temperatures at Alexandria and Giza respectively for the period 1962 - 1969. It will be seen that during heat waves and cold waves, the crests and troughs of the curve of maximum temperatures are nearly always in phase with the changes recorded in the trace of daily minimum temperatures. Appreciable deviations above the average are known as "heat waves" or "hot spells", similarly appreciable deviations below the normal are termed "cold waves".

Heat waves or hot spells that occurred in Alexandria and Giza during a period of 15 years (1960 - 1974) have been investigated and the results are summarized in Table 3.b. This shows the frequency of occurrence of hot spells in the different months of the year. In this table hot spells are classified into :-

a) Small, in which the deviation of temperature is between 3°C and 5°C above the mean temperature of the

Fig 3·7

ALEXANDRIA(1962–1969)

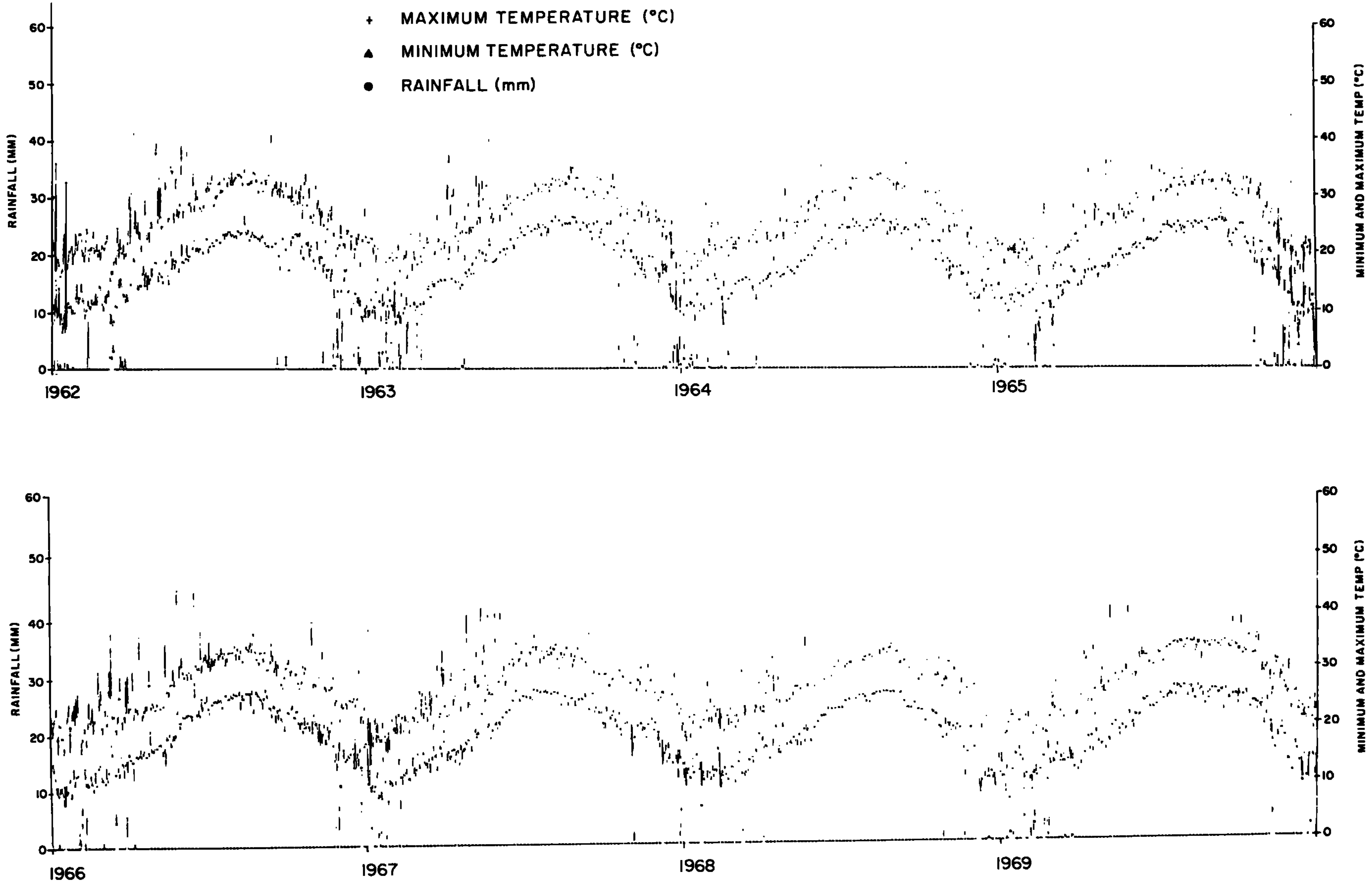


Fig 3·8

GIZA (1962-1969)

+ MAXIMUM TEMPERATURE (°C)

▲ MINIMUM TEMPERATURE (°C)

● RAINFALL (mm)

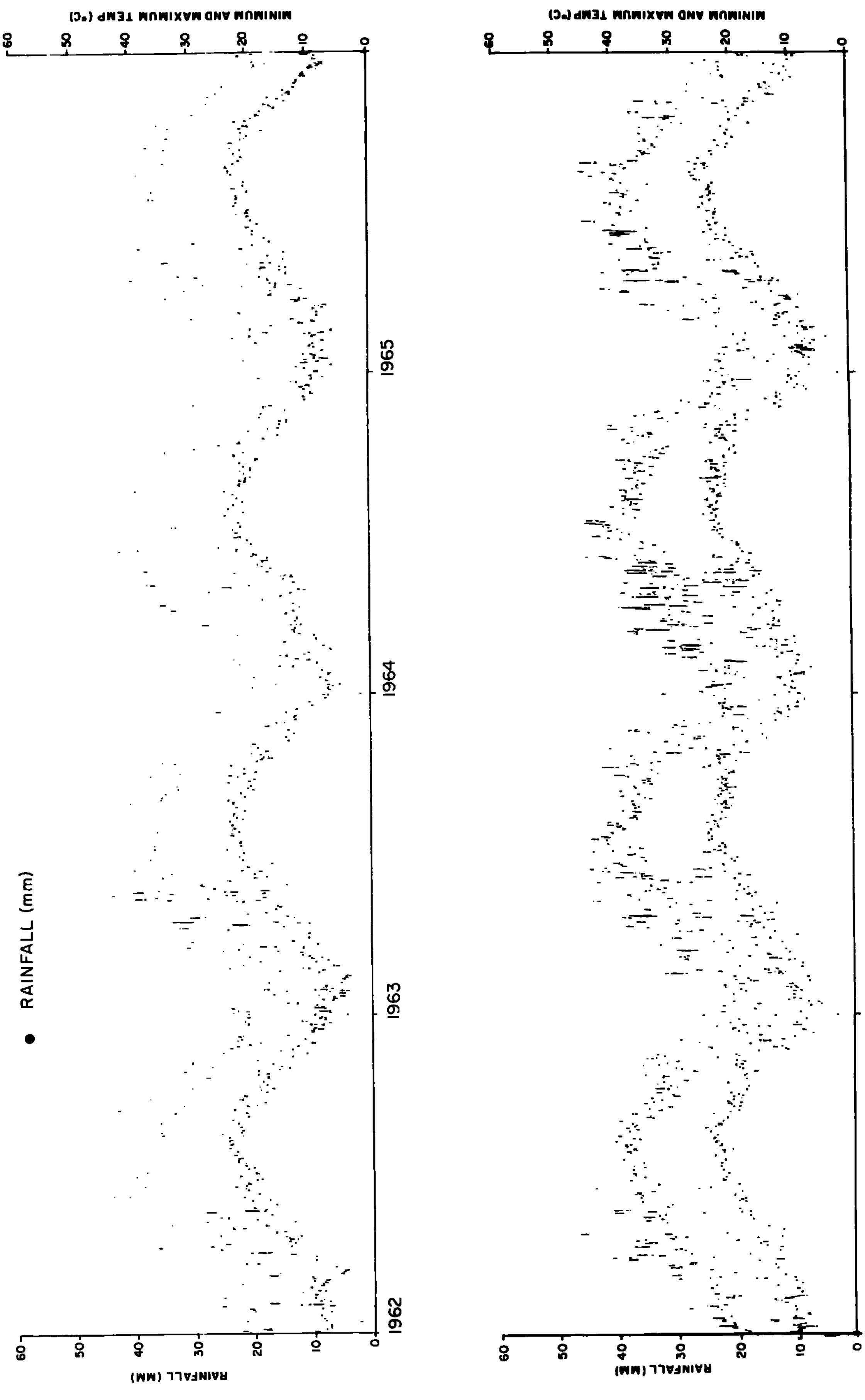


Table 3.b

Monthly Frequency of Occurrence of Hot Spells at Alexandria and Giza for the Period 1960-1974 Inclusive

Month	Alexandria				Giza			
	Small 3°C-5°C	Moderate 5°C-8°C	Severe ≥ 8°C	Total	Small 3°C-5°C	Moderate 5°C-8°C	Severe ≥ 8°C	Total
January	50	16	-	66	61	14	1	76
February	67	18	3	88	58	19	2	79
March	65	18	13	96	85	42	9	136
April	90	50	38	178	127	46	22	195
May	60	48	31	139	95	45	12	152
June	37	33	21	91	51	36	6	93
July	9	6	3	18	31	9	2	42
August	5	2	2	9	15	5	-	20
September	9	6	3	18	15	5	2	22
October	52	12	2	66	61	9	-	70
November	49	7	-	56	45	7	-	52
December	58	7	-	65	34	11	-	45

Source of raw data :- Daily weather reports for the year 1960 to 1974, meteorological Dept. Cairo, Egypt.

previous day.

b) Moderate, in which the deviations range between 5°C and 8°C above the mean temperature of the previous day.

c) Severe, in which deviations exceed 8°C above the mean temperature of the previous day.

It will be seen from Table 3.b and Figure 3.9 that :-

1) Spring, especially, April and May, is the period in which the frequency and the severity of hot spells in Alexandria and Giza is greatest.

2) July, August and September are the months of lowest frequency of hot spells in spite of their high average temperatures, showing relatively much lower temperature variations.

3) The frequency of hot spells increases once more in autumn (October and November), especially in October when the number of occurrences exhibit a second peak, though this is much lower than the spring peak.

4) In winter definite warm spells occur with their frequency increasing from December to February.

3.2 - Earth temperatures in Egypt :-

Observations of earth temperatures down to a depth of two or three metres have been made at various times and places in Egypt by staff of the Physical Department at the Ministry of Irrigation in Cairo, but

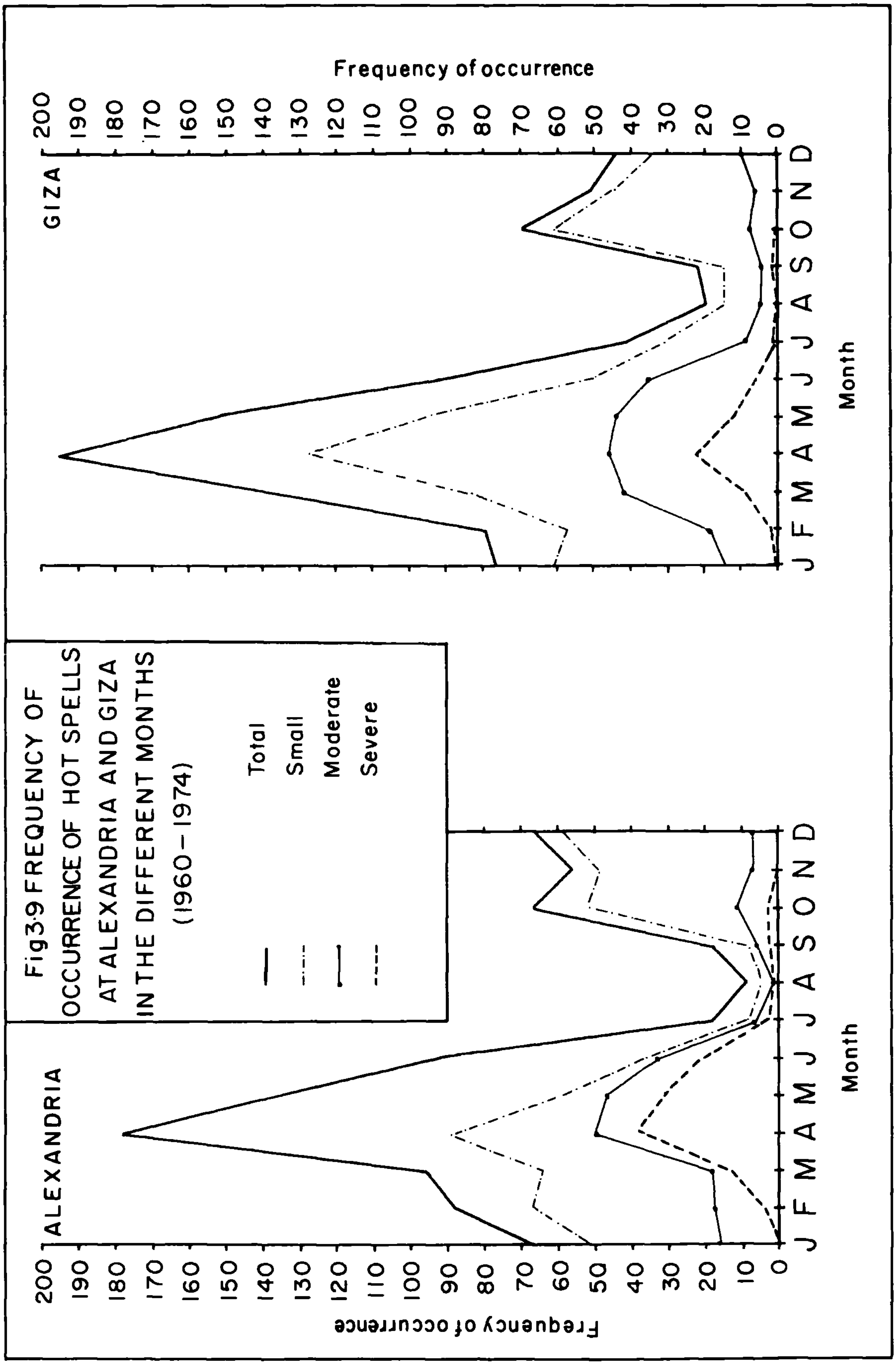


Fig3·9 FREQUENCY OF OCCURRENCE OF HOT SPELLS AT ALEXANDRIA AND GIZA IN THE DIFFERENT MONTHS (1960–1974) few of these results have been published, apart from the monthly means included in the Annual Meteorological Reports. Earth temperatures are of considerable importance in connection with agriculture. They effect seed germination; plant growth and root development (Budyko, 1974; Taylor, 1974; Arnon, 1972).

Annual variations :-

The monthly mean earth temperatures were observed at four stations; 3 in the Delta region and one at the oasis of Kharga. The maximum temperature values decrease with depth from 0.3 cm to 3 metres for all the stations. In contrast the minimum temperature values increase with depth. This means that the temperature range decreases markedly with depth. It is noticed that the highest range (i.e. between the highest and lowest maximum and the highest and lowest minimum) occurred at the Giza and Kharga stations, whilst lowest ranges are recorded at El-Kaser and Tharir stations (Table 3.c).

Variability of monthly mean earth temperature :-

The extent to which the extreme earth temperatures may vary from month to month can be seen from Tables 3.d and 3.e, which give the extreme soil temperature values for each month at Giza during the five years (1956 - 1960). The earth temperatures at this station are affected by variations in the level of subsoil water (Sutton, 1946).

The extreme soil temperatures in dry and wet

Table 3.c

Extreme Soil Temperatures at Different Depths in Different Fields for the Year 1965

Station		Extreme soil temperature (c) in dry field at different depth (cm)										
		0.3	1	2	5	10	20	50	100	200	300	Range
El-Kaser	Max.	56.0	48.4	48.2	41.6	35.6	32.0	28.9	27.2	25.1	-	(30.9)
	Min.	3.0	4.0	4.4	5.8	7.8	10.1	12.8	15.4	18.0	-	(15.0)
Tharir	Max.	59.5	58.0	53.4	49.4	44.0	37.5	33.7	31.8	29.7	28.4	31.1
	Min.	5.1	5.1	5.5	5.4	8.4	10.4	12.9	16.5	19.0	20.5	15.4
Giza	Max.	67.8	67.0	65.0	45.0	39.5	35.2	34.1	32.0	29.3	27.7	40.1
	Min.	1.2	2.0	2.8	7.2	11.3	15.0	17.1	19.6	22.0	23.1	21.9
Kharga	Max.	70.0	63.0	59.8	53.8	44.8	39.4	35.5	33.4	31.3	30.1	39.9
	Min.	0.8	2.7	4.0	7.0	12.6	16.4	19.8	22.2	24.6	26.0	25.2

Source :- Annual meteorological report, 1965, Meteorological Department, Cairo, Egypt.

fields in the Giza area during January (the month with the coldest air temperature) and July (the month with the hottest air temperature) are generally similar (Fig. 3.10). It can be seen that the maximum values of temperature decrease with depth to 20 cm in a dry field and to 50 cm in a wet field. Below these depths maximum temperature values increase again in January.

The range in soil temperatures between the maximum and minimum values is very clear. It is greatest at the surface and then decreases to a minimum at a depth of 300 cm (Fig. 3.10).

The extreme maximum and minimum earth temperatures in dry and wet fields at Giza for the months of January to December inclusive have been graphed (Fig. 3.11). In general, it can be seen that the maximum values either in dry or wet fields decreased with depth, whilst the reverse is the case for the minimum values in both dry and wet fields.

The highest values recorded in dry and wet fields are 68.0°C (June) and 53.5°C (August) respectively at 0.3 cm deep. The lowest values are -4.0°C for the dry field and 0.5°C for the wet field at a depth of 0.3 cm in January (Tables 3.d and 3.e and Fig. 3.11).

Comparison between soil and air temperatures :-

The differences between the extreme temperature of dry and wet soil at Giza in January and July and extreme air temperature in the screen at their respective

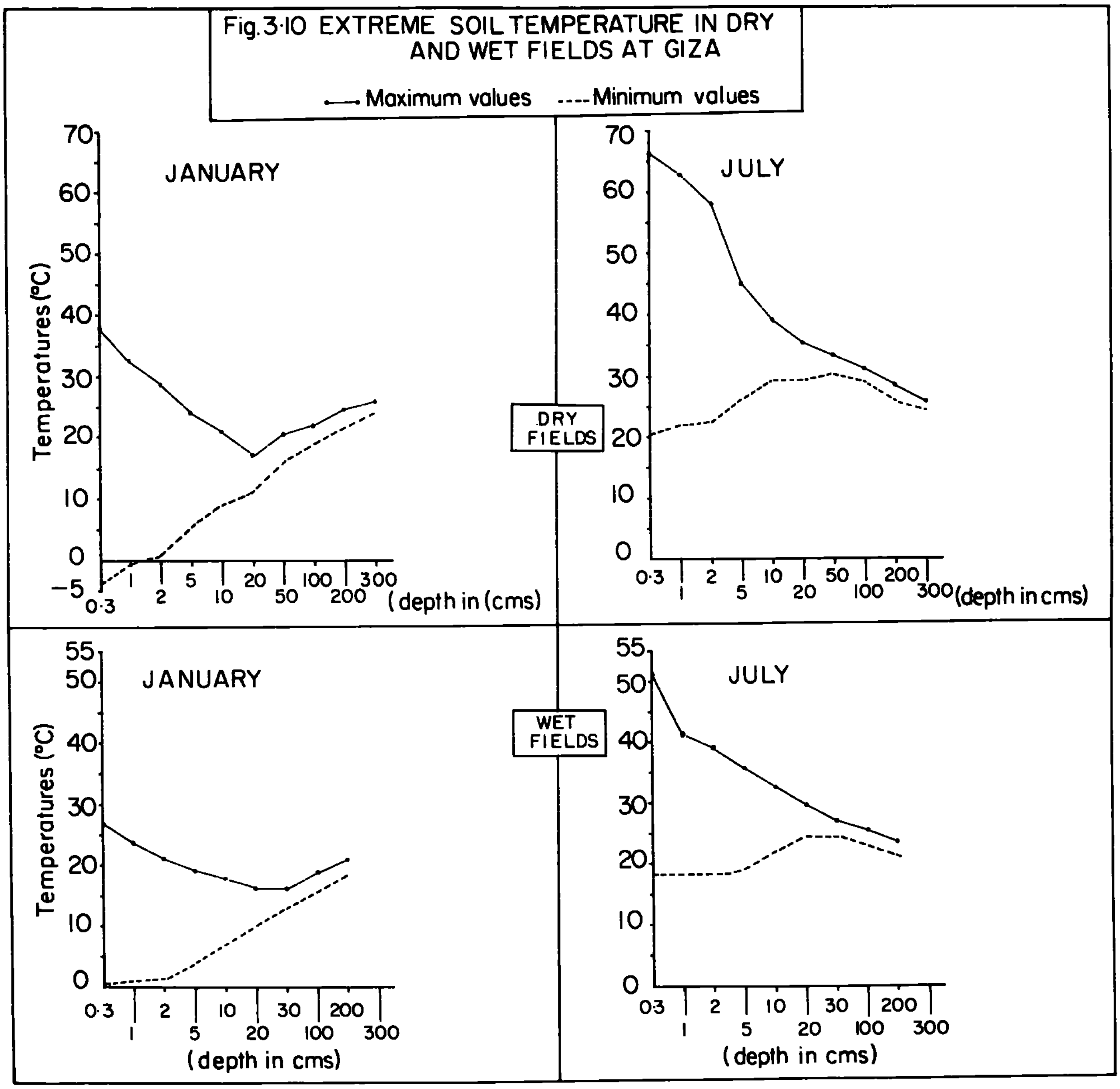
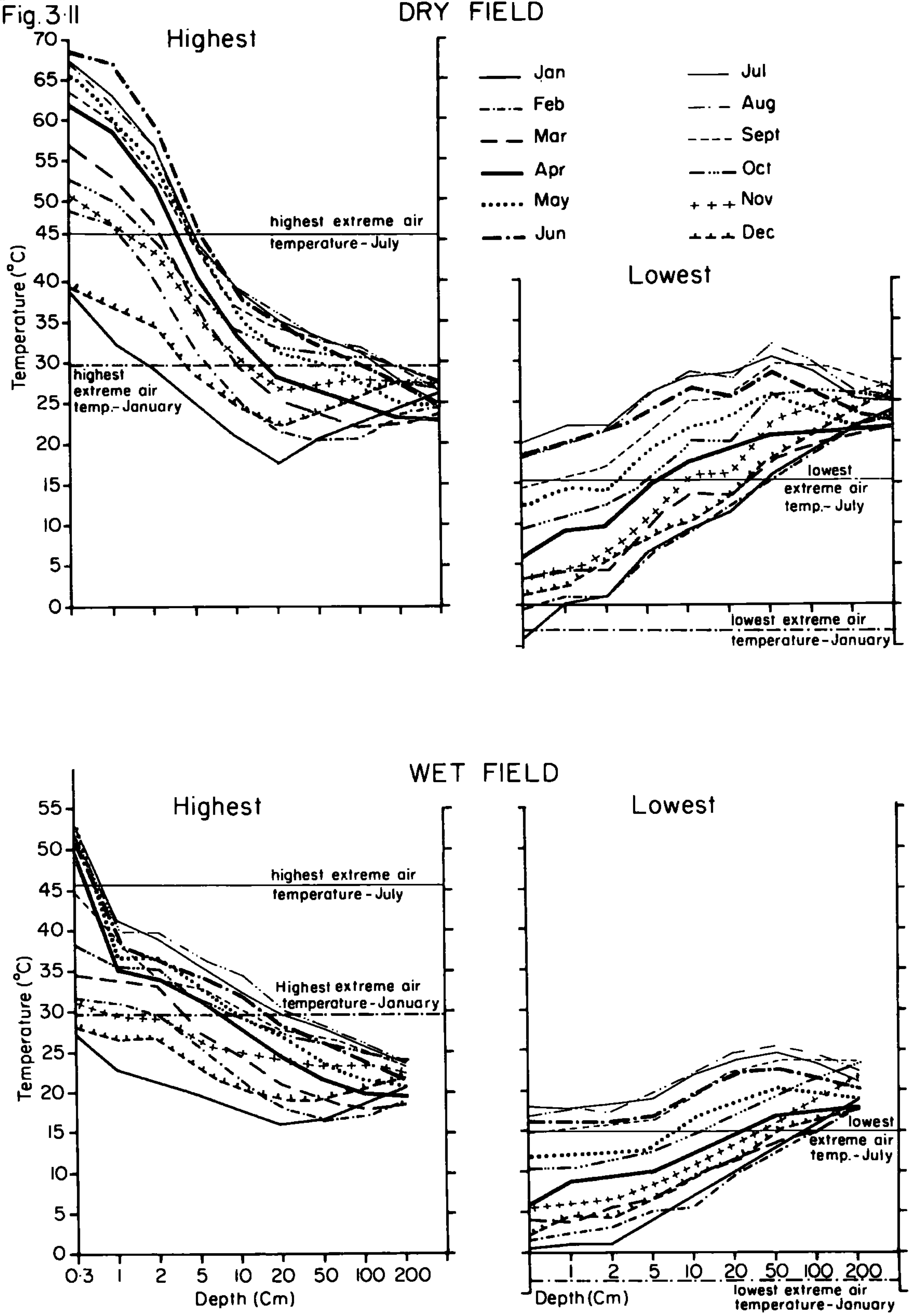


Fig.3·10 EXTREME SOIL TEMPERATURE IN DRY AND WET FIELDS AT GIZA

Fig. 3·11



EXTREME SOIL TEMPERATURES IN DRY AND WET FIELDS AT GIZA (1956-1960)

GIZA

Period 1956—1960

TABLE 3.d Extreme Soil Temperatures in Dry Field at Depths (centimetres)

Month	0.3		1		2		5		10		20		50		100		200		300	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
January	38.5	— 4.0	32.5	0.0	29.0	0.3	24.7	6.5	21.0	9.0	17.5	11.3	20.3	16.0	22.5	18.5	24.8	21.5	25.7	23.5
February	48.5	— 0.5	47.0	0.7	40.5	1.0	31.5	6.0	25.3	7.4	21.5	11.5	20.2	15.0	20.5	18.0	23.2	21.0	24.6	22.5
March	56.7	3.0	53.0	4.0	47.3	4.0	37.1	9.5	29.2	13.2	25.5	13.1	23.5	17.2	22.0	19.2	22.1	21.0	23.7	22.0
April	61.6	6.0	58.2	9.0	51.5	9.5	40.4	14.7	33.0	17.5	28.0	19.0	25.5	20.5	24.6	21.0	23.1	21.0	23.0	22.0
May	65.3	12.0	61.1	14.0	55.0	14.0	45.0	18.5	35.7	21.5	31.0	22.9	29.6	25.5	27.3	23.5	24.6	21.5	23.6	22.5
June	68.0	18.5	66.5	19.5	59.5	21.5	46.2	23.6	37.5	26.5	34.5	25.7	32.0	28.0	29.5	26.0	26.3	23.5	24.5	23.0
July	66.7	20.0	62.8	22.0	57.0	22.0	44.9	26.0	38.1	28.0	35.0	28.2	33.1	30.5	31.0	28.5	27.8	25.0	25.5	24.5
August	67.0	18.0	61.5	19.5	55.5	21.5	45.0	26.0	38.6	28.5	36.0	28.0	33.5	32.0	31.1	30.5	28.8	26.5	26.5	25.4
September	63.0	14.4	59.5	15.4	53.0	16.9	44.0	21.3	36.5	25.0	34.0	25.5	33.0	29.9	31.[illegible]	29.9	29.1	28.0	27.0	26.5
October	52.0	9.9	49.5	10.9	45.0	12.4	38.5	15.7	33.5	21.2	31.5	20.4	31.0	25.8	30.5	27.4	29.0	27.5	27.3	26.0
November	50.0	3.3	45.6	4.6	43.6	6.9	35.0	10.9	30.0	16.5	27.5	16.5	28.5	22.2	28.8	24.5	28.5	26.0	27.3	26.4
December	39.0	1.1	36.1	2.1	34.3	5.2	28.0	8.8	24.7	10.0	22.0	13.3	23.5	18.0	25.9	21.0	27.4	24.0	26.9	25.7

Source :- Climatological Normals for U.A.R., up to 1960, Met. Dept., Cairo, Egypt, 1968, p.232.

G I Z A

Period 1956—1960

Extreme Soil Temperatures in Wet Field at Deplths (centimetres)

TABLE 3.e

Month	0.3		1		2		5		10		20		50		100		200		300	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
January	27.0	0.5	23.0	1.0	21.0	1.0	19.5	4.0	17.5	7.0	16.0	10.0	16.3	12.9	18.5	15.5	20.5	18.5	—	—
February	31.5	1.5	31.0	2.4	29.5	3.1	25.5	5.0	21.5	5.3	18.0	9.5	16.5	13.5	17.0	15.0	19.0	17.5	—	—
March	34.5	4.0	34.0	4.0	33.1	5.3	27.5	6.5	24.5	9.1	21.0	11.2	19.0	13.3	18.0	14.9	18.5	17.3	..	—
April	49.5	6.0	35.0	8.9	34.0	9.0	31.5	10.0	27.5	12.0	24.5	14.5	21.5	16.5	20.0	17.1	19.5	17.7	—	—
May	52.5	11.5	36.5	12.0	36.5	12.0	33.0	13.5	29.0	16.5	26.0	18.5	23.3	19.7	21.6	19.4	20.5	18.7	—	—
June	51.0	16.0	37.0	16.0	36.0	16.0	34.5	16.9	32.0	19.9	28.0	22.1	26.0	22.5	23.5	21.3	21.5	20.0	--	—
July	51.5	18.0	41.0	18.0	39.0	18.5	35.5	19.0	32.5	22.0	29.5	24.0	27.0	24.5	25.5	23.2	23.0	21.2	—	—
August	53.5	17.0	40.0	17.5	39.5	18.0	36.5	19.9	34.5	22.5	30.0	24.5	28.0	25.5	26.0	24.5	24.0	22.5	—	—
September	44.5	15.0	39.5	15.1	39.0	15.3	34.0	16.8	33.0	19.9	30.0	22.3	27.5	23.9	26.5	24.0	24.5	23.3	—	—
October	38.0	10.4	35.5	10.9	35.5	11.5	31.5	12.2	29.5	15.0	27.0	17.0	26.0	20.0	25.0	21.6	24.5	22.8	—	—
November	31.0	6.0	29.5	6.0	29.5	7.0	26.0	8.3	25.0	11.3	24.0	13.5	23.5	16.5	24.0	19.4	24.0	21.5	—	—
December	28.0	2.5	26.6	4.9	26.4	4.5	22.7	6.5	20.5	9.5	19.0	11.0	19.0	14.9	21.0	17.0	23.0	19.8	—	—

<u>Source</u> :- Climatological Normals for U.A.R., up to 1960, Met. Dept., Cairo, Egypt, 1968 p. 233.

maxima and minima are shown in Table 3.f and Figure 3.12. It is noticed that in January and July the extreme maximum earth temperature is higher than the extreme maximum air temperature in the screen by 9.3°C in January and 21.2°C in July at a depth of 0.3 cm in dry field.

In general the maximum earth temperatures decrease with an increase in depth. This is true for July below 5 cm in depth, whilst in January the curve increases below 20 cm, but is still lower than the air temperature.

It can also be seen (Table 3.f and Figure 3.12) that the dry soil is warmer than the wet soil. This is the result of the nature of the surface which absorbs more heat by day and may radiate less by night (Fukuoka, 1969). It is noticed that the extreme maximum earth temperature is less than the extreme maximum air temperature in wet fields with the exception of 0.3 cm depth in July. In contrast minimum earth temperatures in January and July are higher than the extreme minimum air temperatures at all depths.

3.3 - Water temperatures (River Nile) :-

The temperature of water in the River Nile was systematically measured first at Aswan in 1922 in connection with an investigation dealing with the expansion of the dam masonary (Hurst, 1944). Observations at that time were weekly, but at several river stations, daily observations have been made regularly during the period 1927 to 1945, chiefly by officials of the Irrigation

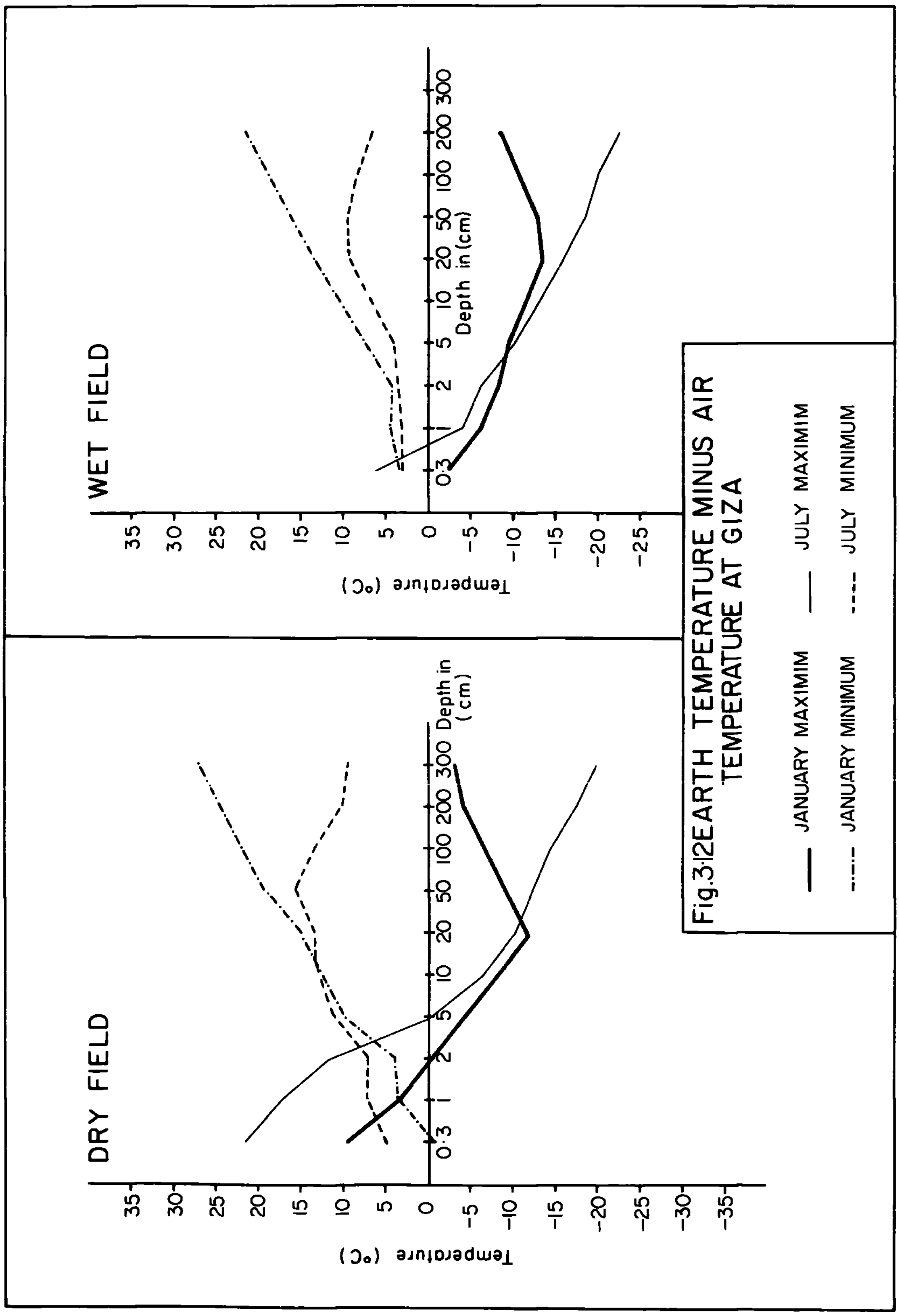


Fig.3.12 EARTH TEMPERATURE MINUS AIR TEMPERATURE AT GIZA

Table 3.f

Extreme Earth Temperatures Minus Extreme Air Temperatures at Giza (^{o}C)

Depth (cms)	Dry field				Wet field			
	Daily maximum		Daily minimum		Daily maximum		Daily minimum	
	January	July	January	July	January	July	January	July
0.3	9.3	21.2	-0.7	5.0	-2.3	6.0	3.3	3.0
1	3.2	17.3	3.3	7.0	-6.3	-4.5	4.3	3.0
2	-0.3	11.5	3.6	7.0	-8.3	-6.5	4.3	3.5
5	-4.6	-0.6	9.8	11.0	-9.8	-10.0	7.3	4.0
10	-8.3	-6.8	12.3	13.0	-11.8	-13.0	10.3	7.0
20	-11.8	-10.5	14.6	13.2	-13.3	-16.0	13.3	9.0
50	-9.0	-12.4	19.3	15.5	-13.0	-18.5	16.2	9.5
100	-6.8	-14.5	21.8	13.5	-10.8	-20.0	18.8	8.2
200	-4.5	-17.7	24.8	10.0	-8.8	-22.5	21.8	6.2
300	-3.6	-20.0	26.8	9.5	-	-	-	-

Department, Cairo. Such measurements were made by means of a thermometer fixed in a bucket which was generally immersed to a depth of two metres and allowed to remain there for five minutes before being withdrawn and read (Sutton, 1946).

The mean river temperature values for each month are given in Table 3.g and shown graphically in Figure 3.13. The values tabulated are those for the temperatures at 0800 hrs. which approximates the mean daily water temperatures (1927 - 1945).

Aswan is practically on the northern boundary of the Tropics at the southern border of the country, while Asyut is over 500 kilometres further downstream. It was expected that the river water would be warmer at Aswan than at Asyut throughout the year. It will, however, be noted that while this is the case from June to February inclusive, the mean values are actually lower for Aswan than for Asyut during the months March, April and May (Fig. 3.13 and Table 3.g). However, these differences are very small.

The river at Nag Hamadi, between Aswan and Asyut 360 Km downstream of Aswan, was as expected always warmer than at Asyut, except during February, March and April.

Comparison with air temperature :-

The mean river temperatures differ from mean air temperatures by values which vary not only with latitude but also seasonally. At Aswan mean river temperature is

Fig.3·13 MEAN WATER TEMPERATURE (°C) AT 0 800 HOURS
(RIVER NILE, DEPTH 2 METRES)

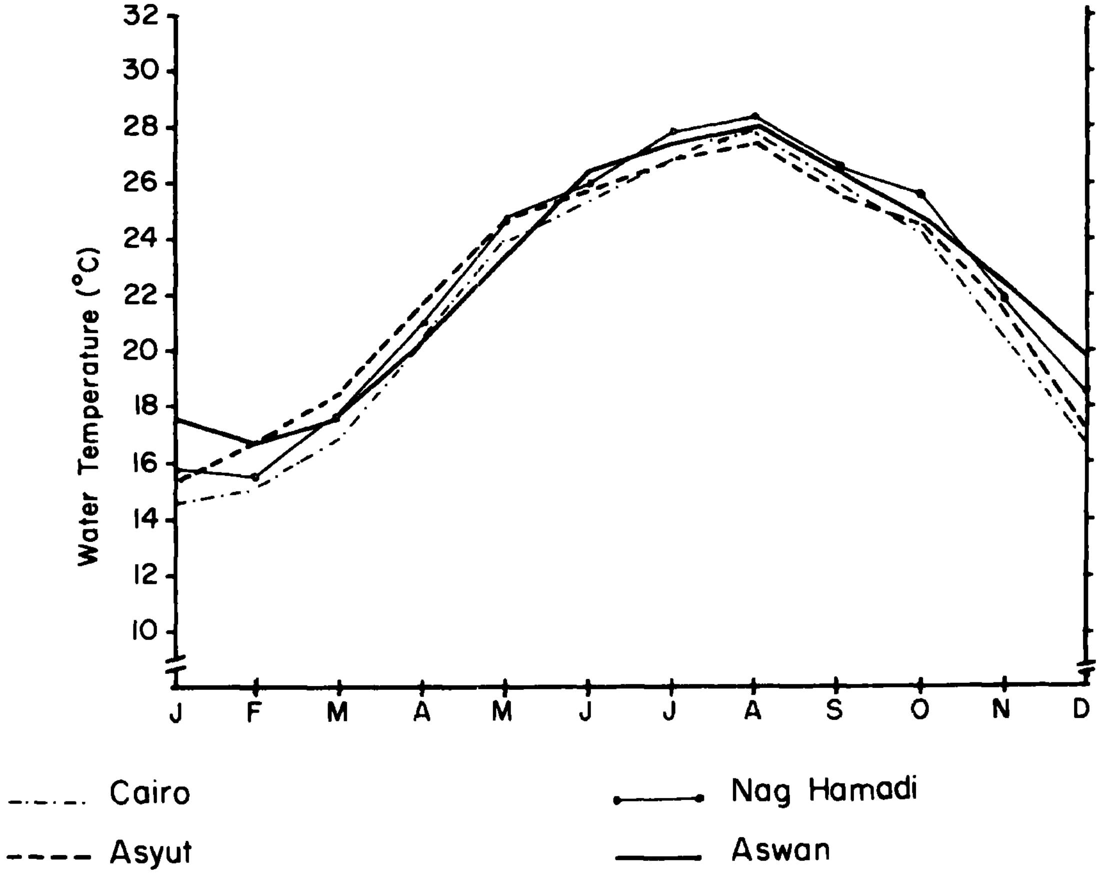


Table 3.g

Mean Water Temperature (^{o}C) at 0800 hrs. (River Nile, Depth 2 m)

Month / Place	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Range
Aswan	17.5	16.7	17.7	20.2	23.6	26.2	27.4	28.0	26.4	24.7	22.4	19.8	11.3
Nag. Hamadi	15.9	15.6	17.6	20.8	24.9	26.0	27.6	28.2	26.4	25.4	21.9	18.5	12.6
Asyut	15.5	16.4	18.6	21.7	24.6	25.5	26.9	27.2	25.8	24.5	21.4	17.2	11.7
Cairo	14.6	15.1	17.0	20.1	23.7	25.2	26.8	27.4	26.0	24.2	20.7	16.9	12.8

0.7°C above the mean air temperature in January, but by May, it is 8.3°C below the air temperature. In June, it is 3.2°C and 4°C below the air temperature at Nag Hamadi and Asyut respectively (Fig. 3.14 and Table 3.h).

In Cairo, the air temperature is above the mean water temperature during March, April, May, June, July and August, while the reverse is true for other months.

The mean annual river temperatures are about 4.5°C below the mean annual air temperatures at Aswan. At Nag Hamadi and Asyut, the averages are 0.6°C and 0.9°C respectively, while at Cairo is only 0.1°C (Table 3.h).

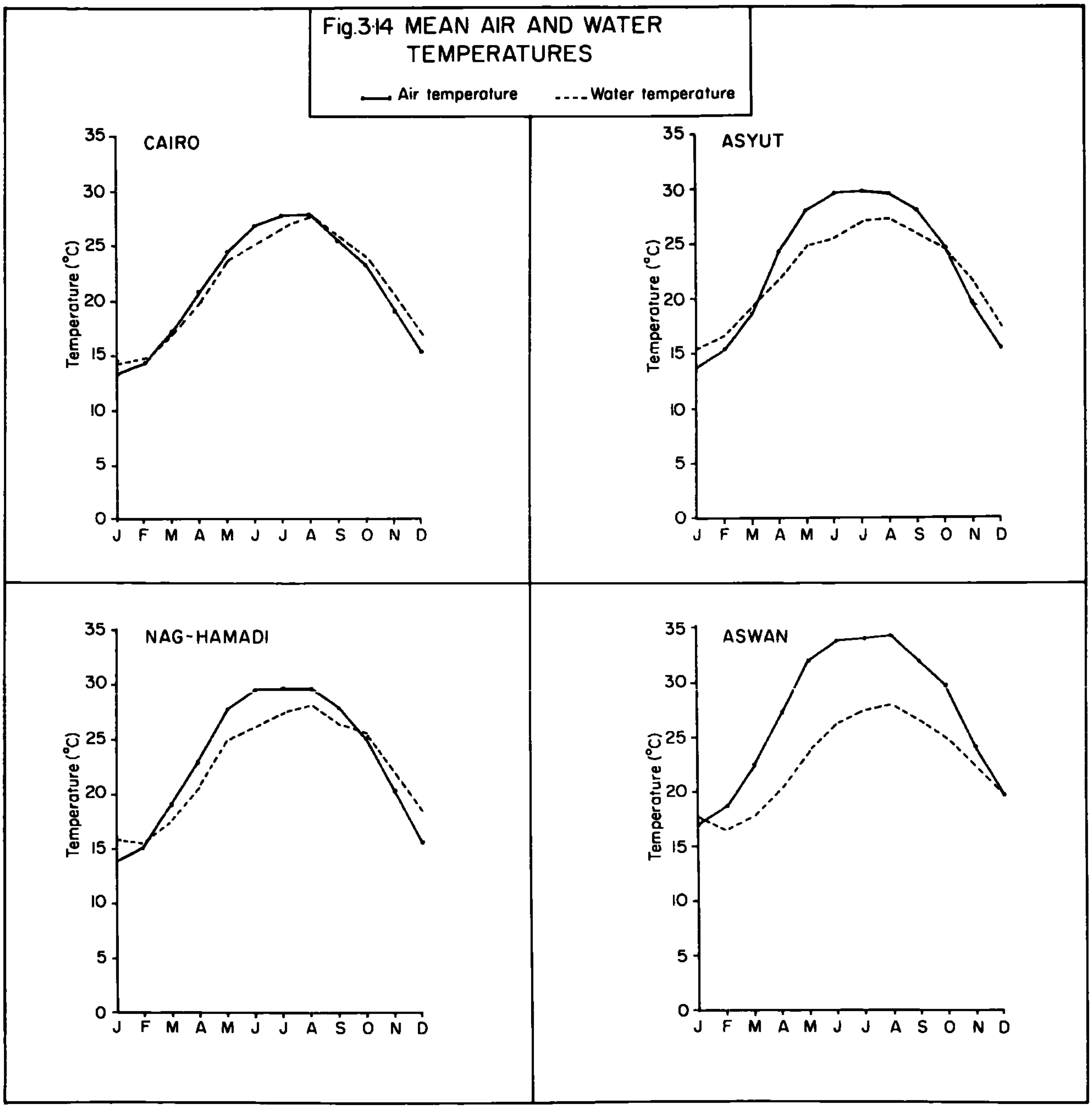


Fig.3·14 MEAN AIR AND WATER TEMPERATURES

Table 3.h

Excess of Mean Air Temperature Over Mean River Temperature (^{o}C)

Month / Place	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Aswan	-0.7	1.9	4.7	7.0	8.3	7.4	6.6	6.2	5.6	4.9	1.6	0.0	4.5
Nag. Hamadi	-2.1	-0.4	1.0	2.2	2.9	3.2	1.8	1.4	1.4	-0.4	-1.5	-2.8	0.6
Asyut	-1.9	-1.0	-0.1	2.2	3.3	4.0	3.0	2.5	2.0	-0.1	-2.0	-1.7	0.9
Cairo	-0.9	-0.2	0.3	0.8	1.1	1.8	1.3	0.5	-0.2	-0.7	-1.4	-1.6	0.1

CHAPTER 4

Precipitation in Egypt

4.1 - Climatological aspects :-

Precipitation in Egypt is mainly of the showery type. Amounts may vary considerably from year to year in the same place and may also differ widely in two neighbouring localities in the same season or year. The rainy season, lasting from October to May, tends to start earlier in the north and west, since secondary Mediterranean air masses are most active in autumn, winter and spring, and generally follow west to east tracks. The dry season is almost totally rainless. Though occasional showers may fall over the Mediterranean coastal region in June or September, it is extremely rare for precipitation to occur during July and August.

4.2 - Mean annual rainfall :-

The distribution of annual rainfall over the country appears to be fairly simple. The rainiest part is the Mediterranean coastal region. Southwards, the mean total amount of rain decreases gradually until Cairo, after which the gradients steepen rapidly. The extreme south of the country is almost rainless (Fig. 4.1). This pattern is explained by the fact that most precipitation is associated with upper cold troughs which only effect Lower Egypt, particularly the coastal areas. The uneven distribution along the coast is explained by the coast line configuration. A decrease from 180 mm/year at Alexandria to only 80 mm/year at Port Said is very striking (Soliman, 1953B; Naguib, 1970). Rainfall, however, decreases rapidly with increasing distance

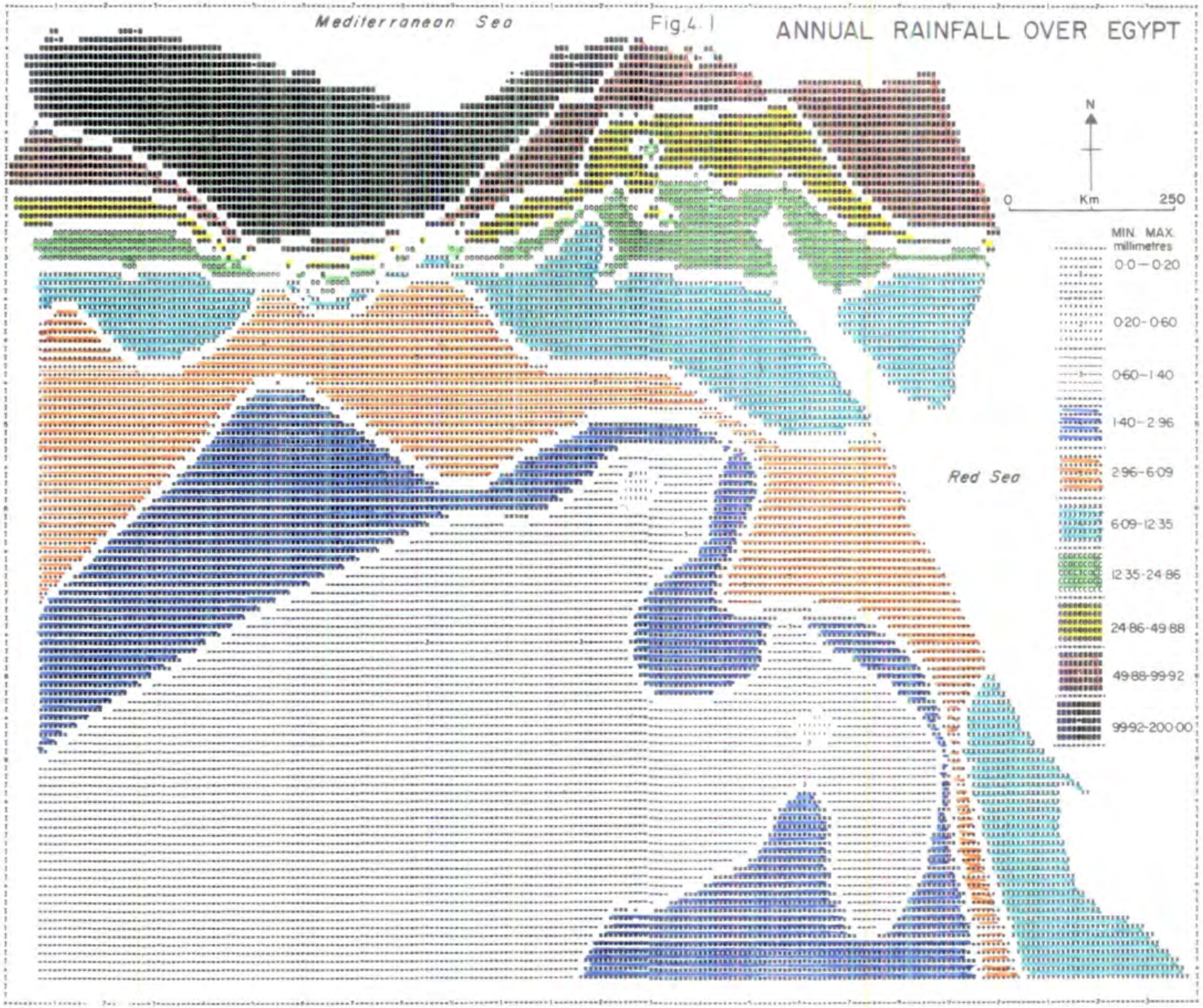


Fig.4.1 ANNUAL RAINFALL OVER EGYPT

from the coast, averaging little over 50 mm/year in the middle of the Delta. In the Delta and the Nile Valley, where cultivation is by irrigation, rain is of little economic importance. In the semi-desert strip west of Alexandria it averages 125-150 mm/year. This comparatively small amount has considerable economic value as practically all of it falls within the six month period from October to March. In a year of fairly good rains, the Bedouin are able to sustain themselves and their flocks on the crops, chiefly barley, which they raise (UNDP / FAO, 1970).

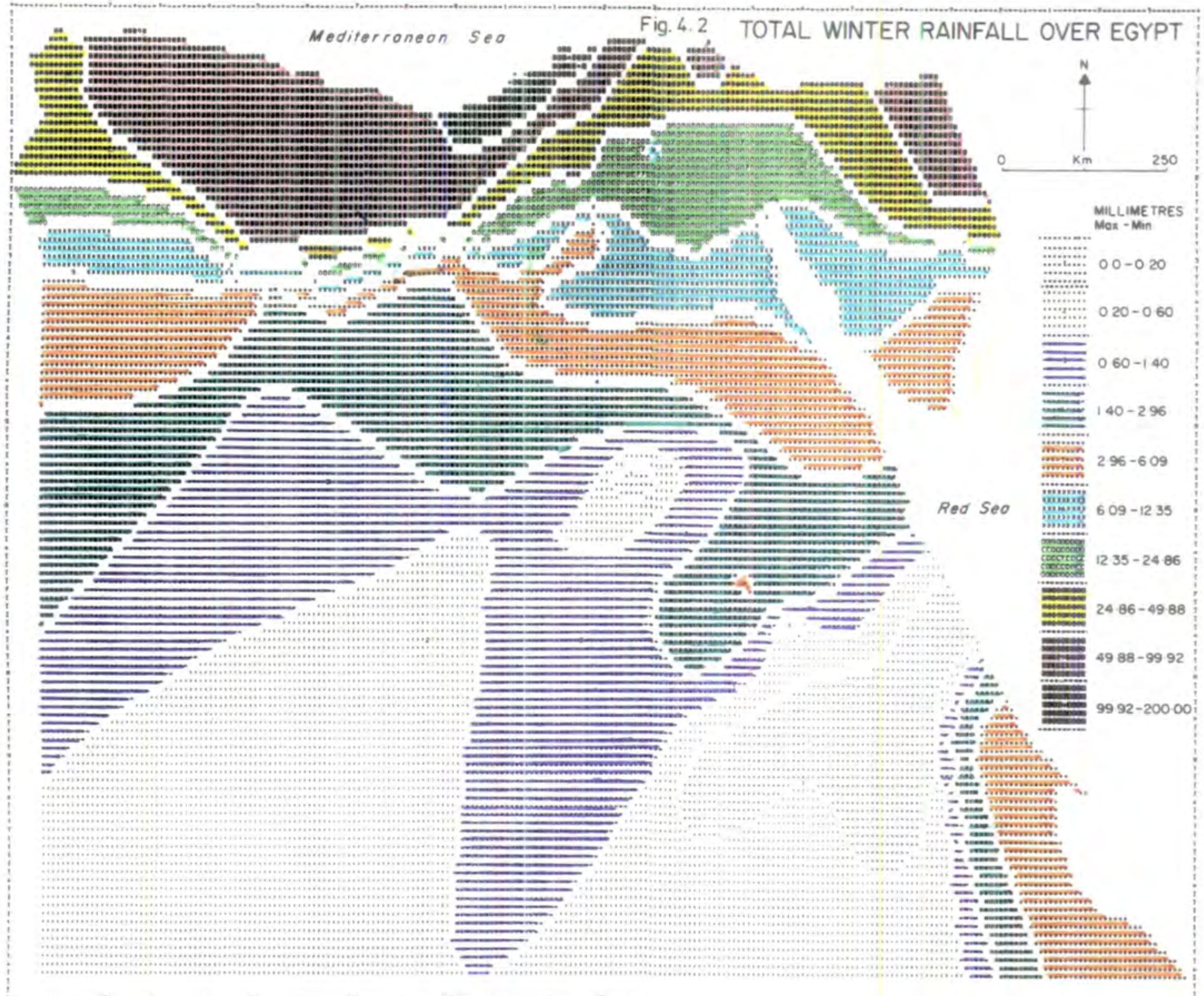
4.3 - Seasonal rainfall conditions :-

The contrasting and changing monthly rainfall conditions clearly indicate an alternation between wet and dry seasons, but both the intensity and duration of precipitation varies from one place to another even in such a limited area as Egypt. Regional variations in seasonal rainfall conditions are shown in Figures 4.2 - 4.5, whilst the seasonal diagrams are presented in Figure 4.6.

Winter rains occur between December and February, and are heaviest on the Mediterranean coast. They result from secondary Mediterranean depressions, which traverse the Mediterranean from west to east and are rainbearing at least over the northern coast. Upper Egypt is practically rainless with warm sunny days, but rather cool nights (see Conrad, 1943; Biel, 1944; Naguib, 1970; Soliman, 1972).

The average winter rainfall is about 80 mm over the western coastal stations with the exception of Sallum station. Over 130 mm of precipitation occurs at Alexandria

Fig. 4.2 TOTAL WINTER RAINFALL OVER EGYPT



and Kon El-Nadura stations, whereas on the eastern part of the Mediterranean coast the winter rainfall values fall to less than 80 mm (Figs. 4.2 and 4.6). The amount of rainfall decreases southwards to about 15 mm in Cairo, and to 4 mm at Minya in Middle Egypt.

In spring and autumn (transitional seasons), rain falls over the coastal region in situations associated with secondary Mediterranean depressions and instability in the upper troposphere. The role played by the Mediterranean water mass in these seasons in producing instability and supplying moisture to cold air masses is obviously less pronounced than in winter. Many of the showers in these seasons originate from unstable mid-troposphere clouds. This fact explains why some showers are characterized by very large water drops, which are actually melted hail. Some of the thunder clouds do not give more than a beautiful display of lighting that continues for many hours and, perhaps, a few scattered large rain drops (Naguib, 1970; Soliman, 1972). Naguib (1970) stated that "It is noticed that rain falls in the transitional seasons (spring and autumn) generally in the afternoon. This is due to the fact that the latent instability of the air cannot be released until the time of maximum temperature is reached. However rain may occur in the morning but in such cases it does not stay long." P. 215.

Spring rainfall in Egypt occurs between March and May and it is heaviest over the coastal and Delta regions (Fig. 4.3). It can also be seen that the precipitation in spring is much heavier even than in the winter season

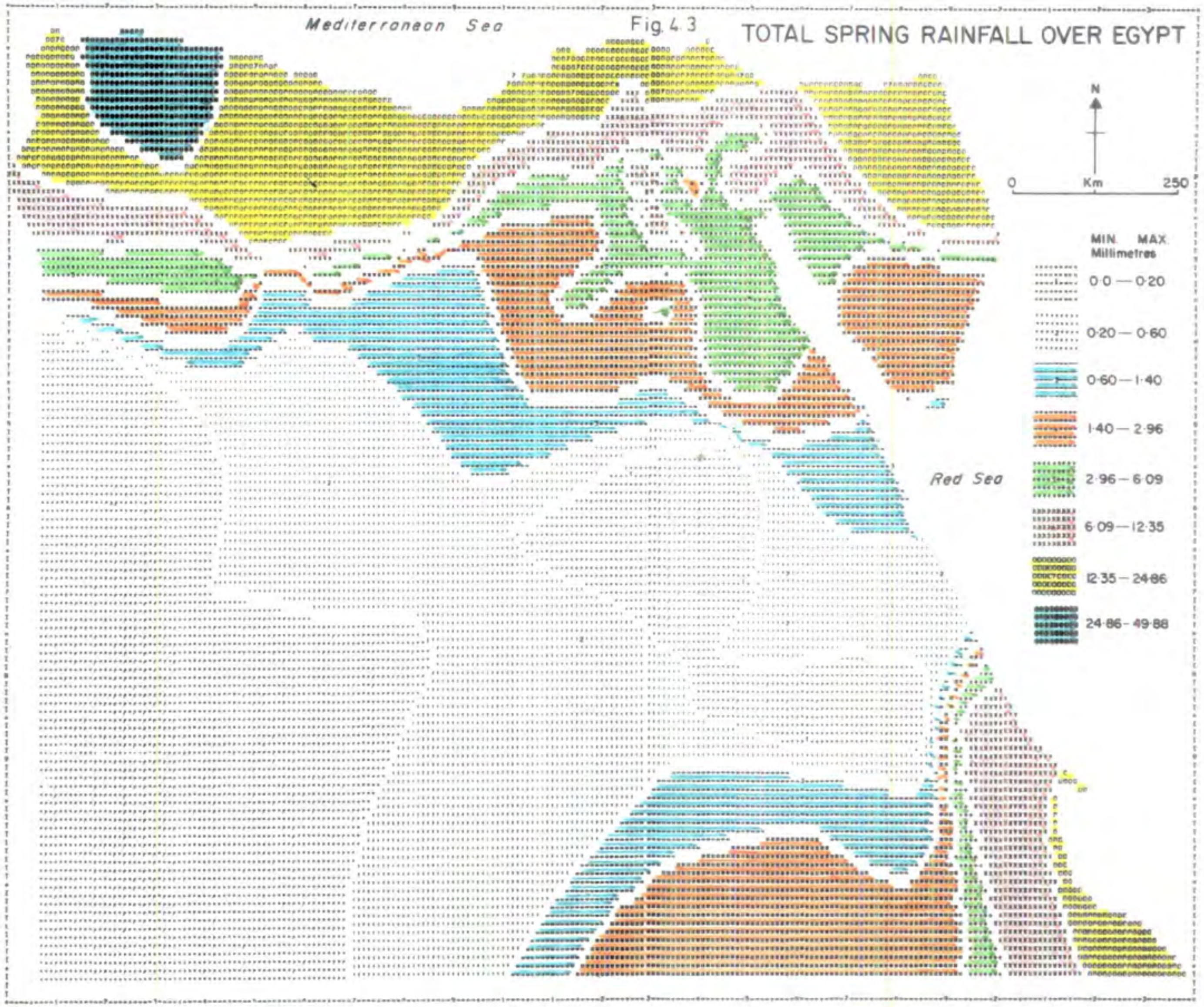


Fig. 4.3 TOTAL SPRING RAINFALL OVER EGYPT

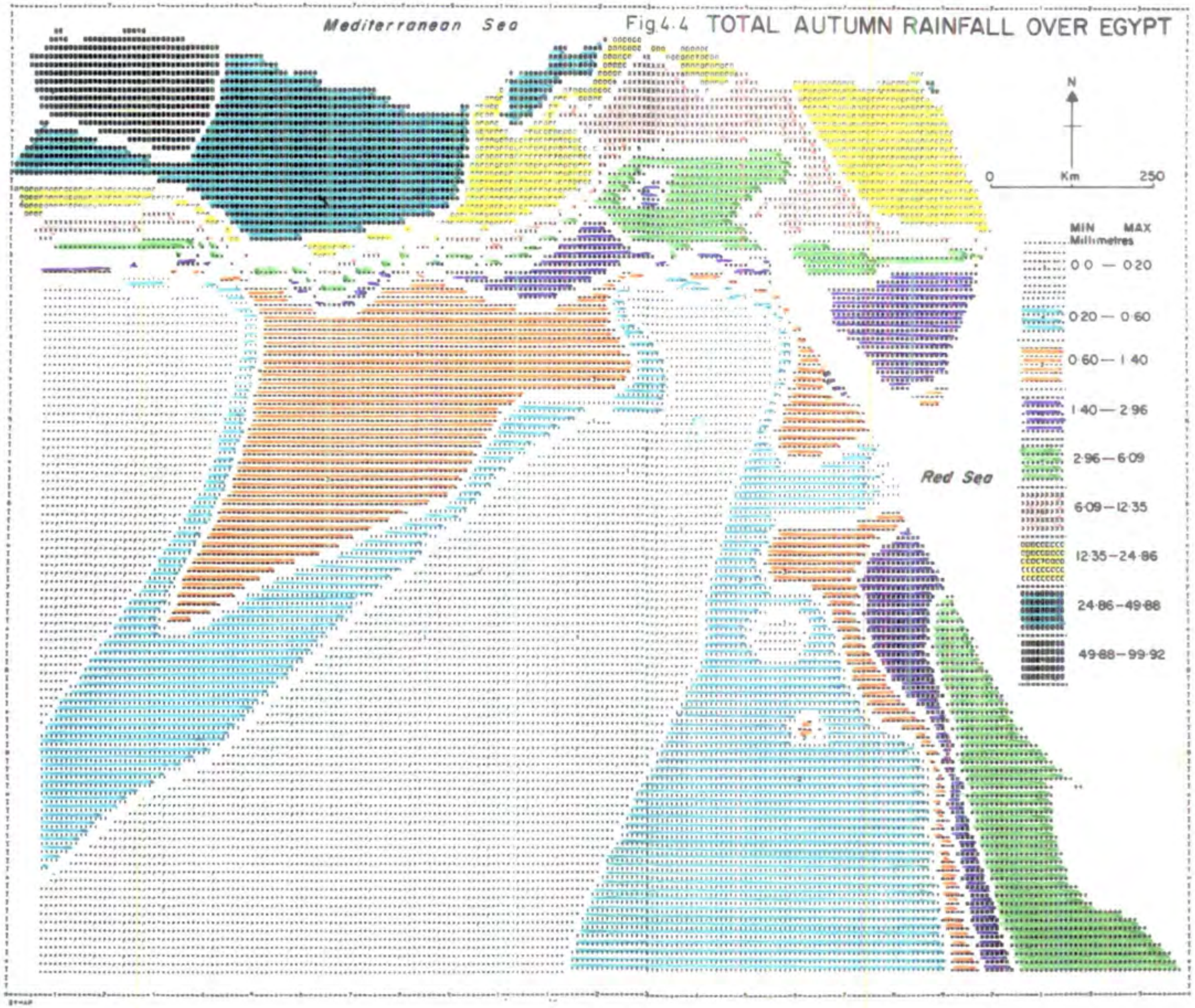


Fig.4.4 TOTAL AUTUMN RAINFALL OVER EGYPT

over some stations in Upper Egypt, for example at Luxor and Aswan stations (Fig. 4.6).

Autumn precipitation is similar to that in spring, for autumn is another transitional season. It is noticed that the greatest amount of rainfall in autumn occurs at Qena, Qusier and Abu El-Kizan. At the Komombo station, precipitation only occurs during Autumn (Figures 4.4 and 4.6).

Rain in the "dry" season (June - September) is a very rare phenomenon, since the country lies under the subtropical high pressure belt where subsidence prevents the formation of convective clouds. This season is dry and rainless (Figs. 4.5 and 4.6), with clear skies, except for some coastal fair weather cumulus or early morning stratus clouds which form over Lower Egypt and disappear a few hours after sunrise. In summer depressions cease to move across Egypt and weather becomes settled.

4.4 - Monthly and daily rainfall conditions :-

The months of June, July, August and September are invariably dry months for the whole country. All Egypt is dry except for a little rain in the coastal region. Nowhere does the amount received, during each of these months rise above 3% level of the annual rainfall. October is the first month that can be considered as a wet or rainy month. By the end of October the whole Mediterranean coastal region has received at least 10% of its annual precipitation. Some rains are experienced over the Delta region, but the amount

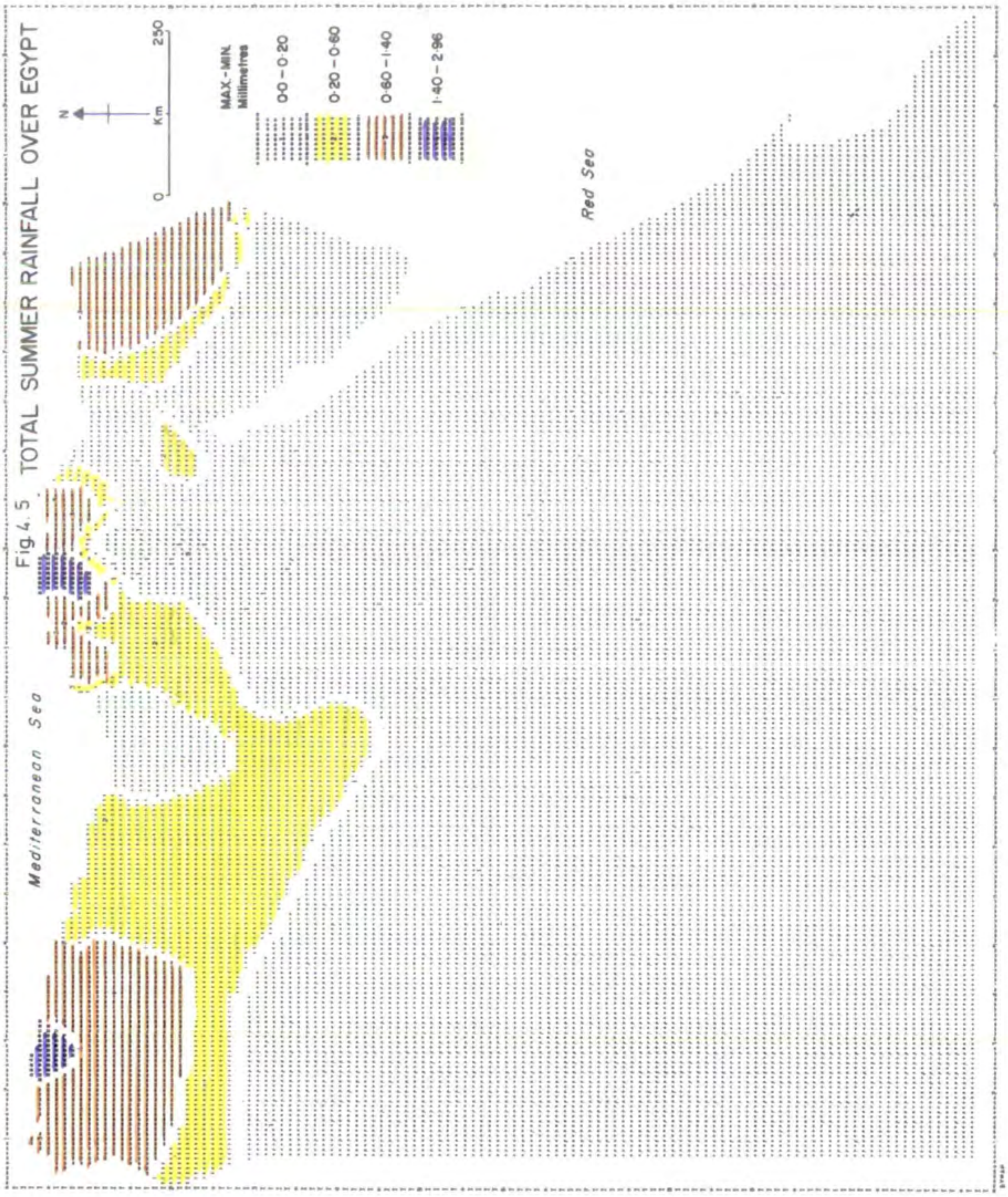
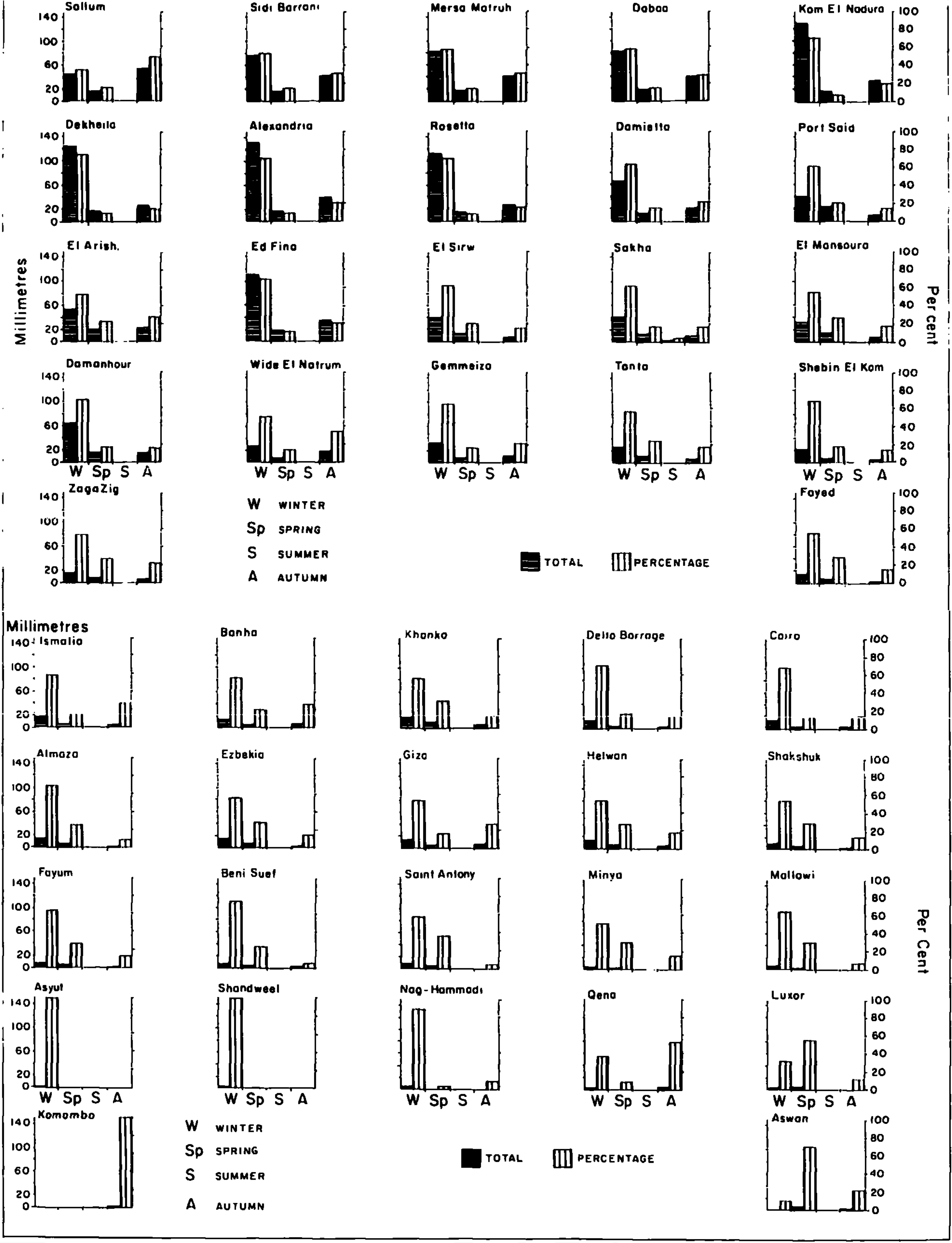


Fig.4.5 TOTAL SUMMER RAINFALL OVER EGYPT

SEASONAL RAINFALL 1931-1960 Fig. 4.6



received does not reach even 5% of the Delta's annual rainfall. During November, December, January, February and March, the rainy zone advanced very quickly to cover the whole coastal region and most of the Delta, though not the southern part of the country. The coastal region receives high amounts of rainfall during this period. All the country north of latitude 29° N receives at least 70% of its annual rainfall during these months (Figs. 4.2 and 4.6).

The mean number of rain days (0.1 mm or more) in Alexandria, Tanta and Minya are given (Table 4.a). It can be seen that the largest number of rainy days on the northern coast occurs in December and January. For Alexandria the number of rain days in December and January are 10.4 and 10.3 respectively. At Tanta, they are 4.0 and 4.1, whilst at Minya the mean number of rainy days in December and January are 0.5 and 0.2 respectively.

A study of rainfall during single 24 hr. periods shows that the largest amounts fall in December and January (Table 4.b). The greatest amount of rainfall recorded at Alexandria was 47.9 mm which occurred on 10.1.1957. At Tanta and Giza the highest amounts were 39.0 mm and 53.2 mm respectively and these fell on 27.10.1937. At Minya and Aswan, the total amounts of rainfall are very low in comparison with other stations. However, the highest amount of rainfall recorded at Minya was 10.2 mm on 19.4.1948 and at Aswan was 5.5 mm registered on 10.5.1935 (Table 4.b). It is noticed that the largest amounts of daily rainfall in the inland localities generally occur in the transitional

Table 4.a

Mean Number of Rainy Days (≥0.1mm) at Alexandria, Tanta and Minya

Place / Month	Alexandria (1942-1960)	Tanta (1931-1960)	Minya (1942-1960)
January	10.3	4.1	0.2
February	6.8	3.0	0.4
March	6.0	2.3	0.3
April	1.7	0.8	0.1
May	1.2	0.6	0.3
June	0.1	0.0	0.0
July	0.0	0.0	0.0
August	0.1	0.0	0.0
September	0.2	0.0	0.0
October	3.0	0.7	0.3
November	7.4	2.0	0.1
December	10.4	4.0	0.5
Total	47.2	17.5	2.2

Source :- Climatological normals for United Arab Republic up to 1960, Cairo, Egypt, 1968.

Table 4.b

Maximum Daily Rainfall Amounts for Selected Stations in Egypt
(millimetres)

Month	Alexandria		Tanta		Giza		Minya		Aswan	
	Max. in one day	Date	Max. in one day	Date	Max. in one day	Date	Max. in one day	Date	Max. in one day	Date
Jan.	47.9	10/1957	14.8	1/1960	5.8	14/1940	6.8	8/1945	1.0	31/1953
Feb.	27.0	3/1948	20.5	20/1942	18.3	22/1943	9.2	14/1942	0.1	10/1954 28/1954
March	12.7	13/1946	12.3	6/1941	15.6	17/1947	3.2	19/1951	2.0	31/1953
April	5.5	18/1949	18.0	23/1936	9.3	1/1954	10.2	19/1948	4.0	27/1950
May	8.0	12/1950	22.5	22/1946	21.2	2/1946	8.4	2/1957	5.5	10/1935
June	0.1	3/1947	-	-	-	-	-	-	-	-
July	0.0	-	-	-	-	-	-	-	-	-
Aug.	8.8	28/1944	-	-	0.1	22/1956	0.1	20/1955	-	-
Sept.	3.6	30/1946	5.7	30/1946	-	-	1.2	29/1957	1.0	9/1957
Oct.	12.0	20/1954	39.0	27/1937	53.2	27/1937	6.5	20/1957	5.0	12/1940
Nov.	32.5	2/1960	13.9	9/1955	19.8	23/1947	2.7	22/1948	1.0	3/1938
Dec.	36.7	6/1957	24.0	1/1954	21.5	6/1951	4.4	30/1944	-	-

Source :- Climatological normals for United Arab Republic, up to 1960, Cairo, Egypt, 1968.

(The maximum value at each station is underlined) seasons and not in the rainy season :-

4.5 - The variability of rainfall over Egypt :-

The following pages present a selection of the statistical methods which are suitable for estimating rainfall variability (see for example, Gregory, 1968; Conrad and Pollak, 1950; Spiegel, 1961, Hammond and McCullagh, 1974; Cole and King, 1970; Stringer, 1972; Dennett et al., 1978). All these methods have been used in the computer analysis.

1. **The Median** :-

The median is given by :-

$$\text{Median} = L_1 + \left(\frac{\frac{N}{2} - (\Sigma F)_1}{F \text{ median}} \right) C$$

Where L_1 = Lower class boundary of the median class.

N = Number of items in the data.

$(\Sigma F)_1$ = Sum of frequencies of all class lower than the median class.

C = Size of median class interval.

F median = Frequency of median class.

2. **The Mode** :-

The mode can be obtained from the formula :-

$$\text{Mode} = L_1 + \left(\frac{\Delta_1}{\Delta_1 + \Delta_2} \right) C$$

Where L_1 = Lower class boundary of modal class.

Δ_1 = Excess of modal frequency over frequency of next lower class.

Δ_2 = Excess of modal frequency over frequency of next higher class.

c = Size of modal class interval.

3. The arithmetic mean :-

The mean may be expressed as :-

$$\bar{x} = \frac{x_1 + x_2 + x_3 + x_n}{N} = \frac{\sum_{j=1}^{n} X_j}{N} = \frac{\Sigma X}{N}$$

Where Σx = The total frequency.

N = The total number of cases.

4. The standard deviation :-

The formula for standard deviation is :-

$$S = \sqrt{\frac{\Sigma x^2}{N} - \left(\frac{\Sigma x}{N}\right)^2} = \sqrt{\bar{x}^2 - \dot{x}^2}$$

Where $\bar{x}^2$ denotes the mean of the squares of the various values of x, while $\dot{x}^2$ denotes the square of the mean of the various values of x.

5. The coefficient of variation :-

The coefficient of variation can be calculated from the following formula :-

$$V = \frac{S}{\bar{x}} \times 100$$

Where S = Standard deviation.

$\bar{x}$ = Arithmetic mean.

The standard deviation and the coefficent of variation are the main statistical methods used, while the range of variability and the dispersion diagrams are included to provide supporting evidence. The simpler parameter of relative variability is not used because, as Gregory (1968) has stated :-

"....it is the coefficient of variation which is mathematically the most correct and which therefore has the greatest potential value for assessing yet further the characteristics of data under review ...." P. 40

The standard deviation and coefficient of variation of monthly rainfall indicate the variability pattern, while the range of variability shows the upper and lower limits of expected rainfall. The results of these analyses are shown in Table 4.c. These are for a monthly rainfall data for a 62 year period in Alexandria and Port Said, 46 year period for Helwan and a 30 year period for the Siwa oasis are illustrated (Figs. 4.7 and 4.8).

A - The variability of monthly and daily rainfall :-

One of the characteristic features of precipitation amounts in Egypt is the high monthly variability (Figs. 4.7 and 4.8). Statistical methods available for measuring such monthly variability are applied to the 62 years of monthly data (1886-1947) for Alexandria and Port Said, the 46 years of monthly data (1904-1949) for Helwan, and the 30 years of monthly data (1920-1949) for the Siwa oasis. The data for the selected four stations are graphed (Figs. 4.7 and 4.8). It can be seen that very marked changes occur from month to month. A study of the statistical methods available for measuring monthly precipitation variability for selected stations indicate that the months with the highest mean rainfall show the greatest variances and standard deviations. This is

Fig.4.7

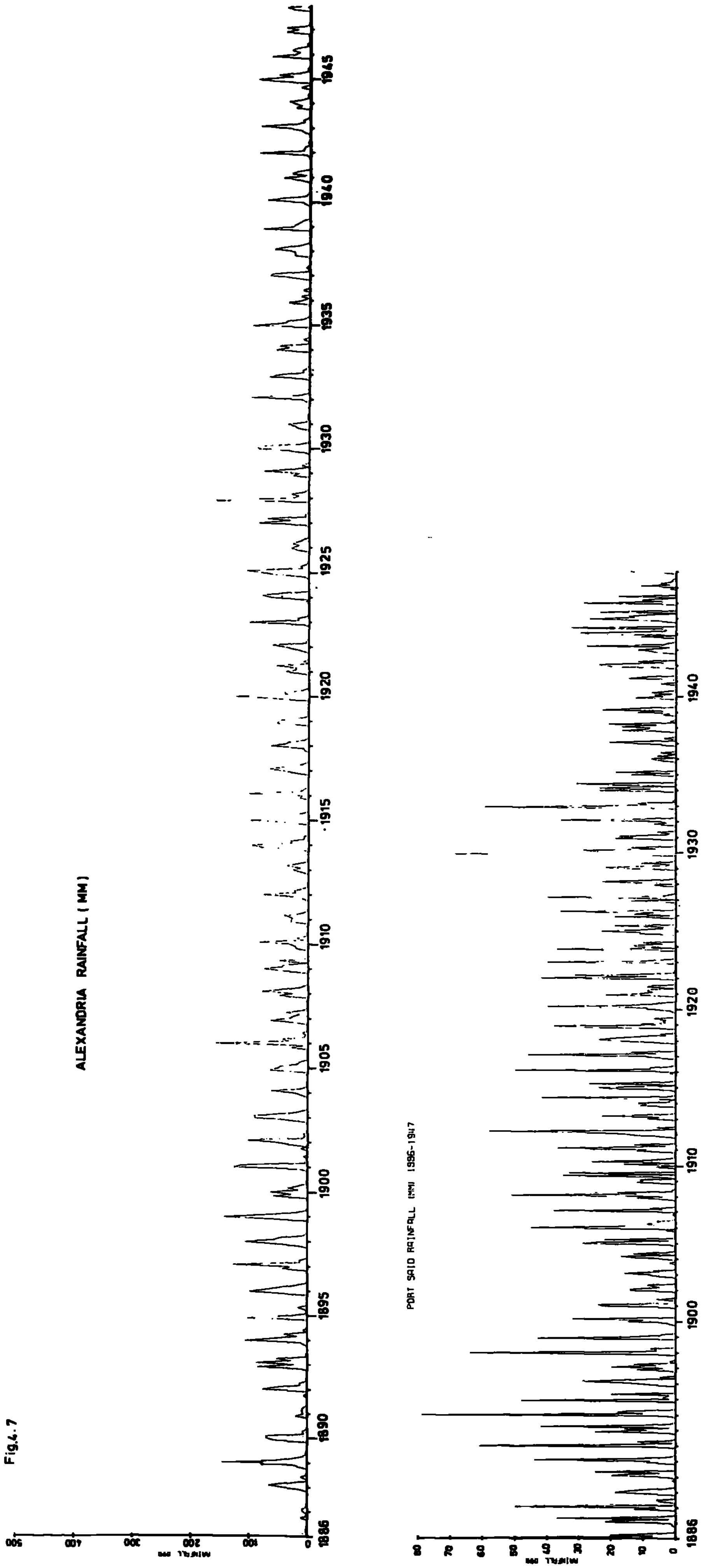

ALEXANDRIA RAINFALL (MM)
RAINFALL mm
0
100
200
300
400
500
1886
1890
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
PORT SAID RAINFALL (MM) 1886-1947
RAINFALL mm
0
10
20
30
40
50
60
70
80
1886
1900
1910
1920
1930
1940

Fig. 4.8

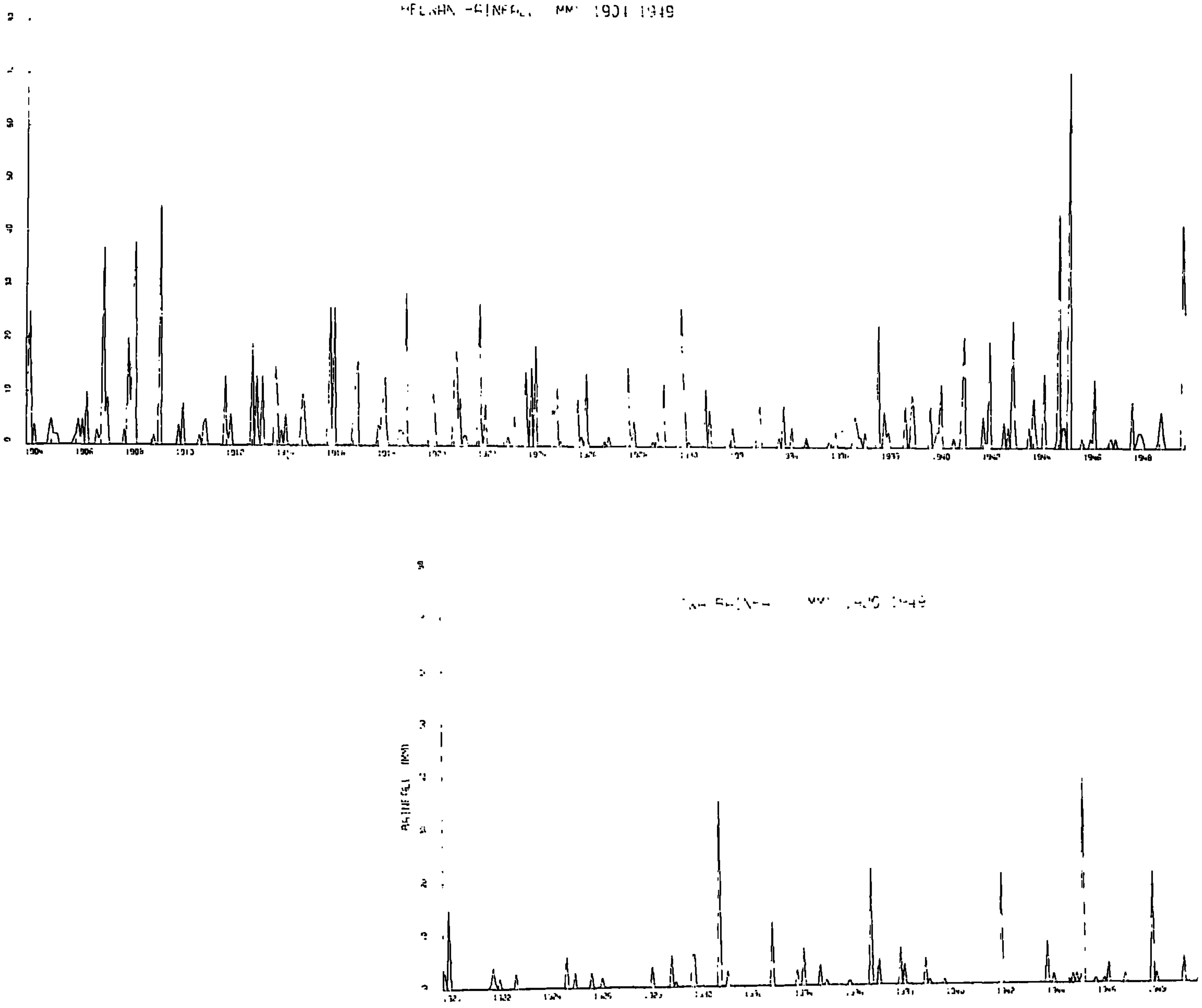

HELWAN RAINFALL (MM) 1904 1949
RAINFALL (MM)
0
10
20
30
40
50
60
1904
1906
1908
1913
1948
RAINFALL (MM) 1920 1949
RAINFALL (MM)

Table 4.c

Statistical Analysis Methods Available for Measuring the Variability of Rainfall at Selected Stations in Egypt

Month	Alexandria 1886-1947							
	Mean	Mode	Median	Max.	Min.	Std. Dev.	Variance	Range
January	48.1	17.0	41.0	127.0	1.0	33.0	1090.2	126.0
February	24.1	12.0	21.5	72.0	1.0	16.1	260.5	71.0
March	10.5	0.0	7.8	57.0	0.0	11.9	140.9	57.0
April	3.1	0.0	1.1	51.0	0.0	7.1	49.8	51.0
May	1.6	0.0	0.3	12.0	0.0	3.1	9.4	12.0
June	0.1	0.0	0.0	2.0	0.0	0.3	0.1	2.0
July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
August	0.3	0.0	0.0	16.0	0.0	2.1	4.2	16.0
September	0.6	0.0	0.1	12.0	0.0	2.2	5.0	12.0
October	6.1	0.0	0.5	58.0	0.0	10.3	106.8	58.0
November	33.8	10.0	25.2	168.0	0.0	29.9	891.7	168.0
December	56.9	14.0	46.5	159.0	0.0	37.8	1428.2	159.0

Table 4.c Continued

Month	Port Said 1886-1947							
	Mean	Mode	Median	Max.	Min.	Std. Dev.	Variance	Range
January	17.5	24.0	14.0	56.0	0.0	13.7	188.8	56.0
February	11.5	0.0	6.3	58.0	0.0	11.9	141.4	58.0
March	8.7	0.0	6.5	42.0	0.0	9.1	82.6	42.0
April	5.4	0.0	1.1	42.0	0.0	9.4	88.1	42.0
May	3.2	0.0	0.4	33.0	0.0	6.8	46.0	33.0
June	0.8	0.0	0.0	33.0	0.0	4.3	18.7	33.0
July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
August	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	0.1	0.0	0.0	2.0	0.0	0.3	0.1	2.0
October	2.6	0.0	0.3	37.0	0.0	6.4	41.5	37.0
November	10.7	0.0	6.8	69.0	0.0	14.2	202.8	69.0
December	15.9	0.0	11.8	79.0	0.0	15.9	253.6	79.0

Table 4.c Continued

Month	Siwa 1924-1949							
	Mean	Mode	Median	Max.	Min.	Std. Dev.	Variance	Range
January	0.9	0.0	0.1	12.0	0.0	2.5	6.2	12.0
February	1.9	0.0	0.1	21.0	0.0	5.4	29.4	21.0
March	0.8	0.0	0.2	15.0	0.0	2.8	7.7	15.0
April	1.0	0.0	0.2	7.0	0.0	1.8	3.3	7.0
May	1.6	0.0	0.1	39.0	0.0	7.2	51.2	39.0
June	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
August	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
October	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
November	0.7	0.0	0.2	6.0	0.0	1.6	2.7	6.0
December	2.7	0.0	0.2	35.0	0.0	7.5	55.9	35.0

Table 4.c Continued

Month	Helwan 1904-1949							
	Mean	Mode	Median	Max.	Min.	Std. Dev.	Variance	Range
January	6.04	0.0	2.50	37.0	0.0	8.4	70.7	37.0
February	4.5	0.0	2.5	25.0	0.0	5.8	33.5	25.0
March	4.8	0.0	1.5	26.0	0.0	7.2	51.9	26.0
April	2.8	0.0	0.2	45.0	0.0	8.8	77.3	45.0
May	2.8	0.0	0.1	71.0	0.0	10.9	118.8	71.0
June	0.0	0.0	0.0	2.0	0.0	0.3	0.1	2.0
July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
August	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
October	1.3	0.0	0.1	23.0	0.0	4.0	16.0	23.0
November	3.8	0.0	1.1	42.0	0.0	7.2	51.2	42.0
December	5.6	0.0	2.0	44.0	0.0	9.1	82.9	44.0

very clear in November, December, January, February and March at Alexandria and Port Said, and in December, May and February at the Siwa and Helwan stations. The lowest mean monthly rainfall data show the lowest amount of variance, median and standard deviation. This is seen for instance during May at the Alexandria and Port Said stations (Table 4.c).

In order to compare the relative amounts of precipitation which fall in different class intervals a frequency table using the monthly precipitation data was prepared (Table 4.d). From this table, the following conclusions can be drawn :-

1. November, December and January are the three months when the highest frequency values are recorded in the highest class intervals of precipitation, especially at the coastal stations (Alexandria and Port Said). The highest precipitation values occurred at Helwan in May and at Siwa in May and December (Table 4.d).

2. June, July, August and September are four months with very little precipitation at the four stations (Table 4.d).

Rainy periods of three to four days are common especially in the coastal region and the middle of the Delta. Longer periods, however, are rare, especially in the southern parts of the country (Figs. 4.9 and 4.10). It is noticed that precipitation varies considerably between the Alexandria, Sallum and Port Said stations. The strip in which Alexandria lies faces into the NW

Figure 4.d

Frequency of Monthly Precipitation Amounts Equalled or Exceeded at Selected Stations in Egypt

Alexandria (62 years)												
Month / Amount	J	F	M	A	M	J	J	A	S	O	N	D
130mm	1	0	0	0	0	0	0	0	0	0	1	2
120	1	0	0	0	0	0	0	0	0	0	0	3
110	4	0	0	0	0	0	0	0	0	0	1	4
100	1	0	0	0	0	0	0	0	0	0	0	3
90	4	0	0	0	0	0	0	0	0	0	2	5
80	6	1	0	0	0	0	0	0	0	0	1	4
70	7	0	0	0	0	0	0	0	0	0	4	5
60	4	2	2	1	0	0	0	0	0	1	7	3
50	4	9	0	0	0	0	0	0	0	0	5	6
40	6	10	2	0	0	0	0	0	0	0	5	5
30	8	10	3	0	0	0	0	0	0	5	13	13
20	8	15	17	3	3	0	0	1	2	5	7	5
10	8	15	29	32	19	2	0	1	7	20	14	3
0	0	0	9	26	40	60	62	60	53	31	2	1

Figure 4.d Continued

Port Said (62 years)												
Month / Amount	J	F	M	A	M	J	J	A	S	O	N	D
130mm	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	1	1
60	2	1	0	0	0	0	0	0	0	0	1	2
50	4	0	1	1	0	0	0	0	0	0	2	2
40	3	4	1	2	2	1	0	0	0	1	1	1
30	11	7	5	1	1	0	0	0	0	1	2	11
20	19	13	11	7	1	0	0	0	0	4	16	17
10	21	31	32	23	22	3	0	0	2	17	28	23
0	2	6	12	28	36	58	62	62	60	39	11	5

Figure 4.d Continued

Helwan (46 years)												
Month / Amount	J	F	M	A	M	J	J	A	S	O	N	D
90mm	0	0	0	0	0	0	0	0	0	0	0	0
80	0	0	0	0	1	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	1	0	0	0	0	0	0	1	1
40	1	0	0	1	0	0	0	0	0	0	0	0
30	2	2	3	0	0	0	0	0	0	1	0	3
20	7	2	4	2	3	0	0	0	0	1	4	3
10	24	29	17	8	4	1	0	0	0	8	22	24
0	12	13	22	34	38	45	46	46	46	36	19	15

Figure 4.d Continued

Siwa (30 years)												
Month / Amount	J	F	M	A	M	J	J	A	S	O	N	D
90mm	0	0	0	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	1	0	0	0	0	0	0	1
30	0	2	0	0	0	0	0	0	0	0	0	1
20	1	0	1	0	0	0	0	0	0	0	0	0
10	5	4	6	9	2	0	0	0	0	0	7	6
0	24	24	23	21	27	30	30	30	30	30	23	22

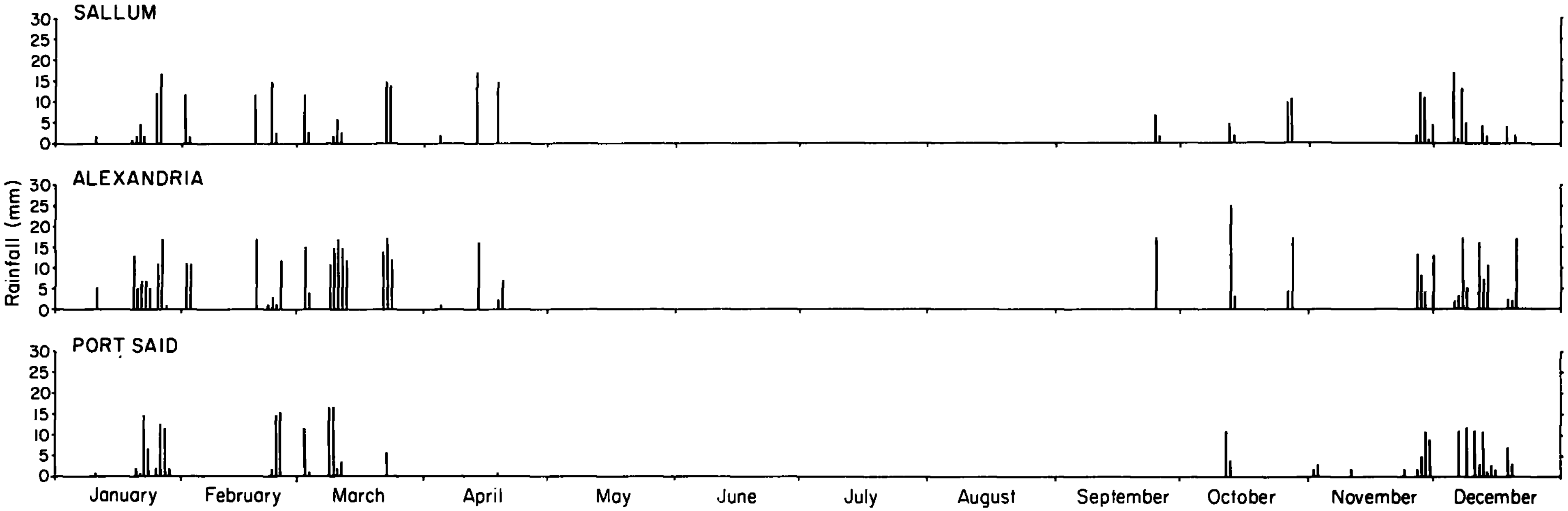


Fig.4.9 Variations in precipitation along the Mediterranean Coast from west to east during 1970

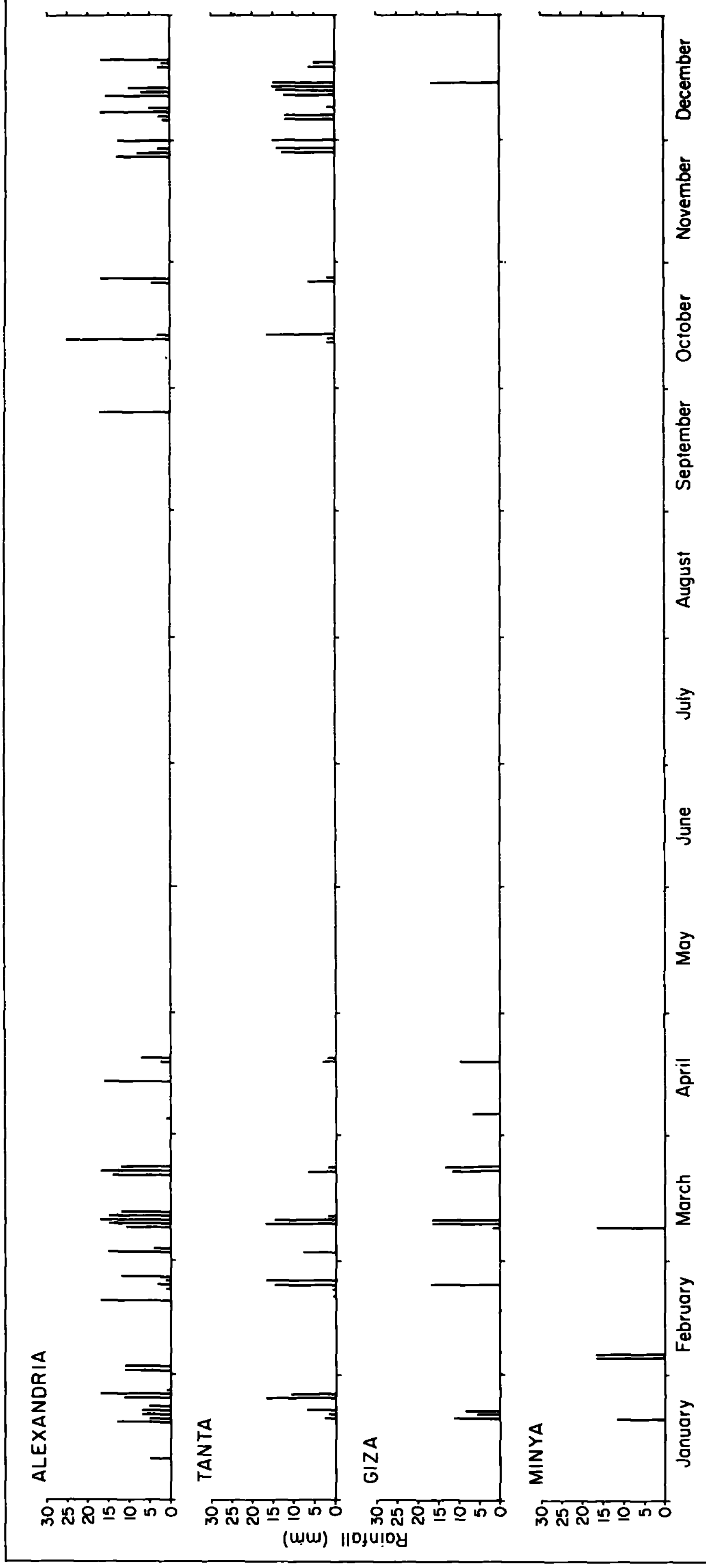


Fig.4.10 Variations in precipitation from Alexandria Station on the Mediterranean Coast to Minya Station in Middle Egypt during 1970

moist currents and thus receives maximum amounts of rainfall, whereas Port Said and Sallum are located where the coastline runs practically parrallel to these currents and, therefore, get minimum amounts of rainfall. The daily amounts of rain decrease southwards until Giza and then continue decreasing more rapidly as shown from selected stations (Fig. 4.10). The rainy season lasts from October to May and tends to start earlier in the north than in the south, since the secondary Mediterranean depressions are most active in winter and the transitional seasons and follow west to east tracks in general.

B - Probability of a day with precipitation :-

The ratio of the number (r) of days with precipitation to the total number (n) of days in the period in question (month, season, year) expressed as a fraction or as a percentage; is termed the probability (P) of a day with precipitation :-

$$P = \frac{r}{n} = 100\frac{r}{n} \text{ percentage}$$

For example, Alexandria has 10.3 days with precipitation in January as an average over a ten year period, therefore :-

$$P = 100 \times \frac{10.3}{31} = 33.2\%$$

The number of days with precipitation at Alexandria, Tanta and Minya are shown in Table 4.e. The percentage probability of receiving rainfall on any one day is high in January and December at Alexandria and

Table 4.e

Probability "P" that A Day Receives Precipitation in Alexandria, Tanta and Minya

Month	Alexandria 1951-1960		Tanta 1931-1960		Minya 1942-1960	
	Number of days with rainfall ≥ 0.1 mm (r)	Pr %	Number of days with rainfall ≥ 0.1 mm (r)	Pr %	Number of days with rainfall ≥ 0.1 mm (r)	Pr %
January	10.3	33.2	4.1	13.2	0.2	0.6
February	6.8	24.3	3.0	10.7	0.4	1.4
March	6.0	19.4	2.3	7.4	0.3	1.0
April	1.7	5.7	0.8	2.7	0.1	0.3
May	1.2	3.9	0.6	1.9	0.3	1.0
June	0.1	0.3	0.0	0.0	0.0	0.0
July	0.0	0.0	0.0	0.0	0.0	0.0
August	0.1	0.3	0.0	0.0	0.0	0.0
September	0.2	0.7	0.0	0.0	0.0	0.0
October	3.0	9.7	0.7	2.3	0.3	1.0
November	7.4	24.7	2.0	6.7	0.1	0.3
December	10.4	33.5	4.0	12.9	0.5	1.6
Total	47.2	12.9	17.5	4.8	2.2	0.6

Source :- Climatological normals for U.A.R., up to 1960, Met. Dept. Cairo, Egypt, 1968.
Pr values : computed by the author.

Tanta, whereas at Minya the highest number of days with precipitation is recorded during February and December. It is also noticed that the total number of days with precipitation and the probability (P) of a day recording precipitation are high at Alexandria and decrease southwards, in an inland direction.

4.6 - Correlation coefficients analysis :-

Rainfall over Egypt, as everywhere else, is the outcome of a combination of several factors. Here an attempt is made to analyse statistically the causal relationships between the rainfall and three of these factors.

The work is based on average data for a period of thirty years, extending between 1931 and 1960. The present attempt follows the approch of Gregory (1965) for Sierra Leone; El-Tom (1966 and 1969) for the Sudan and Johnson (1971) for Nigeria.

The three factors under consideration are :-

1. Latitude (° N).
2. Longitude (° E).
3. Elevation of the ground in metres (Ha).

These three factors are similar to the ones used by Gregory (1965); El-Tom (1966 and 1969) and Johnson (1971). It is thought that these factors may be suitable for Egypt, especially since no other factor seems to be of greater influence on the distribution of rainfall over the country.

Some indication of the relationships between rainfall and each of these factors can be obtained by calculating the product moment correlation coefficients using the formula :-

$$r = \frac{N\Sigma XY - (\Sigma X)\ (\Sigma Y)}{\sqrt{(N\Sigma X^2 - (\Sigma X)^2)\ (N\Sigma Y^2 - (\Sigma Y)^2)}} = \frac{N\Sigma XY - \overline{X}\overline{Y}}{\sigma X \cdot \sigma Y}$$

Where X is the mean rainfall and Y is the factor under consideration (Spiegel, 1961, p. 245). These correlation coefficients are shown in Table 4.f. A significance test has been carried out to find whether the correlation coefficients obtained are due to chance or whether they express the real relationships between mean rainfall and each of these factors. For the annual conditions rainfall has the highest correlation coefficient with factor A (Latitude ^{o}N). This correlation coefficient is 0.669. In spatial terms, this indicates that in Egypt the annual rainfall is positively correlated to a high degree with the latitude north of the Equator. This correlation coefficient is statistically significant at the 1% level. Factor A (Latitude ^{o}N) seems to be succeeded in importance by factor B (Longitude ^{o}E). This latter factor, which produces a correlation coefficient of -0.420 against rainfall reveals a negative relationship. This indicates that the rainfall decreases as longitude increases eastwards. This correlation is also significant at the 1% level. The elevation factor shows a negative correlation with annual rainfall of -0.308 and it is found to be significant at the 5% level (Table 4.f).

The highest monthly correlation coefficients between the rainfall and factor A (Latitude °N) are 0.715 and 0.712. These are experienced during March and May respectively. The lowest monthly correlation coefficient is -0.047 and is recorded during June for the longitude factor (Table 4.f). It can also be seen that October and November have moderately high negative correlation coefficients between mean monthly rainfall and factor B (the longitude factor). These are -0.535 and -0.481 respectively for October and November.

Table 4.f

The Correlation Coefficient Between the Rainfall and Three Main Factors

Month Factor	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
A Latitude °N	0.583	0.620	0.715	0.645	0.712	0.097	0.0	0.237	0.503	0.571	0.581	0.639	0.669
B Longitude °E	-0.357	-0.244	-0.288	-0.104	-0.360	-0.047	0.0	-0.048	-0.324	-0.535	-0.481	-0.401	-0.420
C Elevation	-0.282	-0.277	-0.330	-0.206	-0.186	-0.096	0.0	-0.119	-0.253	-0.245	-0.290	-0.294	-0.308

N = 54

Significance levels :- 0.05 = 0.273 0.02 = 0.322 0.01 = 0.354

CHAPTER 5

Evapotranspiration in Egypt

5.1 - Introduction :-

It is often necessary to make a distinction between the terms "evapotranspiration" and "evaporation". Evapotranspiration is the name given to the combination of two physically similar processes i.e. evaporation and transpiration. Evaporation is the conversion of water in liquid form to vapour from water and soil surfaces. Transpiration is defined as evaporation from plant surfaces. (For more details, see Penman, 1948 and 1956; Tanner, 1967; Morton, 1968; Pegg, 1972; Ward, 1971; Mather, 1974).

Evapotranspiration is a complex process, hence it is extremely difficult to measure or estimate this parameter. In fact, the process of evapotranspiration consists of several distinct components which for climatological purposes, at least are regarded as one.

As Thornthwaite and Hare (1965, p.163) have pointed out, evapotranspiration involves four distinct processes :-

a) The movement of water within the soil either towards the surface of the ground or into the zone of absorption around the roots of the vegetation.

b) Transpiration; the movement of water into the roots and from there through the plants to the leaf surfaces.

c) The vaporisation of the water at the surface of the soil or on the stomata of the plants or on the outer plant surfaces (intercepted water).

d) The removal and transport of the evaporated water into the atmosphere (The aerodynamic sink).

From the foregoing, it is apparent that the rate of evapotranspiration is subject to two major controls. These are :-

1. The availability of moisture at the evaporating surface and

2. The ability of the atmosphere to vaporise the water and remove the vapour.

It is the latter control which has been exploited in the derivation of the various formulae aimed at estimating the rates of evapotranspiration from meteorological data (Ward, 1971; Johnson, 1971).

Potential evapotranspiration is an important agroclimatic factor. It is defined as "combined loss of water by evaporation from water surfaces and soil, and transpiration by vegetation under conditions of unlimited or plentiful water supply" (Thornthwaite, 1948, p. 56). The classic definition of potential evapotranspiration was provided by Penman (1956), who considered it as "....evaporation from an extended surface of short green crops, actively growing, completely shading the ground, of uniform height and not short of water". By this definition and the previous one, the effect of soil and plant factors on evapotranspiration are removed and climatic factors are considered to be the only variables upon which evapotranspiration depends (See, Veihmeyer and Hendrickson, 1955; Thornthwaite and Mather, 1955; Pierce, 1958; Omar, 1973; Shahlaee, 1976). Its accurate determination is of special importance in arid areas where efforts are made to utilize the little water available in the most economic way. Unfortunately there are few accurate measurements of this element in arid areas. A major problem in the measurement of potential evapotranspiration in arid regions is the requirement of a large irrigated area, of not less than 1-2 feddans (0.42-0.84 ha), in order to minimize advection effects. Because potential evapotranspiration is difficult to measure, use has been made of various formulae which have been devised for its estimation from routine meteorological observations. As these formulae are, partly at least, of empirical nature, it is important to compare estimations by them with accurate measurements of evapotranspiration.

5.2 - Measurement of evapotranspiration :-

The methods of estimating evapotranspiration may be divided into three main groups :-

1. Theoretical methods.
2. Empirical methods.
3. Water balance methods.

These methods have been studied in detail by Penman (1948 and 1956); Morton (1968); Pegg (1972); Ward (1971); Thornthwaite (1948); Thornthwaite and Hare (1965); Edwards (1966); Johnson (1971); Omar (1973); Omar and Bakry (1970); Shahlaee (1976) and others. The summary of their studies will be discussed in the following paragraphs.

1) - Theoretical methods of estimating evapotranspiration :-

These methods are divided into two sub-groups: aerodynamic methods and energy balance methods. The first of these is self-contained, while the second depends on some of the principles of the first.

Aerodynamic methods :-

a) Eddy correlation :-

The instrument for measuring eddies and their characteristics, i.e. temperature, humidity and vertical wind velocity, is called an evapotron. This instrument measures fluctuations in the temperature, humidity and wind velocity of minute eddies. This information may be fed directly into a computer and an output of net upward movement of water vapour for the evaporating surface obtained (Ward, 1971).

b) Profile method :-

In this method the vertical flux densities of water vapour, sensible heat and momentum (shearing stress) are represented by a one dimensional form of a general steady state equation, which has been studied in detail by Ferreira and Peixoto (1970) and Shahlaee (1976).

The energy budget method :-

The McIlroy's energy budget equation (Slatyer and McIlroy, 1961) may be written as :-

$$El = \frac{S}{S + \gamma} (R_n - G) + C_p PF (U_a) D_a$$

Where El = Change in energy storage.

C_p = Specific humidity at constant pressure.

D_a = Wet-bulb depression (=T_a - T_w) at a height a.

$F(U_a)$ = Function of wind speed at height a.

P = Air density.

R_n = Net radiation expressed in equivalent mm/day of evaporation.

S = The slope of the saturation specific humidity curve at a temperature that equals the average of the wet-bulb temperature at the reference height and the water-surface temperature.

γ = The psychrometric constant in terms of specific humidity.

This method was applied with success to the measurements of evaporation by Slatyer and McIlory (1961) and Omar (1970).

2) - Empirical methods :-

Various empirical formulae have been suggested for the prediction of evapotranspiration. The development of these equations has been based on the correlation of evapotranspiration with one or more climatic factors, and the degree of empiricism of the formulae varies depending on the number of factors considered and the simplifying assumptions made. The climatic factors which are mostly adopted as variables are radiation (solar and net), mean temperature, humidity and wind (Tanner, 1967; Slatyer and McIlory, 1961; Shahlaee, 1976). Some of the empirical methods are discussed in the following paragraphs :-

Dalton formula :-

This is the oldest aerodynamic formula and is based on an empirical equation of the form :-

$$E = F\ (U_z)\ (e_s - e_z)$$

Where E = The evaporation in mm/day.

$F(U_z)$ = Function of wind speed at height z.

e_s = Saturated vapour pressure at the water surface in mb.

e_z = Vapour pressure at the height z in mb.

Clearly this formula gives values for potential evaporation or evapotranspiration, since the vapour pressure at the water surface is assumed to be saturated. The wind speed function is commonly given in the form of $F\ (U) = (a + bu)$ or $F(U) = bu$, where a and b are constants.

Evapotranspiration by the Prescott equation (E_w) :-

Thirty years ago Prescott was convinced of the importance of evaporation in agricultural studies in which he was involved. In order to supplement the rather sparse network of Australian standard evaporimeter he found it necessary to fall back on values of tank evaporation estimated from other parameter. Whilst appreciating the many factors involved in evaporation, he proposed, and used, an empirical relationship (Prescott and Thomas, 1948-49) :-

$$E_w = 21.2\ (e_a - e_d)\ \text{..........mm/day}$$

Where E_w is estimated evaporation, and $(e_a - e_d)$ is the saturation vapour pressure deficit of the atmosphere in inches of mercury, preferably at the mean daily temperature. This equation has been used extensively in the estimation of mean monthly evaporation and is not intended for daily use.

Blaney and Criddle formula :-

The Blaney and Criddle formula (1950) can be expressed mathematically as :-

$$U = K F$$

Where U = Consumptive use of crop (or evapotranspiration in inches for any period).

F = Sum of the monthly consumptive use factors for the period (sum of the product of mean monthly temperature and monthly per cent of day time hours of the year).

$F = \frac{t \times p}{100}$ = Monthly consumptive use factor.

t = Mean monthly temperatures, in degrees fahrenheit.

P = Monthly per cent of day time hours of the year.

K = Empirical consumptive use coefficient (irrigation season or growing period).

Thornthwaite formula :-

Thornthwaite (1948) suggested an empirical formula for the estimation of potential evapotranspiration. This formula is based on mean temperature data and has been developed from rainfall and runoff data of drainage basins. The simplicity of the formula and the availability of the temperature data for long periods at many locations have been the main reasons for its widespread use. In fact, it is the best known and most widely used of all the empirical formulae. It has, therefore, gained as much popularity as the more theoretically based formula of Penman. Thornthwaite's formula is of the form :-

$$PE = 1.6\ (10\ T/I)^{m}$$

Where T = Mean monthly air temperature in ^{o}C ,I = The annual heat index which is a summation of the monthly heat indices :-

$$I = \sum_{i=1}^{12} i \qquad \text{where } i\left(\frac{T}{5}\right)^{1.514}$$

m is a cubic function of I and is empirically determined being equal to :-

$$(0.675\ I^{3} + 77\ I^{2} + 17920\ I + 492{,}390) \times 10^{-6}$$

PE is unadjusted potential evapotranspiration based upon a 12 hour day 30 day month. By adjusting for the actual day length (h) and days in the month (D), the actual potential evapotranspiration is obtained from the expression :-

$$PE = PE\left(\frac{h}{12}\right)\left(\frac{D}{30}\right)$$

The formula has been criticised for its empiricism and for neglecting vital meteorological factors, such as solar radiation, humidity and wind speed, both of which affect PE rates.

<u>Penman formula</u> :-

Penman in 1948 suggested a formula which was based on his work at Rothamsted experimental station. This formula is by far the most complete of all empirical formulae in which the principles of both energy balance and aerodynamic methods are incorporated. There are three equations in Penman's approach. The most useful equation is of the form :-

$$E_o = 0.35\ (e_a - e_d)\ (1 + U2\ /\ 100)\ \ldots\ldots \text{mm/day}$$

Where e_a = Saturation vapour pressure of water at mean air temperature in mm of mercury.

e_d = That of water at the dew point temperature, or the actual vapour pressure at the mean temperature.

U2 = The wind speed in miles per day at two metres above the ground.

3) - Water balance in Egypt :-

Water balance studies have been relatively neglected aspects of climatological investigations in Egypt. Certain elements of the water balance have, however, been dealt with in studies of climatological elements.

The hydrological cycle for a given area can be summarised by the water balance equation which is a mathematical representation of the flow of water vital in maintaining the heat balance of the earth-atmosphere system (Critchfield, 1974; Mather, 1974; Johnson, 1971). The equation is of the form :-

$$P = E + R + \Delta S + \Delta G$$

Where P = Precipitation, E = Evapotranspiration, R = Runoff

ΔS = Change in soil moisture level and ΔG = Change in groundwater storage over a suitably long period of time.

The change in moisture storage (ΔS and ΔG) are to all intents and purposes nil. We can therefore rewrite the water balance equation as follows :-

$$P = E + R$$

The main largest elements of the equation are precipitation and potential evapotranspiration. Precipitation is the climatic element of greatest economic significance and its variability and reliability are particularly relevant. It alone is not a sufficient index of water availability in Egypt because the River Nile is the main source of water for agricultural purposes.

5.3 - Evaporation over Egypt :-

Evaporation measurements in Egypt are taken once daily at 0600 U.T. from a Piche tube and also from a Class "A" evaporation pan. These give the evaporation amount for the previous 24 hours.

The evaporation readings are measured by a Piche tube freely exposed in sloping double roofed louvred screens. The evaporation disc has an effective area of 10.1 cm^2 and is white in colour and is situated at a height of 140-150 cms above the ground.

The Class "A" evaporation pan is of the type recommended by the Commission of Instruments and Methods of Observation of the World Meteorological Organization

Rec 42 (CIM 0.56). It is of a cylindrical shape, 25.4 cms deep, 120.6 cms in diameter (inside dimensions). The pan is freely exposed in the open air in a dry field, its rim is situated at a height of 41 cms above the ground, and is placed at a distance from obstacles such as buildings or trees. The Class "A" evaporation pan has been used at the Giza and Aswan stations only. Piche tubes have been used at the 54 climatological stations in Egypt.

The mean daily amounts of evaporation in mm for selected stations in Egypt are shown in Table 5.a. It can be seen that the highest annual daily values of evaporation recorded are 15.4mm, 14.9 mm and 16.4 mm at Aswan, Kharga and Dakhla respectively. The lowest values registered are 4.5 mm/day at Tanta, and 5.2 mm/day at Alexandria. It is also noticed that the mean daily values for each month are very high at Aswan, Kharga and Dakhla stations, in contrast with Alexandria in the Mediterranean Coastal area and Tanta in the Middle of the Delta region.

In general, the monthly variation of mean daily values in the Mediterranean coast is very small with the highest values occurring in summer. On the Red Sea Coast the observed values (Table 5.a and Fig. 5.1) are much larger, due to the effect of greater wind speeds and lower humidities. The range of variations have been computed by the author and the results are shown in Table 5.a. This table shows that the coastal area has the smallest range in comparison with inland stations. The smallest range is recorded at Alexandria (2.1 mm/day), whilst the largest range is found at Aswan, Kharga and Dakhla. These values are 13.2, 14.0 and 16.4 mm/day respectively for the three stations.

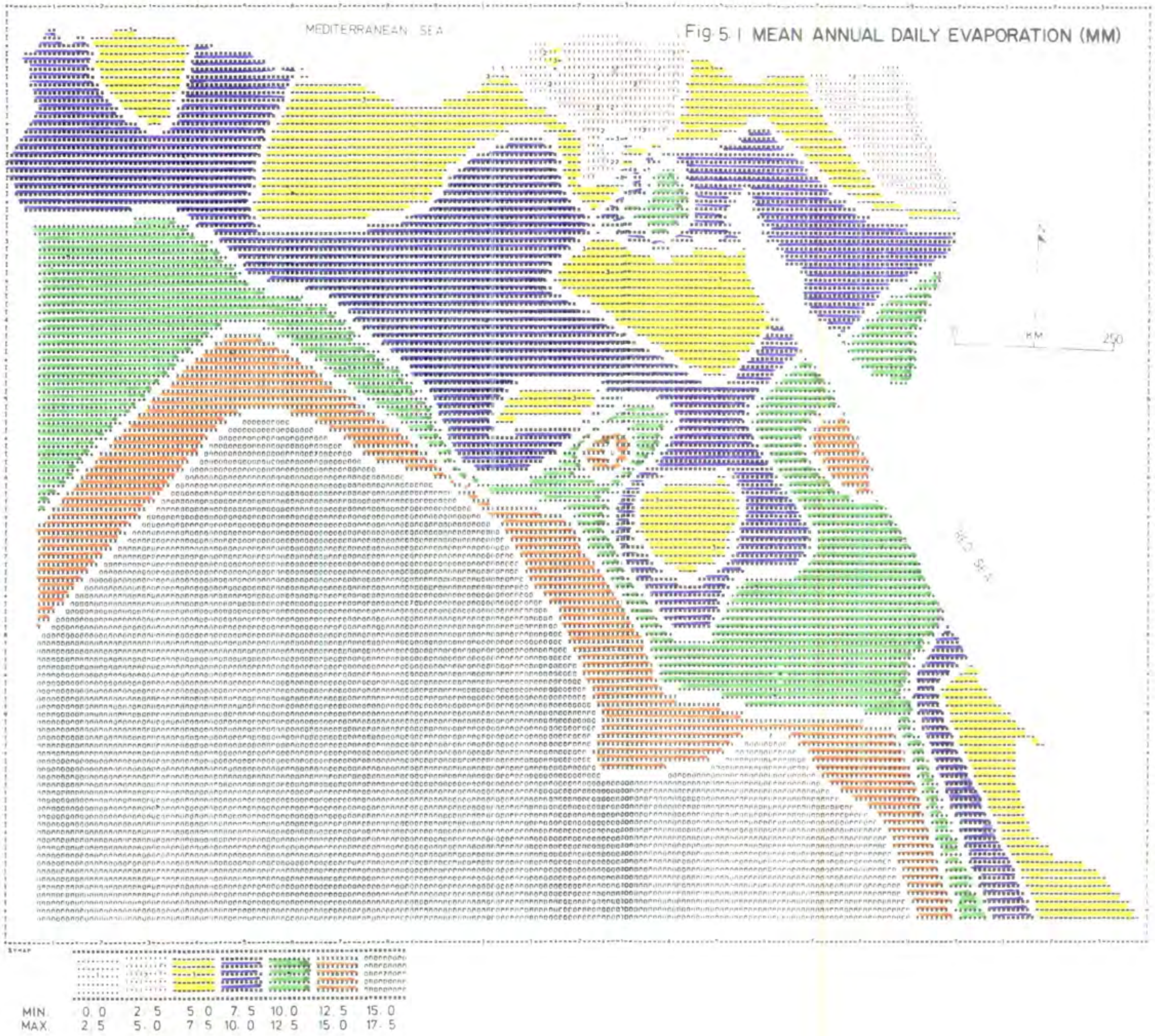


Fig 5.1 MEAN ANNUAL DAILY EVAPORATION (MM)

Table 5.a

Mean Daily Amount of Evaporation in mms. for Selected Stations in Egypt[1] (Piche values)

Place	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year Mean	Range
Sallum	1946-1960	7.9	8.3	8.4	8.7	8.6	10.1	11.1	9.8	8.6	8.4	7.7	7.2	8.7	3.9
Mersa Matruh	1947-1960	7.5	7.1	8.1	8.7	8.5	9.0	9.3	9.4	9.7	8.4	7.4	6.6	8.3	3.1
Alexandria	1942-1960	4.4	4.8	5.4	5.5	5.8	5.7	5.7	5.7	5.9	5.5	4.4	3.8	5.2	2.1
Port Said	1941-1960	4.9	5.4	6.5	6.6	7.1	7.7	7.9	7.7	8.1	7.6	6.3	4.8	6.7	3.3
Tanta	1931-1960	2.1	2.8	3.7	5.4	7.0	7.6	6.6	5.7	4.5	3.6	2.6	2.0	4.5	5.6
Giza	1931-1960	3.3	4.2	5.4	7.5	9.5	9.7	8.9	7.3	6.0	5.2	3.7	2.9	6.1	6.8
Bahariya	1931-1960	5.3	6.7	8.6	11.1	13.5	14.0	13.3	12.5	10.5	8.6	6.3	5.1	9.6	8.9
Minya	1941-1960	4.5	6.0	7.9	10.4	14.2	15.1	14.1	12.2	9.3	7.9	6.1	4.7	9.4	10.6
Qena	1935-1960	3.4	4.3	6.6	9.3	11.6	12.6	11.6	11.8	9.0	8.1	4.5	3.3	8.0	9.3
Aswan	1931-1959	8.6	10.0	13.9	17.0	17.2	21.8	20.1	20.0	19.0	16.9	11.8	9.0	15.4	13.2
Siwa	1921-1960	5.4	7.0	9.2	11.8	13.8	15.2	15.3	14.1	11.4	8.8	6.3	5.0	10.3	10.3
Hurgedia	1943-1960	9.8	10.8	11.3	13.7	15.8	17.7	17.1	16.8	15.5	12.1	10.4	9.6	13.4	8.1
Kharga	1931-1960	7.5	8.8	12.9	16.2	19.8	21.5	20.2	19.2	18.5	15.4	10.7	7.7	14.9	14.0
Dakhla	1931-1960	7.9	9.9	13.6	18.1	22.6	24.3	23.0	22.2	20.3	16.0	11.2	7.9	16.4	16.4
Suez	1931-1960	4.8	5.8	7.4	9.7	12.6	14.0	13.7	12.8	11.6	8.8	6.3	4.8	9.4	9.2

(1) Source: - Climatological normals for United Arab Republic, up to 1960, Met. Dept., Cairo, Egypt, 1968.

Table 5.b gives the mean daily values of measured evaporation by the Piche tube in free air and the Class "A" Pan at Giza and Aswan for the different months of the year. It can be seen, as would be expected, that the results of the Class "A" Pan are less than the values measured by the Piche tube in free air, either at Giza or at Aswan.

The correlation coefficients between measured evaporation by the Piche tube in free air and the Class "A" Pan at Giza and Aswan have been calculated (Figs. 5.2 and 5.3). These are all significant at the 1% level and very high correlation coefficients exist between the values measured by the Piche tube in free air and Class "A" Pan. These correlation values are 0.971 and 0.990 at Giza and Aswan respectively.

5.4- Penman and Thornthwaite evapotranspiration values for six selected stations in Egypt :-

Potential evapotranspiration was also calculated by both the Penman and the Thornthwaite formulae. For the Penman formula, the calculation was facilitated by the application of a computer program supplied by the Institute of Hydrology, which uses the daily values of temperature (maximum, minimum, dry and wet bulb), run of wind and radiation data (either of solar radiation, net radiation or hours of sunshine) as input and produced daily values of Penman Eo1, Eo2 and Et with empirical wind functions (i.e. $F(U) = 0.35\ (1 + \frac{U}{100})$ or $F\ (U) = 0.35\ (0.5 + \frac{U}{100})$ as output. The format of a typical lead card, control

Table 5.b

Measured Evaporation by Piche Exposed in the Free Air and the Class "A" Pan for Giza and Aswan Stations (mm/day)

Month	Giza (1960-1965)(1)		Aswan (1962-1967)	
	Piche exposed	Class "A" pan	Piche exposed(2)	Class "A" pan(3)
Jan.	6.1	3.0	9.1	6.3
Feb.	8.3	4.2	11.3	8.5
March	11.0	6.4	14.9	12.3
April	15.1	8.6	18.9	15.2
May	19.1	11.4	22.3	17.5
June	19.7	12.9	22.7	19.3
July	15.4	11.1	22.4	19.0
Aug.	14.0	10.3	22.1	18.8
Sept.	13.2	9.1	20.6	16.5
Oct.	11.6	6.9	17.1	12.8
Nov.	7.7	4.3	11.7	10.1
Dec.	6.9	3.1	9.2	7.3
Ann. mean	12.3	7.6	16.9	13.6

(1) Omar, M.H., 1969; Correlation between potential evapotranspiration and meteorological and evaporometer data, meteorlogical,Dept., Met. Res. Bull.,Vol 1, p. 113.

(2) Monthly weather reports for years 1962-1967, Meteorological Dept., Cairo, Egypt.

(3) Omar, M.H. and El-Bakry, M.M., 1970; Estimation of Evaporation from Lake Nasser, Meteorological Dept., Met. Res. Bull., Vol. 2, p.8.

Fig 5.2 ASWAN

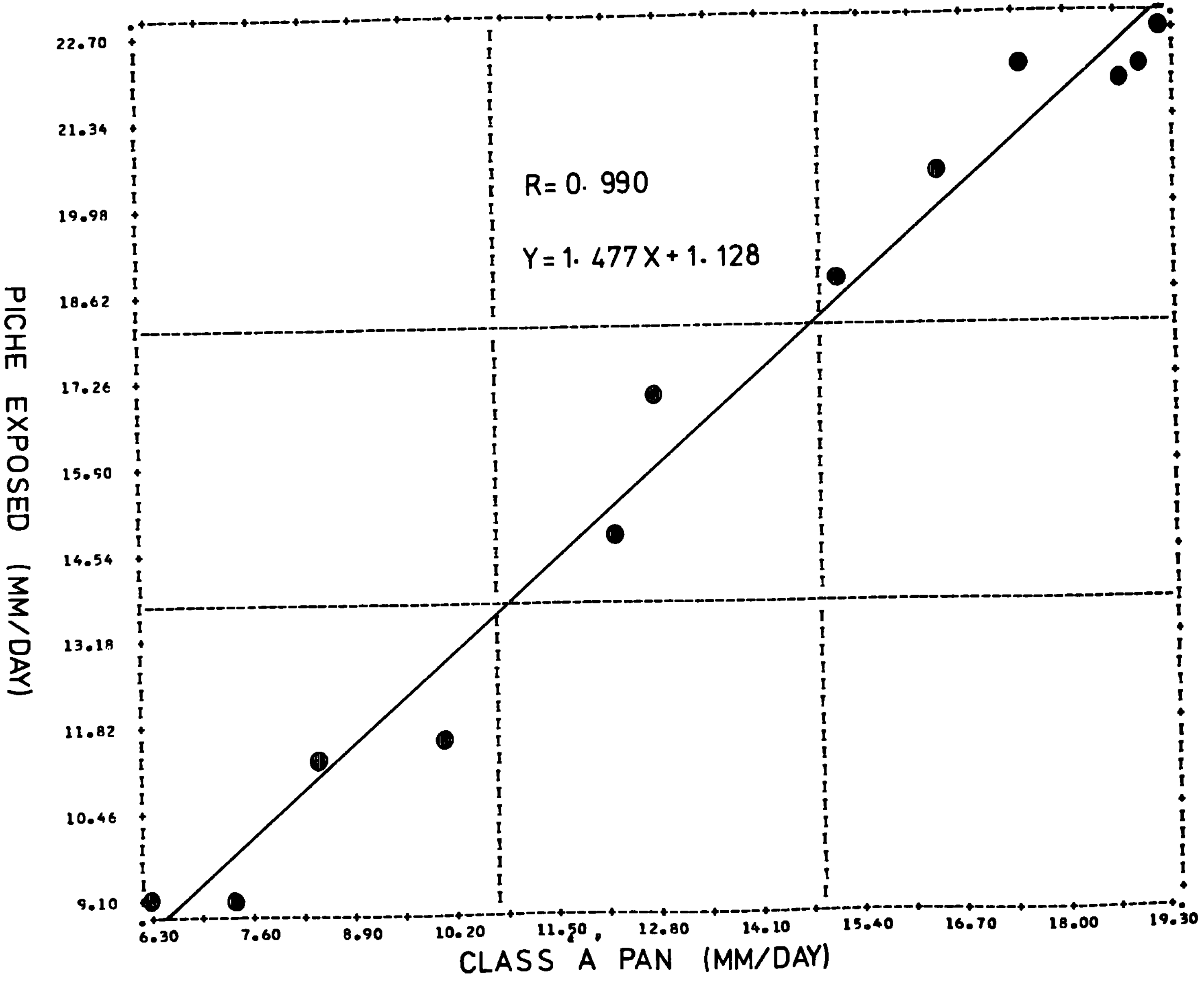
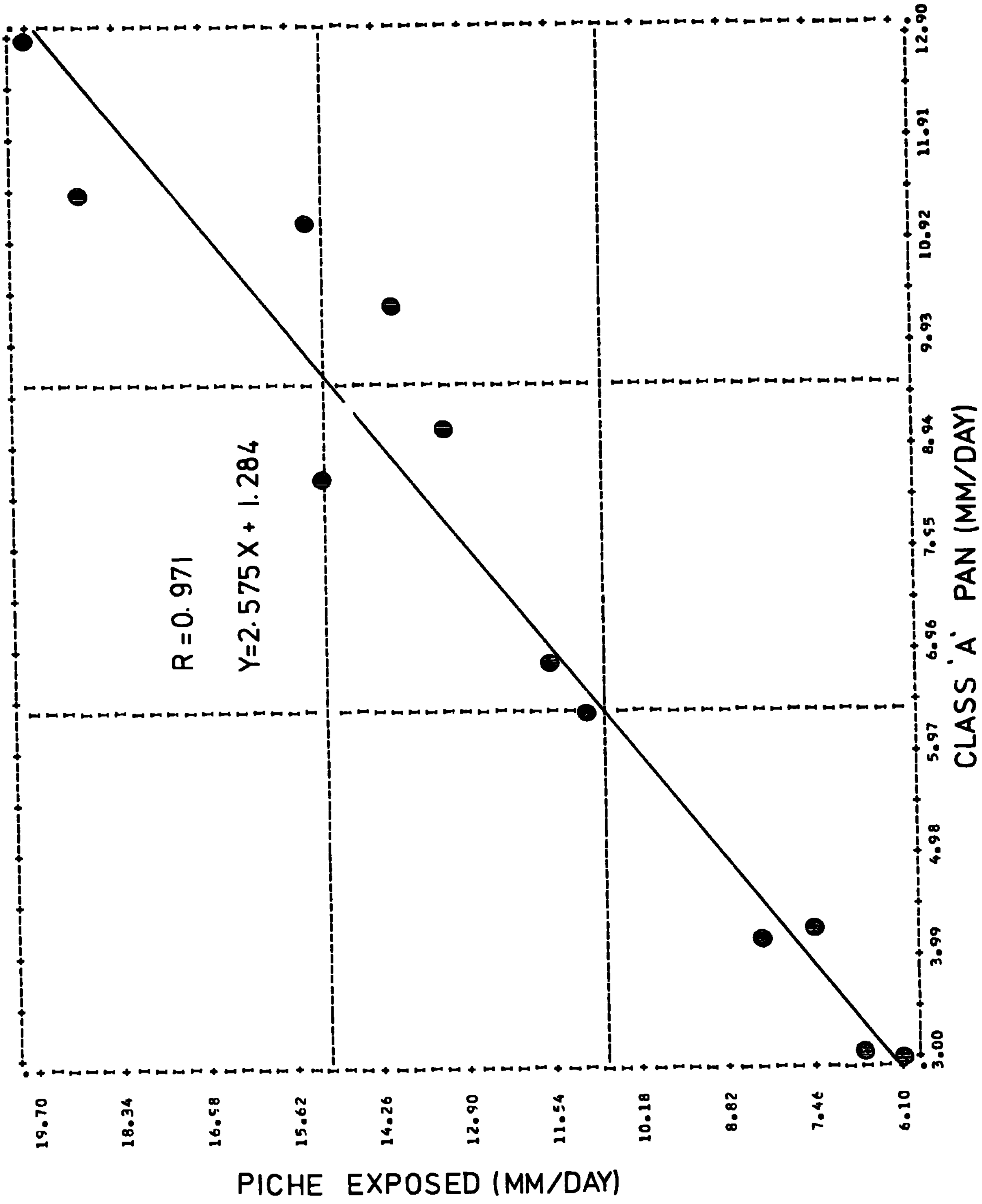

R= 0. 990
Y= 1. 477 X + 1. 128
PICHE EXPOSED (MM/DAY)
22.70
21.34
19.98
18.62
17.26
15.90
14.54
13.18
11.82
10.46
9.10
6.30
7.60
8.90
10.20
11.50
12.80
14.10
15.40
16.70
18.00
19.30
CLASS A PAN (MM/DAY)

Fig. 5. 3 GIZA


R = 0.971
Y=2.575 X + 1.284
PICHE EXPOSED (MM/DAY)
CLASS 'A' PAN (MM/DAY)
6.10
7.46
8.82
10.18
11.54
12.90
14.26
15.62
16.98
18.34
19.70
3.00
3.99
4.98
5.97
6.96
7.95
8.94
9.93
10.92
11.91
12.90

card and data card employed for running the program are discussed in Appendix 1. The program has been used to determine daily values of evaporation and evapotranspiration for the stations at Alexandria, Tanta, Giza, Minya, Aswan and Kharga oasis during 1970. Calculations of the Thornthwaite evapotranspiration values have been made from tables in Thornthwaite and Mather (1957).

The mean daily amounts of (EP) measured by the Piche tubes in the free air at the six selected climatological stations are very high when compared with the evaporation and evapotranspiration values estimated by the Penman and Thornthwaite formulae.

In general, the highest recorded values for evaporation (EP) measured by Piche tube are found in May at Alexandria, Tanta, Giza and Kharga stations, and in June at Minya and Aswan (Fig. 5.4). The lowest measured values are registered during December and January at all stations with the exception of Tanta, whereas the lowest values are found in November and December (Table 5.c and Fig. 5.4). This highest measured (EP) value of evaporation is 31.6 mm/day. This is recorded in June 1970 at Aswan. The lowest evaporation value is found in December at Tanta (2.7 mm/day).

The Penman Eo1 and Eo2 are values of potential evaporation (albedo 0.05). The former has an aerodynamic term with an empirical function of wind speed of $F\ (U2) = 0.35\ (1 + \frac{U_2}{100})$, while the empirical wind function of the Eo2 is $F\ (U_2) = 0.35\ (0.5 + \frac{U_2}{100})$. Penman Et refers to potential evapotranspiration (albedo 0.25) with a wind

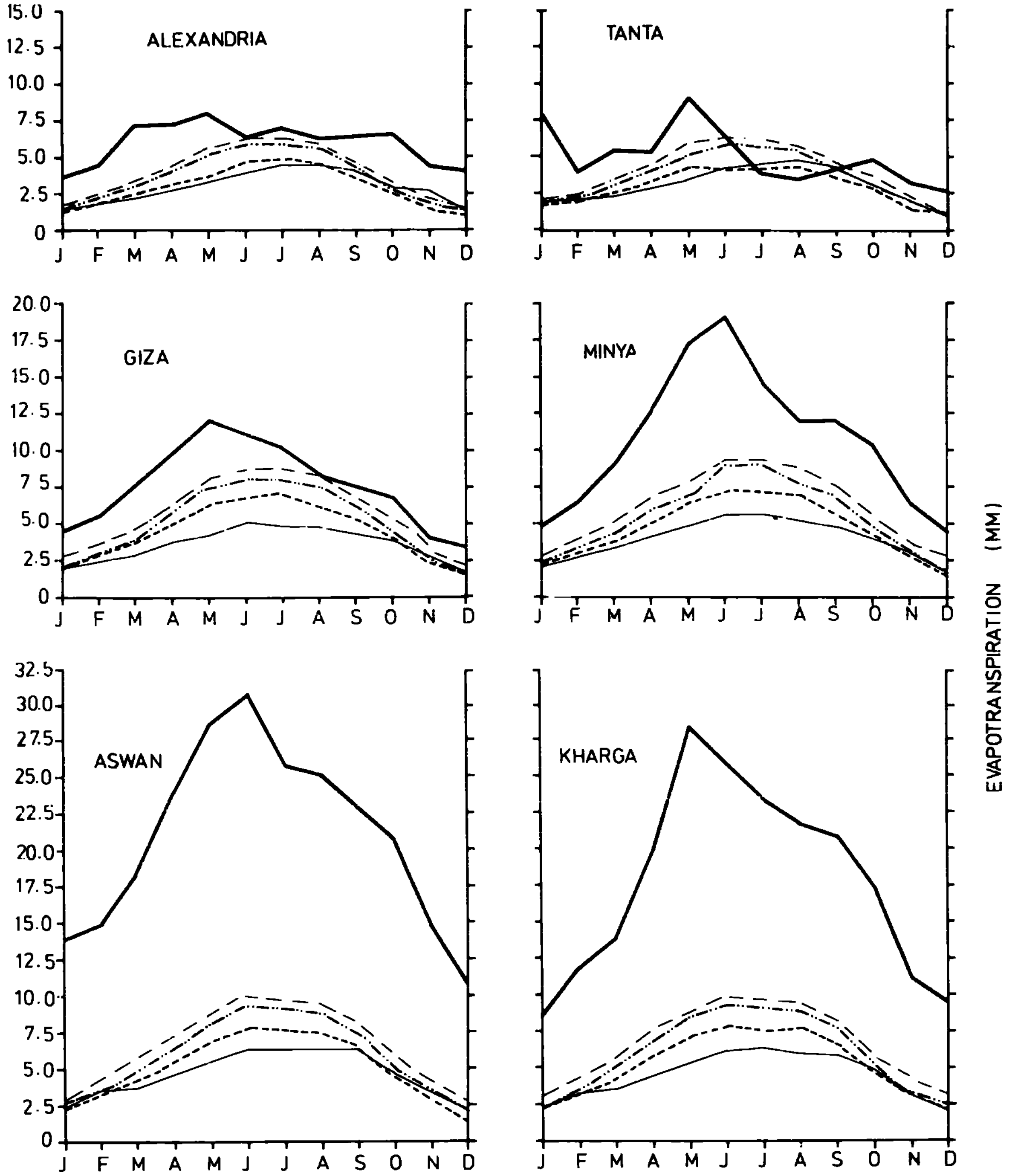


Fig. 5.4 MEASURED AND ESTIMATED EVAPORATION AND EVAPOTRANSPIRATION (1970)

Table 5.c

Evaporation and Evapotranspiration Monthly Values (mm/day) for 1970 at Alexandria, Tanta, Giza, Minya, Aswan and Kharga Stations

Month	Alexandria					Tanta				
	Measured EP (Piche)	Penman			Thornthwaite ET	Measured EP (Piche)	Penman			Thornthwaite ET
		Et	Eo1	Eo2			Et	Eo1	Eo2	
Jan.	3.7	1.2	1.7	1.4	1.4	7.7	1.6	2.0	1.9	1.7
Feb.	4.4	1.7	2.4	2.0	2.0	3.8	1.8	2.3	2.0	2.1
March	7.2	2.5	3.4	2.9	2.2	5.4	2.4	3.3	2.9	2.3
April	7.3	3.1	4.2	3.7	2.7	5.2	3.3	4.4	3.8	2.9
May	8.0	4.1	5.5	5.1	3.3	8.9	4.3	5.8	5.2	3.4
June	6.3	4.6	6.1	5.8	4.0	6.2	4.2	6.3	5.7	4.2
July	7.0	4.7	6.2	5.8	4.3	3.8	4.2	6.1	5.6	4.5
Aug.	6.3	4.5	5.9	5.6	4.5	3.4	4.3	5.6	5.5	4.8
Sept.	6.4	3.5	4.7	4.3	4.1	3.9	3.3	4.5	4.2	4.3
Oct.	6.5	2.4	3.2	2.7	2.9	4.7	2.8	3.8	3.3	3.0
Nov.	4.4	1.4	2.1	1.8	2.6	3.1	1.2	2.0	1.7	2.0
Dec.	4.0	1.1	1.6	1.3	1.4	2.7	1.0	1.4	1.2	1.3
Ann. mean	6.0	2.5	3.9	3.5	3.0	4.9	2.9	4.0	3.6	3.0

Table 5.c Continued

Month	Giza					Minya				
	Measured EP (Piche)	Penman			Thornthwaite ET	Measured EP (Piche)	Penman			Thornthwaite ET
		Et	Eol	Eo2			Et	Eol	Eo2	
Jan.	4.4	2.0	2.6	1.9	1.9	4.8	2.1	2.8	2.3	2.0
Feb.	5.5	2.7	3.6	2.8	2.5	6.4	3.0	3.9	3.1	228
March	7.5	3.5	4.6	3.9	2.9	9.0	3.7	4.9	4.2	3.2
April	9.6	4.9	6.5	5.7	3.7	12.6	5.1	6.8	5.9	4.1
May	12.0	6.2	8.0	7.2	4.2	17.3	6.4	7.8	6.7	4.8
June	11.2	6.7	8.7	8.0	5.0	19.0	7.1	9.3	8.7	5.6
July	10.2	6.8	8.7	8.0	4.9	14.2	7.3	9.4	8.9	5.7
Aug.	8.2	6.3	8.1	7.4	4.8	11.9	6.9	8.7	7.8	5.4
Sept.	7.6	5.3	6.9	6.2	4.3	12.1	5.7	7.6	6.9	4.9
Oct.	6.7	4.0	5.2	4.5	3.9	10.4	4.2	5.4	4.7	4.1
Nov.	4.1	2.3	3.2	2.5	2.8	6.2	2.6	3.7	2.9	3.1
Dec.	3.4	1.6	2.3	1.7	1.7	4.4	1.9	2.8	2.0	1.9
Ann. mean	7.5	4.4	5.2	5.0	3.6	10.7	4.7	6.1	5.3	4.0

<u>Table 5.c Continued</u>

Month	Aswan					Kharga				
	Measured EP (Piche)	Penman			Thornthwaite ET	Measured EP (Piche)	Penman			Thornthwaite ET
		Et	Eol	Eo2			Et	Eol	Eo2	
Jan.	13.9	2.2	3.0	2.3	2.2	8.5	2.2	3.1	2.4	2.1
Feb.	14.8	3.2	4.3	3.5	3.5	11.8	3.1	4.2	3.4	3.4
March	18.4	4.1	5.5	4.7	3.6	13.7	4.2	5.6	5.0	3.5
April	23.8	5.5	7.1	6.4	4.7	19.6	5.8	7.5	6.9	4.4
May	28.6	6.8	8.7	8.0	5.5	28.1	7.0	8.9	8.3	5.3
June	31.6	7.8	9.8	9.2	6.3	25.7	7.9	9.8	9.3	6.1
July	25.6	7.6	9.6	9.0	6.2	23.1	7.5	9.6	9.1	6.3
Aug.	25.3	7.5	9.4	8.8	6.1	21.6	7.6	9.5	8.9	5.9
Sept.	22.8	6.4	8.1	7.4	6.3	20.7	6.5	8.3	7.7	5.7
Oct.	20.6	4.4	5.6	4.9	4.8	17.3	4.6	5.7	5.1	4.9
Nov.	14.7	3.0	4.1	3.4	3.6	11.0	3.1	4.1	3.0	3.5
Dec.	10.8	2.2	3.0	2.4	2.3	9.5	2.2	3.1	2.5	2.1
Ann. mean	20.9	5.1	6.5	5.8	4.6	17.6	5.1	6.6	5.9	4.4

function similar to Eol.

The estimated results of evaporation and evapotranspiration (Table 5.c and Fig. 5.4) show clearly that June, July and August are the months with the highest values, whilst January and December are the months with the lowest estimated values of evaporation and evapotranspiration at all stations. It can also be seen that the Penman Et, Eol and Eo2 values are in general higher than potential evapotranspiration calculated by the Thornthwaite formula (ET). Several factors explain the higher monthly values for Penman equation compared with Thornthwaite formula. The most important factors are the Thornthwaite formula is dependent only on temperature, while the Penman equation is based not only on temperature, but also sunshine, humidity and wind speed.

The correlation coefficient between measured evaporation by Piche tube in free air and estimated evapotranspiration by the Penman and Thornthwaite formulae at Alexandria, Tanta, Giza, Minya, Aswan and Kharga oasis have been calculated (Table 5.d). This table shows clearly that all the results of the correlation coefficients are very high and highly significant. These are found to be significant at the 1% level with the exception of the Tanta values. These just are reached the 5% level of significance for the relationship between Piche tube and the Penman Et, Eol and Eo2 equations, but fail to reach the 5% level for the relationship between Piche tube and the Thornthwaite formula (ET).

Table 5.d

The Correlation Coefficients between Measured Evaporation (EP) by Pich Tube in Free Air and Estimated Evaporation and Evapotranspiration by Penman and Thornthwaite Formulae (mm/day)

Variables	Alexandria					Tanta				
	Piche tube EP	Penman			Thorn-thwaite ET	Piche tube EP	Penman			Thorn-thwaite ET
		Et	Eol	Eo2			Et	Eol	Eo2	
Piche EP	1.000	0.771	0.773	0.746	0.711	1.000	0.638	0.582	0.579	0.408
Penman Et		1.000	0.999	0.998	0.915		1.000	0.990	0.991	0.915
Penman Eol			1.000	0.999	0.916			1.000	0.996	0.917
Penman Eo2				1.000	0.919				1.000	0.939
Thornthwaite ET					1.000					1.000

N = 12

Significance level :- 0.576 = 5%   0.658 = 2%   0.708 = 1%

Table 5.d Continued

Variables	Giza					Minya				
	Piche tube EP	Penman			Thorn-thwaite ET	Piche tube EP	Penman			Thorn-thwaite ET
		Et	Eol	Eo2			Et	Eol	Eo2	
Piche EP	1.000	0.920	0.922	0.916	0.834	1.000	0.919	0.915	0.905	0.894
Penman Et		1.000	0.999	0.999	0.967		1.000	0.997	0.992	0.980
Penman Eol			1.000	0.999	0.968			1.000	0.998	0.983
Penman Eo2				1.000	0.969				1.000	0.981
Thornthwaite ET					1.000					1.000

Table 5.d Continued

Variables	Aswan					Kharga				
	Piche tube EP	Penman			Thorn-thwaite ET	Piche tube EP	Penman			Thorn-thwaite ET
		Et	Eo1	Eo2			Et	Eo1	Eo2	
Piche EP	1.000	0.951	0.953	0.951	0.902	1.000	0.955	0.953	0.952	0.907
Penman Et		1.000	0.999	0.999	0.963		1.000	0.999	0.998	0.959
Penman Eo1			1.000	0.999	0.960			1.000	0.999	0.952
Penman Eo2				1.000	0.959				1.000	0.946
Thornthwaite ET					1.000					1.000

CHAPTER 6

Khamsin Condition in Egypt

6.1 - Introduction :-

On the occasion of the Khamsin of April 1st and 2nd, 1922, the Meteorological observer in Cairo remarks in his register :-

April 1st - "The sky is covered with dust. No-one can decide whether it is cloudy or not. This wind is too hot."

April 2nd - "I never met with a day like this, especially the afternoon. The hot wind blows, the sky is turned yellow, the small stones are carried by the wind. Life is hateful on such days." (Sutton, 1923, p. 8; and Conrad, 1943, p. 142).

The word "Khamsin" is applied in Egypt to a local wind which is hot, very dry and dust-laden, and which blows from between south and east. Usually this wind is associated with desert depressions that move almost parallel to the Mediterranean Coast. "Khamsin" is an Arabic word meaning fifty, and it refers to the fifty days after Shem El-Nessim - the Coptic Easter Monday - during which this type of wind was thought to occur. However, it may occur at any time in the period from February to June, and normally lasts from 1 to 10 days, depending on the nature and origin of the two pressure systems concerned.

6.2 - Geographical and local aspects :-

The most important synoptic feature in spring all over the great African desert is the tendency for desert depressions to form. Such depressions generally take a preferred eastward track near the north African coast over the desert or over the southern Mediterranean. In these regions, especially in spring, the pronounced contrast in surface temperatures between the water and the desert air acts as a further factor aiding the genesis and development of these desert depressions. These depressions are associated, in most cases with an active system of strong southerly and southeasterly hot, dry and dust-laden surface winds blowing in front of them. These winds frequently cause intensive temperature and humidity anomalies as well as rising dust and severe duststorms all over north Africa. Because of the great influence of such winds on human activities, they have been known from oldest times and have been given special local names. "Scirrocco" is the general name used for these winds of continental, tropical origin when they blow over the Mediterranean Sea and its coastal fringes.

They are known by the term "Chili" in Morocco, Algeria and Tunisia, "Gibli" in Libya, and "Khamsin" in Egypt. If these depressions move further to the east, similar violent winds blow over the countries of the eastern Mediterranean, Syria, Lebanon, Israel, Jordan, Iraq, Iran and Arabia, where they are called "Simoom". This means that the air is unhealthy or poisonous. In spite of the different names, these winds have the same character and origin in the south and east Mediterranean regions; i.e., the desert, especially the sand desert.

This is the source region of the dry air masses of high temperature. These winds are caused by the depressions which move either along the northern coast of Africa or cross the deserts in southwesterly to northeasterly directions. Hot dry air masses from the interior of the desert are transported northward and westward associated with the frontal systems of the depressions.

6.3 - Khamsin depressions :-

Khamsin depressions travel from west to east, to the south of, and roughly parallel with the north African Coast. As a rule, the more vigorous depressions usually originate far to the west of Egypt, while shallow depressions form over Egypt or slightly to the west of it.

For many years meteorologists mainly from Egypt have published some works describing these Khamsin depressions, discussing some of their structural features and tracks as well as suggesting possible atmospheric processes leading to their genesis. The earliest studies were made by Sutton (1923). He distinguished two types of Khamsin depressions. These were a desert type which follows a desert track along the African coast, and a sea type which originates in the Atlantic and usually travels along the African coast and over the Mediterranean Sea. He gave the number of Khamsin depressions as 185 in the 16 year period from 1907 to 1922. These were distributed as follows : February 41; March 44; April 48; May 34; and June 18. He also found that the sea depressions were rather more frequent : 98 in number compared with

87 desert depressions. During February all the Khamsin depressions travelled along the Mediterranean Sea, but as spring approaches the number of depressions coming from the Sahara increases. The sea depressions generally have to break through a system of high pressure over the central Mediterranean.

Sutton (1923) analysed the movement of a desert depression which occurred on 1st - 2nd April, 1922. In this he mapped the progress of the depression, the track of its centre, and the changes of various meteorological elements during the approach of the depression at some stations in the eastern Mediterranean. Sutton also assumed that the low pressure in the south (the Sudan low) is not in any way connected with the cyclonic depression coming from the Sahara, but is part of the system of low pressure which prevails over the Sudan with little modifications from October to May (Sutton, 1923, p. 7).

El-Fandy (1940) assumed that the modifications of the Sudan low are directly responsible for the formation of Khamsin disturbances. He distinguished between two types of Khamsin depressions, those of track C (expanding from south-west to north-east across Egypt) and of track B (parallel to the African coast and extending from south of the mountains of Tunisia and Algeria through the Sahara to Egypt). The two tracks are shown in Figure 6.1. He also assumed that depressions of track C form over Egypt on the surface of separation of the cold north-easterly winds and the warm south-easterly winds. The north-easterly winds blow along the southern edge of a high

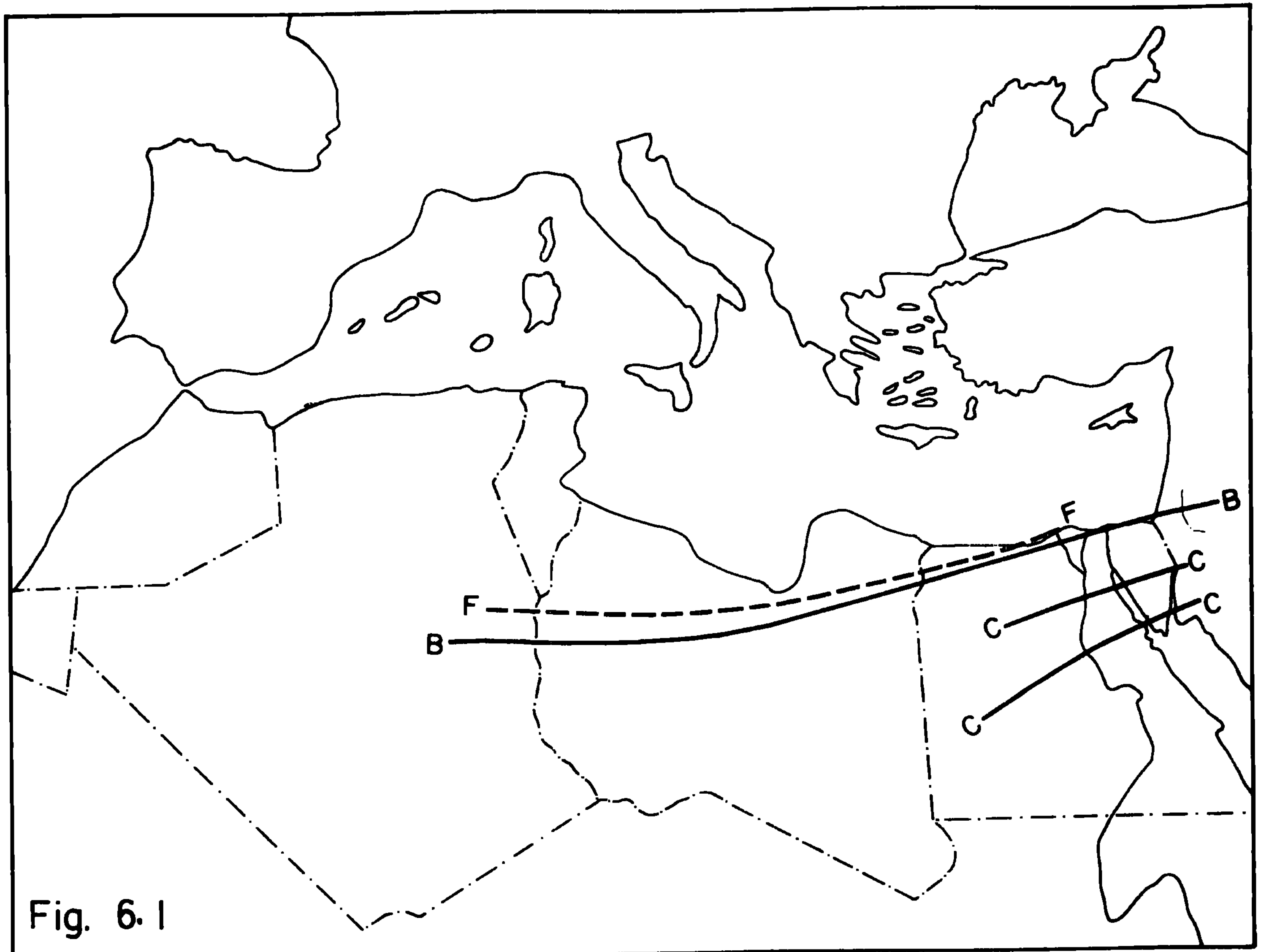


Fig. 6.1

Tracks followed by Khamsin depressions and surface F, as given by EL-Fandy pressure situated somewhere north of Egypt, and the south-easterly winds blow around the Sudan low. The surface of separation is called "F" and is located south of the African coast crossing Lower Egypt between Alexandria and Mersa Matruh (Fig. 6.1).

The surface or zone called "F" by El-Fandy (1940, p. 330) has been mentioned above as occupying the latitude of the northern Red Sea in the Spring, but it suffers large displacements. Its existence is marked by differences of humidity and of surface temperature. The Mediterranean front develops when the temperature distribution is favourable. This happens only in the cold season and so this front disappears in summer. Usually this front is located to the north of the Mediterranean separating the cold winter air over Europe and the warm air over the Mediterranean and Africa. However, this front may sometimes move southwards and reach the northern part of Egypt, (see, Beaumont et aL, 1976, p. 52).

In their work on Khamsin depressions, Sutton (1923), and El-Fandy (1940) both described two types, originating over the desert and the sea respectively. Ahamed (1949) and Abdel-Salam and Sowelim (1967A); classified Khamsin depressions into three types; according to their tracks across Egypt and the eastern part of the Western Desert. These were known as sea, desert and coastal depressions. Banoub (1970) and Tantawy (1969), have also studied Khamsin depressions and described only one type originating over the desert.

6.4 - Desert depressions :-

Desert depressions which produce the most typical Khamsin conditions form usually to the south of the Atlas mountains either when a cold north-westerly or a north-easterly outbreak of air moves towards the Atlas range. The depressions give rise to "Scirrocco" or "Khamsin" winds are, therefore, called "Scirrocco" or "Khamsin" depressions. These depressions form most frequently in spring when the Mediterranean frontal zone has moved well south into the Western Desert. During this transitional period (February - June), the sea temperatures are still rather low in comparison with those of the rapidly heated land and the Mediterranean front is often very sharply defined.

In addition the NE to easterly winds which usually become established at this time over the western part of north Africa increase the cyclonic circulation around the depressions. During this season and to a lesser extent in autumn we have the greatest desert depression activity and they are at that time perhaps the most important type of Mediterranean depression. Desert depressions develop most readily when polar or arctic air stream from NW or NE flows in their rear. When this happens there is a corresponding induced flow of continental Tropical (Tc) air northwards, often bringing dust with it to give the duststorms which are most common over north Africa in spring (see Abdel-Salam and Sowelim, 1967A and 1967B, and Banoub, 1970).

A desert depression generally begins to move eastwards along the Mediterranean front. If there is pronounced northward steering the depression moves north-eastwards to Europe before reaching the eastern Mediterranean. If there is a high pressure established over the Balkans and the Black Sea, the desert depression will keep near the African coast either over the sea or over land affecting the Arab Republic of Egypt. This is always maintained if there is a continued flow of polar air behind the depression. There may be frontal rain ahead of and to the north of the depression and showers in the polar air. This is most likely to occur with a desert depression in late winter and early spring.

6.5 - Statistical analyses :-

Attempts have been made by the author to investigate the tracks of Khamsin depressions for the four year period from 1970 to 1973. The tracks of each depression have been traced by drawing a line from the centre of the depression and following the movement of each depression. These depression tracks were derived from the Daily Weather Reports issued by the Meteorological Department in Cairo, Egypt. The results of the analysis are shown in Figures 6.2 to 6.6. It is noticed that during the four years there were 24 depressions in February; 23 in March; 18 in April; 18 in May and only one depression in June 1971. The tracks of the Khamsin depressions show clearly that :-

1. Depressions originating over the Atlantic

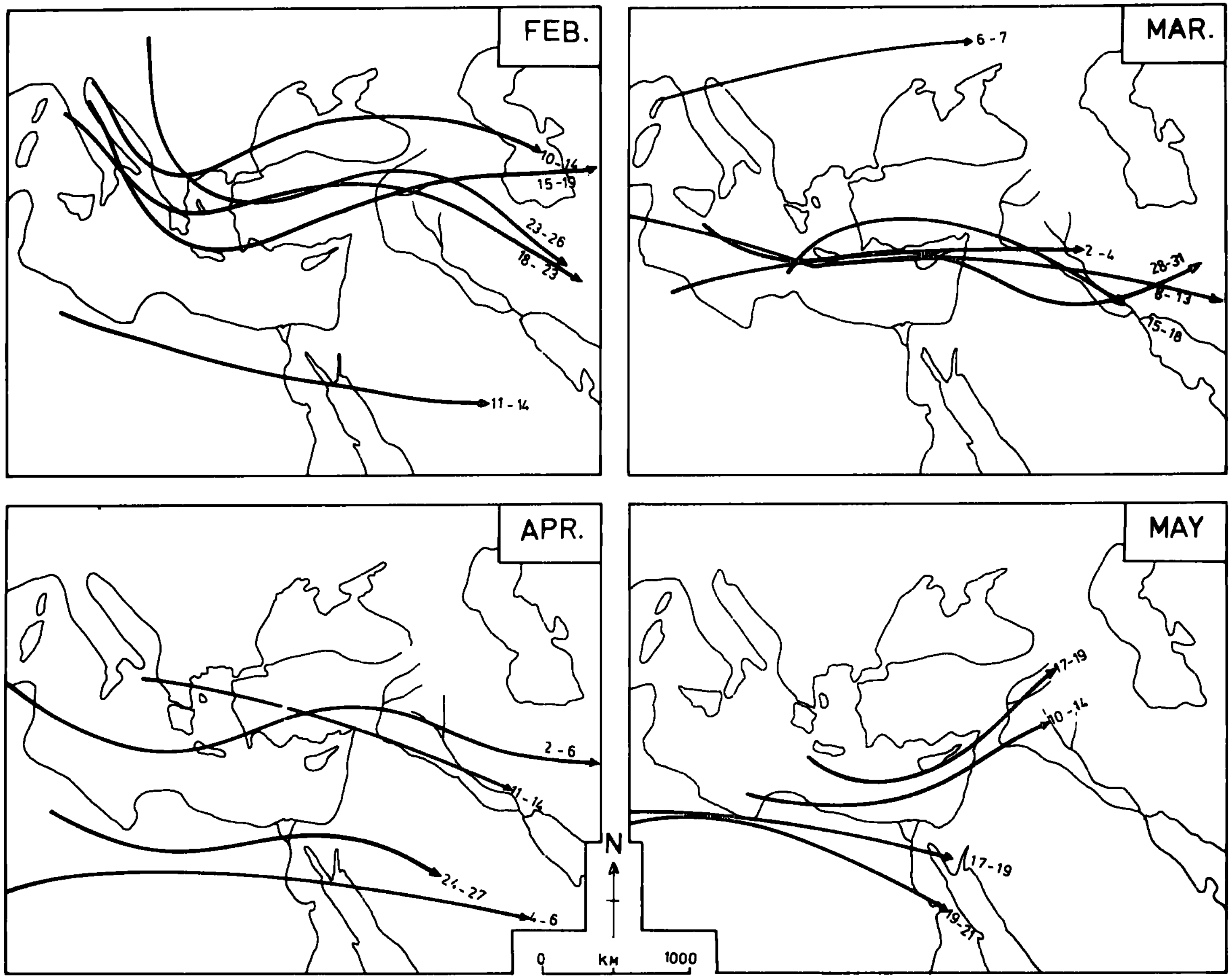


Fig. 6.2 TRACKS OF KHAMSIN DEPRESSIONS IN 1970

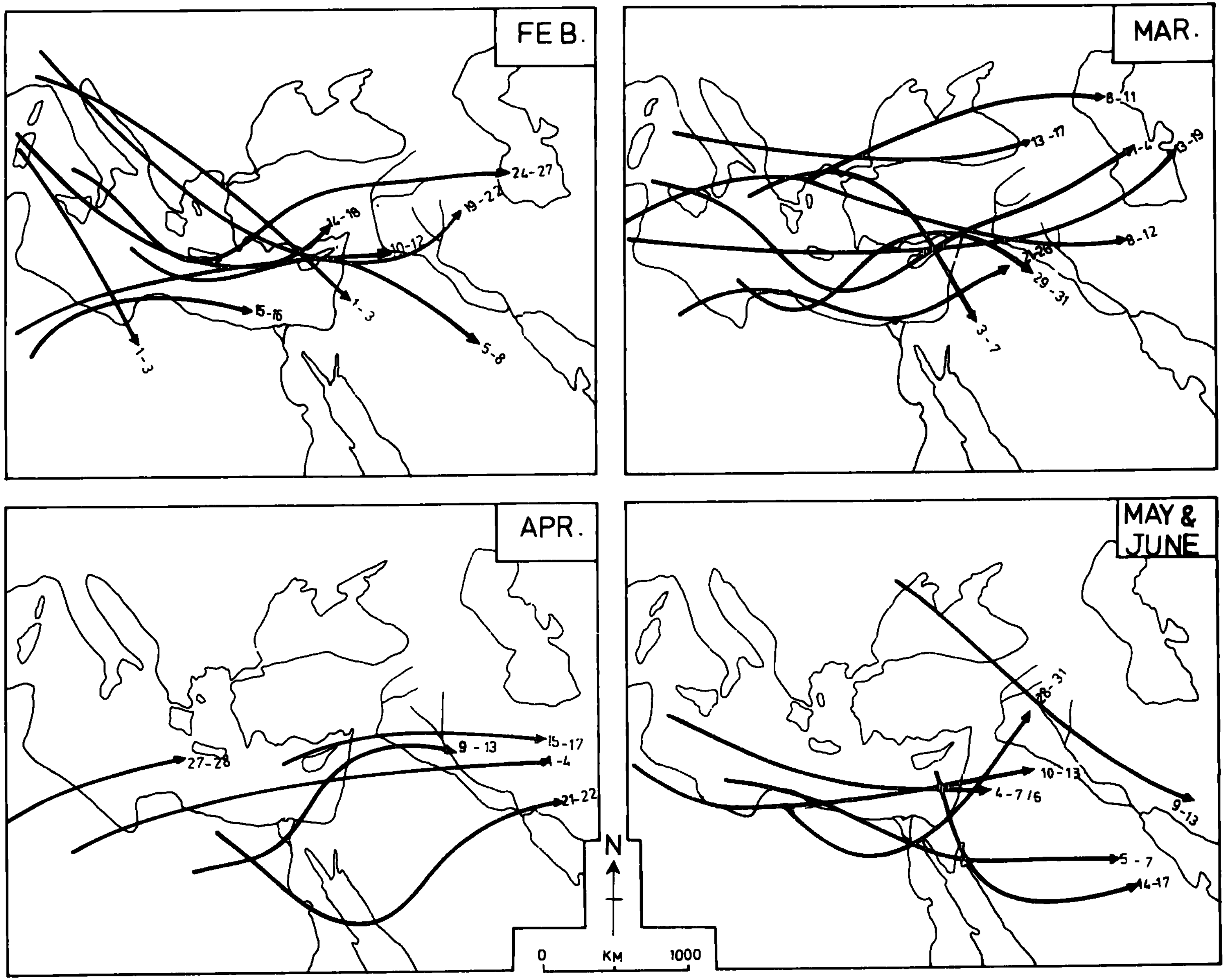


Fig 6.3 TRACKS OF KHAMSIN DEPRESSIONS IN 1971

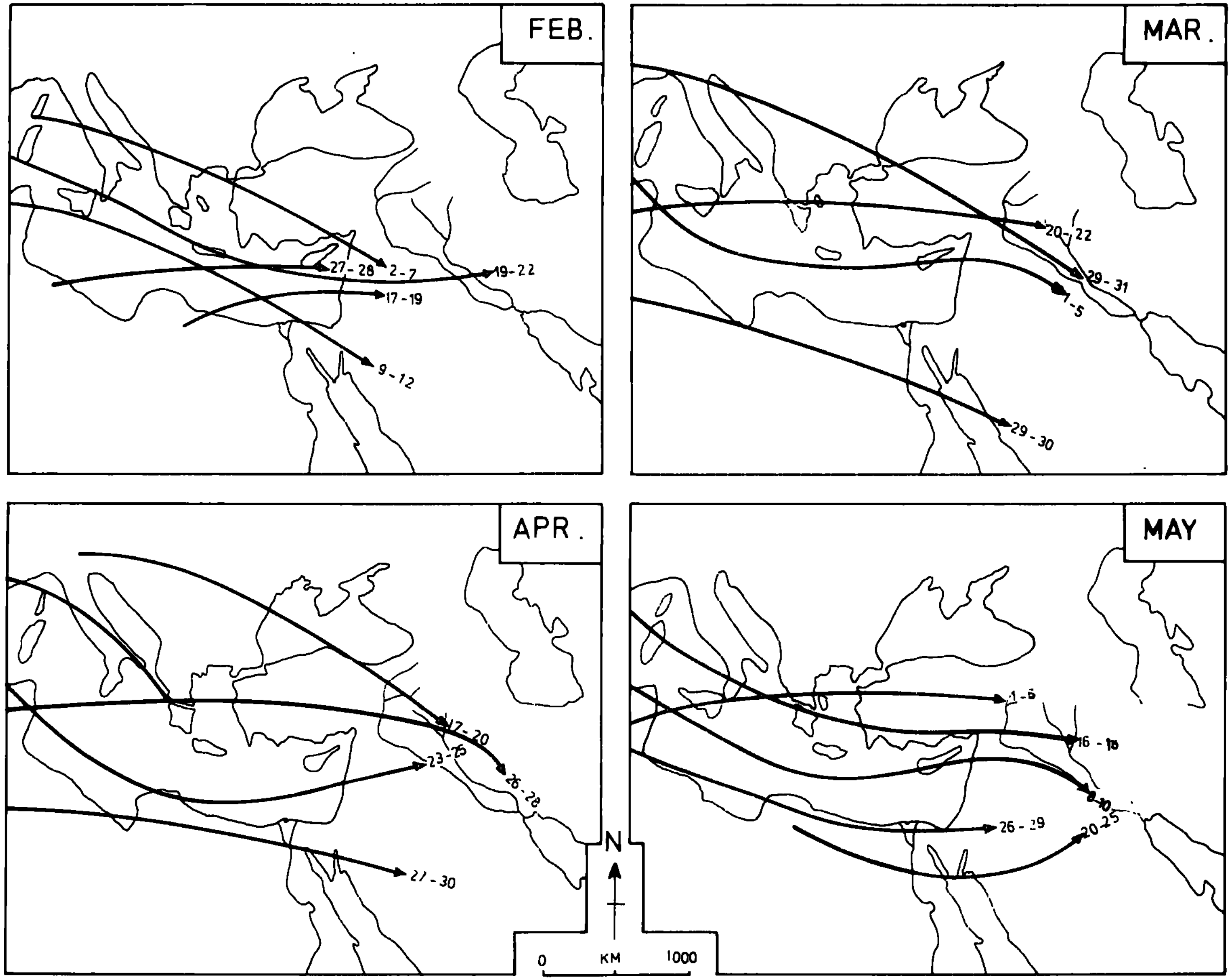


Fig. 6.4 TRACKS OF KHAMSIN DEPRESSIONS IN 1972

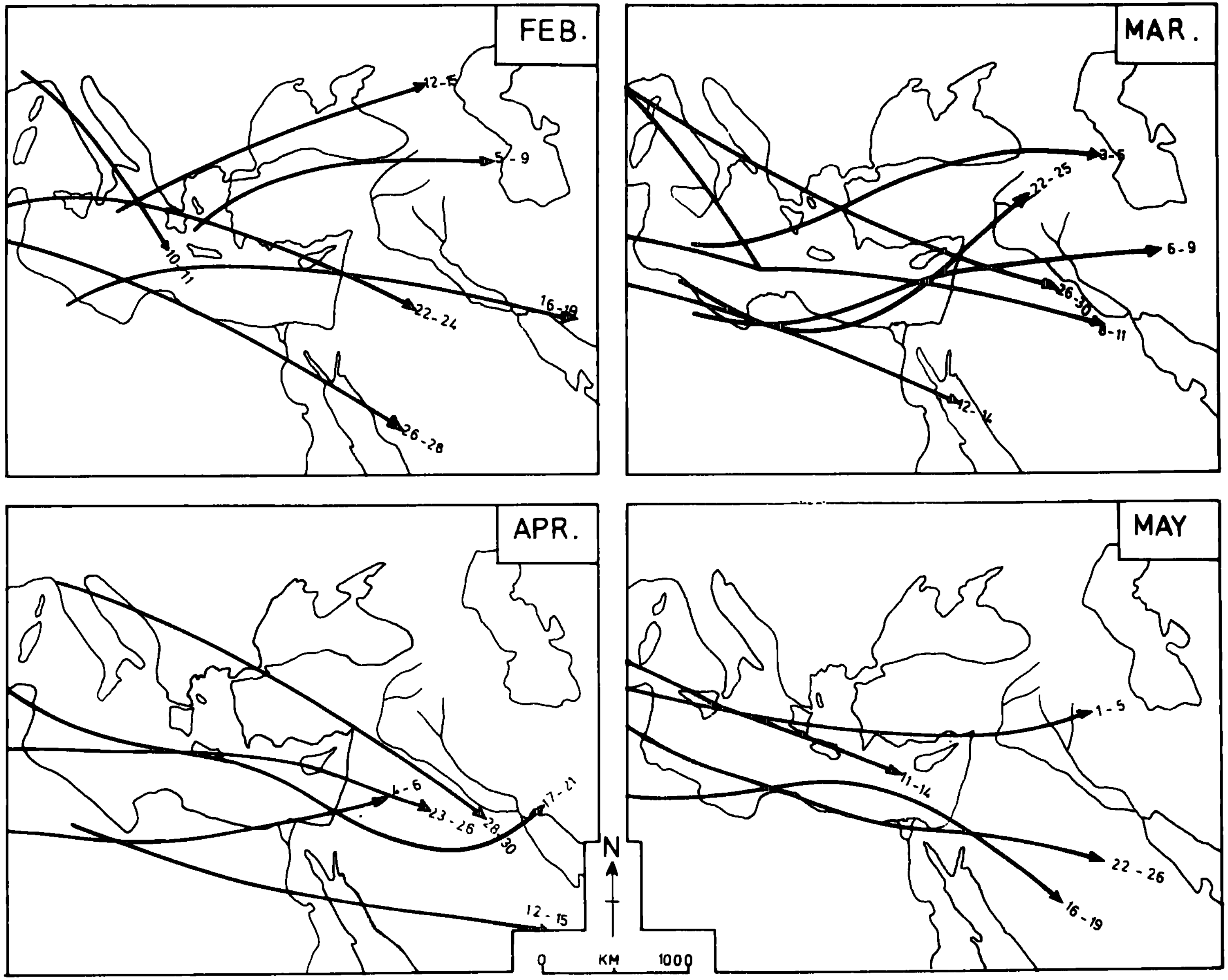


Fig. 6.5 TRACKS OF KHAMSIN DEPRESSIONS IN 1973

travel with their centres over the Mediterranean Sea close to the north African coast until they reach Egypt. They follow more than one track, i.e., sea and coastal tracks or coastal and desert tracks. Overall a wide variety of tracks over the Mediterranean Sea are noticed.

2. Depressions which form to the south of the Atlas mountains, sometimes follow more than one track. Some of these have their tracks entirely across the Mediterranean Sea, while others move entirely over land. When these depressions reach Egypt they bring Khamsin conditions.

Both the depressions which form to the south of the Atlas mountains and those which originate over the Atlantic affect the climate of Egypt. The former depressions usually produce the most intense Khamsin conditions.

6.6. - Khamsin weather conditions :-

Khamsin weather conditions in Egypt mostly take place in association with the passage of desert depressions. The main weather features which give rise to Khamsin weather conditions are the excessively high surface temperatures and the extremely low humidities, associated with the invasion of S or SE winds of continental Tropical (Tc) origin. There are other factors which are not sufficient to be called Khamsin weather conditions but which may be associated with them on some occasions. These include a strengthening of the S and SE winds which

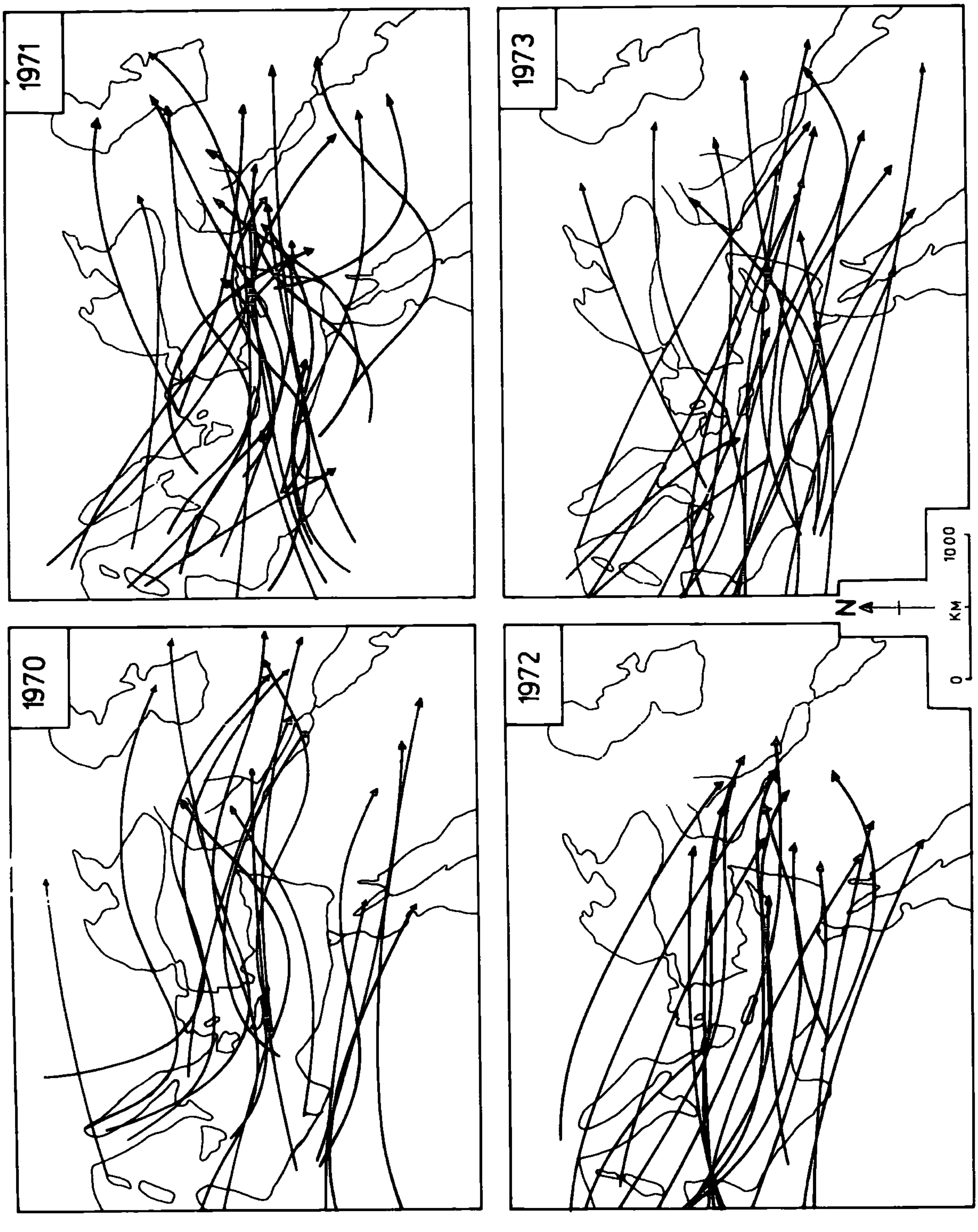


Fig. 6.6 KHAMSIN DEPRESSION TRACKS

produce rising dust and duststorms and the occurrence of active cloud formation, rainfall and thunderstorms.

In spring continental Tropical (Tc) air over its source region in Africa is very hot and dry. The surface air temperature may be as high as 45°C and the relative humidity as low as 15%. Khamsin winds always have a long fetch over the desert of north Africa. In spring the temperature of a continental Tropical (Tc) air stream continues to rise as long as it remains over the desert and reaches its maximum temperature near the Mediterranean coast.

The temperature rises and the decreases of relative humidity with the southerly stream are the main phenomena which occur on every Khamsin occasion. Consequently the first step in this investigation is to find typical values of maximum temperatures and relative humidities during the Khamsin period (February - June). For this purpose the data for the daily maximum temperatures and relative humidities for nine stations during the years 1970 and 1971, and three stations during the years 1972 and 1973, have been plotted (Figs. 6.7 - 6.10). These figures show clearly that large and sudden changes in surface air temperatures to produce values in excess of 42°C, occurred when Khamsin winds were suddenly followed by a hot front. Drops of the order of 10°C sometimes occurred when Khamsin winds were followed by a cold front. The most marked changes of humidity occurred with the passage of cold fronts in Khamsin conditions during the transitional period from February to June. Sudden changes in relative humidity values may also be noticed. A value of 15% was

Fig. 6.7 MAXIMUM TEMPERATURE (°C) 1970-1971

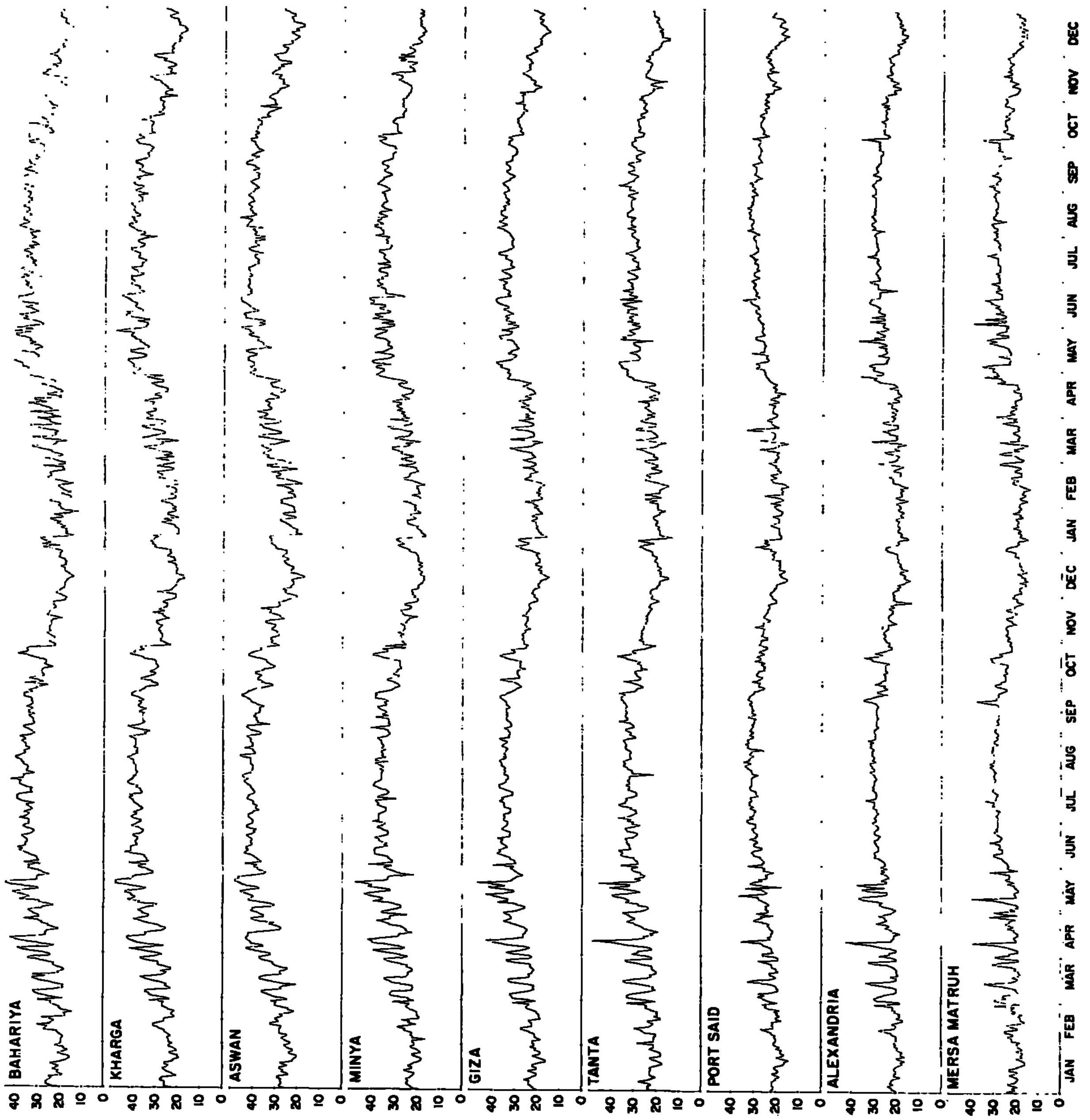


Fig. 6.8

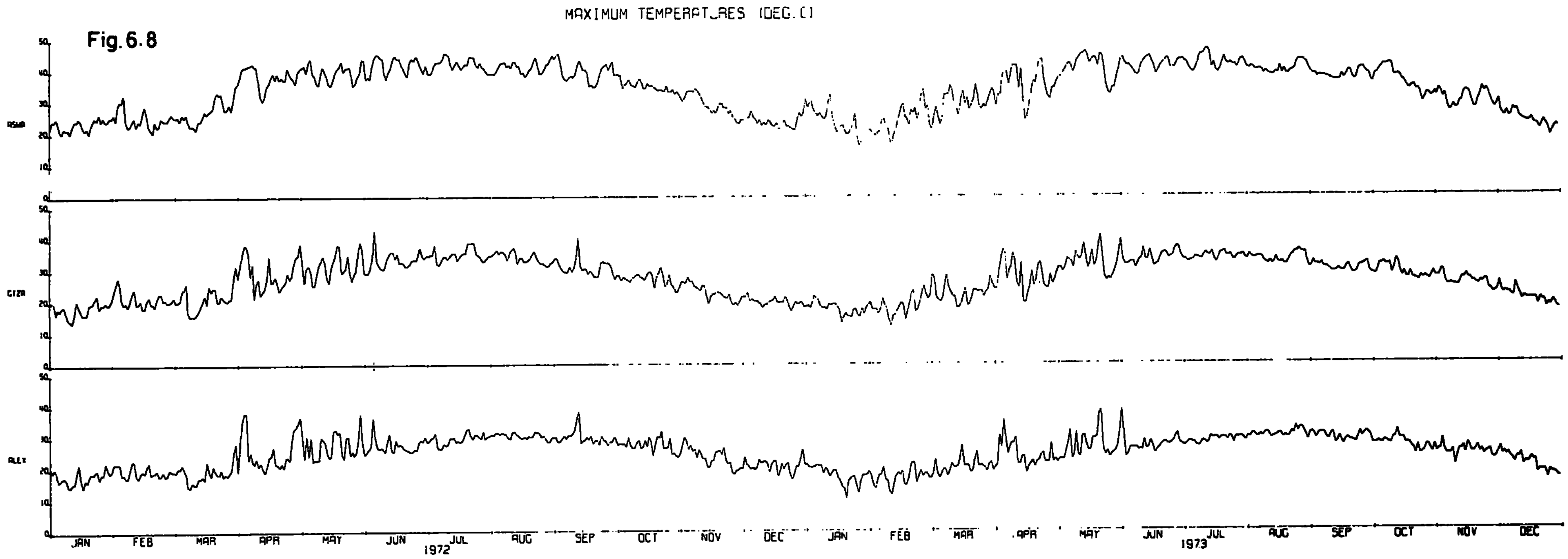

MAXIMUM TEMPERAT_RES (DEG.C)
ASWA
GIZA
ALEX
50
40
30
20
10
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
1972
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
1973
AUG
SEP
OCT
NOV
DEC

Fig 6.9 RELATIVE HUMIDITY (%) 1970-1971

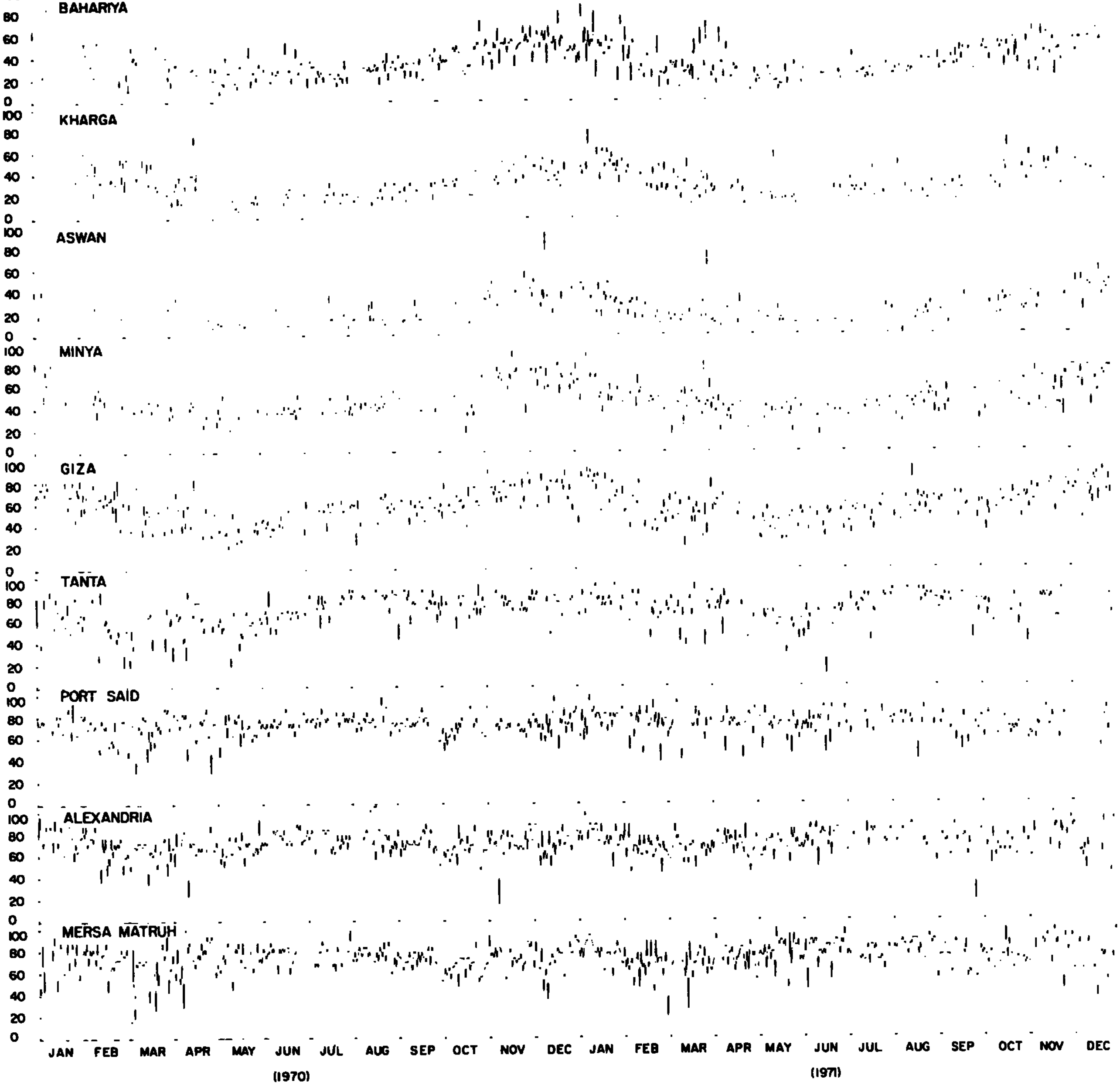
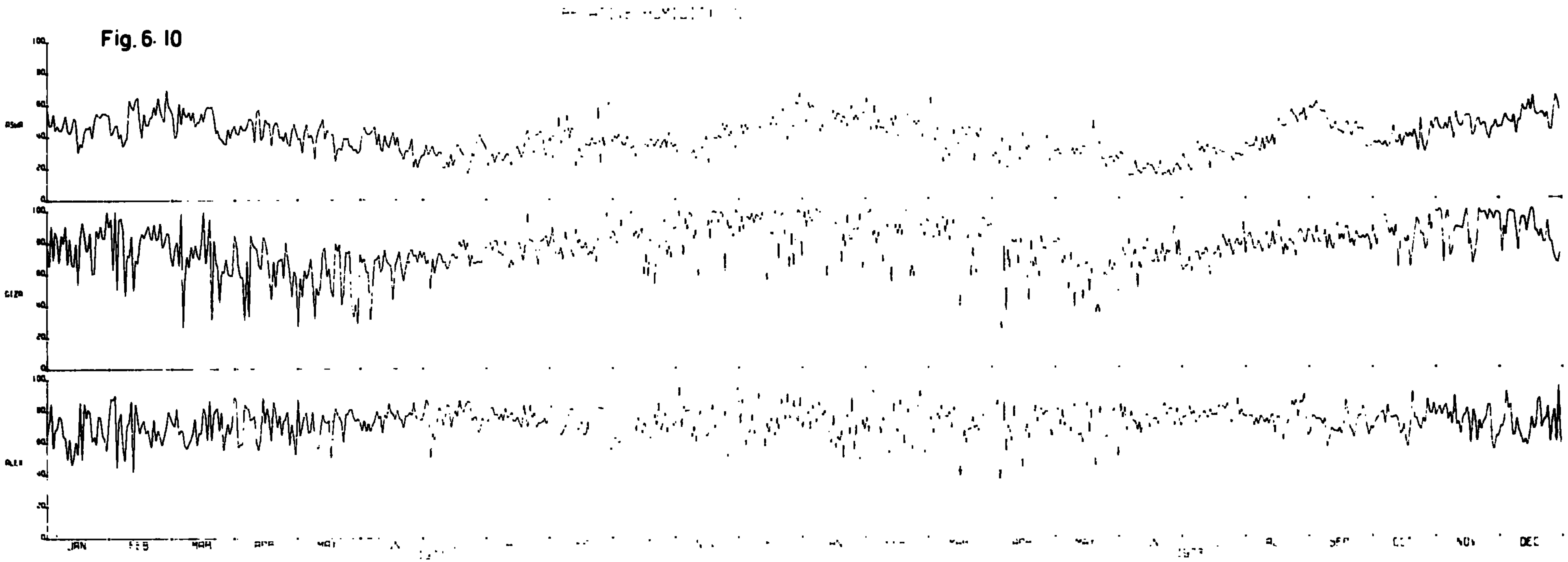


Fig. 6.10



recorded at Aswan during the passage of the hot front, while 90% was registered at Mersa-Matruh and Alexandria, during the passage of the cold front. It is also seen that the wind blows mainly from between east and south directions during the Khamsin period (February - June) (Fig. 6.11).

Analyses have been made to investigate the actual number of times that maximum temperatures and relative humidities either increase above or fall below certain values during the period of study. The results of this investigation are illustrated (Table 6.a). It can be seen that during the Khamsin period (February - June) there are major changes in temperatures especially of between 5-8°C and > 8°C, and a high frequency of humidity values below 30% especially at inland stations. The coastal stations such as Mersa-Matruh, Alexandria and Port Said had the lowest frequency of relative humidity below 30%, whilst the reverse was the case for the inland stations especially Bahariya, Kharga and Aswan stations, which had the highest number of such observations during the Khamsin period (Table 6.a).

The second investigation during the same period has been carried out by the author to find the month and the date in which sudden changes in temperature ≥ 6°C occurred. The results of this analysis are shown in Table 6.b. It is noticed that the main change in temperature values occurred in the Khamsin season (February - June). It can also be seen that the frequency distribution of the sudden change in temperatures is much higher

Wind Direction and Wind Speed at Giza (1970-1971)

Fig. 6.11

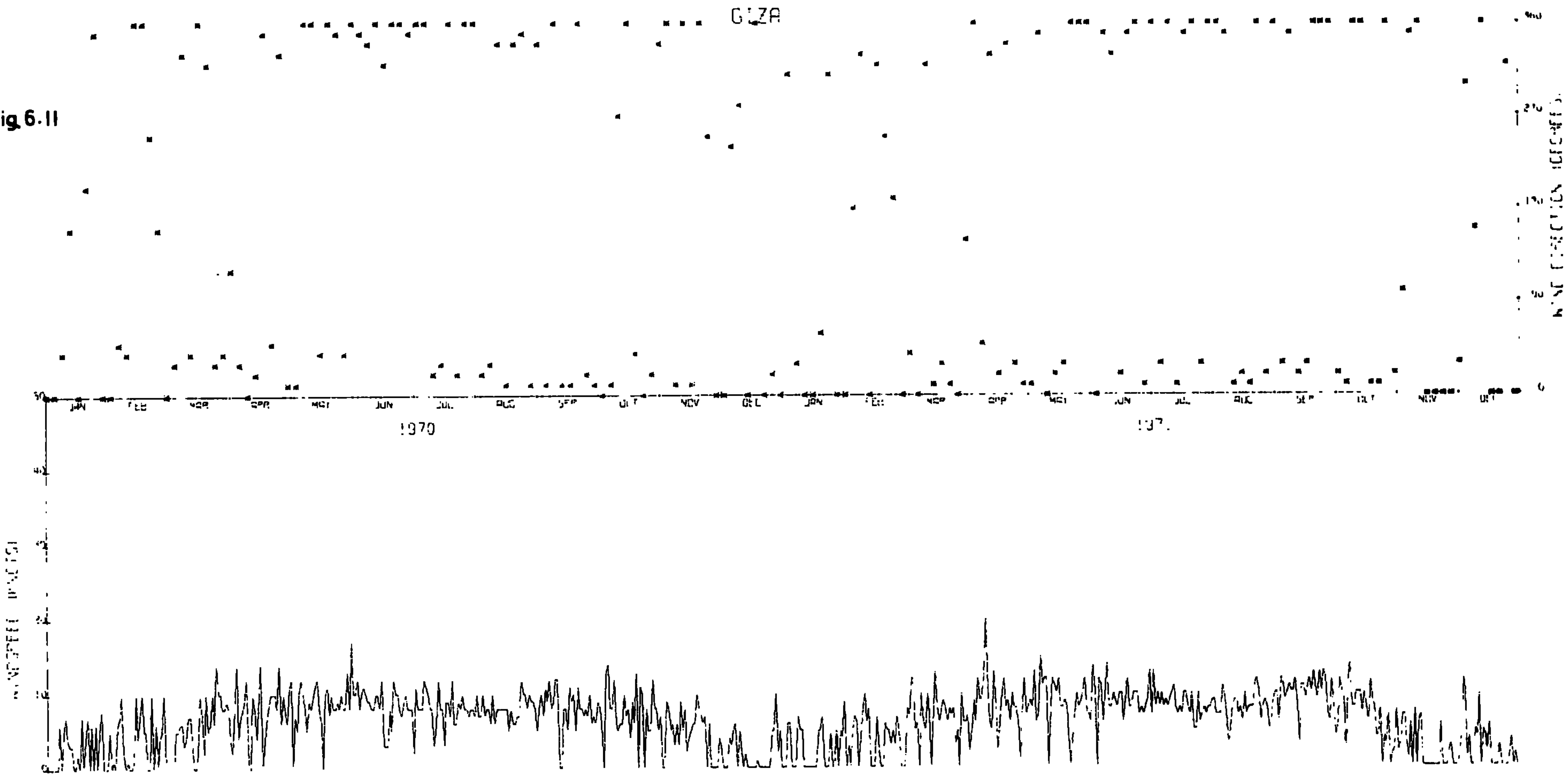


Table (6.a)

```
C******* HEAT WAVES IN 1970 **************

STAT   MONTH    3-5   5-8   >8   HUMD<30
====   =====    ===   ===   ==   ========

MERS    JAN     11     0     0      0
MERS    FEB      5     2     0      0
MERS    MAR      9     3     3      2
MERS    APR      7     3     3      0
MERS    MAY      9     1     5      0
MERS    JUN      3     0     0      0
MERS    JUL      2     0     0      0
MERS    AUG      0     0     0      0
MERS    SEP      2     0     1      0
MERS    OCT      5     1     0      0
MERS    NOV      5     0     0      0
MERS    DEC      4     0     0      0
```

```
STAT   MONTH    3-5   5-8   >8   HUMD<30
====   =====    ===   ===   ==   ========

ALEX    JAN      5     0     0      0
ALEX    FEB      5     1     0      0
ALEX    MAR      6     1     4      0
ALEX    APR     10     1     2      1
ALEX    MAY      7     1     5      0
ALEX    JUN      1     0     0      0
ALEX    JUL      2     0     0      0
ALEX    AUG      3     0     0      0
ALEX    SEP      5     0     0      0
ALEX    OCT      7     1     0      0
ALEX    NOV      2     1     1      0
ALEX    DEC      3     0     0      0
```

```
STAT   MONTH    3-5   5-8   >8   HUMD<30
====   =====    ===   ===   ==   ========

PORT    JAN      6     0     0      0
PORT    FEB      5     1     0      0
PORT    MAR      8     2     3      1
PORT    APR      4     2     2      0
PORT    MAY      5     0     5      0
PORT    JUN      5     1     1      0
PORT    JUL      2     0     0      0
PORT    AUG      3     2     0      0
PORT    SEP      1     0     0      0
PORT    OCT      8     0     0      0
PORT    NOV      5     0     0      0
PORT    DEC      2     0     0      0
```

```
STAT   MONTH    3-5   5-8   >8   HUMD<30
====   =====    ===   ===   ==   ========

PHAR    JAN      7     1     0      1
PHAR    FEB      4     2     1      2
PHAR    MAR      9     4     4     10
PHAR    APR      9     4     2      7
PHAR    MAY     11     4     2     14
PHAR    JUN      4     1     1      6
PHAR    JUL      8     2     0      8
PHAR    AUG      2     0     0      0
PHAR    SEP      8     0     0      2
PHAR    OCT      8     0     2      4
PHAR    NOV      4     0     0      0
PHAR    DEC      3     0     0      0
```

```
STAT   MONTH    3-5   5-8   >8   HUMD<30
====   =====    ===   ===   ==   ========

TANT    JAN      5     0     0      0
TANT    FEB      4     2     2      1
TANT    MAR     12     3     2      4
TANT    APR     11     3     2      2
TANT    MAY      8     2     5      0
TANT    JUN      6     1     2      0
TANT    JUL      6     1     0      0
TANT    AUG      1     0     2      0
TANT    SEP      5     1     0      0
TANT    OCT     10     2     0      0
TANT    NOV      0     0     0      0
TANT    DEC      2     0     0      0
```

```
STAT   MONTH    3-5   5-8   >8   HUMD<30
====   =====    ===   ===   ==   ========

GIZA    JAN      6     0     0      0
GIZA    FEB      3     1     0      0
GIZA    MAR      6     2     3      1
GIZA    APR      7     4     1      1
GIZA    MAY      9     2     5      6
GIZA    JUN      1     1     2      0
GIZA    JUL      3     0     0      0
GIZA    AUG      2     0     0      0
GIZA    SEP      1     0     0      0
GIZA    OCT      7     1     1      0
GIZA    NOV      2     0     0      0
GIZA    DEC      2     0     0      0
```

```
STAT   MONTH    3-5   5-8   >8   HUMD<30
====   =====    ===   ===   ==   ========

KHAR    JAN      5     1     0      0
KHAR    FEB      3     0     0      1
KHAR    MAR     10     1     3      8
KHAR    APR     11     3     2     12
KHAR    MAY      9     3     1     13
KHAR    JUN      5     1     2      8
KHAR    JUL      2     1     0      3
KHAR    AUG      4     0     0      4
KHAR    SEP      8     0     0      7
KHAR    OCT      8     0     1      7
KHAR    NOV      4     1     0      2
KHAR    DEC      6     2     0      1
```

```
STAT   MONTH    3-5   5-8   >8   HUMD<30
====   =====    ===   ===   ==   ========

MINY    JAN      4     0     0      0
MINY    FEB      5     3     1      1
MINY    MAR      4     2     4      1
MINY    APR      9     5     3      4
MINY    MAY     11     2     3      6
MINY    JUN      5     0     2      1
MINY    JUL      3     0     2      1
MINY    AUG      2     2     0      1
MINY    SEP      5     3     1      0
MINY    OCT      8     0     3      2
MINY    NOV      6     1     0      0
MINY    DEC      2     0     0      0
```

```
STAT   MONTH    3-5   5-8   >8   HUMD<30
====   =====    ===   ===   ==   ========

ASWN    JAN      6     1     0      3
ASWN    FEB      7     0     0      5
ASWN    MAR      7     2     3     12
ASWN    APR      7     4     1     12
ASWN    MAY      6     2     1      9
ASWN    JUN      3     1     1      5
ASWN    JUL      1     0     0      1
ASWN    AUG      5     2     0      6
ASWN    SEP      3     1     1      4
ASWN    OCT      8     1     0      9
ASWN    NOV      5     1     1      6
ASWN    DEC      4     0     0      1
EXECUTION TERMINATED
```

MERS = MERSA MATRUH
PORT = PORT SAID
TANT = TANTA
MINY = MINYA
ALEX = ALEXANDRIA
PHAR = BAHARIYA
KHAR = KHARGA
ASWN = ASWAN

Table(6-a) continued

```
C***** HEAT WAVES IN 1971 *********

STAT  MONTH  3-5  5-8  >8  HUMD<30    STAT  MONTH  3-5  5-8  >8  HUMD<30    STAT  MONTH  3-5  5-8  >8  HUMD<30
====  =====  ===  ===  ==  ========    ====  =====  ===  ===  ==  ========    ====  =====  ===  ===  ==  ========

MERS  JAN      9    0   0     0       ALEX  JAN      4    0   0     0       PORT  JAN      3    0   2     0
MERS  FEB     10    0   0     0       ALEX  FEB      9    1   0     0       PORT  FEB      8    0   1     0
MERS  MAR      5    3   3     1       ALEX  MAR     11    2   2     0       PORT  MAR      7    3   3     0
MERS  APR      7    1   3     0       ALEX  APR      4    2   2     0       PORT  APR      6    0   0     0
MERS  MAY      8    4   1     0       ALEX  MAY     10    1   2     0       PORT  MAY      5    1   1     0
MERS  JUN      4    0   5     0       ALEX  JUN      1    4   2     0       PORT  JUN      1    1   0     0
MERS  JUL      3    0   0     0       ALEX  JUL      3    0   0     0       PORT  JUL      0    0   0     0
MERS  AUG      2    0   0     0       ALEX  AUG      1    1   0     0       PORT  AUG      4    0   0     0
MERS  SEP      5    0   0     0       ALEX  SEP      1    0   0     0       PORT  SEP      3    0   0     0
MERS  OCT      0    1   1     0       ALEX  OCT      3    1   1     0       PORT  OCT      2    1   0     0
MERS  NOV      3    0   0     0       ALEX  NOV      4    0   0     0       PORT  NOV      5    0   0     0
MERS  DEC      3    0   0     0       ALEX  DEC      2    0   0     0       PORT  DEC      3    0   0     0


STAT  MONTH  3-5  5-8  >8  HUMD<30    STAT  MONTH  3-5  5-8  >8  HUMD<30    STAT  MONTH  3-5  5-8  >8  HUMD<30
====  =====  ===  ===  ==  ========    ====  =====  ===  ===  ==  ========    ====  =====  ===  ===  ==  ========

PHAR  JAN      7    2   4     1       TANT  JAN      6    0   2     0       GIZA  JAN      3    1   1     0
PHAR  FEB      8    1   3     3       TANT  FEB     10    2   1     0       GIZA  FEB      6    1   0     0
PHAR  MAR      9    2   6    11       TANT  MAR      5    4   3     0       GIZA  MAR     10    2   4     3
PHAR  APR     11    2   4    12       TANT  APR      8    0   1     0       GIZA  APR     10    0   0     1
PHAR  MAY      7    6   3    15       TANT  MAY      5    0   3     1       GIZA  MAY      9    0   0     1
PHAR  JUN      7    2   0     8       TANT  JUN     12    2   1     1       GIZA  JUN      6    0   0     0
PHAR  JUL     10    0   0    10       TANT  JUL      4    0   0     0       GIZA  JUL      5    0   0     0
PHAR  AUG      5    0   0     4       TANT  AUG      4    0   0     0       GIZA  AUG      2    0   0     0
PHAR  SEP      5    0   0     1       TANT  SEP      3    1   0     0       GIZA  SEP      1    0   0     0
PHAR  OCT      5    0   3     2       TANT  OCT      2    0   0     0       GIZA  OCT      4    0   0     0
PHAR  NOV      6    0   0     1       TANT  NOV      3    2   0     0       GIZA  NOV      2    1   0     0
PHAR  DEC      0    0   0     0       TANT  DEC      2    0   0     0       GIZA  DEC      0    0   0     0


STAT  MONTH  3-5  5-8  >8  HUMD<30    STAT  MONTH  3-5  5-8  >8  HUMD<30    STAT  MONTH  3-5  5-8  >8  HUMD<30
====  =====  ===  ===  ==  ========    ====  =====  ===  ===  ==  ========    ====  =====  ===  ===  ==  ========

KHAR  JAN      7    1   1     0       MINY  JAN      6    0   1     0       ASWN  JAN      3    2   1     1
KHAR  FEB     11    1   0     4       MINY  FEB      9    3   0     0       ASWN  FEB      8    4   2    13
KHAR  MAR     10    3   4    11       MINY  MAR     10    3   3     0       ASWN  MAR     10    1   2    11
KHAR  APR      9    1   2    10       MINY  APR     12    0   0     5       ASWN  APR      7    2   0     6
KHAR  MAY      9    1   1    10       MINY  MAY      5    4   1     4       ASWN  MAY      7    0   2     9
KHAR  JUN      5    2   1     8       MINY  JUN      8    5   1     6       ASWN  JUN      5    1   0     6
KHAR  JUL      4    1   1     5       MINY  JUL      5    3   0     0       ASWN  JUL      7    0   0     7
KHAR  AUG      5    0   0     4       MINY  AUG      5    0   0     1       ASWN  AUG      2    1   1     4
KHAR  SEP      5    0   0     4       MINY  SEP      1    0   0     0       ASWN  SEP      4    0   0     4
KHAR  OCT      5    0   1     3       MINY  OCT      4    0   1     0       ASWN  OCT      2    0   2     3
KHAR  NOV      6    1   2     4       MINY  NOV      4    1   3     1       ASWN  NOV      7    0   0     4
KHAR  DEC      3    0   0     1       MINY  DEC      1    0   0     0       ASWN  DEC      3    0   0     1
                                                                            EXECUTION TERMINATED
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Table(6·a) continued

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                   C****** HEAT WAVES IN 1972  **********

STAT   MONTH   3-5  5-8  >8  HUMD<30    STAT   MONTH   3-5  5-8  >8  HUMD<30    STAT   MONTH   3-5  5-8  >8  HUMD<30
====   =====   ===  ===  ==  ========   ====   =====   ===  ===  ==  ========   ====   =====   ===  ===  ==  ========

ALEX   JAN       0    0   0        0    GIZA   JAN       0    0   0        0    ASWN   JAN       3    0   0        0
ALEX   FEB       4    2   0        1    GIZA   FEB       4    1   0        1    ASWN   FEB       9    0   0        9
ALEX   MAR       4    4   1        4    GIZA   MAR       9    4   0        2    ASWN   MAR      10    1   1       12
ALEX   APR       7    6   1        0    GIZA   APR       6    6   3        3    ASWN   APR       6    0   4        9
ALEX   MAY       5    2   1        1    GIZA   MAY       4    3   1        2    ASWN   MAY       5    2   1       12
ALEX   JUN       3    1   1        0    GIZA   JUN       2    1   2        4    ASWN   JUN       4    0   0        4
ALEX   JUL       3    1   0        1    GIZA   JUL       1    0   0        0    ASWN   JUL       7    0   0        7
ALEX   AUG       2    2   0        0    GIZA   AUG       1    0   0        0    ASWN   AUG       3    1   0        4
ALEX   SEP       0    0   0        0    GIZA   SEP       4    0   0        0    ASWN   SEP       2    1   0        2
ALEX   OCT       2    1   1        0    GIZA   OCT       5    1   1        0    ASWN   OCT       1    1   0        2
ALEX   NOV       2    0   0        0    GIZA   NOV       3    0   0        0    ASWN   NOV       3    0   0        2
ALEX   DEC       3    1   0        0    GIZA   DEC       0    0   0        0    ASWN   DEC       6    1   0        2
                                                                                EXECUTION TERMINATED


                   C****** HEAT WAVES IN 1973  **********


STAT   MONTH   3-5  5-8  >8  HUMD<30    STAT   MONTH   3-5  5-8  >8  HUMD<30    STAT   MONTH   3-5  5-8  >8  HUMD<30
====   =====   ===  ===  ==  ========   ====   =====   ===  ===  ==  ========   ====   =====   ===  ===  ==  ========

ALEX   JAN       1    0   0        0    GIZA   JAN       2    0   0        0    ASWN   JAN       4    2   0        0
ALEX   FEB       2    2   2        0    GIZA   FEB       8    1   0        1    ASWN   FEB       6    2   1        0
ALEX   MAR       3    4   0        0    GIZA   MAR       8    2   0        0    ASWN   MAR       9    3   1        4
ALEX   APR       9    3   0        0    GIZA   APR       6    3   3        0    ASWN   APR       5    3   1        3
ALEX   MAY       6    1   0        0    GIZA   MAY       1    2   2        0    ASWN   MAY       5    3   3        8
ALEX   JUN       2    1   1        0    GIZA   JUN       2    2   0        0    ASWN   JUN       6    0   0        3
ALEX   JUL       3    0   0        0    GIZA   JUL       1    2   0        0    ASWN   JUL       1    0   0        1
ALEX   AUG       0    0   0        0    GIZA   AUG       0    1   0        0    ASWN   AUG       2    0   0        0
ALEX   SEP       1    0   0        0    GIZA   SEP       2    0   0        0    ASWN   SEP       2    0   1        0
ALEX   OCT       3    2   0        0    GIZA   OCT       2    1   1        0    ASWN   OCT       5    0   0        0
ALEX   NOV       4    0   0        0    GIZA   NOV       0    1   0        0    ASWN   NOV       2    0   0        0
ALEX   DEC       2    0   0        0    GIZA   DEC       0    1   0        0    ASWN   DEC       3    1   0        0
                                                                                EXECUTION TERMINATED
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TABLE (6. b)

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SIX DEGREE (C) TEMPERATURE CHANGES RECORDED IN 1970
                                                                MINY  OCT  26  27
STATION MONTH DAY DAY   PORS  JUN   2   3   BAHR  MAR   1   2   MINY  OCT  27  28
                        PORS  AUG  18  19   BAHR  MAR   2   3   MINY  NOV  16  17
  ALEX  FEB  12  13     PORS  AUG  19  20   BAHR  MAR   7   8   KHAR  JAN   8   9
  ALEX  MAR   1   2     TANT  FEB   1   2   BAHR  MAR   8   9   KHAR  MAR   1   2
  ALEX  MAR   3   4     TANT  FEB   2   3   BAHR  MAR  16  17   KHAR  MAR   8   9
  ALEX  MAR  16  17     TANT  FEB  12  13   BAHR  MAR  17  18   KHAR  MAR  17  18
  ALEX  MAR  28  29     TANT  FEB  17  18   BAHR  MAR  18  19   KHAR  MAR  30  31
  ALEX  MAR  30  31     TANT  MAR   1   2   BAHR  MAR  30  31   KHAR  APR   5   6
  ALEX  APR   2   3     TANT  MAR   3   4   BAHR  APR   2   3   KHAR  APR   6   7
  ALEX  APR  11  12     TANT  MAR  14  15   BAHR  APR   5   6   KHAR  APR   7   8
  ALEX  APR  12  13     TANT  MAR  17  18   BAHR  APR   7   8   KHAR  APR  13  14
  ALEX  MAY  10  11     TANT  MAR  30  31   BAHR  APR  12  13   KHAR  APR  16  17
  ALEX  MAY  13  14     TANT  APR   2   3   BAHR  APR  24  25   KHAR  MAY   5   6
  ALEX  MAY  16  17     TANT  APR   5   6   BAHR  APR  25  26   KHAR  MAY   7   8
  ALEX  MAY  18  19     TANT  APR   8   9   BAHR  MAY   1   2   KHAR  MAY  14  15
  ALEX  MAY  19  20     TANT  APR  11  12   BAHR  MAY   7   8   KHAR  MAY  21  22
  ALEX  MAY  21  22     TANT  APR  12  13   BAHR  MAY  14  15   KHAR  JUN   1   2
  ALEX  OCT  21  22     TANT  MAY   1   2   BAHR  MAY  16  17   KHAR  JUN   2   3
  ALEX  NOV  26  27     TANT  MAY   7   8   BAHR  MAY  17  18   KHAR  JUN   8   9
  ALEX  NOV  27  28     TANT  MAY  13  14   BAHR  MAY  20  21   KHAR  JUL  18  19
  MERS  FEB  12  13     TANT  MAY  17  18   BAHR  JUN   1   2   KHAR  OCT  26  27
  MERS  FEB  16  17     TANT  MAY  18  19   BAHR  JUN   2   3   KHAR  NOV  18  19
  MERS  MAR   1   2     TANT  MAY  20  21   BAHR  JUL  18  19   KHAR  DEC   1   2
  MERS  MAR   2   3     TANT  MAY  21  22   BAHR  JUL  28  29   KHAR  DEC   2   3
  MERS  MAR   5   6     TANT  JUN   1   2   BAHR  OCT   1   2   ASWA  JAN  18  19
  MERS  MAR  16  17     TANT  JUN   2   3   BAHR  OCT  25  26   ASWA  MAR   1   2
  MERS  MAR  27  28     TANT  JUN  12  13   MINY  FEB   3   4   ASWA  MAR   8   9
  MERS  MAR  30  31     TANT  JUL   3   4   MINY  FEB   4   5   ASWA  MAR  11  12
  MERS  APR   1   2     TANT  AUG   1   2   MINY  FEB  13  14   ASWA  MAR  12  13
  MERS  APR   3   4     TANT  AUG   2   3   MINY  FEB  17  18   ASWA  MAR  18  19
  MERS  APR  11  12     TANT  SEP  26  27   MINY  MAR   1   2   ASWA  APR   6   7
  MERS  APR  12  13     TANT  OCT   4   5   MINY  MAR   4   5   ASWA  APR  16  17
  MERS  APR  28  29     TANT  OCT  28  29   MINY  MAR   8   9   ASWA  APR  17  18
  MERS  APR  29  30     GIZA  FEB  17  18   MINY  MAR  13  14   ASWA  APR  23  24
  MERS  MAY   1   2     GIZA  MAR   1   2   MINY  MAR  17  18   ASWA  APR  26  27
  MERS  MAY   3   4     GIZA  MAR   3   4   MINY  MAR  30  31   ASWA  MAY   3   4
  MERS  MAY  11  12     GIZA  MAR  17  18   MINY  APR   5   6   ASWA  MAY  15  16
  MERS  MAY  12  13     GIZA  MAR  27  28   MINY  APR   9  10   ASWA  MAY  24  25
  MERS  MAY  29  30     GIZA  MAR  30  31   MINY  APR  12  13   ASWA  JUN   1   2
  MERS  MAY  30  31     GIZA  APR   2   3   MINY  APR  13  14   ASWA  JUN   2   3
  MERS  SEP  22  23     GIZA  APR   4   5   MINY  APR  16  17   ASWA  AUG  14  15
  MERS  OCT  17  18     GIZA  APR   8   9   MINY  APR  25  26   ASWA  AUG  27  28
  PORS  FEB  12  13     GIZA  APR  12  13   MINY  APR  28  29   ASWA  SEP   3   4
  PORS  MAR   1   2     GIZA  APR  13  14   MINY  APR  29  30   ASWA  SEP   4   5
  PORS  MAR   8   9     GIZA  MAY   1   2   MINY  MAY   7   8   ASWA  OCT  26  27
  PORS  MAR  15  16     GIZA  MAY   7   8   MINY  MAY  14  15   ASWA  NOV  13  14
  PORS  MAR  17  18     GIZA  MAY  13  14   MINY  MAY  21  22   ASWA  NOV  21  22
  PORS  MAR  30  31     GIZA  MAY  17  18   MINY  MAY  25  26 EXECUTION TERMINATED
  PORS  APR   2   3     GIZA  MAY  18  19   MINY  MAY  26  27
  PORS  APR  11  12     GIZA  MAY  20  21   MINY  JUN   1   2
  PORS  APR  12  13     GIZA  MAY  21  22   MINY  JUN   2   3
  PORS  APR  29  30     GIZA  JUN   1   2   MINY  JUL  15  16
  PORS  MAY  12  13     GIZA  JUN   2   3   MINY  JUL  16  17
  PORS  MAY  13  14     GIZA  JUN  20  21   MINY  AUG   9  10
  PORS  MAY  17  18     GIZA  OCT   5   6   MINY  AUG  10  11
  PORS  MAY  18  19     GIZA  OCT  25  26   MINY  SEP   1   2
  PORS  MAY  19  20     BAHR  JAN   8   9   MINY  SEP   2   3
  PORS  JUN   1   2     BAHR  FEB   8   9   MINY  SEP   8   9
                        BAHR  FEB  12  13   MINY  SEP   9  10
                        BAHR  FEB  17  18   MINY  OCT  25  26
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TABLE (6.b) CONT.

SIX DEGREE (C) TEMPERATURE CHANGES RECORDED IN 1971

STATION	MONTH	DAY	DAY
ALEX	FEB	20	21
ALEX	MAR	9	10
ALEX	MAR	15	16
ALEX	MAR	16	17
ALEX	MAR	27	28
ALEX	APR	11	12
ALEX	APR	24	25
ALEX	APR	28	29
ALEX	APR	29	30
ALEX	MAY	7	8
ALEX	MAY	22	23
ALEX	MAY	23	24
ALEX	JUN	4	5
ALEX	JUN	5	6
ALEX	JUN	7	8
ALEX	JUN	8	9
ALEX	JUN	25	26
ALEX	JUN	26	27
ALEX	AUG	5	6
ALEX	OCT	5	6
ALEX	OCT	6	7
MERS	MAR	2	3
MERS	MAR	7	8
MERS	MAR	9	10
MERS	MAR	14	15
MERS	MAR	16	17
MERS	MAR	29	30
MERS	APR	1	2
MERS	APR	24	25
MERS	APR	28	29
MERS	APR	29	30
MERS	MAY	5	6
MERS	MAY	7	8
MERS	MAY	13	14
MERS	MAY	25	26
MERS	MAY	27	28
MERS	JUN	3	4
MERS	JUN	4	5
MERS	JUN	6	7
MERS	JUN	7	8
MERS	JUN	20	21
MERS	OCT	4	5
MERS	OCT	6	7
PORS	JAN	2	3
PORS	JAN	8	9
PORS	FEB	7	8
PORS	MAR	9	10
PORS	MAR	10	11
PORS	MAR	15	16
PORS	MAR	16	17
PORS	MAR	22	23
PORS	MAR	24	25
PORS	MAY	13	14
PORS	MAY	14	15
PORS	JUN	19	20
PORS	OCT	6	7
TANT	JAN	7	8
TANT	JAN	8	9
TANT	FEB	3	4
TANT	FEB	4	5
TANT	FEB	7	8
TANT	MAR	2	3
TANT	MAR	10	11
TANT	MAR	14	15
TANT	MAR	15	16
TANT	MAR	16	17
TANT	MAR	22	23
TANT	MAR	24	25
TANT	APR	11	12
TANT	MAY	8	9
TANT	MAY	21	22
TANT	MAY	22	23
TANT	JUN	3	4
TANT	JUN	18	19
TANT	JUN	19	20
TANT	SEP	3	4
TANT	NOV	12	13
TANT	NOV	13	14
GIZA	JAN	3	4
GIZA	JAN	8	9
GIZA	FEB	2	3
GIZA	MAR	10	11
GIZA	MAR	15	16
GIZA	MAR	16	17
GIZA	MAR	22	23
GIZA	MAR	24	25
GIZA	MAR	29	30
GIZA	NOV	5	6
BAHR	JAN	1	2
BAHR	JAN	2	3
BAHR	JAN	7	8
BAHR	JAN	20	21
BAHR	JAN	23	24
BAHR	JAN	25	26
BAHR	FEB	2	3
BAHR	FEB	12	13
BAHR	FEB	24	25
BAHR	FEB	25	26
BAHR	MAR	2	3
BAHR	MAR	10	11
BAHR	MAR	14	15
BAHR	MAR	15	16
BAHR	MAR	16	17
BAHR	MAR	24	25
BAHR	MAR	28	29
BAHR	MAR	29	30
BAHR	APR	1	2
BAHR	APR	2	3
BAHR	APR	8	9
BAHR	APR	11	12
BAHR	APR	13	14
BAHR	APR	15	16
BAHR	MAY	8	9
BAHR	MAY	12	13
BAHR	MAY	13	14
BAHR	MAY	25	26
BAHR	MAY	26	27
BAHR	MAY	27	28
BAHR	MAY	28	29
BAHR	MAY	29	30
BAHR	MAY	30	31
BAHR	JUN	7	8
BAHR	JUN	14	15
BAHR	OCT	7	8
BAHR	OCT	13	14
BAHR	OCT	14	15
MINY	JAN	8	9
MINY	FEB	2	3
MINY	FEB	25	26
MINY	FEB	26	27
MINY	MAR	10	11
MINY	MAR	13	14
MINY	MAR	15	16
MINY	MAR	24	25
MINY	MAR	28	29
MINY	MAR	29	30
MINY	MAY	4	5
MINY	MAY	5	6
MINY	MAY	8	9
MINY	MAY	12	13
MINY	MAY	28	29
MINY	JUN	1	2
MINY	JUN	2	3
MINY	JUN	4	5
MINY	JUN	8	9
MINY	JUN	14	15
MINY	JUN	19	20
MINY	JUL	11	12
MINY	JUL	12	13
MINY	JUL	30	31
MINY	OCT	7	8
MINY	NOV	18	19
MINY	NOV	25	26
MINY	NOV	28	29
MINY	NOV	29	30
KHAR	JAN	9	10
KHAR	JAN	20	21
KHAR	FEB	21	22
KHAR	MAR	2	3
KHAR	MAR	10	11
KHAR	MAR	13	14
KHAR	MAR	14	15
KHAR	MAR	15	16
KHAR	MAR	24	25
KHAR	MAR	28	29
KHAR	APR	22	23
KHAR	APR	26	27
KHAR	APR	27	28
KHAR	MAY	26	27
KHAR	MAY	28	29
KHAR	JUN	3	4
KHAR	JUN	5	6
KHAR	JUN	9	10
KHAR	JUL	29	30
KHAR	JUL	30	31
KHAR	OCT	7	8
KHAR	NOV	1	2
KHAR	NOV	2	3
KHAR	NOV	16	17
ASWA	JAN	9	10
ASWA	JAN	20	21
ASWA	JAN	24	25
ASWA	FEB	12	13
ASWA	FEB	21	22
ASWA	FEB	22	23
ASWA	FEB	23	24
ASWA	FEB	24	25
ASWA	FEB	26	27
ASWA	MAR	11	12
ASWA	MAR	18	19
ASWA	MAR	25	26
ASWA	APR	3	4
ASWA	APR	15	16
ASWA	MAY	15	16
ASWA	MAY	30	31
ASWA	JUN	4	5
ASWA	AUG	5	6
ASWA	AUG	12	13
ASWA	OCT	25	26
ASWA	OCT	26	27

EXECUTION TERMINATED

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TABLE (6·b) CONT

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SIX DEGREE (C) TEMPERATURE CHANGES RECORDED IN 1972

STATION MONTH DAY DAY

  ALEX    FEB    4   5
  ALEX    MAR    8   9
  ALEX    MAR   25  26
  ALEX    MAR   27  28
  ALEX    MAR   29  30
  ALEX    APR    7   8
  ALEX    APR   11  12
  ALEX    APR   23  24
  ALEX    APR   24  25
  ALEX    APR   28  29
  ALEX    MAY    1   2
  ALEX    MAY    6   7
  ALEX    JUN    7   8
  ALEX    JUN    8   9
  ALEX    OCT    5   6
  ALEX    OCT    6   7
  ALEX    DEC    9  10
  GIZA    FEB   27  28
  GIZA    MAR   29  30
  GIZA    MAR   30  31
  GIZA    APR    7   8
  GIZA    APR   13  14
  GIZA    APR   14  15
  GIZA    APR   18  19
  GIZA    APR   28  29
  GIZA    MAY    1   2
  GIZA    MAY    3   4
  GIZA    MAY    4   5
  GIZA    MAY    6   7
  GIZA    JUN    7   8
  GIZA    JUN   19  20
  GIZA    OCT   24  25
  ASWA    MAR    3   4
  ASWA    MAR   20  21
  ASWA    APR   10  11
  ASWA    APR   11  12
  ASWA    APR   14  15
  ASWA    APR   28  29
  ASWA    MAY    2   3
  ASWA    MAY    6   7
  ASWA    MAY   11  12
  ASWA    AUG   26  27
  ASWA    SEP   26  27
  ASWA    DEC   23  24
EXECUTION TERMINATED
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SIX DEGREE (C) TEMPERATURE CHANGES RECORDED IN 1973

STATION MONTH DAY DAY

  ALEX    FEB   15  16
  ALEX    FEB   17  18
  ALEX    MAR   12  13
  ALEX    MAR   18  19
  ALEX    APR   24  25
  ALEX    JUN    9  10
  ALEX    JUN   10  11
  ALEX    OCT    6   7
  ALEX    OCT    7   8
  GIZA    FEB   17  18
  GIZA    MAR   14  15
  GIZA    APR    2   3
  GIZA    APR   18  19
  GIZA    APR   19  20
  GIZA    APR   23  24
  GIZA    MAY    1   2
  GIZA    MAY   14  15
  GIZA    MAY   22  23
  GIZA    MAY   23  24
  GIZA    JUN   11  12
  GIZA    JUL   21  22
  GIZA    OCT   12  13
  GIZA    NOV   22  23
  ASWA    JAN   14  15
  ASWA    JAN   30  31
  ASWA    FEB    7   8
  ASWA    FEB   21  22
  ASWA    MAR    2   3
  ASWA    MAR    3   4
  ASWA    MAR    4   5
  ASWA    MAR   14  15
  ASWA    APR    7   8
  ASWA    APR   25  26
  ASWA    MAY    1   2
  ASWA    MAY    5   6
  ASWA    MAY    6   7
  ASWA    MAY    7   8
  ASWA    MAY    8   9
  ASWA    MAY   14  15
  ASWA    SEP   29  30
  ASWA    DEC   16  17
EXECUTION TERMINATED

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during the Khamsin period in contrast with any other month in the year. However, there is another small peak in the autumn and winter seasons (Fig. 6.12).

The relationship between maximum temperatures and relative humidities has also been analysed. The correlation coefficients between the two values during 1970 (using daily data) for nine selected stations over the country have been computed (Table 6.c). In general, the inland stations have a high negative correlation coefficient between temperatures and relative humidities. This correlation coefficient is very significant statistically during the Khamsin period. The highest correlation coefficient is -0.863 (March) at Bahariya station. This is significant at the 1% level. The lowest correlattion coefficient which occurs between maximum temperatures and relative humidities during the Khamsin period is -0.279 (June) at the Alexandria station and this correlation fails to reach the 5% level of significance.

Correlation coefficients between maximum temperatures and wind speeds have been computed (Table 6.d). It can be seen that there is a significant positive correlation between maximum temperatures and wind speeds especially during the Khamsin period (February - June). It is noticed that all the correlation values between maximum temperatures and wind speeds are positive values during the Khamsin season with the exception of Giza (June), Kharga (May) and Aswan (February). The highest value recorded during the Khamsin period is 0.565 which

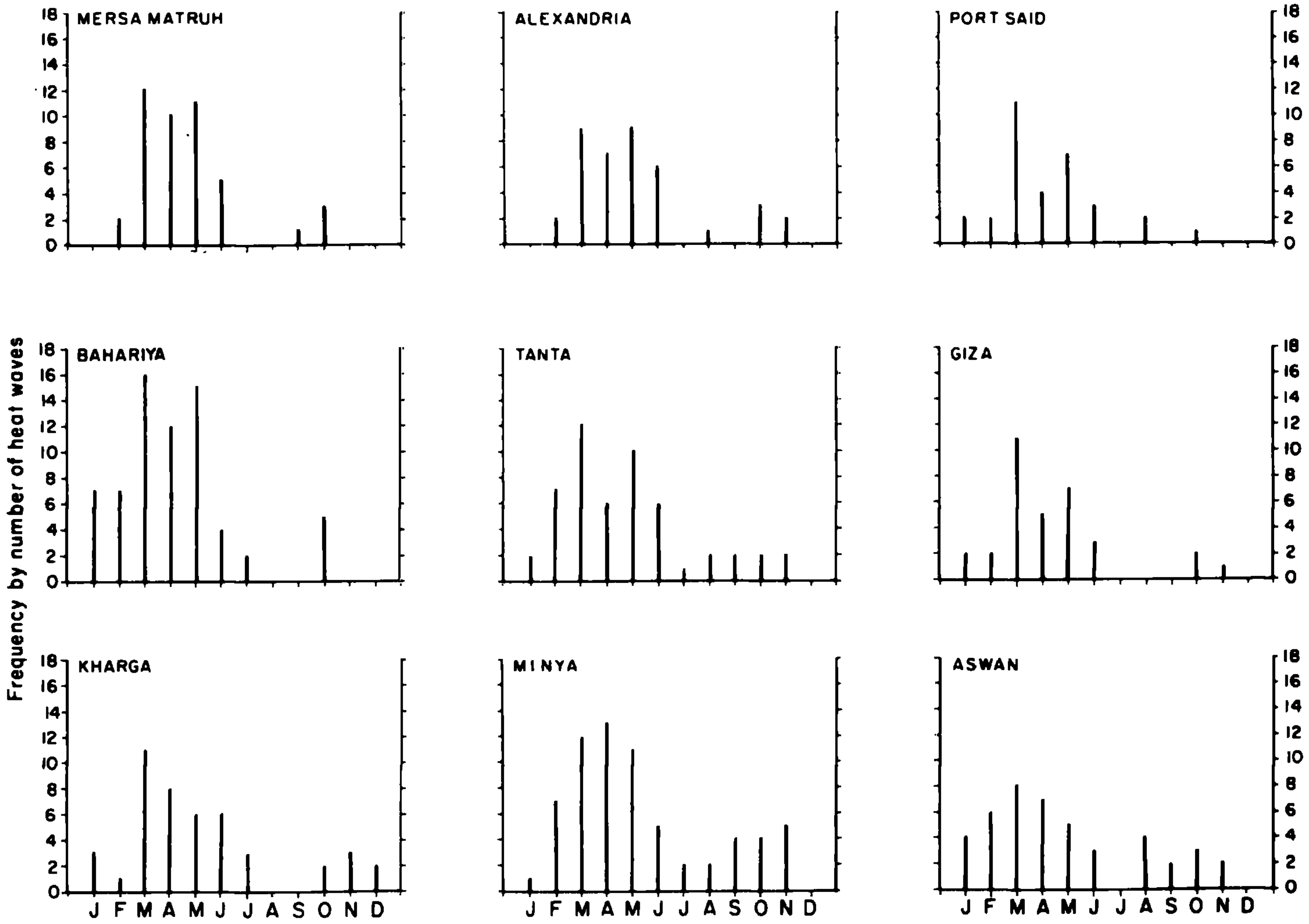


Fig. 6.12 FREQUENCY OF HEAT WAVES FOR SELECTED STATIONS IN EGYPT
1970 - 1971
(Heat waves >6°C)

Table 6.c

Correlation Coefficients between Maximum Temperatures and Relative Humidities for 1970 at Selected Stations in Egypt (Using Daily Data)

Station / Month	Mersa Mutruh	Alexandria	Port Said	Tanta	Bahariya	Giza	Minya	Kharga	Aswan
January	-0.072	-0.337	-0.020	-0.265	-0.189	-0.098	-0.181	-0.537	-0.334
February	-0.288	-0.514	-0.401	-0.625	-0.556	-0.374	-0.599	-0.397	-0.471
March	-0.389	-0.468	-0.487	-0.550	-0.863	-0.582	-0.654	-0.635	-0.680
April	-0.509	-0.623	-0.593	-0.785	-0.748	-0.677	-0.803	-0.568	-0.541
May	-0.683	-0.730	-0.382	-0.718	-0.735	-0.579	-0.624	-0.785	-0.312
June	-0.346	-0.279	-0.286	-0.678	-0.453	-0.389	-0.714	-0.716	-0.480
July	-0.032	-0.089	-0.120	-0.079	-0.440	-0.243	-0.397	-0.632	-0.201
August	0.308	0.135	0.120	0.172	-0.458	0.068	-0.468	-0.643	-0.374
September	0.374	0.416	0.622	0.395	-0.414	-0.114	-0.470	-0.577	-0.487
October	-0.438	-0.268	-0.352	-0.257	-0.701	-0.286	-0.697	-0.752	-0.678
November	0.061	0.057	0.158	0.378	-0.155	0.076	-0.217	-0.430	-0.546
December	0.463	0.354	0.259	0.218	0.069	0.123	-0.094	-0.396	-0.430

Significance level :- 0.349 = 5% 0.409 = 2% 0.449 = 1%

Khamsin period : - (February - June)

Table 6.d

The Correlation Coefficients between Maximum Temperatures and Wind Speeds during 1970 (Using Daily Data)

Station / Month	Mersa Mutruh	Alexandria	Port Said	Tanta	Bahariya	Giza	Minya	Kharga	Aswan
January	0.161	-0.361	-0.211	-0.220	-0.317	-0.266	-0.076	0.068	-0.329
February	0.346	0.354	0.313	0.370	0.238	0.276	0.209	0.298	-0.023
March	0.452	0.510	0.460	0.363	0.338	0.327	0.347	0.395	0.309
April	0.461	0.312	0.396	0.392	0.565	0.418	0.459	0.314	0.468
May	0.501	0.447	0.533	0.412	0.483	0.514	0.251	-0.241	0.216
June	0.311	0.408	0.216	0.221	0.319	-0.388	0.311	0.219	0.194
July	-0.196	-0.419	-0.013	-0.231	-0.208	-0.283	-0.203	0.061	-0.520
August	0.162	0.173	-0.116	0.076	-0.192	-0.112	0.085	0.260	0.411
September	-0.213	-0.316	-0.197	-0.358	0.129	0.097	0.212	-0.041	0.008
October	-0.306	-0.263	-0.260	-0.310	-0.293	-0.007	0.229	-0.202	-0.154
November	-0.012	-0.052	-0.101	-0.283	-0.083	0.350	0.123	0.187	0.336
December	-0.161	-0.119	-0.178	-0.189	0.012	0.157	0.319	0.204	-0.141

Significance level :- 0.349 = 5% 0.409 = 2% 0.449 = 1%

Khamsin period : - (February - June)

occurred in April at the Bahariya station. This is found to be significant at the 1% level. The lowest value is -0.023 found in February at Aswan.

The relationship between relative humidities and wind speeds has been analysed (Table 6.e). The correlation coefficients between relative humidity and wind speed values are negative especially during the Khamsin period (February - June). The highest correlation coefficient is -0.745 and this occurred in March at the Bahariya station. It is significant at the 1% level. The lowest correlation coefficient value during the Khamsin period is -0.201 and was registered in June at the Kharga station. It is also noticed that the correlation coefficients between relative humidities and wind speeds are highly significant during March, April and May at all stations with the exception of the April value at the Kharga station (Table 6.e), which fails to reach the 5% level of significance.

The Khamsin depression of May 10th-13th, 1971, (Fig. 6.13) has been chosen as an example to investigate the weather conditions prevailing during the above period with regard to temperatures, wind direction and speeds, relative humidities and pressure systems.

On the 10th of May, 1971, there were two deepening systems of two low pressure, the first covered an area to the south of Tunisia and over west Libya and the second covered north Iraq and east Syria (Fig. 6.13). It can also be seen that there were two shallow depressions over

Table 6.e

The Correlation Coefficients between Wind Speeds and Relative Humidities during 1970 (Using Daily Data)

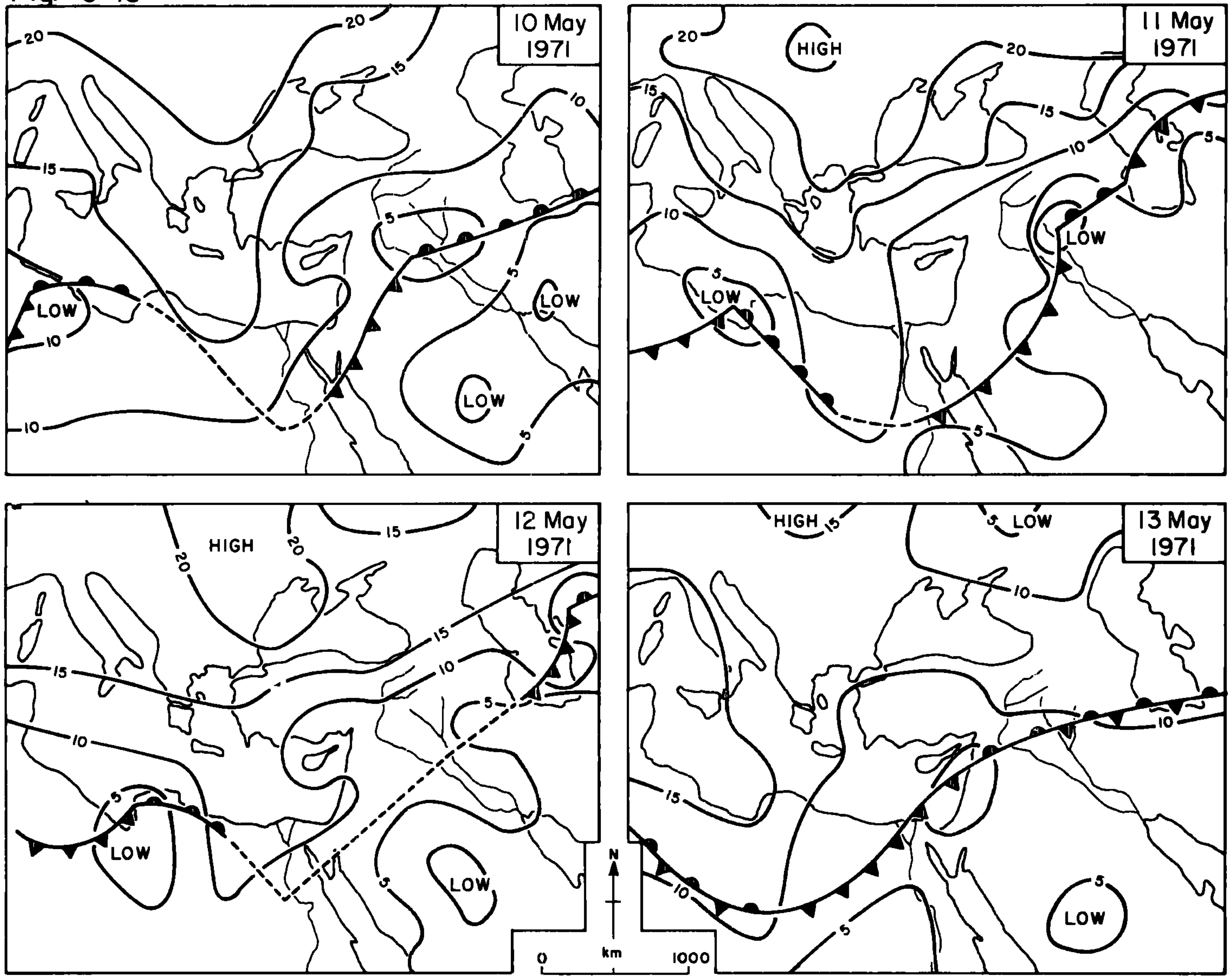
Station / Month	Mersa Mutruh	Alexandria	Port Said	Tanta	Bahariya	Giza	Minya	Kharga	Aswan
January	0.235	0.159	0.132	-0.266	-0.236	-0.221	-0.116	-0.156	-0.102
February	-0.398	-0.487	-0.219	-0.398	-0.340	-0.372	-0.248	-0.218	-0.224
March	-0.561	-0.612	-0.436	-0.560	-0.745	-0.661	-0.417	-0.406	-0.394
April	-0.349	-0.404	-0.511	-0.410	-0.548	-0.488	-0.517	-0.314	-0.485
May	-0.436	-0.355	-0.461	-0.532	-0.483	-0.412	-0.566	-0.421	-0.364
June	-0.411	-0.374	-0.406	-0.208	-0.296	-0.340	-0.449	-0.201	-0.447
July	-0.061	-0.363	-0.196	0.102	-0.223	-0.240	-0.263	-0.064	-0.320
August	-0.029	-0.136	-0.004	0.189	0.007	0.332	-0.286	-0.299	-0.145
September	0.216	0.366	0.201	0.119	0.046	-0.160	-0.561	-0.145	0.018
October	0.439	0.331	0.316	-0.099	0.351	-0.340	-0.364	-0.120	-0.068
November	0.213	0.189	0.126	0.143	0.103	-0.149	-0.058	0.112	-0.443
December	0.409	0.322	0.139	-0.137	-0.162	-0.357	-0.392	0.288	0.201

Significance level :- 0.349 = 5% 0.409 = 2% 0.449 = 1%

Khamsin period :- (February - June)

Movement of a Khamsim Depression over the Eastern Mediterranean

Fig. 6.13



south-east Iran and central Arabia.

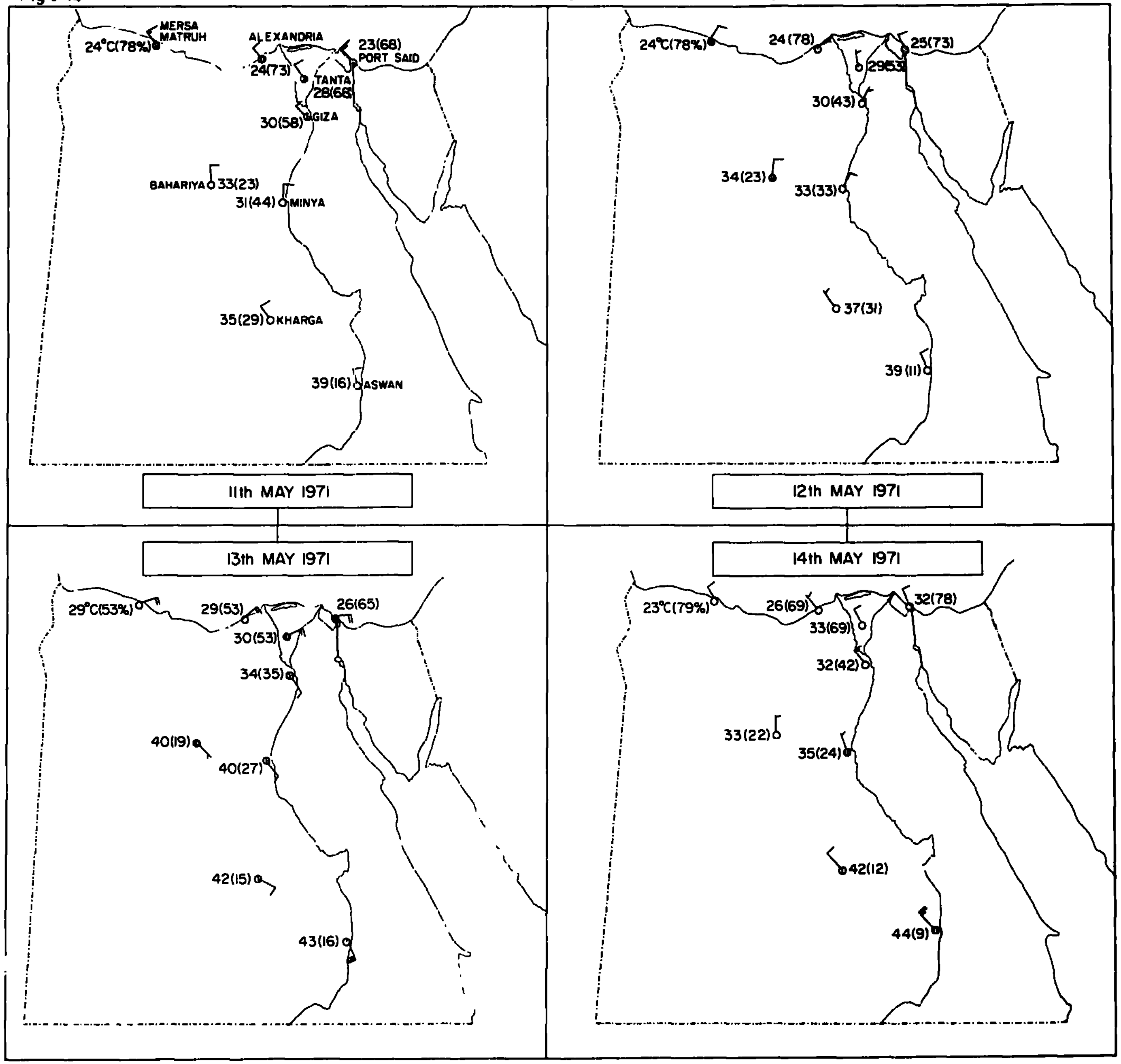
On the 11th of May, 1971, the centres of the two main low pressure systems had moved eastwards. The first depression covered west Libya and the second was centred on north-east Iraq. It is also noticed that a high pressure system covered the general area of Czechoslovakia.

The surface chart of 1200 U.T. on the 12th of May, 1971 shows that the deepening low pressure systems had moved eastwards with the first one covering east Libya and west Egypt. The second was concentrated over the south-eastern part of the Caspian Sea. There was a shallow depression over Arabia. It is also noticed that a high pressure system covered the area of south-east Europe and the north-west Black Sea.

On May the 13th, 1971 the whole of Egypt came under the warm sector effect with the exception of the extreme north-west corner of the country. This area was possibly under the influence of the warm sector during the morning of this particular day. There were also two shallow depressions, the first covered the centre of Arabia, and the second covered the north-east Black Sea area. A high pressure system was centred over European Russia (Fig. 6.13).

The weather conditions associated with the above depression have also been analysed (Fig. 6.14). This figure shows clearly that there was not much change in

Fig.6. 14 MAXIMUM TEMPERATURE (RELATIVE HUMIDITY)



maximum temperatures, relative humidities, wind speeds and wind directions during the 11th and 12th of May, 1971. On the 13th of May, 1971, when Egypt came under the effect of the warm sector of the depression which was centred over the eastern Mediterranean, the temperature suddenly increased, the relative humidity decreased and the wind blew from a south and south-easterly direction (Fig. 6.14). On May 14th, 1971, the depression had moved eastwards away from Egypt, taking the warm dry Khamsin conditions with it.

6.7 - Dust and Khamsin conditions :-

During Khamsin conditions duststorms raised by the winds in desert depressions give visibilities of less than 50 metres at times. The wind carrying the dust may cause reduction of visibilities in regions far distant from the originating duststorms. These duststorms reach their most severe ahead of the cold front of the desert depression. Occasionally strong to gale force winds ahead of the warm front of a Khamsin depression may also raise much dust.

With exceptionally deep and extensive desert depressions a belt of duststorms may be more than 200 kilometres in width and thick dust may be carried up to 6000 metres above ground level. Such dust may travel great distances northwards even over the sea. A duststorm at any one place seldom lasts for more than 12 hours although the depression may cause duststorms for a number of days as it moves along its track. Generally the dust clears after the passage of the cold front (see Ahemed, 1949; Lunson, 1950; Abdel-Salam and Sowelim, 1967A and 1967B; and Banoub, 1970).

Abdel-Salam and Sowelim (1967A) studied dustfall caused by the spring Khamsin storms in Cairo during the period 1962 and 1963. It seems clear from this study that the spring dust deposit in Cairo is greatly affected by the Khamsin storms. They found that the mean aggregate deposit per storm in successive months in round figures is : February 12 tons/mile^2; March 23 tons/mile^2; April 22 tons/mile^2; May 17 tons/mile^2, and the mean rates of deposition are respectively 0.54 tons/mile^2, 1.30 tons/mile^2, 2.25 tons/mile^2 and 1.41 tons/mile^2 per hour, (Abdel-Salam and Sowelim, 1967A, p. 224).

The monthly values for dust deposits in the city of Cairo during 1960 were measured by Abdel-Salam and Sowelim (1967B). The highest average values of dust deposits, all over the city, were found to occur in the months of April through June with the maximum deposition occurring in April (Table 6.f). This season of the year is characterized by the passage of a number of Khamsin depressions. The passage of such depressions is always associated with hot southerly winds loaded with dust and sand. It is also noticed that the highest frequency and duration of the storms was concentrated in the Khamsin period although some were found in the winter season (Table 6.f). It can be seen that the main direction of the wind during these storm periods was from the south,

Table 6.f

Mean Total Deposits in Cairo as Obtained from the Six Sites for the year 1960

Month	Mean deposits tons/mile^2 per month	No. of passing storms of duration 5-10	No. of passing storms of duration ≥ 10	Total duration of dust storms (hr)	Mean wind speed (M.P.H.)	Direction of wind during storms	Mean wind speeds during storms (M.P.H.)	Rainfall mm
January	56.8	1	-	6	7.9	SSSW	25.1	5.6
February	69.2	1	-	7	6.4	SSW	20.9	Tr
March	83.1	-	-	-	7.3	-	-	0.2
April	129.4	5	1	50	7.4	SSE/SSW	26.9	0.5
May	100.2	2	-	13	8.6	SE/S	23.2	-
June	104.0	-	1	16	10.0	SW	29.0	-
July	74.5	-	-	-	4.4	-	-	-
August	67.6	-	-	-	5.8	-	-	-
September	70.3	-	-	-	6.6	-	-	-
October	77.6	-	-	-	7.8	-	-	-
November	50.3	-	-	-	6.4	-	-	4.2
December	59.6	1	-	9	6.1	WSW	18.6	0.1

Source :- Abdel-Salam, M.S., and Sowelim, M.A., 1967B, "Dust deposits in City of Cairo, Atmospheric Environment, Oxford, England, Vol.1, (3), p.215.

south-easterly and south-westerly directions.

The coastal type of depression arises over the north African coast and remains stationary for at least twenty-four hours over the great Qattara Depression before moving across Egypt towards Cairo. During this period of stagnation, the low pressure, weather system picks up huge amounts of fine dust and sand from the hot, bare desert which characterizes the Qattara Depression. These particles are carried within layers of air from ground level up to a height of a few thousand feet. For this reason, an urgent plea for action was made by Abdel-Salam and Sowelim (1967B). They suggested that the Qattara Depression ought to be filled with water from the Mediterranean Sea, and claimed that when filled, the Qattara Depression would be a source, not of dust and sand, but of water - clouds, during the sojourn of the coastal type storms in the region. In this way the volume of dustfall over Cairo during the spring season might be diminished.

The mean number of days of occurrence of duststorms and rising dust in selected stations for periods of at least forty years are presented (Table 6.g). This table shows clearly that the mean number of days of occurrence of duststorms and rising dust are high in the Khamsin period and also the winter season at all stations with the exception of Minya and Luxor. At these latter stations duststorms are found mainly in January, March, April and May at Minya, and from February to

Table 6.g

Mean Number of Days of Occurrence of Duststorms and Rising Dust in Selected Stations in Egypt

Station	Element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Period (Years)
Mersa Mutruh	Duststorm	1.3	1.4	1.3	1.0	0.8	0.2	0.1	0.0	0.1	0.4	0.9	2.0	47
	Rising dust	3.0	3.3	2.3	2.3	1.6	0.9	1.1	0.3	0.6	1.3	1.1	2.3	65
Alexandria	Duststorm	0.3	0.5	0.6	0.3	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.2	42
	Rising dust	1.2	1.3	1.6	1.5	0.7	0.3	0.2	0.0	0.0	0.3	0.3	1.0	65
Port Said	Duststorm	0.2	0.2	0.4	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.5	42
	Rising dust	0.8	0.8	1.3	1.3	0.6	0.1	0.1	0.0	0.0	0.3	0.4	0.7	65
Cairo Airport	Duststorm	0.4	0.5	0.6	0.8	0.4	0.1	0.0	0.0	0.1	0.1	0.1	0.5	47
	Rising dust	2.6	2.9	3.2	3.0	2.2	1.2	0.1	0.1	0.2	0.7	0.8	2.7	65
Minya	Duststorm	0.2	0.0	0.1	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42
	Rising dust	0.4	0.6	0.8	1.5	1.6	0.6	0.0	0.1	0.0	0.3	0.1	0.2	65
Luxor	Duststorm	0.0	0.1	0.2	0.6	0.6	0.1	0.1	0.1	0.0	0.0	0.0	0.0	47
	Rising dust	0.5	0.5	1.1	1.3	2.1	0.4	0.2	0.3	0.1	0.2	0.2	0.3	65
Aswan	Duststorm	0.4	0.1	0.3	1.0	1.1	0.1	0.0	0.6	0.1	0.1	0.6	0.1	60
	Rising dust	1.4	3.1	5.9	6.1	4.9	2.6	3.1	4.1	1.0	1.0	1.7	2.1	66

<u>Source</u>:- Banoub, E.F., 1970, Sandstorms and duststorms in U.A.R., Meteorol. Dept. Cairo, Egypt. technical note No. 1, p. 25.

August inclusive at Luxor. Rising dust is frequent throughout the year at most of the stations (Table 6.g). The highest number of days with rising dust is recorded at Aswan especially during the Khamsin period (February - June).

Finally, the Khamsin has been defined as a very hot, dry and dusty wind which blows from between S and E over Egypt. It is the Egyptian Scirrocco. As it does not pass over the sea it remains dry. The Khamsin as well as the different types of the Scirrocco are composed of continental Tropical air (Tc) which has originated over the desert.

Khamsin weather conditions in Egypt mainly take place in association with the passage of Khamsin depressions. These depressions originated either over the Atlantic or south of the Atlas mountains and follow more than one track until they reach Egypt.

The main weather features which are sufficient to specify what is called Khamsin weather have been analysed in detail in the present chapter, and these are the excessively high surface temperatures and the extremely low humidities, associated with the invasion of S or SE winds which produce rising dust and duststorms. These conditions usually cause damage to the crops in Egypt especially the vegetables and cereal crops. For example, these hot and dry east winds may scorch the young ear of shrivel the ripening grain. The cereal crops must also contend with a variety of pests and diseases. Severe duststorms sometimes cause extensive damage to aircraft engines by the penetration of sand or dust particles either during flight or to inadequately protected parked aircraft on the ground. These duststorms usually produce visibilities of less than 50 metres and because of this the traffic accidents normally increase.

CHAPTER 7

Climatic Classification in Egypt

7.1 - Introduction

By the late nineteenth century the idea that climates might be classified on the basis of vegetation or physiological response was accepted, but it was not until many years later that the distinguished meteorologist and climatologist Wladimir Köppen was able to develop this idea sufficiently to produce a useful and practical classification employing readily available climatic variables. Köppen first published his classification in 1884, in which some modifications were subsequently made. The Köppen system attempts to relate vegetation development to certain monthly values of temperature and precipitation. It does, however, have a number of faults including the fact that inadequate concern is given to the vegetation - limiting variables, such as water need in relation to supply, soil moisture storage, and actual evapotranspiration. At the same time, it only seeks to define fairly large climatic regions which are, in many cases, only poorly related to the major vegetation regions of the World.

De-Martonne's classification (1926) is a descriptive type of classification where the boundaries are separated by use of an "Index of Aridity". This type of climatic classification has also been used in the present chapter.

Carter and Mather (1966) suggested that a common mistake in climatic classification is to consider that climates merely identify regions between the various climatic isolines that coincide with the major vegetation boundaries on distribution maps. It is the boundaries of the climatic types rather than the core areas between isolines that should be the real focus of a classification, and it is in these regions that recent major emphasis in classification has produced the most significant results. Many climatic classifications are judged on the basis of how well the climatic variables accord with the vegetation mapping.

Carter believes there is inadequate recognition of the fact that a climatic classification has a special intellectual significance by itself, based on how well it expresses those climatic factors considered to be "active" within the particular group of natural physical processes under investigation. While recognizing that climate in all its complexity is never quite the same from one place to another, it is of little value for classification purposes if we are continually concerned with the minutiae of differences between places. Rather we need to work with those climatic factors that are capable of the same degree of broad generalization of categorization.

The water - budget approach became the basis of Thornthwaite's 1948 climatic classification. Thornthwaite's main classification which was based on potential evapotranspiration also relied on information gleaned from vegetation and soil maps. Therefore, in both Thornthwaite's and Köppen's classifications external factors related to, but not wholly identifiable with, climate are employed. Ideally what is required is a classification having reference only to climatic data, and one which avoids any subjective judgement in delimiting the boundaries between different climatic types.

7.2 - Methods and analyses :-

In the present chapter, climatic classifications of Egypt have been made using three popular systems of classification.

1 - Köppen's classification :-

This is primarily based upon annual and monthly means of temperature and precipitation. The latest scheme (1936) has been considered as the basis for climatic classification in the present chapter. The symbols used in Köppen's classification are explained below. Only those symbols which are applicable to Egypt are included. Köppen used capital letters to designate the major categories of climate, such as :-

BW = Arid climate or desert.

BS = Semi-arid or steppe climate (for precise definitions of the steppe and desert boundaries), the following formula was used :-

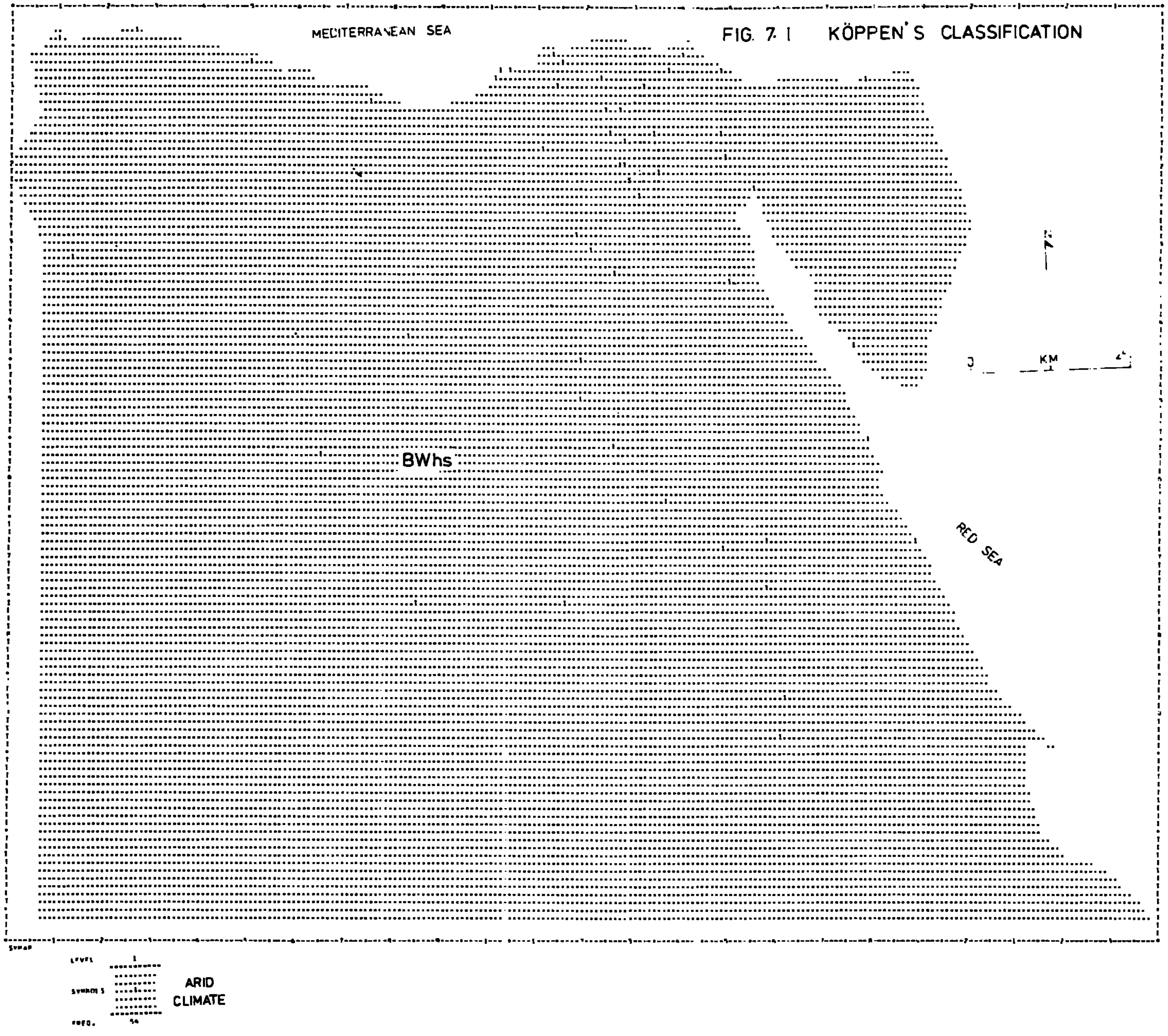
$$r = \frac{0.44\ t - 14}{2}$$

Where r = annual rainfall, inches.

t = average annual temperature, ^{o}F

Other small letters used with B climates are

FIG. 7.1 KÖPPEN'S CLASSIFICATION



as follows :-

h (heiss) = average annual temperature over 64.4°E (18°C)

s = summer drought (For more details, see Trewartha, 1968).

Based on the above system, the climatic types of Egypt have been worked out for the 54 climatological stations (Fig. 7.1). This shows that Egypt consists of one type of climate. This is as follows :-

BWhs = Arid climate, it is noticed that this type extends over the whole area of the country. This is because Egypt mainly experiences hot and arid climate (Fig. 7.1).

2 - De-Martonne's classification :-

De-Martonne has defined the "Index of Aridity" as the ratio between the annual precipitation in millimetres and the mean annual temperatures in degree centigrade plus ten. The Index of Aridity, has been calculated for the 54 climatological stations in Egypt (Fig. 7.2).

According to De-Martonne's classification, the whole of Egypt is arid, except for the northern region, where the "Index of Aridity" is greater than 6. The severity of aridity, however, decreases from the south

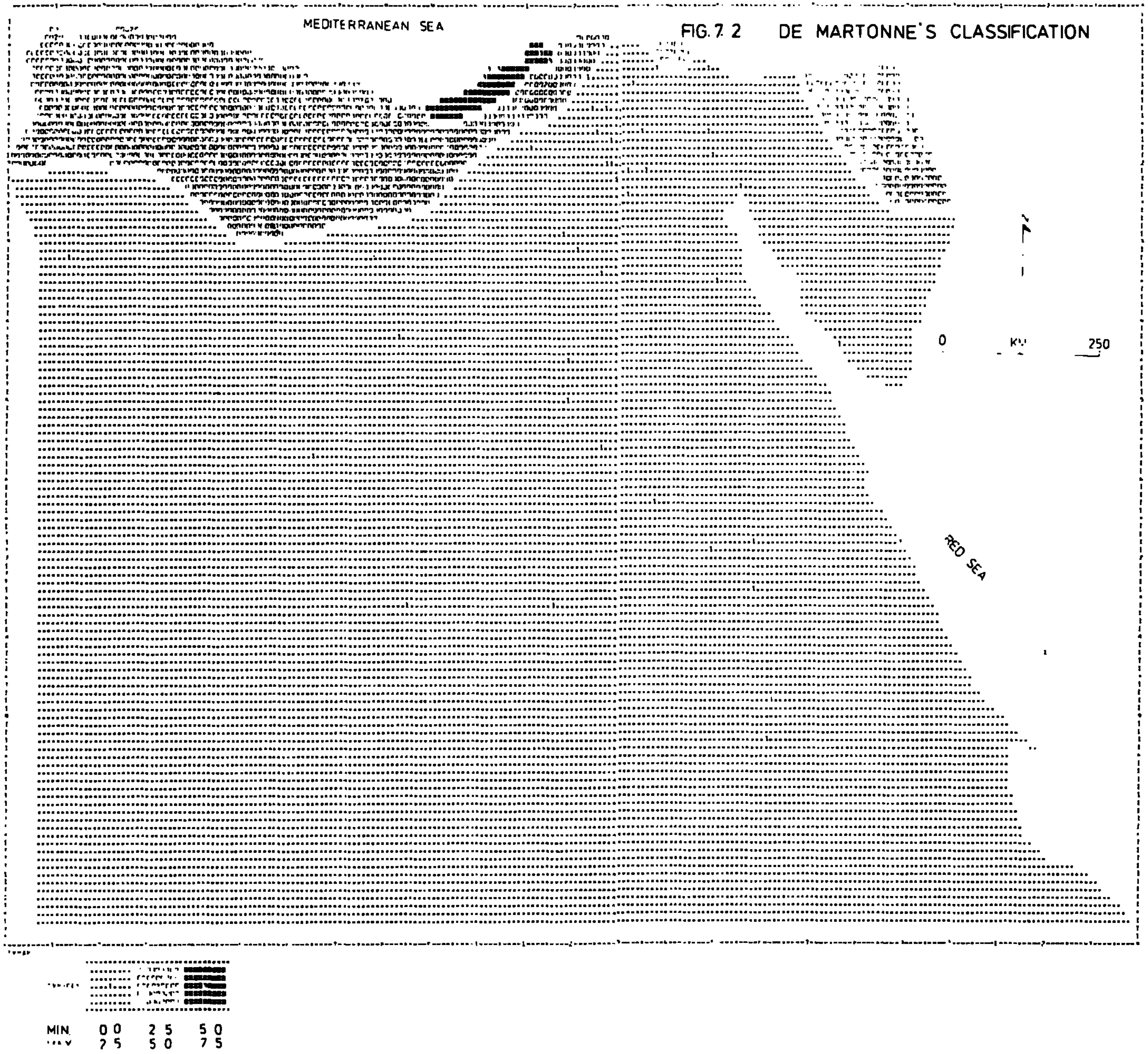


FIG. 7.2 DE MARTONNE'S CLASSIFICATION

to the north and to the north-west. The lowest value of the "Aridity Index" is 0.01 which occurs in south and middle Egypt. The area of west Egypt lying between 25 and 30°N is comparatively more arid than the rest of the country (Fig. 7.2).

3 - Thornthwaite's classification :-

In Thornthwaite's system of climatic classification the boundaries are established by using empirical or theoretical formulae. Moreoever, two new climatic concepts, i.e. precipitation effectiveness and temperature efficiency, are used in this system.

Thornthwaite's classification is like Köppen's in that it is quantitative and attempts to determine the critical climatic limits significant to the distribution of vegetation and also in that it employs a symbolic nomenclature in designating the climatic types. It differs from Köppen's classification in that it makes use of new climatic concepts, namely precipitation effectiveness and temperature efficiency (Thornthwaite, 1933, p. 433).

The Thornthwaite's P/E Index is then obtained by adding the monthly P/E ratio as follows :-

$$\text{P/E Index} = \sum_{n-1}^{12} 115\,(P/T - 10)_n$$

Where P is the monthly total precipitation in inches and T is the mean daily temperature for each month in °F. This formula has been calculated for the 54 climatol-

FIG. 7.3. THORNTHWAITE'S CLASSIFICATON

ogical stations in Egypt, and the results are shown in Figure 7.3. On the basis of the P/E Index, two provinces have been defined.

1. Semi-arid 'D' (P/E Index between 16 and 32), this zone includes only four stations on the coastal region. These are Kom El-Nadura; Dekheila; Alexandria and Edfina stations (Fig. 7.3).

2. Arid 'E' (P/E Index less than 16), this type covers the whole area of Egypt with the exception of the Alexandria region and the Edfina station (Fig. 7.3).

7.3 - Climatic classification of Egypt using factor analysis techniques :-

The use of factor analysis for the purposes of delimiting economic regions has been employed by Berry (1967), Berry and Ray (1966) and others, Steiner (1965) has used the factor analysis technique to classify the climate of the United States of America. He based his analysis on sixteen climatic variables for 67 climatological stations using monthly data for the period 1931 to 1960.

McBoyle (1971) has also classified the climate of Australia on the basis of factor loadings. He used twenty climatic variables on a monthly basis for the sixty-six climatic stations. Russel and Moore (1976) have used factor analysis techniques to classify the climate of both Australia and South Africa. Their classification was based on sixteen climatic variables on a monthly basis. 206 stations were used in South Africa and 94 in Australia. Similar attempts have been made by the author to classify the climate of Egypt.

The following regionalization of the climate of Egypt has been obtained through factor analysis using solely climatic elements. The result is a classification which is easy to map and interpret on both large and small scales, giving a general, yet useful, end product which is an efficient arrangement of the data in as simple a form as possible. Starting with sixteen variables from each of the fifty-four stations (Fig. 2.2), a matrix of simple correlations between the input variables was obtained (Table 7.b).

The climatic data for the sixteen variables for each of the stations were obtained from the Meteorological Office at Cairo, for the period 1931 to 1960. Mean monthly data were employed as input information.

The variables used in the analysis were :-

1. Mean annual temperature, °C.
2. Average monthly mean temperature, °C, January.
3. Average monthly minimum temperature, °C, January.
4. Average monthly maximum temperature, °C, January.
5. Average monthly mean temperature, °C, July.
6. Average monthly minimum temperature, °C, July.
7. Average monthly maximum temperature, °C, July.
8. Mean annual relative humidity, per cent.
9. Average monthly relative humidity, per cent, January.
10. Average monthly relative humidity, per cent, July.
11. Mean annual precipitation, mm.

12. Average monthly precipitation, January, mm.
13. Mean annual number of raindays (with 0.1 mm or more).
14. Average monthly number of raindays, January.
15. Temperature range, °C, (January - July).
16. Humidity ratio (July/January).

The data derived from the Meteorological Office Bulletin were subjected to factor analysis. Having evaluated all components with eigenvalues equal to or greater than one, the computer output resulted in a rotated factor solution with three factors explaining 100% of the total variation. In order to simplify the explanation of the factor structure a Varimax rotation was applied. "From a mathematical viewpoint" says King (1969), "the rotation of the factors can be viewed as a consequence of the indeterminacy of the solution". In other words a rotation is applied if there are many intermediate values between 0 and 1 and if the values are spread between two or more factors. Thus a rotation attempts to elucidate the situation by eliminating the intermediate values and giving a result that has most of the factor loadings either as high or low values (see Nie et al., 1975). The most commonly used of these rotations is the Varimax routine, which by a series of orthogonal transformations of pairs of factors, seeks to simplify the columns of the factor loading matrix (King, 1969). The factor scores of the rotated solution, the eigenvalues, and the percentage explanation of the total variance (or communality) of each of the three

Table 7.a

Matrix of Rotated Factor Loadings

Factor Number			I	II	III
Eigenvalue			11.153	3.217	1.923
Percentage of total variance communality			68.5	19.7	11.8
Variable		Percentage communality over these factors			
1	T_1	95.48	-0.5928	-0.5518	0.5467
2	T_2	98.60	-0.2143	-0.0755	0.9667
3	T_3	71.13	-0.6847	-0.3633	0.3324
4	T_4	83.97	0.1866	0.1197	0.8891
5	T_5	91.30	-0.6627	-0.6568	0.2063
6	T_6	84.57	-0.7486	-0.4951	-0.2004
7	T_7	82.37	-0.0621	-0.4549	0.7829
8	H_1	99.05	0.3577	0.9205	0.1229
9	H_2	84.21	0.208.	0.8908	-0.0718
10	H_3	98.59	0.4451	0.8668	0.1909
11	P_1	94.05	0.9294	0.2642	0.0828
12	P_2	92.59	0.9337	0.1948	0.1271
13	P_3	95.51	0.9299	0.2960	0.0533
14	P_4	96.53	0.9336	0.2930	0.0888
15	T_8	61.37	-0.5676	-0.4202	0.3391
16	H_4	92.70	0.9339	0.1959	0.1284

High factor loadings are underlined (over ± 0.60)

Table 7.b

Matrix of Simple Correlations between Input Variables

Variable No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
T_1	1	1.000															
T_2	2	0.684	1.000														
T_3	3	0.867	0.539	1.000													
T_4	4	0.282	0.855	0.033	1.000												
T_5	5	0.914	0.363	0.799	-0.058	1.000											
T_6	6	0.669	-0.017	0.704	-0.448	0.873	1.000										
T_7	7	0.721	0.791	0.401	0.697	0.530	0.063	1.000									
H_1	8	-0.640	-0.033	-0.529	0.284	-0.799	-0.744	-0.331	1.000								
H_2	9	-0.607	-0.188	-0.440	0.042	-0.689	-0.521	-0.495	0.925	1.000							
H_3	10	-0.635	0.016	-0.551	0.359	-0.825	-0.814	-0.262	0.980	0.861	1.000						
P_1	11	-0.640	-0.132	-0.668	0.258	-0.768	-0.840	-0.127	0.593	0.437	0.664	1.000					
P_2	12	-0.559	-0.102	-0.616	0.257	-0.690	-0.787	-0.059	0.540	0.394	0.610	0.960	1.000				
P_3	13	-0.675	-0.163	-0.721	0.262	-0.793	-0.845	-0.154	0.612	0.457	0.684	0.958	0.917	1.000			
P_4	14	-0.640	-0.139	-0.634	0.270	-0.765	-0.820	-0.138	0.617	0.479	0.681	0.953	0.952	0.168	1.000		
T_8	15	0.781	0.462	0.744	0.091	0.753	0.607	0.483	-0.544	0.481	-0.547	-0.566	-0.529	-0.009	-0.619	1.000	
H_4	16	-0.559	-0.101	-0.616	0.258	-0.690	-0.788	-0.059	0.541	0.395	0.611	0.960	0.999	0.161	0.953	0.135	1.000

Significance level:- 0.273 = 5%   0.322 = 2%   0.354 = 1%

factors is given in Table 7.a.

Factor 1, explaining 68.5% of the total variance, is the most important one. High loadings on this factor are given by, January minimum temperature (-0.685), July mean temperature (-0.663), July minimum temperature (-0.749), mean annual rainfall (0.929), mean January precipitation (0.934), mean annual number of raindays $\geq$ 0.1mm (0.930), January number of raindays (0.934) and humidity ratio (July/January), (0.934).

Therefore, factor 1 appears to be a general index of "Precipitation" conditions with special emphasis on winter moisture and summer coolness. "The Precipitation Index", may be obtained from the following equations derived from the first factor loadings which are $\geq$ 0.60 (Table 7.a).

$$\text{Precipitation Index} = -0.68\ T_3 - 0.66\ T_5 - 0.75\ T_6 + 0.93\ P_1 + 0.93\ P_2 + 0.93\ P_3 + 0.93\ P_4 + 0.93\ H_4.$$

Where T_3 = Average monthly minimum temperature, °C, January.
T_5 = Average monthly mean temperature, °C, July.
T_6 = Average monthly minimum temperature, °C, July.
P_1 = Mean annual precipitation, mm.
P_2 = Average precipitation, January, mm.
P_3 = Mean annual number of raindays (with 0.L mm or more).
PP_4 = Average number of raindays, January.
H_4 = Humidity ratio (July/January).

This equation has been calculated for the 54

FIG 7.4 PRECIPITATION INDEX

climatic stations. The results of this calculation have been used as input values. The following is example for three stations to show how this equation has been used :-

Alexandria:-

$$\begin{aligned}\text{Precipitation Index} = & -(0.68 \times 9.3) - (0.66 \times 26.1) \\ & -(0.75 \times 22.7) + (0.93 \times 192.1) \\ & +(0.93 \times 48.3) + (0.93 \times 47.2) \\ & +(0.93 \times 10.3) + (0.93 \times 1.0) \\ = & \ \underline{237.4}\end{aligned}$$

Tanta :-

$$\begin{aligned}\text{Precipitation Index} = & -(0.68 \times 6.0) - (0.66 \times 26.8) \\ & -(0.75 \times 19.1) + (0.93 \times 45.5) \\ & +(0.93 \times 9.0) + (0.93 \times 17.5) \\ & +(0.93 \times 4.1) + (0.93 \times 0.8) \\ = & \ \underline{34.7}\end{aligned}$$

Aswan :-

$$\begin{aligned}\text{Precipitation Index} = & -(0.68 \times 9.5) - (0.66 \times 34.0) \\ & -(0.75 \times 26.1) + (0.93 \times 1.4) \\ & +(0.93 \times 0.1) + (0.93 \times 0.8) \\ & +(0.93 \times 0.1) + (0.93 \times 0.6) \\ = & \ \underline{-45.7}\end{aligned}$$

In the factor scores of each of the 54 climatic stations are mapped for the factor 1 and isolines drawn (Fig. 7.4), the coastal areas are clearly seen as a separate region, (high positive figures), particularly the area of north and north-west Egypt.

The second factor explains 19.7% of the total variance. The high loadings of this factor are the July average mean temperature (-0.657), the mean annual relative humidity (0.921), the average monthly relative humidity in January (0.891) and the average monthly relative humidity in July (0.867). As these factor loadings are high with regard to humidity values, the second factor is termed the "Humidity Index". These high factor loadings have been calculated for the 54 climatic stations using the following equation :-

$$\text{Humidity Index} = -0.66\ T_5 + 0.92\ H_1 + 0.89\ H_2 + 0.87\ H_3$$

Where T_5 = July average mean temperature, °C.
H_1 = Mean annual relative humidity, per cent.
H_2 = Average relative humidity in January, per cent
H_3 = Average relative humidity in July, per cent.

Three stations have been calculated to illustrate how this technique has been used :-

Alexandria :-

$$\text{Humidity Index} = -0.66 \times 26.1 + 0.92 \times 70 + 0.89 \times 71 + 0.87 \times 73 = \underline{173.9}$$

Tanta :-

$$\text{Humidity Index} = -0.66 \times 26.8 + 0.92 \times 59 + 0.89 \times 70 + 0.87 \times 59 = \underline{150.2}$$

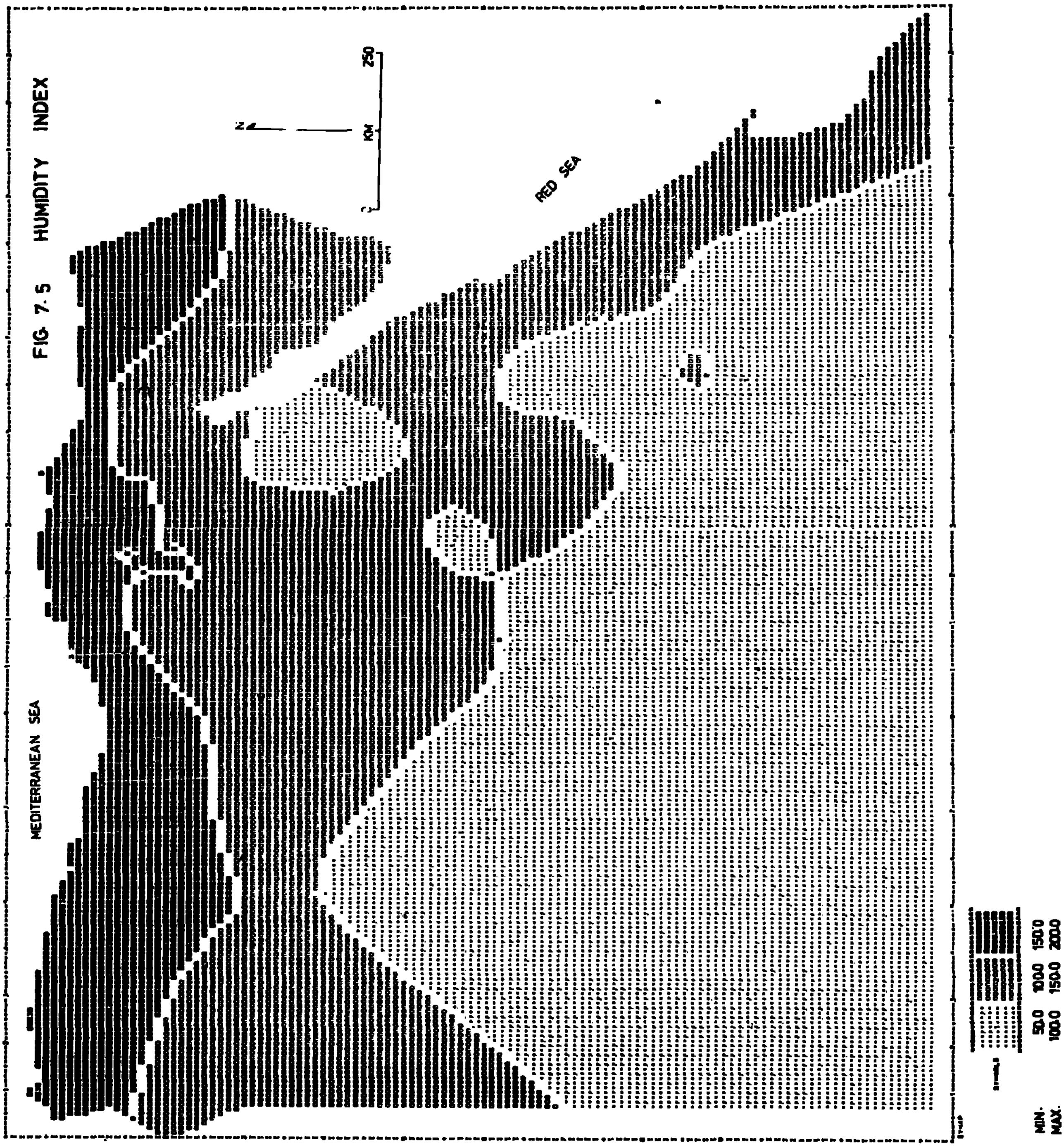


FIG. 7.5 HUMIDITY INDEX

Aswan :-

$$\text{Humidity Index} = -0.66 \times 34.0 + 0.92 \times 27 + 0.89 \times 38.0 + 0.87 \times 21 = \underline{54.5}$$

The results of this calculation for the 54 climatic stations in Egypt are used as input values, and from these data isolines have been drawn (Fig. 7.5). The Mediterranean areas are seen as a separate region. In the south a broad intermediate zone which in the east parallels the Red Sea coast is found before the low values of the southern desert regions are reached (Fig. 7.5).

Finally, factor 3 accounts for only 11.8% of the total variance. January mean and maximum temperatures (0.967 and 0.889 respectively), and July maximum temperatures (0.783) give the highest factor loadings $\geqslant 0.60$. This could, therefore, be called a "Temperature Index", with its emphasis on maximum temperatures in both January and July.

The "Temperature Index" may be obtained from the following equation :-

$$\text{Temperature Index} = 0.97\ T_2 + 0.89\ T_4 + 0.78\ T_7$$

Where T_2 = Average monthly mean temperature, January, $^\circ$C.
T_4 = Average monthly maximum temperature, January, $^\circ$C.
T_7 = Average monthly maximum temperature, July, $^\circ$C.

The "Temperature Index" equation has been computed for the 54 climatic stations (Fig. 7.6). The following

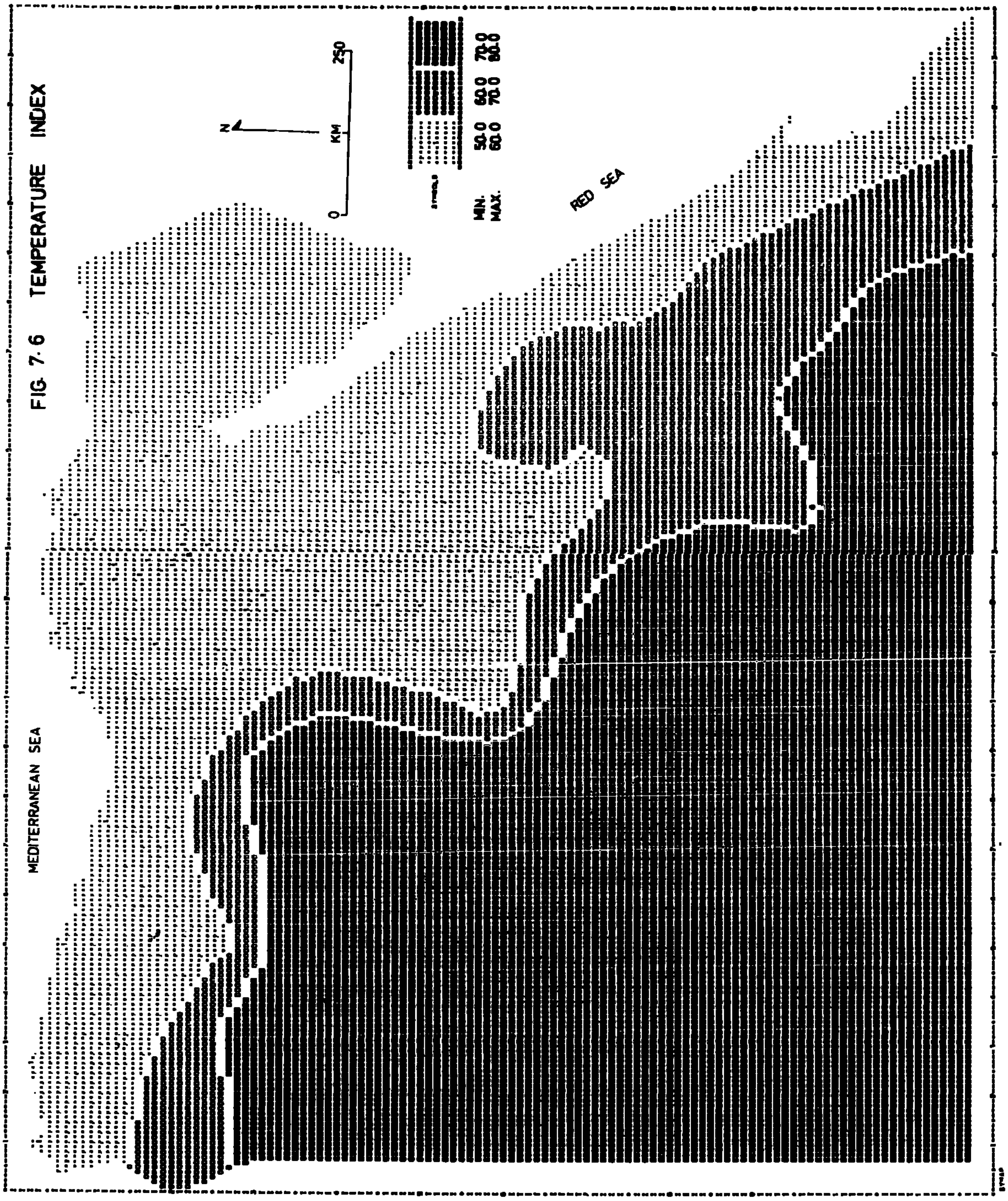


FIG. 7.6 TEMPERATURE INDEX

is an example for three selected stations :-

Alexandria :-

Temperature Index = 0.97 x 13.5 + 0.89 x 18.3 + 0.78 x 29.6 = 52.5

Tanta :-

Temperature Index = 0.97 x 12.8 + 0.89 x 19.7 + 0.78 x 34.5 = 56.8

Aswan :-

Temperature Index = 0.97 x 16.8 + 0.89 x 24.2 + 0.78 x 41.9 = 70.5

The results of the calculation for each station have been taken as input values to draw the isolines using "SYMAP" program (Fig. 7.6). This figure shows clearly that the Mediterranean coastal region, the lower part of the Nile Valley, including the Delta, the Sinai peninsula and the Red Sea coastal zone are seen as a separate region characterized by low factor loadings. To the south of this zone is a narrow intermediate zone trending north-west to south-east which separates the high factor loadings of the desert area from the coastal regions.

7.4 - Grouping of the climatological stations :-

The stations can be grouped on the basis of the similarity of the factor loadings using the "Single linkage tree" method of cluster analysis. This procedure has been used by Steiner (1965). He has grouped 67 climatological stations in the U.S. of America, based on the similarity of the factor loadings recorded at each station. McBoyle (1971) has used the loadings of the three factors derived from the twenty climatic variables of the original sixty-six climatic stations in Australia as input variables. He tried to detect homogenous regions using factor loadings as a similarity measure to produce a complete Linkage tree. Russell and Moore (1976) have used the same technique and they produced a "Dendogram" setting out the hierarchical arrangement of the 300 climatic stations in Australia and South Africa, based on their degree of similarity in terms of matrix correlation coefficients.

An attempt has been made by the present author to identify homogenous climatological regions in Egypt on the basis of the similarity of the factor loadings, using the "Single linkage tree" method of cluster analysis (see, Ward, 1963 and Everitt, 1974). This technique produces a dendogram setting out the hierarchical arrangement of the climatological stations based on the degree of similarity of the factor loadings (Fig. 7.7). The loadings of the three factors derived from the sixteen climatic variables (Tables 7.a) of the original 54 climatic stations (Fig. 2.2) have been used as input values.

These are :-

$$\begin{aligned}\text{Factor 1} = {} & -0.59\ T_1 - 0.21\ T_2 - 0.68\ T_3 + 0.19\ T_4 \\ & -0.66\ T_5 - 0.75\ T_6 - 0.06\ T_7 + 0.36\ H_1 \\ & + 0.21\ H_2 + 0.45\ H_3 + 0.93\ P_1 + 0.93\ P_2 \\ & +0.93\ P_3 + 0.93\ P_4 - 0.57\ T_8 + 0.93\ H_4\end{aligned}$$

$$\begin{aligned}\text{Factor 2} = {} & -0.55\ T_1 - 0.08\ T_2 - 0.36\ T_3 \\ & +0.12\ T_4 - 0.66\ T_5 - 0.50\ T_6 \\ & -0.45\ T_7 + 0.92\ H_1 + 0.89\ H_2 \\ & + 0.87\ H_3 + 0.26\ P_1 + 0.19\ P_2 + 0.30\ P_3 \\ & +0.29\ P_4 - 0.42\ T_8 + 0.20\ H_4\end{aligned}$$

$$\begin{aligned}\text{Factor 3} = {} & 0.55\ T_1 + 0.97\ T_2 + 0.33\ T_3 + 0.89\ T_4 \\ & +0.21\ T_5 - 0.20\ T_6 + 0.78\ T_7 + 0.12\ H_1 \\ & -0.07\ H_2 + 0.19\ H_3 + 0.08\ P_1 + 0.13\ P_2 \\ & +0.05\ P_3 + 0.09\ P_4 + 0.34\ T_8 + 0.13\ H_4\end{aligned}$$

These three factor loadings have been computed for each of the 54 climatic stations in Egypt. An example is shown for the Alexandria station :-

<u>Alexandria</u>

$$\begin{aligned}\text{Factor 1} = {} & -(0.59 \times 20.2)-(0.21 \times 13.5)-(0.68 \times 9.3) \\ & +(0.19 \times 18.3)-(0.66 \times 26.1)-(0.75 \times 22.7) \\ & -(0.06 \times 29.6)-(0.36 \times 70)+(0.21 \times 71) \\ & +(0.45 \times 73)+(0.93 \times 192.1)+(0.93 \times 48.3) \\ & +(0.93 \times 47.2)+(0.93 \times 10.3)-(0.57 \times 12.6) \\ & +(0.93 \times 1.0) \quad = \underline{290.12}\end{aligned}$$

$$\begin{aligned}\text{Factor 2} = {} & -(0.55 \times 20.2)-(0.08 \times 13.5)-(0.36 \times 9.3)\\ & +(0.12 \times 18.3)-(0.66 \times 26.1)-(0.50 \times 22.7)\\ & -(0.45 \times 29.6)+(0.92 \times 70)+(0.89 \times 71)\\ & +(0.87 \times 73)+(0.26 \times 192.1)+(0.19 \times 48.3)\\ & +(0.30 \times 47.2)+(0.29 \times 10.3)-(0.42 \times 12.6)\\ & +(0.20 \times 1.0) = \underline{207.05}\end{aligned}$$

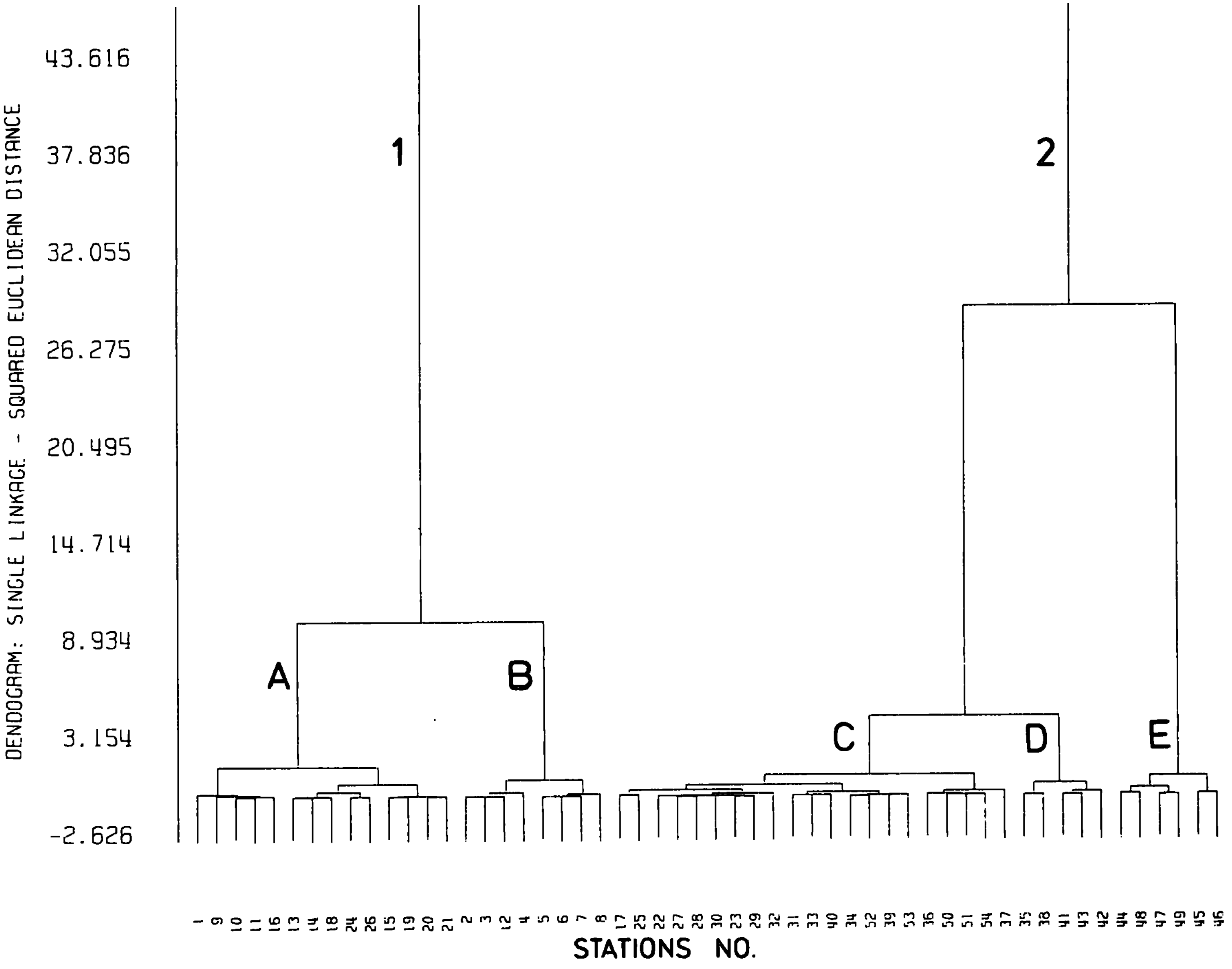
$$\begin{aligned}\text{Factor 3} = {} & (0.55 \times 20.2)+(0.97 \times 13.5)+(0.33 \times 9.3)\\ & +(0.89 \times 18.3)+(0.21 \times 26.1)-(0.20 \times 22.7)\\ & +(0.78 \times 29.6)+(0.12 \times 70)-(0.07 \times 71)\\ & +(0.19 \times 73)+(0.08 \times 192.1)+(0.13 \times 48.3)\\ & +(0.05 \times 47.2)+(0.09 \times 10.3)+(0.34 \times 12.6)\\ & +(0.13 \times 1.0) = \underline{114.25}\end{aligned}$$

The results of these factors have been used as the input data to produce a linkage tree of the 54 climatological stations (Fig. 7.7).

The results indicate that two groups of stations can be identified at the highest level (Fig. 7.7). The first group includes the Mediterranean coastal and Delta stations. In this region the climate is mainly humid and wet in winter and warm and dry in summer. The second region covers the rest of Egypt south of Cairo (Fig. 7.8). The climate of this region is of the desert type, which is characterized by a warm and dry winter and very hot and dry summer.

At the next level, five sub-regions can be identified (Fig. 7.7 and 7.9) :-

FIG. 7. 7 DENDOGRAM: SINGLE LINKAGE - SQUARED EUCLIDEAN DISTANCE



List of Climatological Stations shown in Figure 7.7

1 - SALLUM
2 - SIDI BARRANI
3 - MERSA MATRUH
4 - DABAA
5 - KOM EL-NADURA
6 - DEKHEILA
7 - ALEXANDRIA
8 - ROSETTA
9 - DAMIETTA
10 - PORT SAID
11 - EL-ARISH
12 - EDFINA
13 - EL-SIRW
14 - SAKHA
15 - MANSURA
16 - DAMANHOUR
17 - WADI EL-NATRUN
18 - GEMMEIZA
19 - TANTA
20 - SHEBIN EL-KOM
21 - ZAGAZIG
22 - FAYED
23 - ISMAILIA
24 - BANHA
25 - KHANKA
26 - DELTA BARRAGE
27 - ALMAZA
28 - CAIRO
29 - EZBEKIA
30 - GIZA
31 - HELWAN
32.- SHAKSHUK
33 - FAYUM
34 - BENI SUEF
35 - SAINT ANTONY
36 - MINYA
37 - MALLAWI
38 - ASYUT
39 - SHANDWEEL
40 - NAG HAMMADI
41 - QENA
42 - LUXOR
43 - KOMOMBO
44 - ASWAN
45 - SIWA
46 - BAHARIYA
47 - FARAFRA
48 - DAKHLA
49 - KHARGA
50 - SUEZ
51 - EL-TOR
52 - HURGHADA
53 - QUSEIR
54 - ABU EL-KIZAN

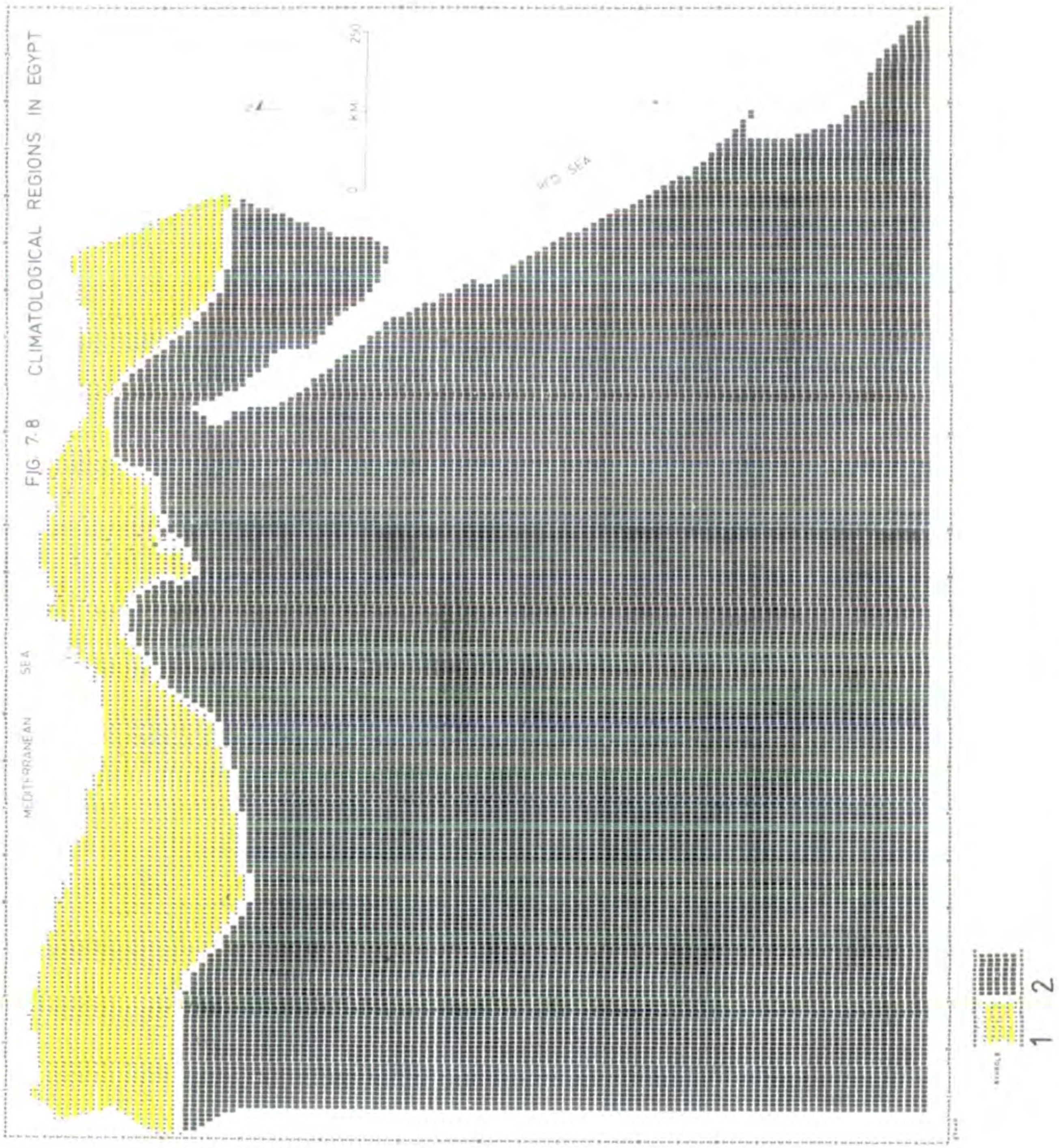


FIG. 7.8 CLIMATOLOGICAL REGIONS IN EGYPT

A - The first includes 14 stations mainly in the Delta and along the eastern and western extremities of the Mediterranean coast. The climate of this zone is mild winter with some rain and a warm dry, rainless summer.

B - The second sub-region covers the Mediterranean coastal area to the west of the Delta with the exception of Sallum station, this zone is the wettest part of the country as seen from the precipitation index (Fig. 7.9).

C - The third zone includes all the stations along the Red Sea coast, Suez Canal as well as the Fayum area and the Nile Valley to the south of Cairo (Fig. 7.9). The climate of this area is generally hot, but rather humid and rainless.

D - The fourth zone extends to the south of the third sub-region trending north-west to south-east and separates the desert area from the coastal regions (Fig. 7.9).

E - The fifth sub-region includes Aswan and the five oases in the Western Desert. This zone is the hottest area in the country as illustrated by the temperature index (Fig. 7.9).

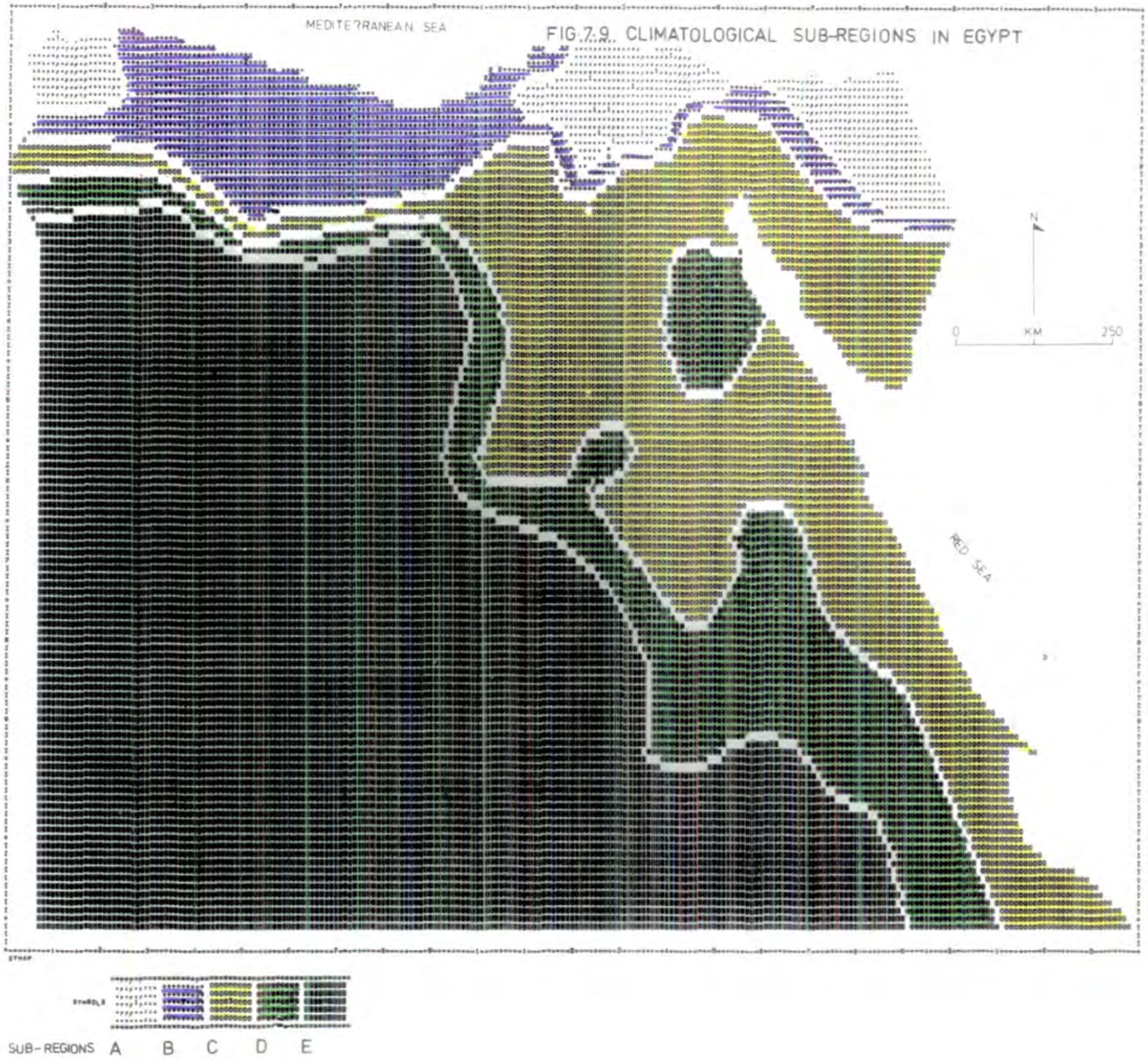


FIG.7.9. CLIMATOLOGICAL SUB-REGIONS IN EGYPT

SECTION 2

Chapter 8 - Introduction

Chapter 9 - The Expansion of the Cultivated Area and the Major Crops in Egypt

Chapter 10 - Irrigation and Drainage in Egypt

CHAPTER 8

Agriculture in Egypt

Introduction

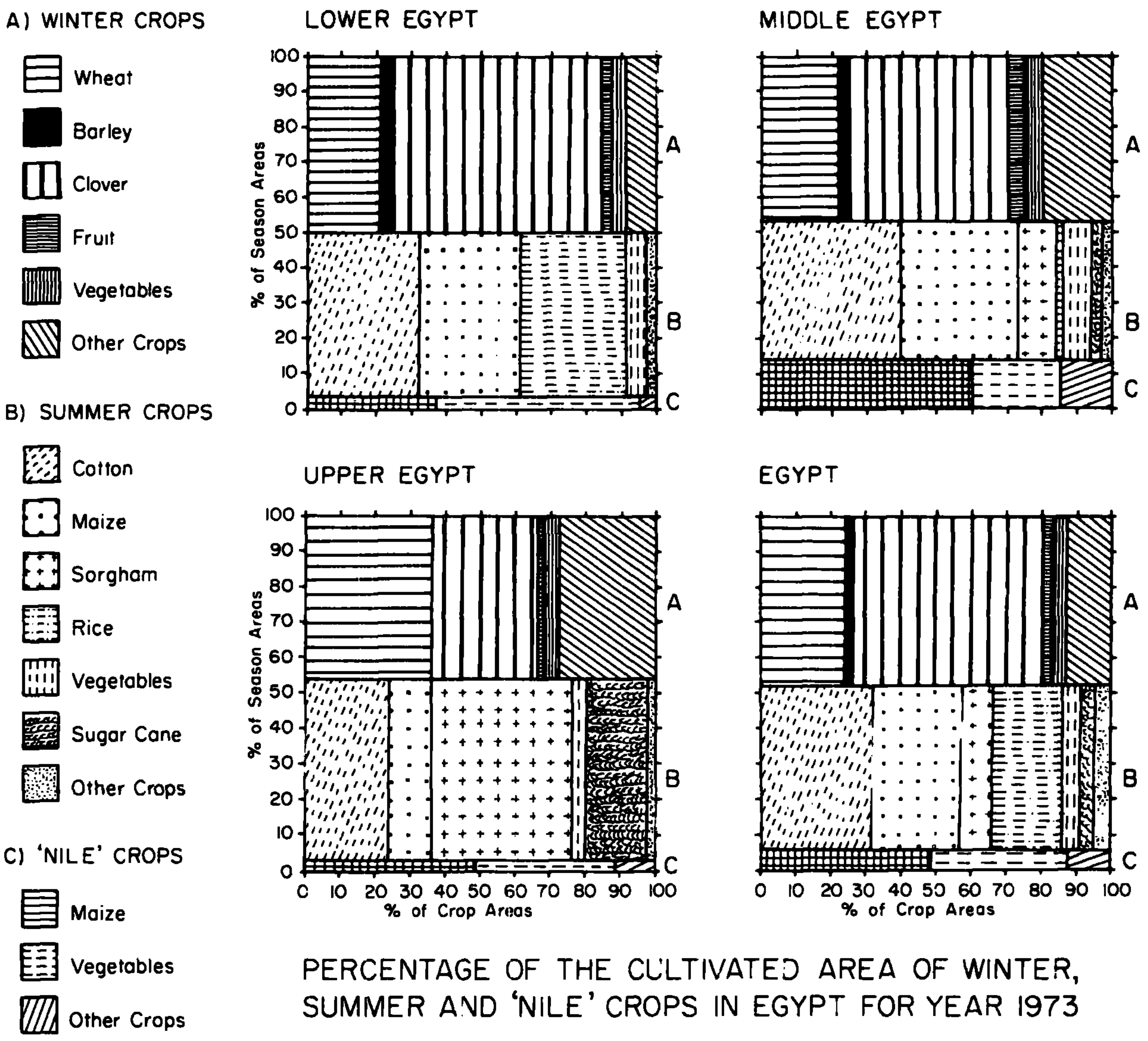
Agriculturally Egypt can be described as a giant oasis situated within the confines of the flat plains and delta of the River Nile, where cultivation can only be carried out with the aid of irrigation. Crop production may be virtually continuous over the total cultivated area if water is available. The country has practically no permanent pastures or forests and owing to the lack of rain and water almost 96% of the land area of Egypt is waste.

The area that can be cultivated in the country depends entirely on the altitude of the land in relation to the height of the nearest water supply. Since the economic lift of water is at present limited in Egypt to about 20 metres (see Aboukhaled et al., 1975), the total cultivated area is estimated at 11 million feddans. About 60% of Egypt's productive land is located in the Delta. Middle Egypt has about 20%, and Upper Egypt about the same amount.

8.1 - The agricultural seasons and rotation :-

The agricultural year of Egypt is divided into three seasons in each of which particular crops can be sown (Fig. 8.1). However, with the perennial irrigation system two crops per year can be grown on the same land i.e. winter crops (October to April) and summer crops (largely between April and October), (Table 8.a). Sometimes a third crop may be grown on the same land; for example a crop of corn or millet can be obtained between September and November after maize or clover.

Fig. 8.1



PERCENTAGE OF THE CULTIVATED AREA OF WINTER, SUMMER AND 'NILE' CROPS IN EGYPT FOR YEAR 1973

Table 8.a

Planting and Harvesting Periods of Major Crops in Egypt

Crop	Lower Egypt		Middle and Upper Egypt	
	planting	harvesting	planting	harvesting
Cotton	March 1st	September 1st	March 1st	September 1st
Maize	April 15th	August 8th	April 15th	August 8th
Wheat	November 10th	May 10th	November 10th	May 10th
Rice	May 1st	September 30th	May 1st	September 30th
Sugar cane	February 1st	January 13th	February 1st	January 13th

Source :- Agricultural Research Review, Vol. 44, No. 1, 1966, Cairo, Egypt, pp. 133-135 (in Arabic).

In the winter season, which extends from mid-October until late December, the main crops that may be grown are wheat, barley, clover, beans, flax, onions and lentils. The summer season lasts from mid-January till mid-June, and during it cotton, rice, sugar cane, sesame and millet are grown. By the beginning of July the 'Nile' season starts (this term refers to the flood season of the Nile), lasting through until mid-August. Corn, millet and rice are the chief crops grown during this season (Fig. 8.1).

Crop cultivation mostly follows a two or three year rotation. With a two year rotation a given crop is grown on the same plot every other year, while with a three year rotation two years elapse before a given crop is again cultivated on the same plot.

According to the two-year rotation, winter crops (including clover, wheat, beans, barley and flax) take up about 50 per cent of the area. They are followed by summer or 'Nile' crops, i.e. rice and maize. A part of the area may be left fallow. In the neighbourhood of towns and districts, vegetables are included in the rotation as summer or 'Nile' crops. The other 50 per cent of the area is either cultivated with clover (one cut) or left fallow until cultivated with cotton as a summer crop.

In the three-year rotation the area is divided into three equal parts. The first is either sown with clover (one cut), or left fallow until cultivated with cotton. The second part is taken up by beans and/or clover. These crops are succeeded by maize and/or rice. The third part is sown with wheat, barley and flax, followed by maize and/or rice.

Both systems of rotation are applied in the Delta as well as in Middle Egypt. In Upper Egypt sugar cane becomes the main crop and has a four-year rotation. The sugar cane occupies one quarter of the land in the first year; in the second year one half; and in the third and fourth years three quarters. The rest of the area is either cultivated with winter crops succeeded by 'nile' crops or with cotton, or left fallow succeeded by maize (For more details, see Nuttonson, 1961; Abd El-Ilah, 1965; Clawson et al., 1971).

8.2 - Agrarian reform :-

Three land reform measures in 1952, 1961 and 1969 dealt first with the small number of large landowners. This reform lowered the maximum holding per family to 100 feddans and individual ownership to 50 feddans. Given the quality of Egypt's land, 50 feddans is a substantial holding, and the general effect of land reform has been the destruction of a landed aristocracy; the swelling of the ranks of those with less than five feddans; and the maintenance of the class of middle-range landowners of 10-50 feddans. By 1971, 850,000 feddans had been redistributed to 410,000 families owning less than two feddans (Hagrass, 1972).

Cooperatives in Egypt :-

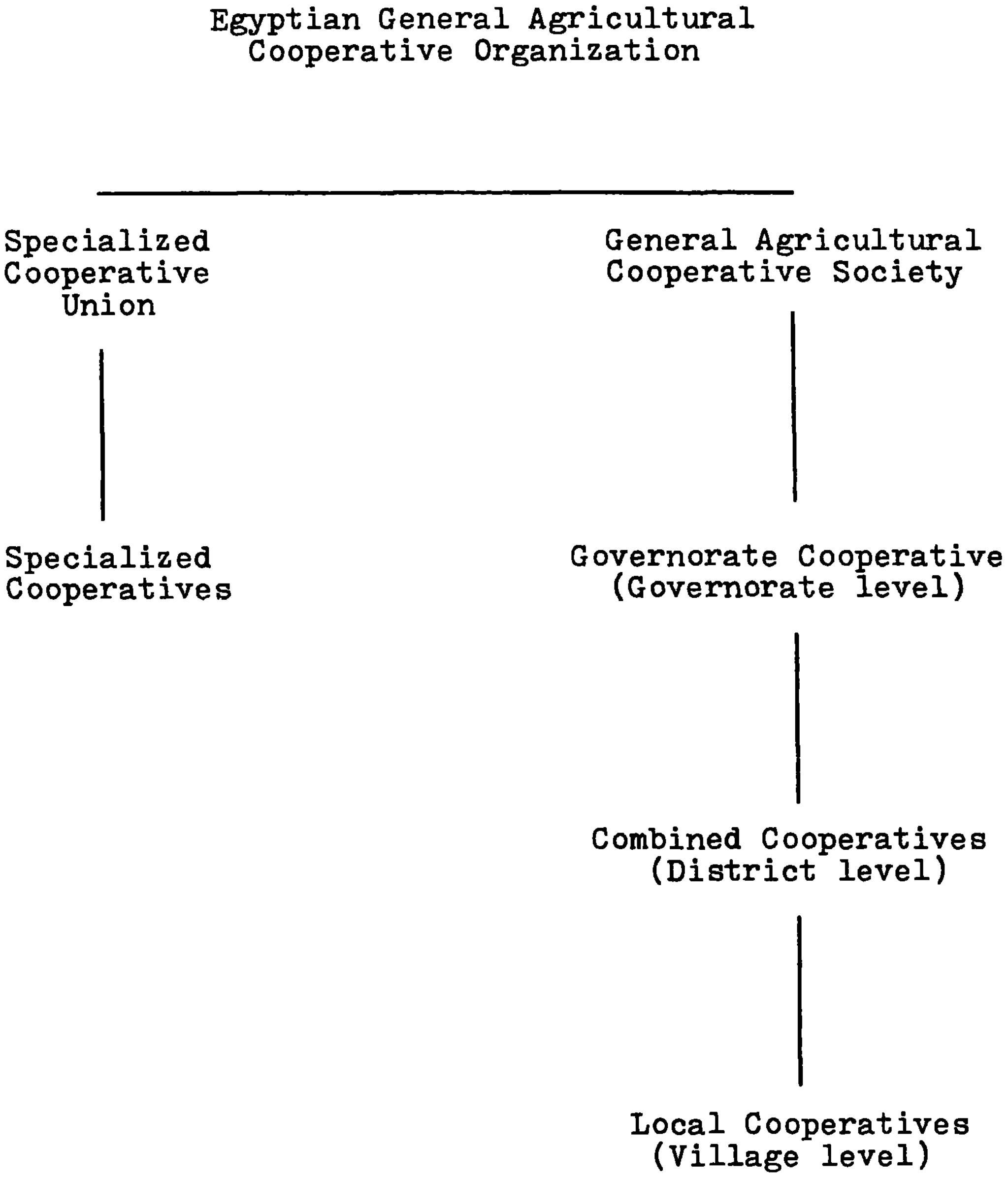
Agricultural cooperatives play a key role in Egypt at the present time.

The agricultural cooperative structure is headed by the General Cooperative Organization (Fig. 8.2). This body is responsible for the promotion of the cooperative movement through the formulation of the general cooperative policy, the provision of the requisite technical and financial help to the cooperatives and the supervision of their activities.

In addition, realizing the importance of efficient management, each cooperative is being provided with a trained agricultural supervisor well versed in local conditions, an accountant for the disbursement and the collection of loans, and a clerk for administrative matters and store-keeping. It is also provided with ample office, meeting and storage facilities as well as housing premises for the resident agricultural supervisors and other members of staff (Abdel-Ilah, 1965 and Waterbury, 1974).

It is not uncommon in Egypt to see labourers using ancient methods and tools along with some of the more modern farming techniques. There is great dependence on the use of manpower and chemical fertilizers, but little reliance on the use of cultivating or harvesting machinery. Regardless of the method of production, farming is very intensive with irrigation being essential. The use of modern agricultural machinery is limited chiefly to the large cooperative farms under Governmental super-

Figure 8.2


Egyptian General Agricultural Cooperative Organization
Specialized Cooperative Union
Specialized Cooperatives
General Agricultural Cooperative Society
Governorate Cooperative (Governorate level)
Combined Cooperatives (District level)
Local Cooperatives (Village level)

vision.

8.3 - The soils of Egypt :-

The cultivated soils of Egypt are mainly alluvial in origin and are generally of a clayey nature differing mainly in the proportion of the clay present. This type of soil constitutes about 75% of the area under cultivation. Residual calcareous soils exist along the Mediterranean coast as well as in Fayum province.

The various kinds of soils of Egypt and their general distribution are indicated in the soil map of Egypt (Fig. 8.3) (see El-Gabaly et al., 1969; Beaumont et al., 1976). The soil types of Egypt on the basis of their general characteristics can be classified into the following groups :-

1. Lithosols :- These soils cover a large portion of the country (about 17%) and are found in the Eastern Desert, south Sinai and on the Gilf El-Kebir plateau (Fig. 8.3). The profiles of this group are mainly shallow and stony, and possess only weakly developed horizons. Rock outcrops are common, and slopes nearly everywhere steep.

2. Limestone Lithic Ermolithosols :- This type is mainly found on the central and northern parts of the Western Desert, the central part of Sinai and the north east portion of the Eastern Desert (Fig. 8.3). It accounts for a quarter of all the soils of the country.

3. Sandstone Lithic Ermolithosols :- These are

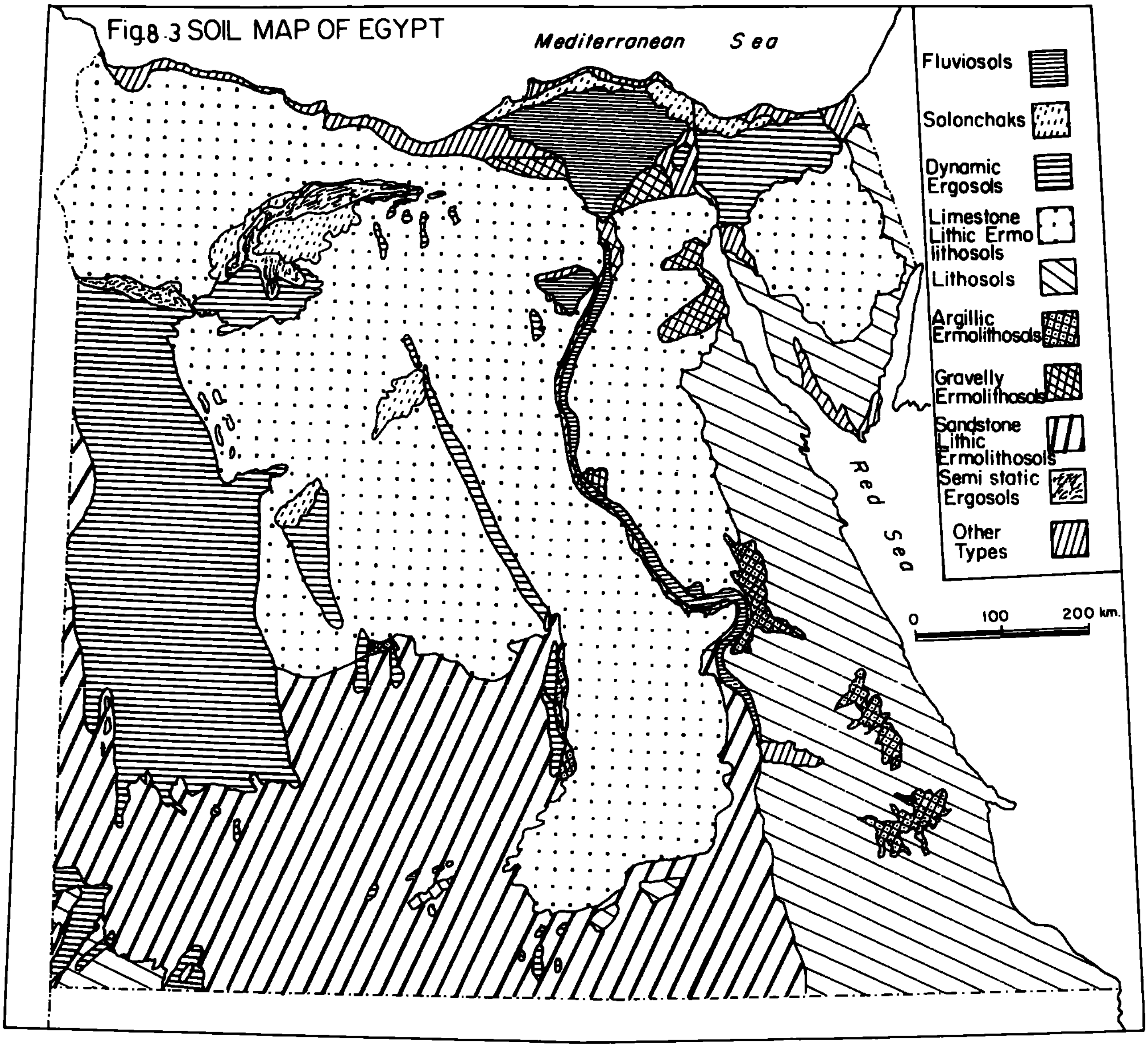


Fig.8.3 SOIL MAP OF EGYPT

developed on the Nubian Sandstone and cover an area of about 20% of the country. These soils are found mainly in the southern part of the Western Desert (Fig. 8.3).

4. Fluviosols (Alluvial Soils) :- These are formed from geologically young materials deposited by running water in stream valleys, deltas, or at the foot of slopes. They are level, deep, black coloured and heavy to medium in texture. This group of soils is cultivated and shown in the Delta and throughout the Nile Valley. These soils however, cover only about 2.5% of the total area of Egypt (Fig. 8.3).

All other soil types cover only very small parts of the country (For more details, see Abd El- Llah, 1965; Hamdi, 1972; El-Gabaly et al., 1969; Clawson et al., 1971; Beaumont et al., 1976 and others).

The soils of the Delta and the Nile Valley :-

The soils of the Delta and the Nile Valley are the most productive soils in Egypt. They consist largely of loams, clays, and sands. Loam soils are mainly composed of silt deposited by the Nile River, and heavy or light loams form the bulk of the cultivated soils of Egypt. Clay soils may occur in small patches, while sandy soils are principally found skirting the edges of the desert.

The Nile silts - or mud, as it is sometimes called - have been famous for their fertility throughout recorded history. Part of this fertility is undoubtedly due to the fresh, weatherable minerals that can serve as a source of inorganic nutrients required by the plants. Another contributing factor is the high content of organic matter of the silts when deposited.

According to Ball (1939), the average organic matter content of the suspended matter of the Nile River at Cairo in 1924-27 was 2.5%. This organic fraction had a carbon-to-nitrogen ratio of 11. Thus, good supplies of nitrogen needed for plant growth are deposited along with the mineral nutrients. One must conclude that the fertility of the alluvial soils of Egypt is due to the loss of fertile soil mainly in Ethiopia (Clawson et al., 1971; Hamdi, 1972). It should be pointed out that though the natural fertility of the Nile alluvial soils is justly world famous, it is not adequate for the sustained high levels of production associated with modern agriculture.

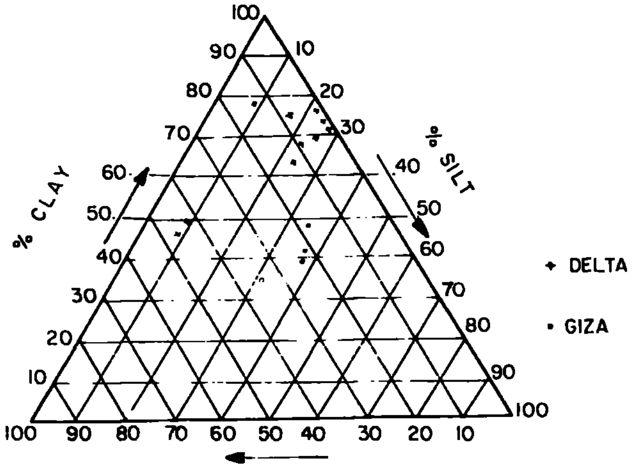
The lack of adequate drains and the overuse of irrigation water has led to high water tables in many of the Nile Valley and Delta soils (See Schulze and de Ridder, 1974). This problem has become more acute since it has become common to take more than one crop per year from the land (See Irrigation and Drainage chapter).

The nature of the alluvial Delta soils, according to Money-Kyrle (1957), is affected by many factors, the most important of which are the annual flood which deposits silt, the distance from the desert, the depth of the water table, drainage, the composition of the silt, and the type of irrigation and cultivation (See Beaumont et al., 1976).

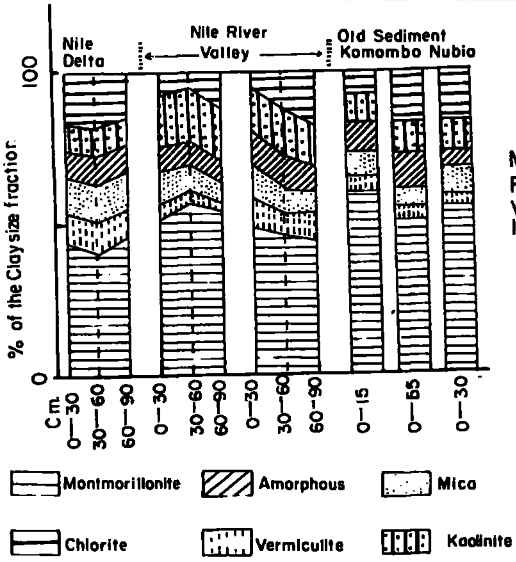
Money-Kyrle states that the composition of river water used to vary, according to the time of year, from 700 to 1,600 P.P.m. of solid matter and 130 to 212 P.P.m. of soluble salts, (Principally bicarbonates of calcium and magnesium). The water-table level has been rising because of seepage from canals and barrage ponds as well as due to excessive irrigation. Thus, he points out, in 1900 the flood caused a rise in the water-table from a depth of 4 metres to 2 metres, while in 1950 the rise was from a depth of 1.7 metres to 0.5 metres below the ground surface. Schulze and de Ridder (1974) have studied the rising water-table in the west Nubarya area of Egypt and showed that after irrigation started in 1968, the water-table gradually rose. Measurements taken over a period of three years (September, 1969 to September, 1972) revealed that in certain places the water-table rose by as much as 12 metres, or an average of 4 metres per year and at the present time is found locally at depths of no more than 3 metres below ground surface. The high water-table limits root growth and causes many soil changes. When the water-table is near the surface, water moves upwards by capillarity, carrying salt from deeper layers. As the water evaporates, salt is deposited, forming saline soils such as those existing in the northern part of the Delta. Under certain conditions these soils become alkaline.

Attar and Jackson (1973) have studies the montmorillonitic soils developed on the Nile River sediments. They showed that the texture of samples of Nile alluvium varied along the river; across the valley, and from the

Fig.8.4



TEXTURAL CLASSIFICATION OF NILE ALLUVIAL SAMPLES FROM EGYPT



MINERALOGY OF CLAY FRACTIONS (< 2 μ) FROM VARIOUS LOCALITIES IN EGYPT.

soil surface down the profile (Fig. 8.4). As is characteristic of stream sediments laid down under variable water velocities and loads, the Nile and Delta lacustrinal soils have a clayey texture, except for those close to the desert or those containing remnants of marine fossil shells known as "turtlebacks".

The soils of the Delta and the Nile Valley have also been studied by Hamdi (1972). He divided these soils into five groups. These are :-

1. Stream Alluvium :- This group is located in the Nile Valley and the southern part of the Delta. These soils are sandy clay loam to clay loam.

2. Marine Alluvium :- The soils of this group cover the area to the north-west of the Rosetta Branch and are also found in the neighbourhood of the northern lakes. The main area covered by this group represents a depression between the Western Desert and the Delta proper. The soil profiles are characterized by the presence of appreciable amounts of $CaCO_3$ (30%) and gypsum veins.

3. Desert Alluvium :- The soils of this group are found in the eastern part of the Delta. They are man-made soils produced through agriculture practices using irrigation with water rich in Nile suspended matter. These are sandy and loamy soils.

4. Lithosols :- These soils are found in the Fayum Depression.

5. Regosols :- This group consists of sand dunes

or unconsolidated bedrock located near the Mediterranean coast and in the Fayum Depression.

The salinity of the Delta and Nile soils :-

In the northern half of the delta as well as in the Fayum province, the salt content of the soil exerts a major influence on cultivation. It is related in the Fayum area to inadequate internal drainage to Lake Qarun which lies below sea level. In the northern half of the Delta salinity is connected with the formation of 'berari', (swamps), the low lying nature of the land and perennial irrigation. Good cultivated land has an average salt content of about 0.3 per cent and medium land 0.5 per cent. Poorly land has a salt of 0.8 per cent and barren land may contain anything up to 25 per cent salt (Hamdan, 1961). The gradual transition from good land in the south through medium to bad and barren in the north of the Delta region is a fundamental feature of the cultivated area of Egypt. The less porous and permeable black soils favour capillary attraction more than the sandy soils, hence the rise of the water-table (Connected with perennial irrigation and neglected drainage) is accompanied by more salt efflorescences and salinization in the northern Delta area.

Drar (1953), states that soils impregnated with salt are found in the Delta and the Fayum region and that alkali land occurs around the lower edge of the Delta from Alexandria in the west to beyond the Suez Canal in the East. Salt affected regions are also found in some districts of Upper Egypt. The formation of alkali soils is, according to Drar the result of :-

A - The change from basin to perennial irrigation without the provision for sufficient drainage.

B - Water seepage through the banks of high level canals. The formation of alkaline soils is encouraged when drainage is poor. With good drainage, salts do not accumulate and the soils remain fertile (For more details, see Clawson et al., 1971 ; Hamdi, 1972; Aboukhaled et al., 1975; Waterbury, 1974).

The following section is comprised of two main chapters. The first considers the major crops and the expansion of the new cultivated lands in Egypt. 125 districts (Fi g. 8.5 and 8.6) and 19 governorates (Fig. 8.7) have been used in this analysis.

The second main chapter analyses the irrigation and drainage in Egypt. Irrigation requirements for the major crops are obtained using the Penman equation and the Blaney and Criddle formula.

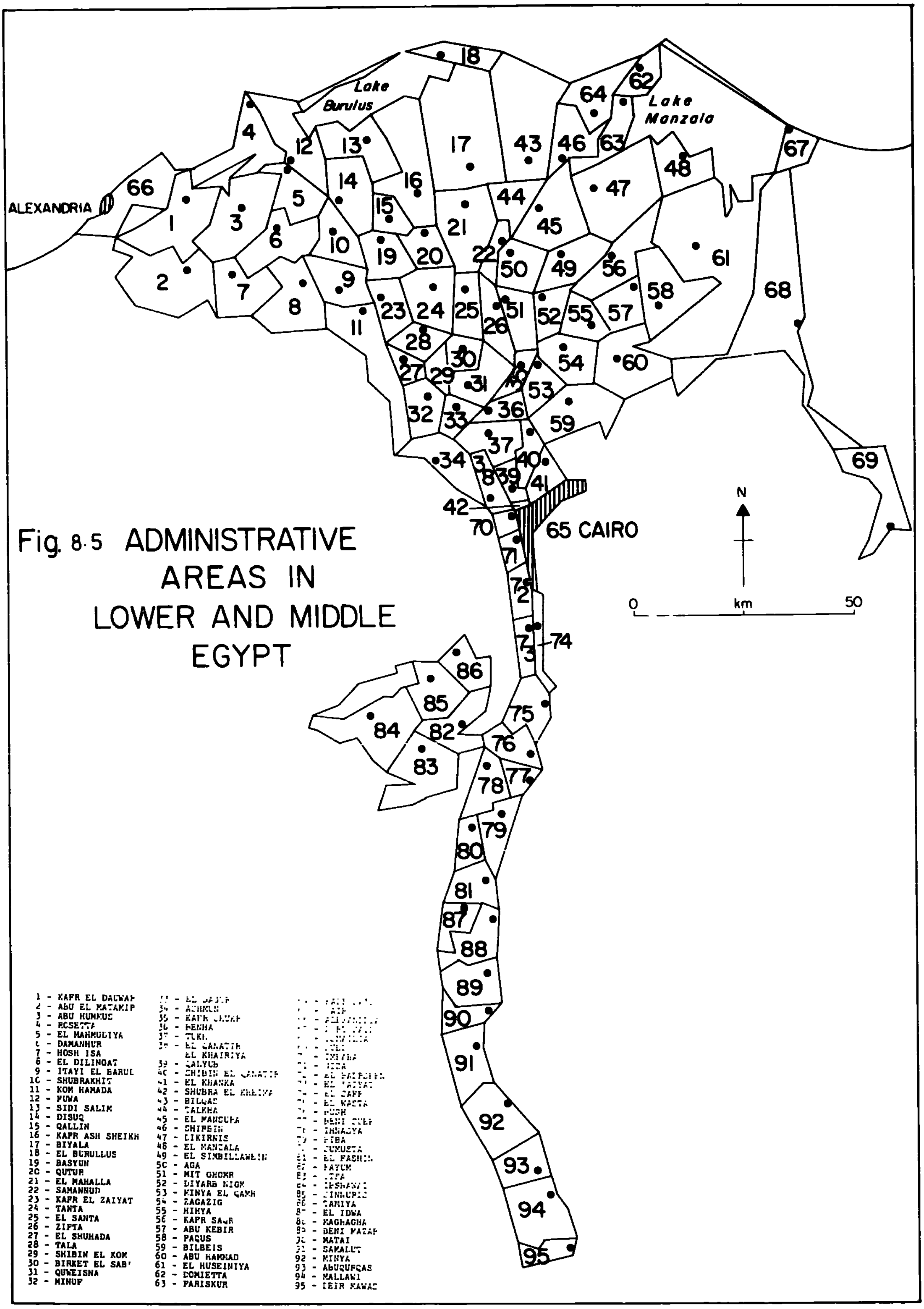


Fig. 8.5 ADMINISTRATIVE AREAS IN LOWER AND MIDDLE EGYPT

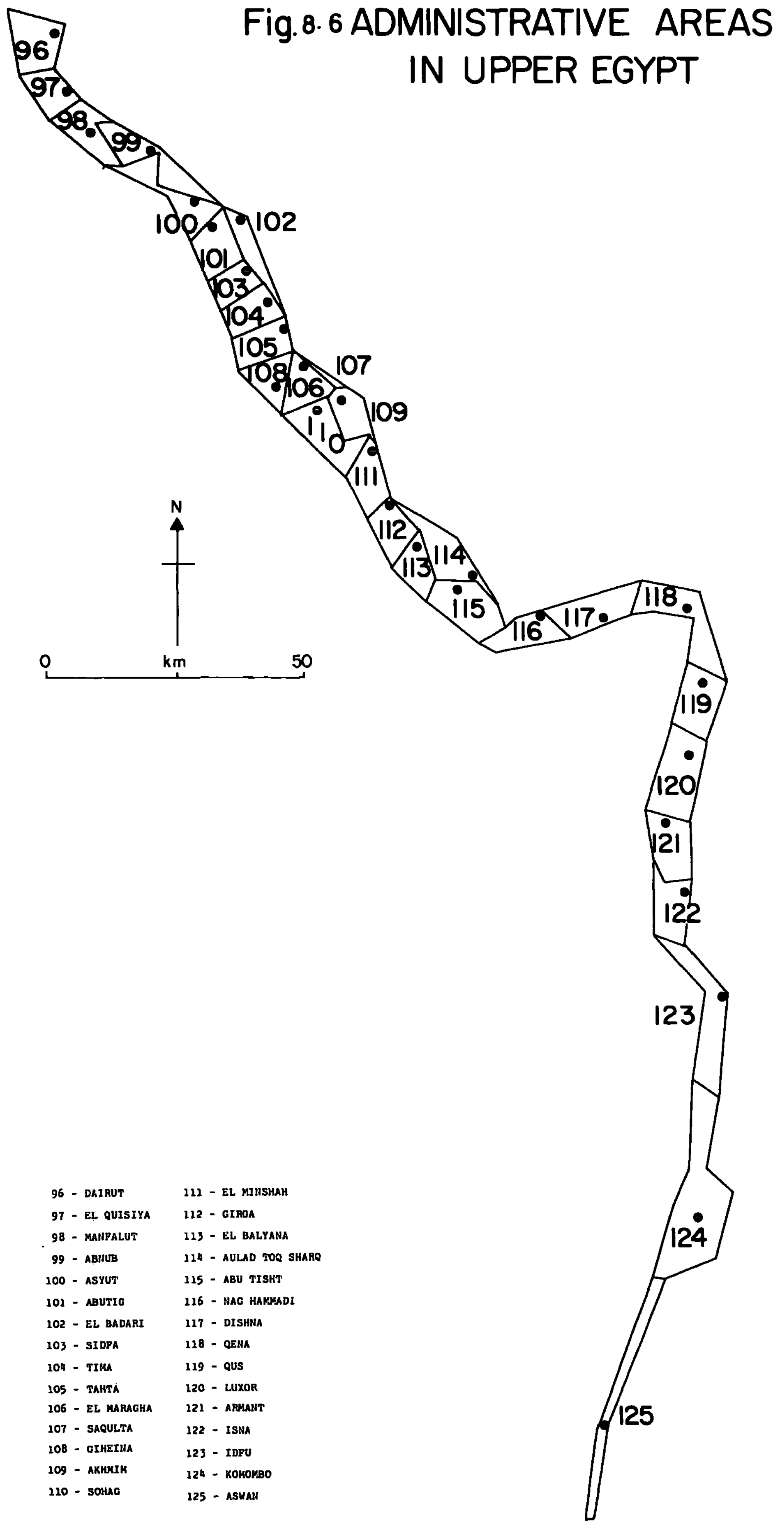


Fig. 8.6 ADMINISTRATIVE AREAS IN UPPER EGYPT

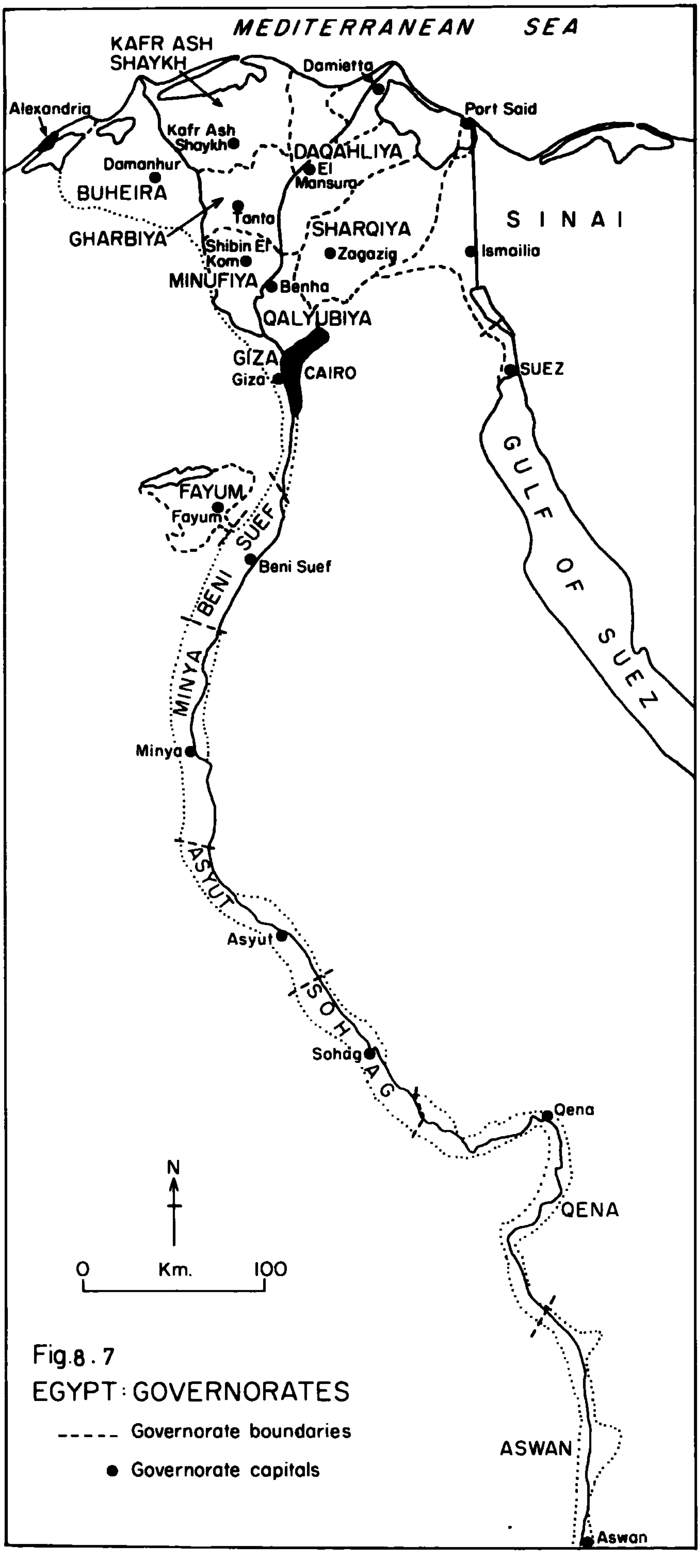


Fig.8.7

EGYPT: GOVERNORATES

CHAPTER 9

The Expansion of the Cultivated Area and the the Major Crops in Egypt

9.1 - Expansion of the cultivated area in Egypt :-

Before the construction of the Aswan High Dam (Sadd El-Aali), the water from the Nile could irrigate little more than six million feddans. Apart from some minor cultivated areas in oases in the Western Desert and along the northwest coast (Fig. 9.1), this figure represented most of the cultivated area of Egypt in the early 1960's.

Table 9.a shows clearly that up to 1970 more than 880,000 feddans had been reclaimed for cultivation using Nile water and most of this area was already producing crops. More than 48% of the newly cultivated lands were in Buheira and Kafr ash Shaykh governorates (Table 9.a). It can also be seen that the years of 1964 and 1965 were the ones which saw the reclamation of the highest per cent of land. During these years the figures were 18.03% and 15.49% respectively. The main reason for this expansion was the additional water made available by the Aswan High Dam.

The chief features of the expansion of cultivation in Egypt from 1960 to 1980 and the major reclamation schemes are included in Figure 9.1. These schemes have already been discussed by Field (1973); Mountjoy (1972); Naur El-Din (1968); Schulze and de Ridder (1974); Beaumont et al. (1976); Fisher (1971); Waterbury (1974). The two major schemes for the expansion of farmland by desert reclamation, the Tahrir (Liberation) province and the New Valley project will be discussed in the following pages.

Fig.9·1 EXPANSION OF THE CULTIVATED AREA IN EGYPT (1960-1978)

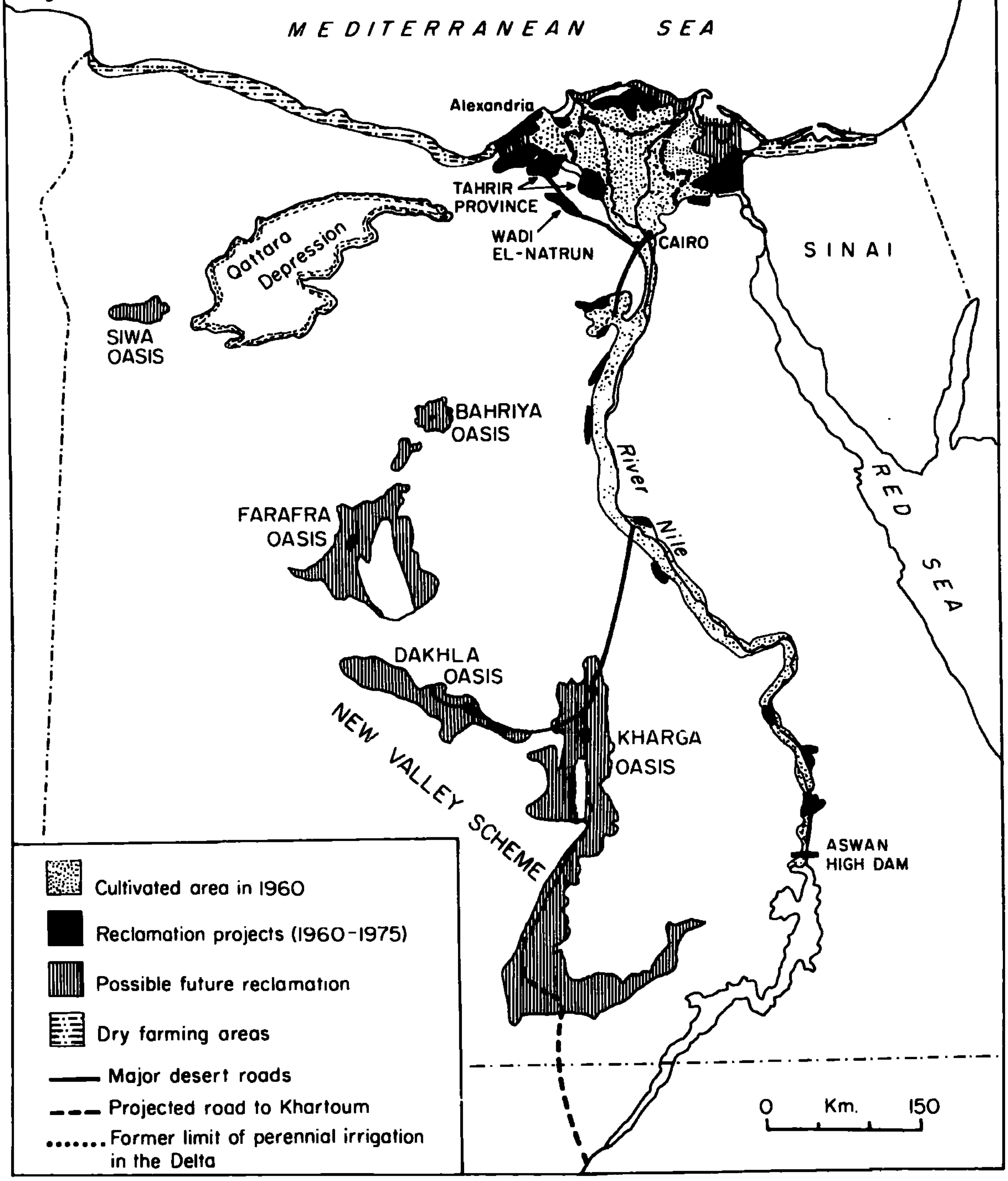


Table 9.a

Expansion of the Cultivated Areas in Egypt for the Period up to 1970 (Feddan)

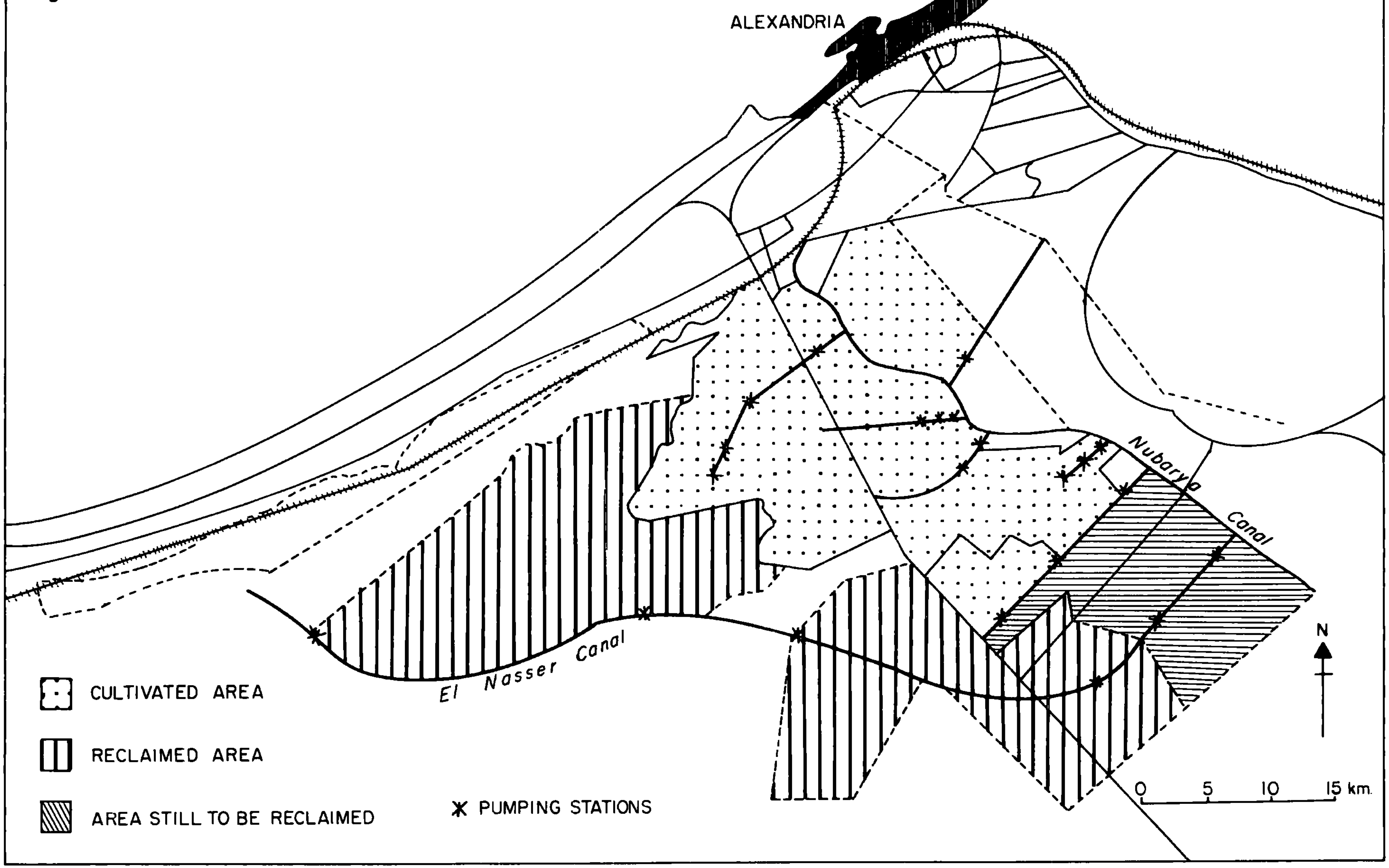
Year / Governorate	Up to 1960	1960/ 61	61/62	62/63	63/64	64/65	65/66	66/67	67/68	68/69	69/70	Total	%
Alexandria	-	-	-	-	3521	4589	51890	3062	-	-	-	63,062	7.13
Ismailia	4369	-	-	-	1000	4000	-	-	-	-	-	9,369	1.06
Suez	340	-	-	-	-	-	-	-	-	-	-	340	0.04
Daqahliya	8160	-	1700	3320	-	-	-	-	-	-	-	13,180	1.49
Sharqiya	10250	1500	8964	9811	7000	4500	-	-	-	7000	5000	54,025	6.11
Qalyubiya	522	-	-	-	-	-	-	-	-	-	-	522	0.06
Kafr ash Shaykh	2500	2000	17650	23585	33700	28000	4000	4000	2000	19000	7000	143,435	16.22
Buheira	42446	4700	21795	37852	48420	51800	12600	18500	32000	14100	-	284,214	32.14
Giza	2732	-	-	1000	-	-	-	-	-	5000	6000	14,732	1.67
Fayum	4000	-	3100	2400	-	-	-	-	-	-	-	9,500	1.07
Minya	-	-	-	1500	5500	12000	22000	21500	-	-	-	62,500	7.07
Sohag	-	-	-	-	-	5700	-	-	-	-	-	5,700	0.64
Qena	-	-	-	1000	9000	7000	-	-	-	-	-	17,000	1.92
Aswan	-	-	9573	12603	14817	4000	11100	2130	-	-	3000	57,223	6.47
New Valley	3006	7220	8700	9456	8477	6961	2000	1092	-	-	-	46,912	5.30
Matruh	440	980	3400	5110	2000	2450	1000	1350	-	-	-	16,730	1.89
Sinai	118	2530	2500	1210	4000	1000	-	1028	-	-	-	12,386	1.40
Waste land in the reclaimed area	-	9343	11948	13465	22000	5000	11837	-	-	-	-	73,593	8.32
Total area	78883	28273	89330	122313	159435	137000	116427	52662	34000	45100	21000	884,423	100
%	8.92	3.20	10.10	13.83	18.03	15.49	13.16	5.96	3.84	5.10	2.37	100	

Source:- Ministry of Land Reclamation, Land Reclamation Development in Arab Republic of Egypt, Cairo, 1973, p. 14.

A - Tahrir (Liberation) province :-

This major reclamation scheme, is located in the desert at the western edge of the Delta midway between Cairo and Alexandria (Fig. 9.1). The somewhat grandiose title "Liberation province" has been given to this project, which was put under army direction and began as something of a military operation. Reclamation and settlement proceeds in two sectors, termed the southern and the northern sectors. The southern sector relies on water from the Nile and from numerous wells. In this sector the soils are sandy and have proved less responsive than had been hoped. In the northern sector soils are highly calcareous with a calcium carbonate content varying from 20 to 50 per cent. Locally they are slightly saline, but salinity is not considered to be a major problem as the hydraulic conductivity is rather high and sodium is not dominant. They have, in general, a low fertility and their water availability is very limited. To improve the structure of the soils and to increase their content of organic matter, alfalfa is cultivated during the first three to five years. In this period the salinity content should drop to levels acceptable for normal cultivation. The northern sector area depends on water from the Nubarya canal, whose water level is from 4 to 5 m above mean sea level. Since the project area west of the canal rises gradually to elevations as high as 10 to 50 metres above mean sea level, all the water needed for irrigation is pumped to these elevations by a series of electrical pumping stations (Fi.g 9.2) (Schulze and de Ridder, 1974).

Fig. 9.2 WEST NUBARYA PROJECT AREA 1974



Work on the project was begun in 1952 and by 1972 over 150,000 feddans had been reclaimed and 25,000 people had been established in seven villages (Beaumont et al., 1976; Mountjoy, 1972 and Schulze and de Ridder, 1974).

B - The New Valley project :-

The New Valley project is the name given to five main oases lying in the eastern part of the Sahara and running from south to north almost parallel to the Nile River. Their names from south to north are: Kharga, Dakhla, Farafra, Bahariya and Siwa (Fig. 9.1). These oases are depressions of irregular shape. The southern most oasis of Kharga lies between latitudes 24^{o} 20 N and 26^{o} 00 N and between longitudes 30^{o} 00 E and 30^{o} 50 E. Its main axis trends north-south for a distance of about 170 km. The width of the depression is approximately 50 km. This oasis is connected to the Nile Valley by an asphalt road. The remaining four oases vary in shape and alignment (Fig. 9.1).

Water supplies in this valley are obtained from artesian wells 300 to 600 metres deep drawing on the vast natural water supplies which exist in the Nubian Sandstones. The irrigation potential of this water may have been exaggerated (Hammad, 1970; Fisher, 1971; Himida, 1970 and Beaumont et al., 1976), but there seems to be a reasonable prospect of cultivating some 400,000 feddans of the level sandy soil of the New Valley. A proposal to bring water to the southern parts of Kharga direct from Lake Nasser by underground canal could greatly increase this amount. In 1972 only about 50,000 feddans had been reclaimed and cultivated, chiefly in the Kharga and Dakhla oases.

Hammad (1970) studied the ground water potentialities in the African Sahara and the Nile Valley. He concluded that the Kharga oasis is receiving a steady guaranteed recharge of 174,000 m^3/day, which flows to the ground surface through wells under artesian pressure. Water is also being drawn from storage at a daily rate of 96,000 m^3/day. This latter quantity is smaller than the steady recharge and is declining with time. It can only be exploited for temporary land expansion. The installation of pumps in the Kharga wells has increased their discharge by about 15% under reasonable working conditions.

The Dakhla oasis is drawing a steady guaranteed recharge of 384,000 m^3/day which flows to the ground surface through wells under artesian pressure. It is also drawing from storage an extra daily discharge of 86,000 m^3/day. This latter amount will decrease with time. The installation of pumps in the Dakhla wells has increased their discharge by about 7%.

At present the free flow discharge of Kharga can irrigate a cultivated area of about 10,500 feddans at a daily consumption of 20 m^3/feddan. The corresponding area which can be irrigated at the Dakhla oasis is 22,000 feddans.

The ground water resources of the New Valley area are generally limited. Consequently very efficient irrigation practices will have to be used, and crops which need little water consumption must be chosen. There is at present considerable wastage of the valuable water resources. Related to the problem of improving irrigation practices is the problem of controlling the salinity of the soil in the oases through efficient drainage. This is because the ground water contains a relatively high percentage of salt (For more details, see Himida. 1970; Hammad, 1970; Lamoreaux, 1962).

The total area of the depressions is estimated by the Executive Agency for Desert Projects (E.A.D.P.) at eight million feddans. It is hoped that up to 25% of this area may be reclaimed using subterranean water supplies. It represents in effect the creation of a second irrigated valley alongside the Nile Valley to produce more food crops to supply the population's food demands.

9.2 - The major crops in Egypt :-

The major crops in Egypt at the present day are cotton, wheat, maize, sugar cane and rice. Clover, beans, sesame, lentils, fenugreek and flax are of lesser importance. The main crops are grown throughout the whole of the Nile Valley and Delta areas, whereas the less important crops tend to be more localized in their distribution.

Cotton is the principal cash crop of Egypt and is the main source of foreign exchange. The average cotton yield for each district is graphed (Figs. 9.3 and 9.4), for the years 1965 and 1966. These years have been

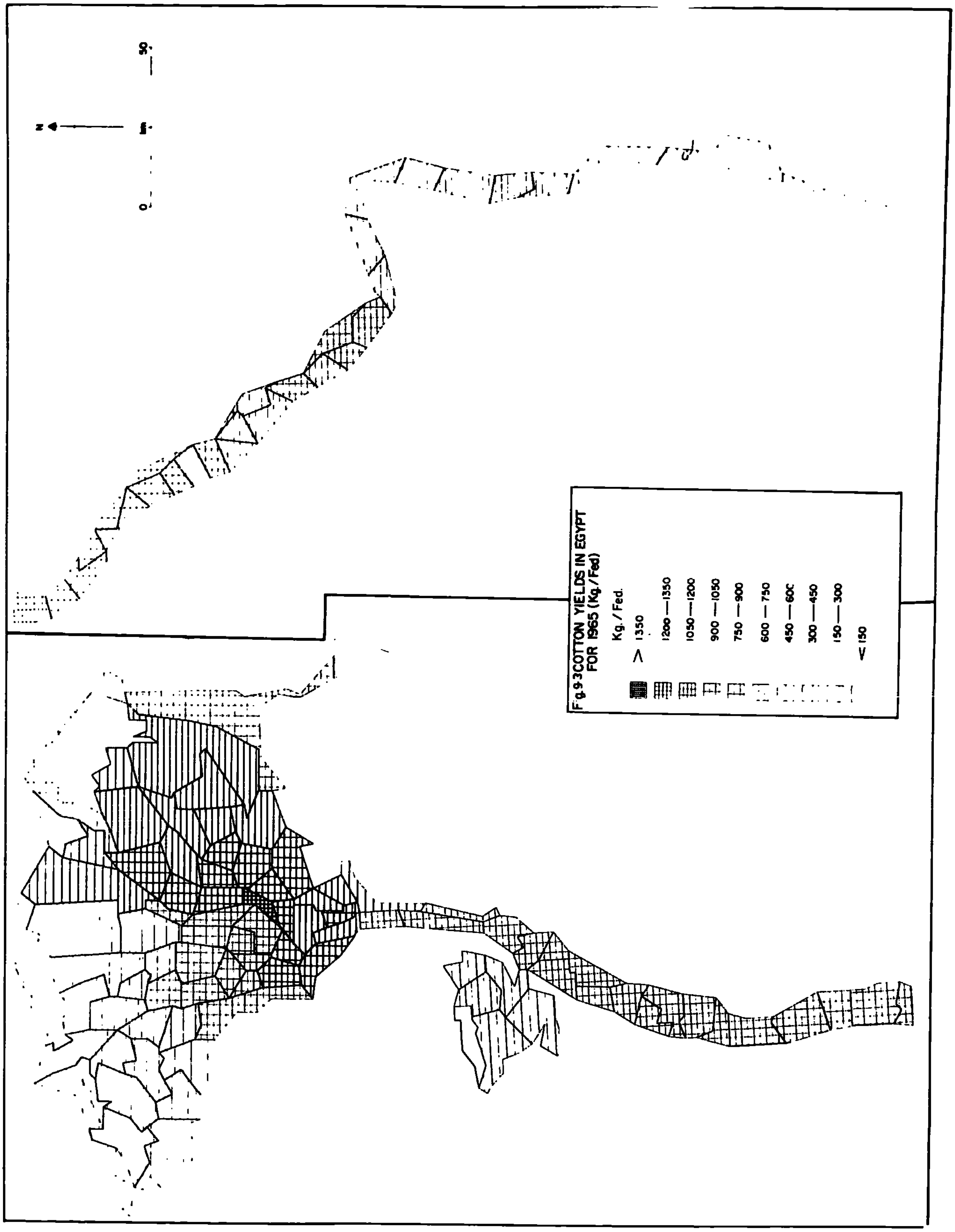


Fig. 9.3 COTTON YIELDS IN EGYPT FOR 1965 (Kg./Fed)

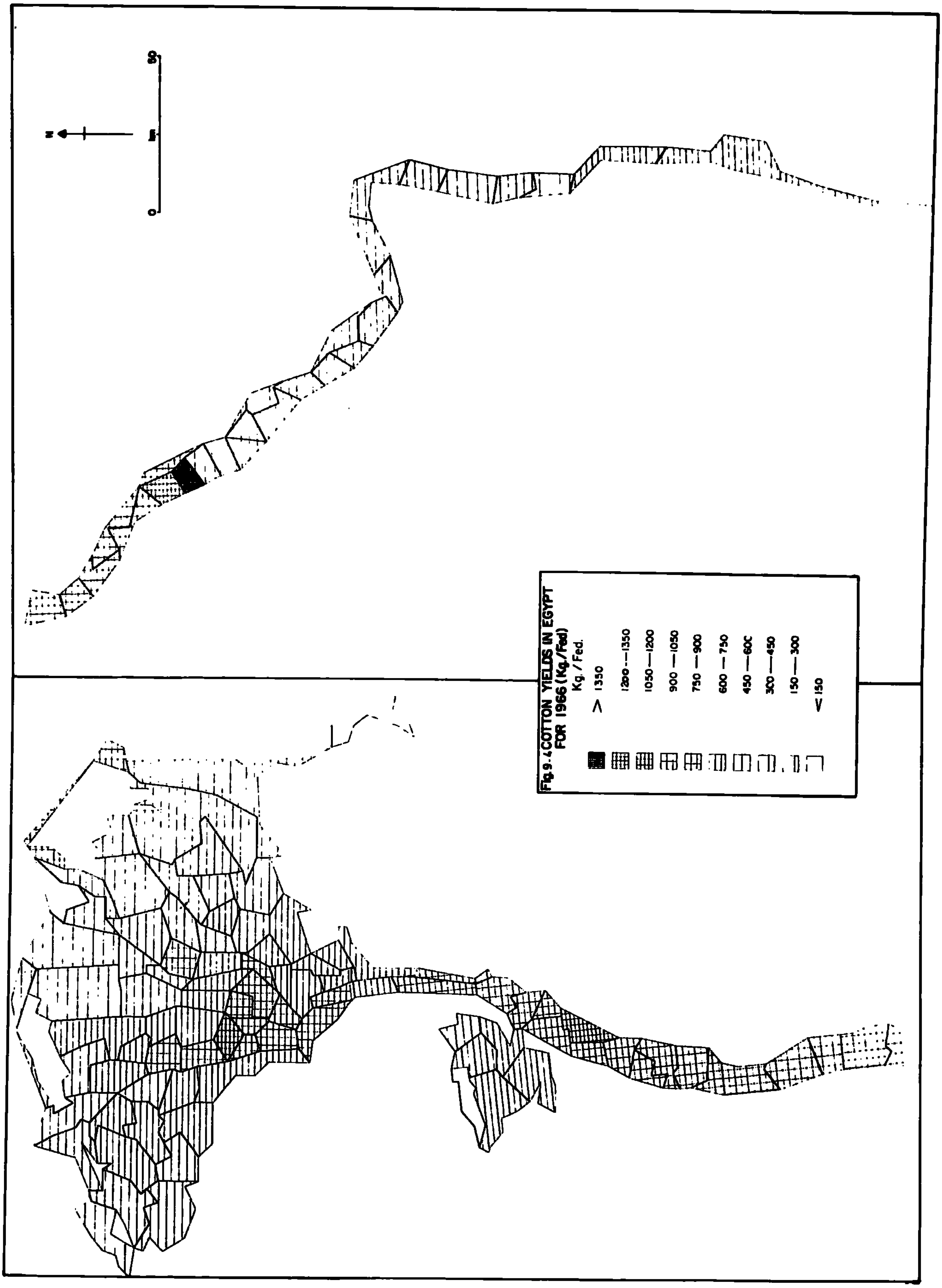


Fig.9.4 COTTON YIELDS IN EGYPT FOR 1966 (Kg./Fed)

selected as they are the only two years for which data on crop yields for 125 districts are available. These figures show clearly that the highest average yields were produced in Middle and Upper Egypt, whilst the lowest average yields were found in the northern part of the country and in the extreme south. The spread of cotton cultivation into the newly reclaimed lands was clearly one of the causes of this drop in average yield in the northern Delta area. In the new lands the soil is mostly sandy or calcareous and in either case is unsuited to the traditional crops of the valley, mainly wheat, maize and rice. When such crops have been planted their yields are much lower than the yields in the old lands. In addition, the drainage systems of the newlands have not always been well-planned, and salinity has become a serious problem (Waterbury, 1974). The second cause of low yields was a drop in real fertility due to progressive soil deterioration. A rise in the water-table caused by the extension of perennial irrigation can also cause serious cultivation problems (Schulze and de Ridder, 1974). The fourth cause was the spread of the pink boll worm in 1965 and 1966 (Al-Didi, 1973).

Wheat is Egypt's principal winter crop and normally accounts for 15% of the crop area of the country. Wheat is grown in Egypt on about 1,300,000 feddans of land each year. The average wheat yield/feddan in each district over the whole of the country has been plotted for the years 1965 and 1966 (Figs. 9.5 and 9.6). These figures show clearly that the highest average yield/feddan occurred

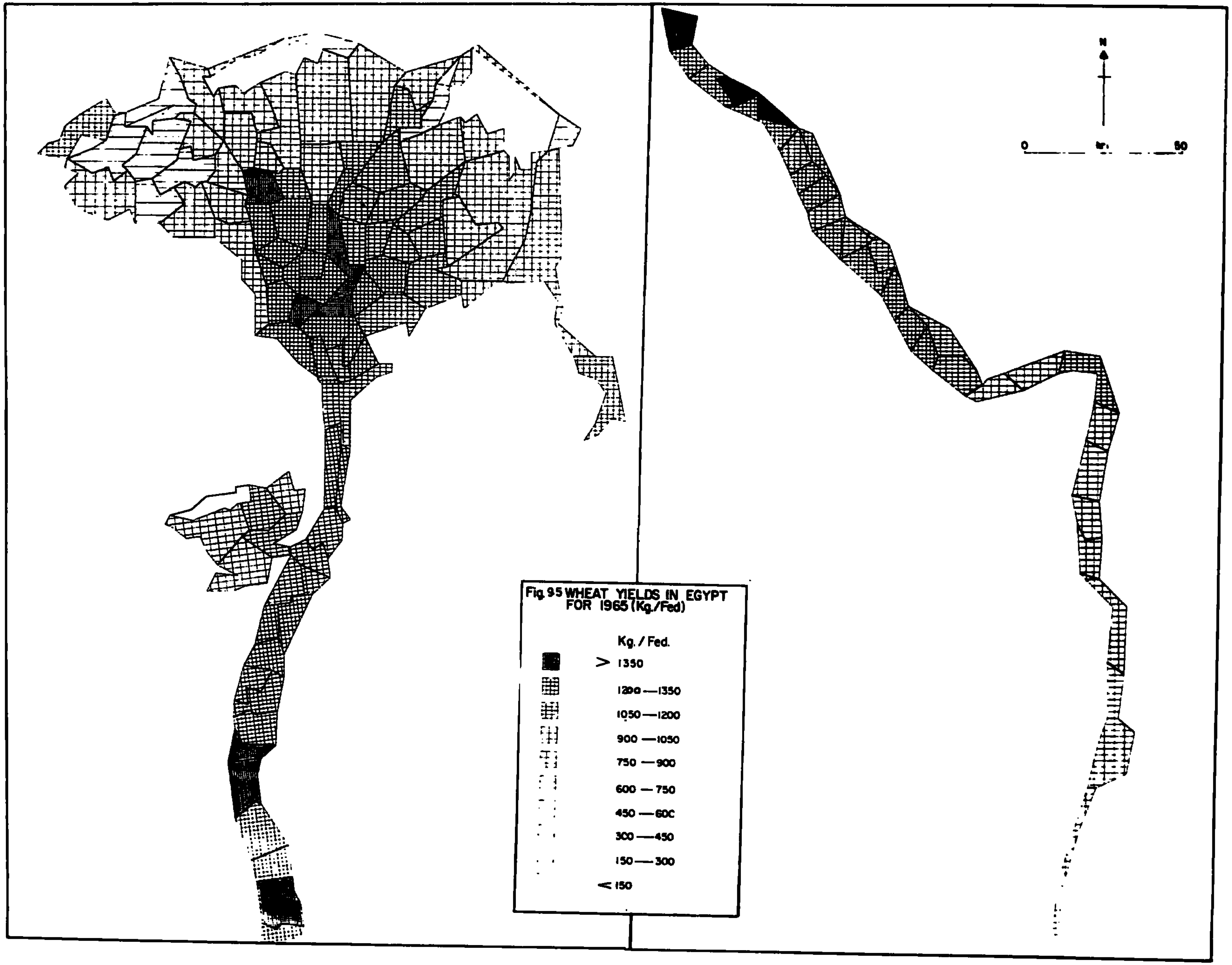


Fig. 95 WHEAT YIELDS IN EGYPT FOR 1965 (Kg./Fed)

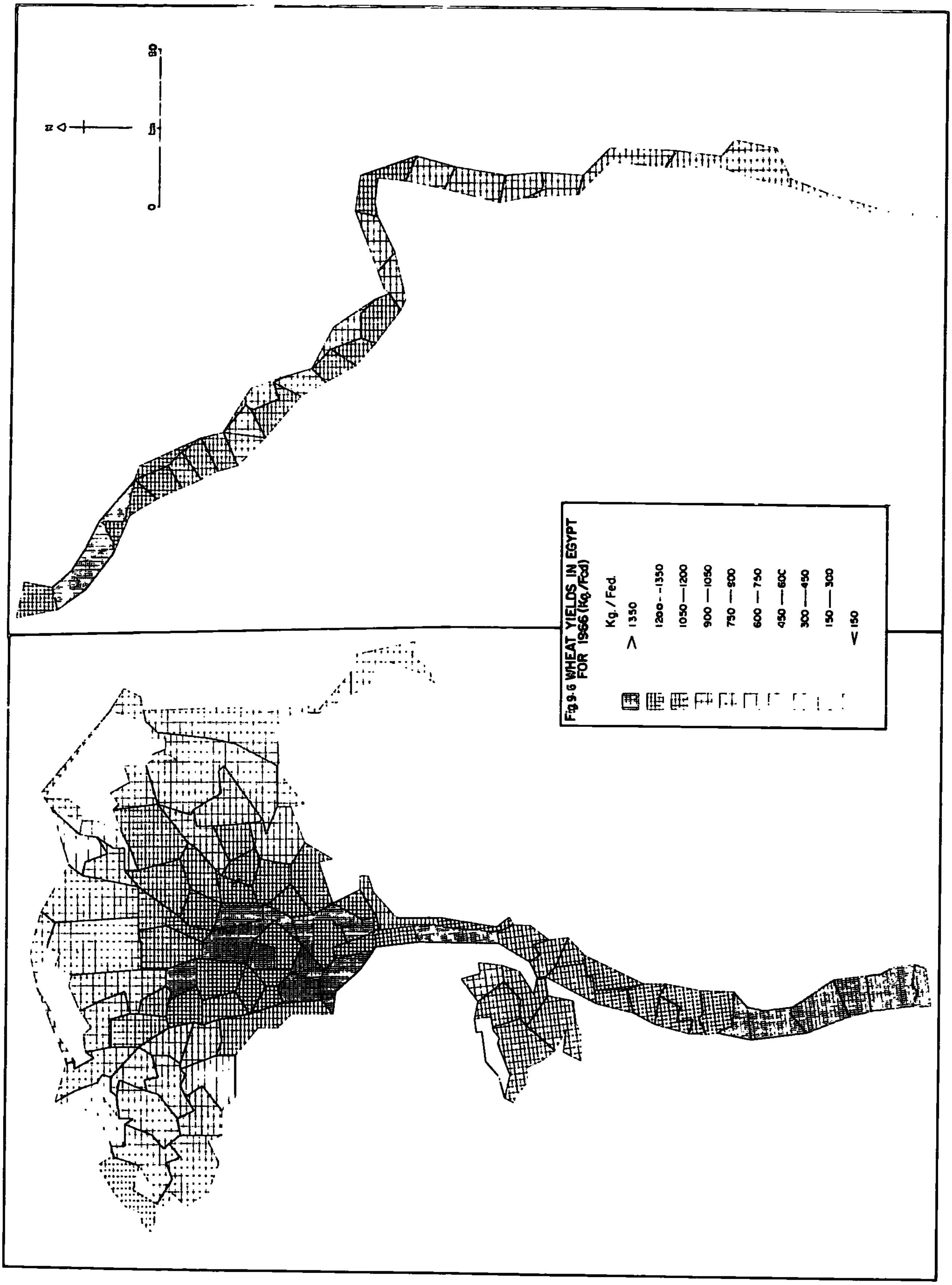


Fig 9.6 WHEAT YIELDS IN EGYPT FOR 1966 (Kg./Fcd)

in the Kafr Shukr district (Qalyubiya governorate) and was 1485.0 kg/fed. and 1528.5 kg/fed. in 1965 and 1966 respectively. In Middle Egypt, the highest average yield occurred in the Matai district (Minya governorate) and was 1398.0 kg/fed. in 1965 and 1453.5 kg/fed. in 1966. In Upper Egypt the highest average yield occurred in the Abnub district (Asyut governorate) and was 1455.0 kg/fed. in 1965 and 1386.0 kg/fed. in 1966. The lowest average wheat yield occurred in the El-Burullus district (Kafr ash Shaykh governorate) and was 541.5 kg/fed. in 1965. The main factor here for low yields are thoughtto be saline and alkaline soil conditions.

Maize is the food of the fellah and, in order to guarantee his daily bread, is the first item in his rotation. The maize crop is the principal staple food crop in the rural areas of Egypt (Hamdan, 1961, p. 130). Maize yields for each district for the whole of the country are illustrated (Figs. 9.7 and 9.8) for the years 1965 and 1966. It can be seen that the highest maize yields recorded in the Delta region are 2385.0 kg/fed. in 1966 in the El-Bagur district (Minufiya governorate), and between 2250.0 and 2400.0 kg/fed. respectively in a number of districts in the Asyut and Sohag governorates in Upper Egypt. These high yields can be explained by several factors, such as climatic conditions, the plant type used, soil conditions, special management inputs and the density of population which is very high in these district. The lowest maize yield was recorded at Aswan and was 690.0 kg/fed. in 1965 (Fig. 9.7).

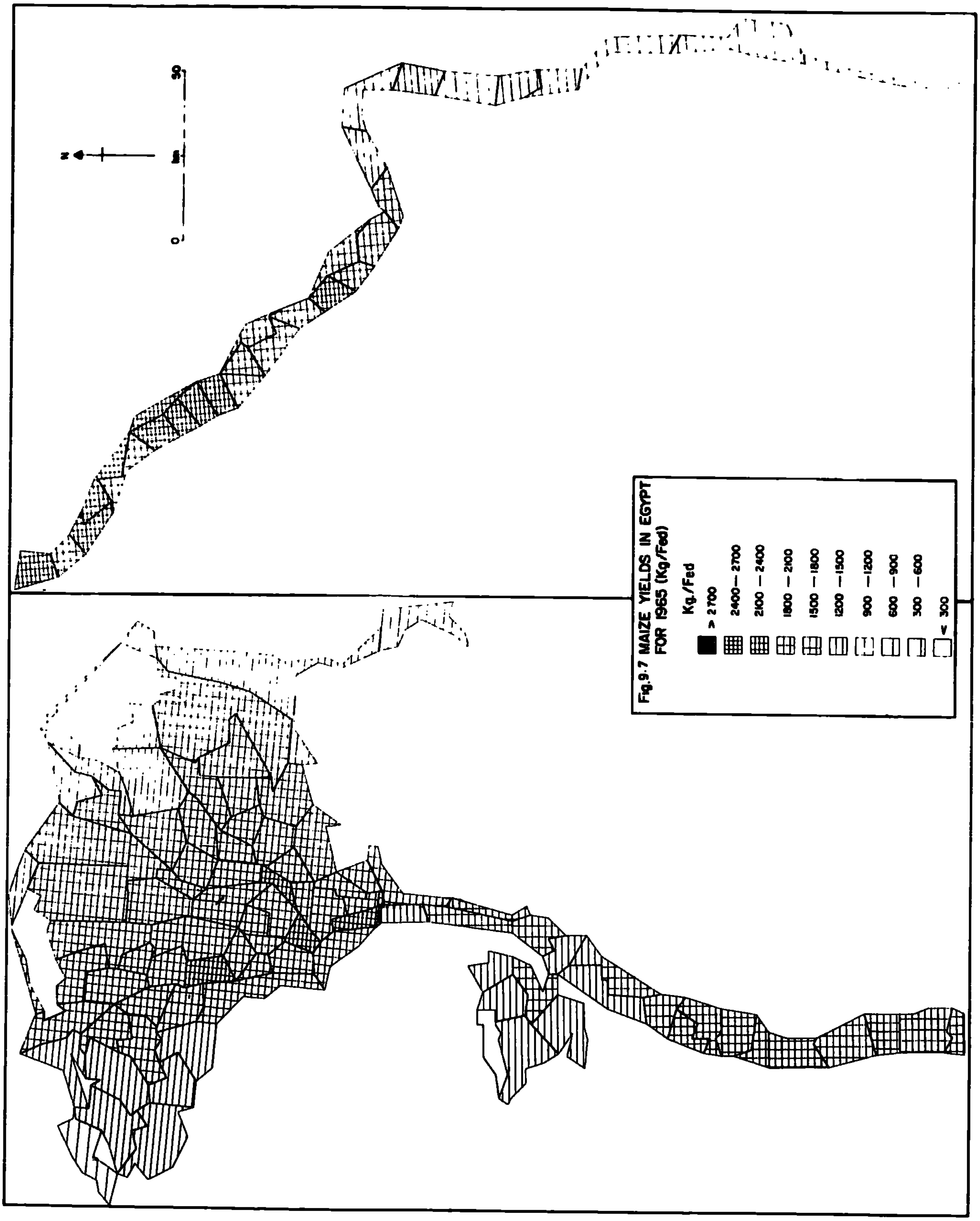


Fig.9.7 MAIZE YIELDS IN EGYPT FOR 1965 (Kg/Fed)

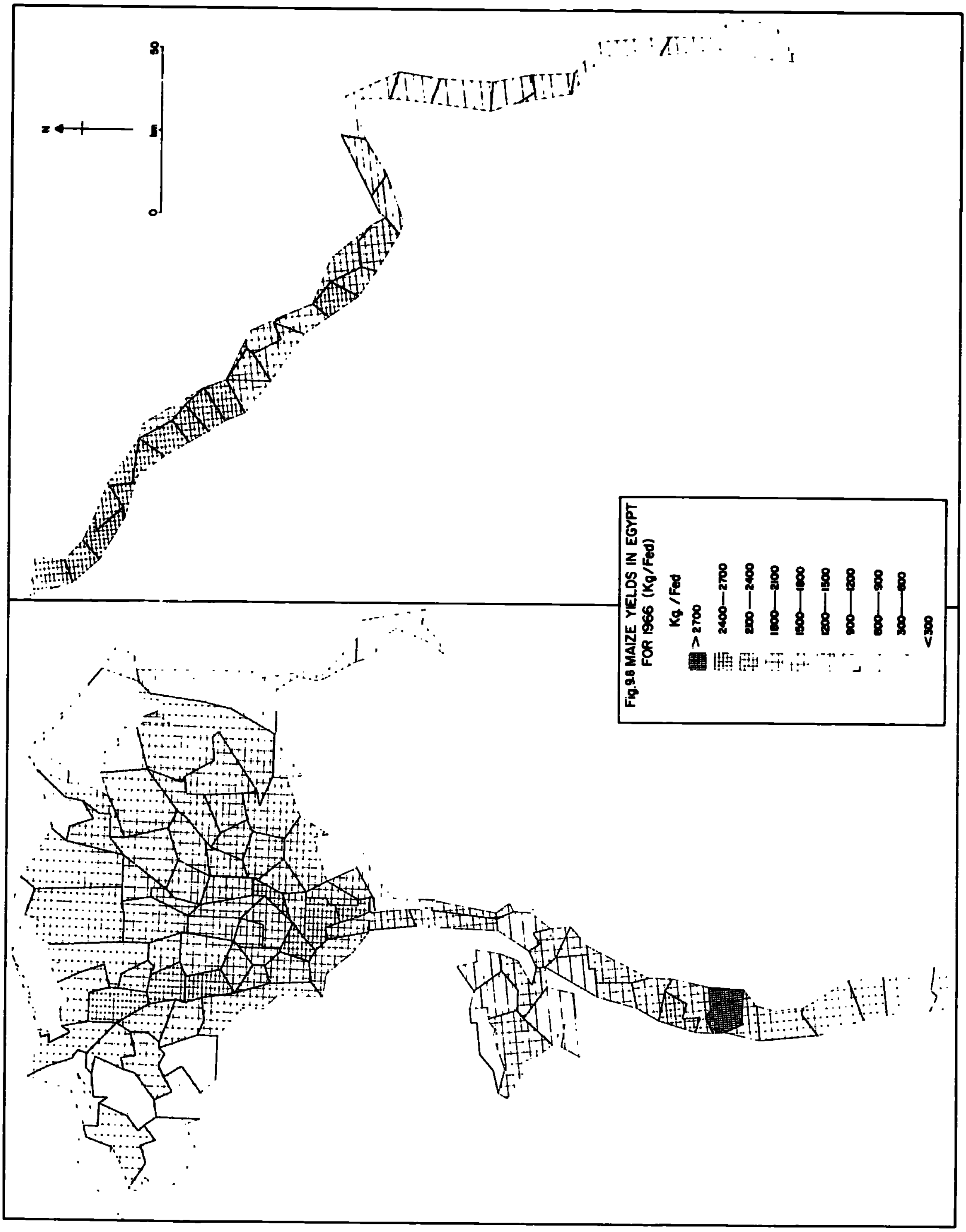


Fig.9.8 MAIZE YIELDS IN EGYPT FOR 1966 (Kg/Fed)

The most important feature of recent years has been the great increase of rice-growing, which developed as more irrigation water became available from the High Dam for reclamation schemes. The production of rice is confined mainly to the northerly areas of the country (Delta and Middle Egypt). There are many factors to explain this fact, i.e. optimum climatological conditions, especially temperature and relative humidity conditions, soil texture and population density which is higher in the Delta area than in Upper and Middle Egypt. The average yields of rice in 1965 and 1966 for each district are shown in Figure 9.9. It is noticed that the highest average rice yield/fed. recorded in the El-Shuhada district (Minufiya governorate) was 36000 kg/fed. in 1965 (Fig. 9.9).

Sugar cane is the main source of sugar in Egypt and it is the oldest industrial crop (Hamdan, 1961, p. 131). Sugar cane is typically a crop of the tropical and subtropical regions, and requires mean temperatures of about 20°C in order to thrive. It is a perennial, that requires eight to twenty four months growth to produce a crop (Arnon, 1972, p. 463). Because of these conditions some 93.6% of the total crop area of sugar cane is concentrated in Upper Egypt, where two regions, Minya and Qena-Aswan, account for 85% of the total national area. Qena alone accounts for 53 per cent. In the last century sugar cane culture was centred in Minya, but now a definite shift has taken place towards the far south no doubt in search of higher temperatures (Hamdan, 1961, p. 132).

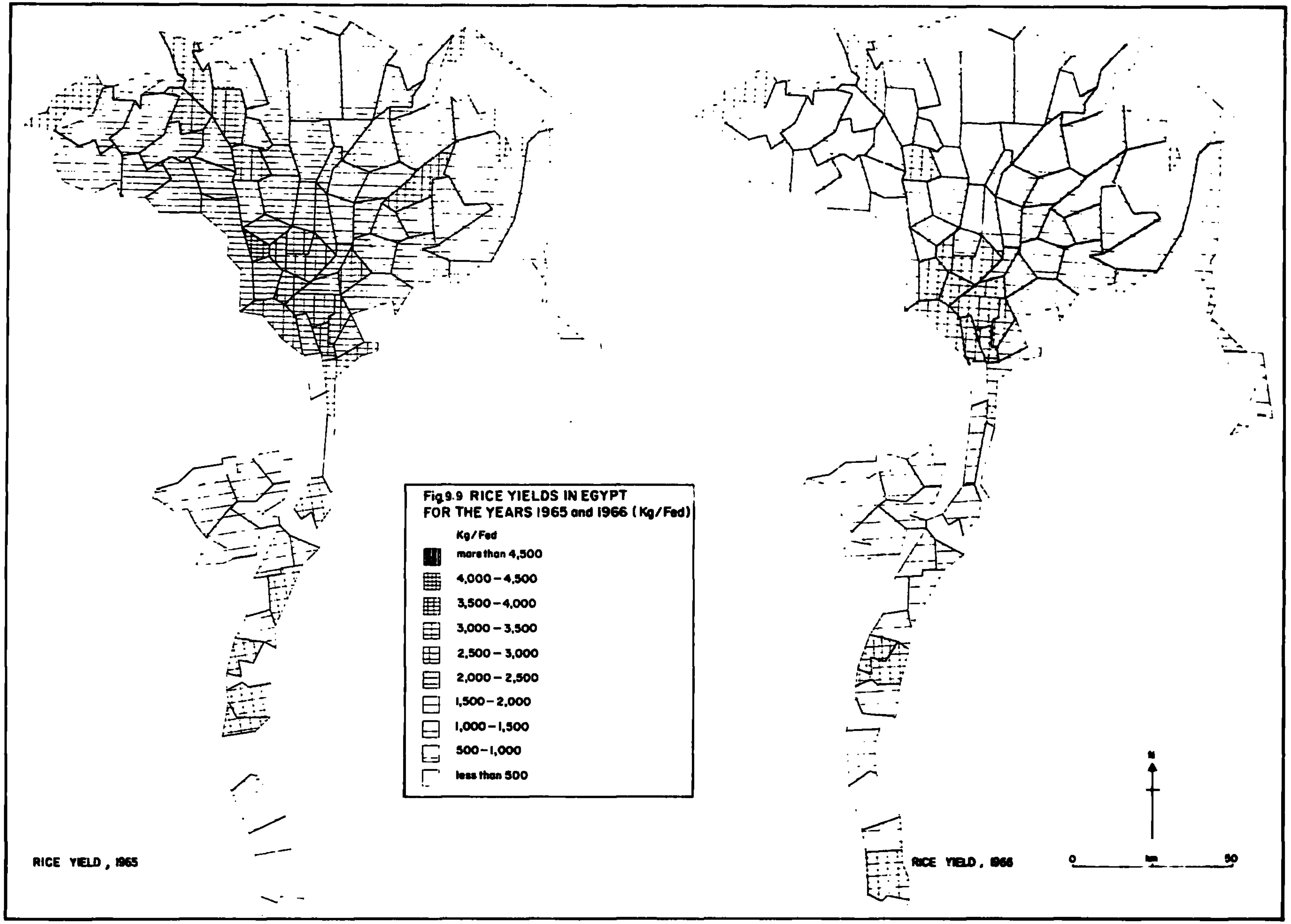


Fig.9.9 RICE YIELDS IN EGYPT FOR THE YEARS 1965 and 1966 (Kg/Fed)

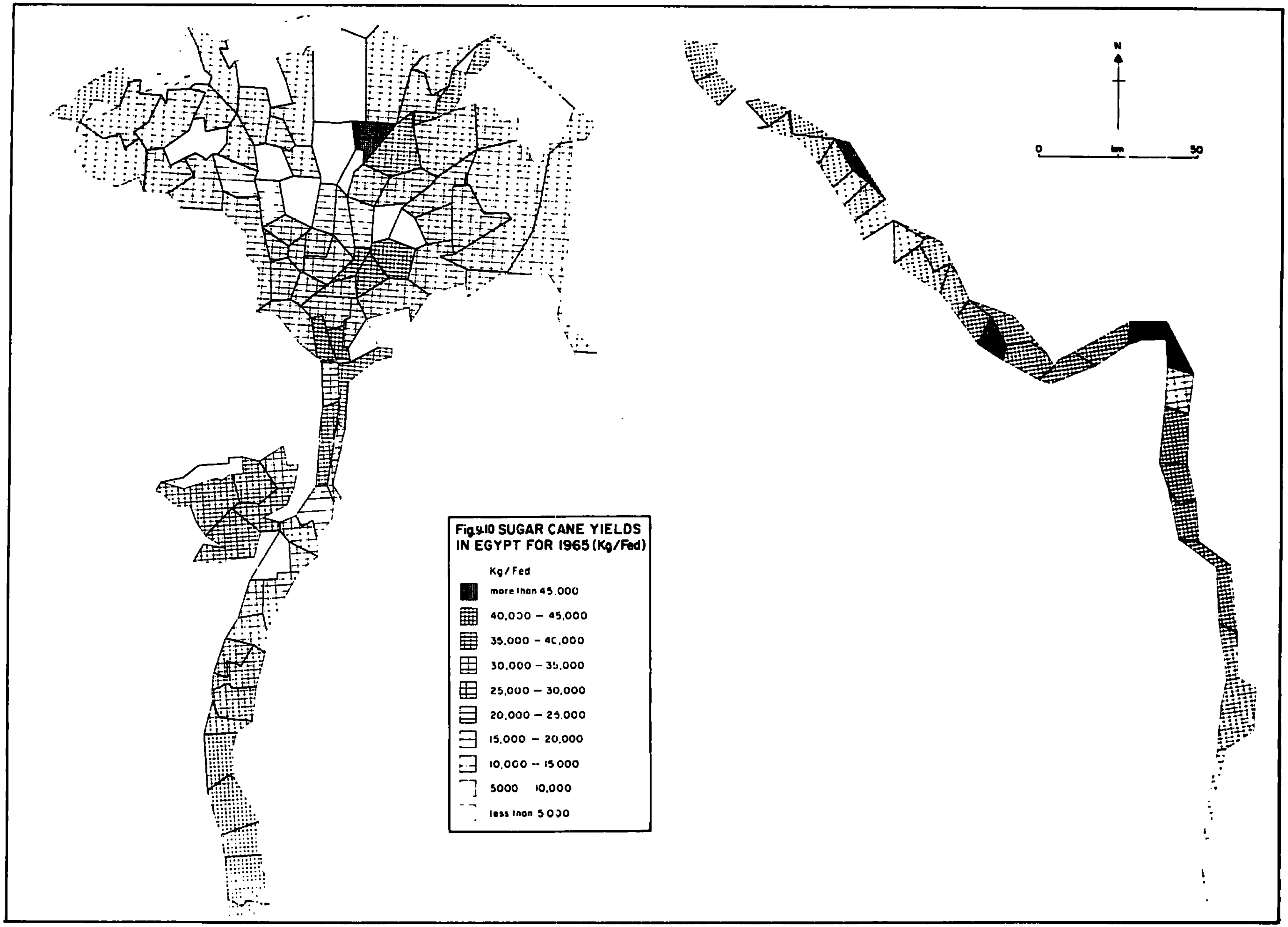


Fig.9.10 SUGAR CANE YIELDS IN EGYPT FOR 1965 (Kg/Fed)

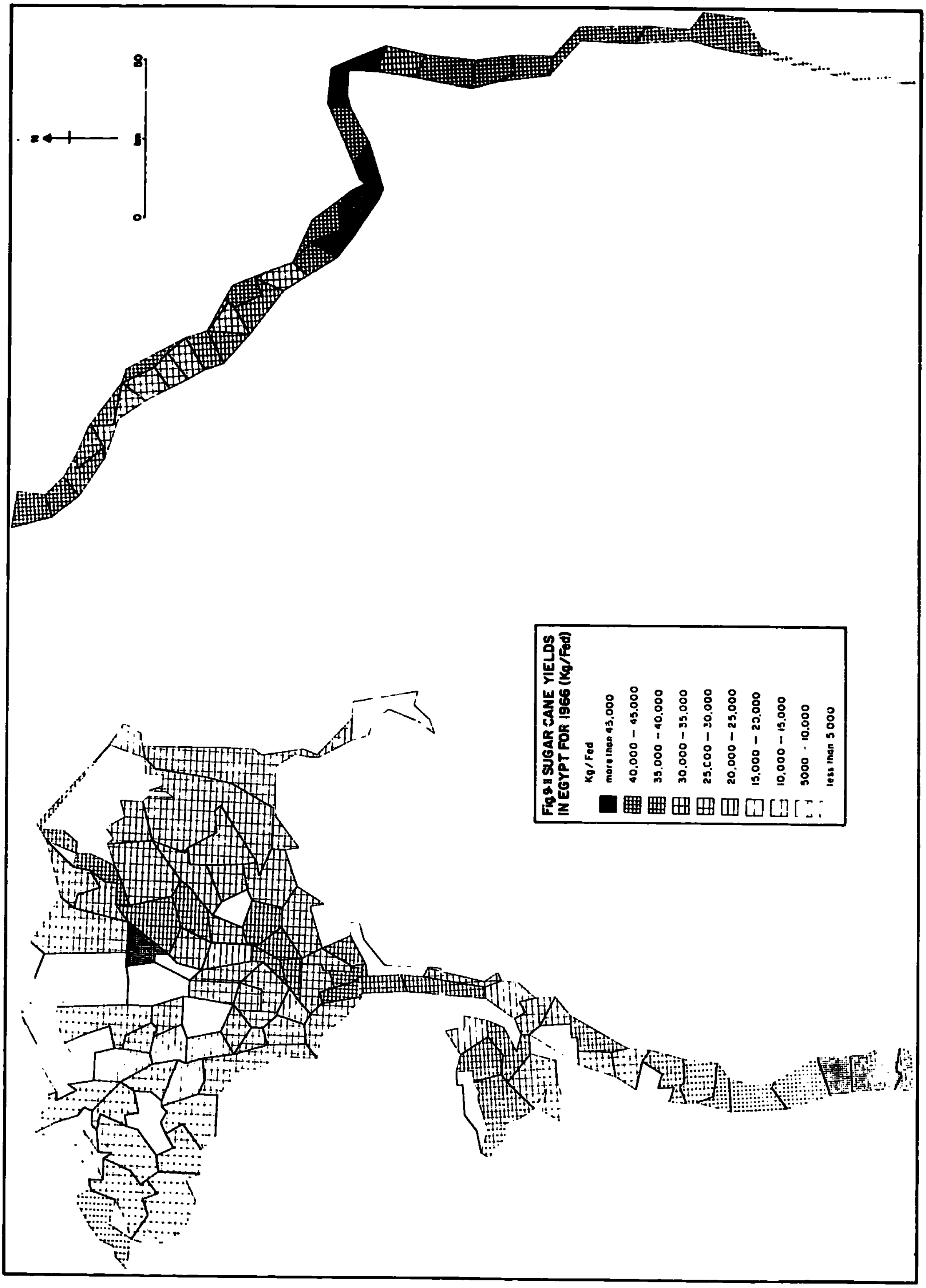


Fig 9.11 SUGAR CANE YIELDS IN EGYPT FOR 1966 (Kg/Fed)

The sugar cane yields in each district have been plotted for the years 1965 and 1966 (Figs. 9.10 and 9.11). These figures show clearly that the highest yields of sugar cane occurred in the Qena, Aswan and Minya districts, while much lower yields are found in the Delta. The highest average yields/fed. were 49550.0 and 45150.0 kg/fed. which occurred at El-Balyana and Qena districts respectively in 1965. In 1966 the highest average yields/fed. occurred in the same districts and were 49500.0 and 46850.0 kg/fed. respectively (Figs. 9.10 and 9.11).

9.3 - Statistical analysis :-

Lorenz Curves have been drawn in Figure 9.12 to show the relationship between the total area under cultivation in Egypt in 1973 and the areas under the major crops. These are cotton, rice, wheat, sugar cane and maize.

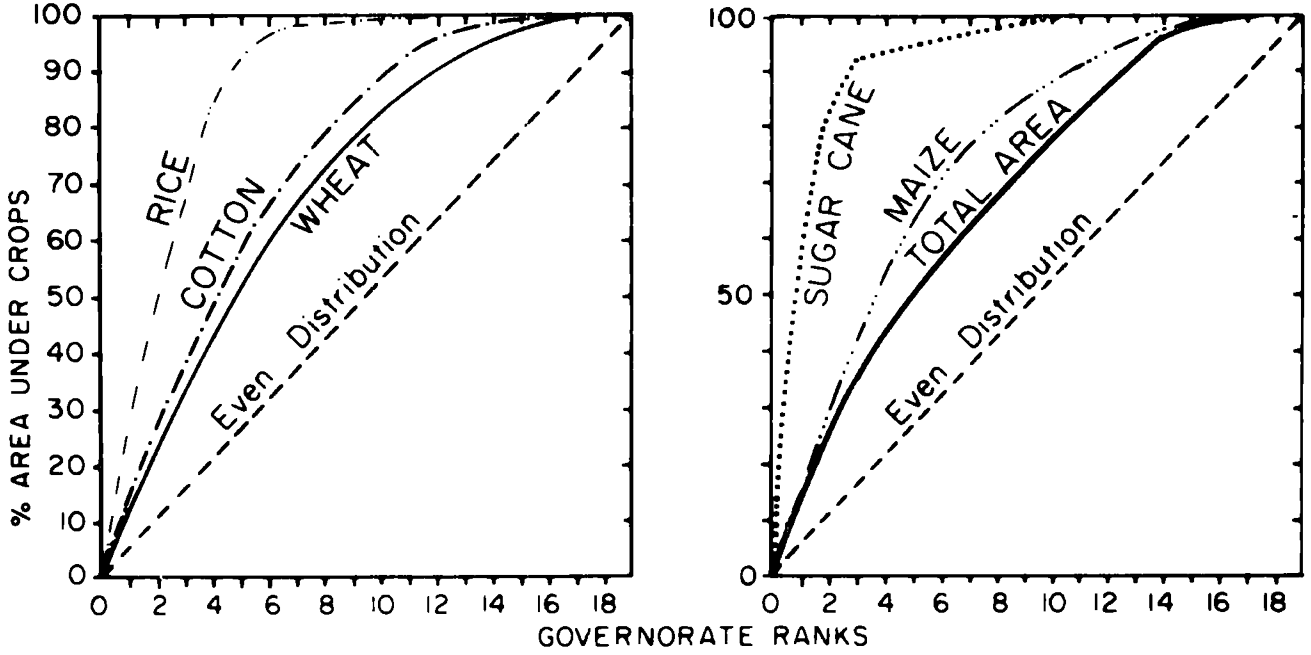
Table 9.b and Figure 9.12 show clearly that sugar cane is concentrated in Upper Egypt and rice is concentrated in Lower Egypt, while the other major crops are widely distributed throughout the country. These facts are obtained also from Lorenz's index of concentration. The index may be found by :-

$$I = \frac{A - R}{M - R}$$

Where I is the index of concentration

A is the area cumulative percentage total

Fig.9·12 LORENZ CURVES COMPARING THE TOTAL AREA UNDER CULTIVATION AND AREA UNDER OTHER SELECTED CROPS IN EGYPT 1973



R is the regional cumulative percentage total
M is the maximum cumulative percentage total
assuming 100% of the frequencies in Rank (1) (see
Hammond et al., 1974, p. 20).

In our data R is (1355) and M, because we have 19 categories, is 1900.

Indexes for cotton, rice, wheat, sugar cane and maize are therefore :-

$$I \quad \text{Cotton} = \frac{1458 - 1355}{1900 - 1355} = 0.19$$

$$I \quad \text{Rice} = \frac{1709 - 1355}{1900 - 1355} = 0.65$$

$$I \quad \text{Wheat} = \frac{1365 - 1355}{1900 - 1355} = 0.02$$

$$I \quad \text{Sugar cane} = \frac{1797 - 1355}{1900 - 1355} = 0.81$$

$$I \quad \text{Maize} = \frac{1484 - 1355}{1900 - 1355} = 0.24$$

The indexes show marked concentrations of sugar cane (81) and rice (65) production into two or three main governorates (Table 9.b).

Table 9.b

Area Under the Major Crops in Egypt

Cotton				
Rank	Governorate	Area under crop in feddan	% of total	Cumulative %
1	Daqahliya	239172	14.9	14.9
2	Buheira	186848	11.7	26.6
3	Sharqiya	172182	10.8	37.4
4	Minya	162908	10.2	47.6
5	Gharbiya	150727	9.4	57.0
6	Kafr ash Shaykh	134288	8.4	65.4
7	Asyut	102829	6.4	71.8
8	Sohag	97675	6.1	77.9
9	Beni Suef	91043	5.7	83.6
10	Minufiya	88240	5.5	89.1
11	Fayum	76795	4.8	93.9
12	Qalyubiya	39847	2.5	96.4
13	Damietta	24595	1.6	98.0
14	Qena	21811	1.2	99.2
15	Giza	7232	0.5	99.7
16	Alexandria	3303	0.2	99.9
17	Ismailia	606	0.1	100.0
18	Aswan	10	0.0	100.0
19	Suez	-	0.0	100.0
Total		1600122	100.0	1458.4 Approx. total (1458)

Table 9.b Continued

Rice				
Rank	Governorate	Area under crop in feddan	% of total	Cumulative %
1	Daqahliya	258586	25.9	25.9
2	Kafr ash Shaykh	220767	22.2	48.1
3	Buheira	183521	18.4	66.5
4	Sharqiya	173269	17.5	84.0
5	Gharbiya	79593	8.0	92.0
6	Damietta	44255	4.5	96.5
7	Fayum	16395	1.6	98.1
8	Qalyubiya	7467	0.8	98.9
9	Alexandria	4027	0.4	99.3
10	Ismailia	3345	0.3	99.6
11	Minufiya	1478	0.2	99.8
12	Minya	997	0.1	99.9
13	Giza'	903	0.1	100.0
14	Beni Suef	414	0.0	100.0
15	Suez	154	0.0	100.0
16	Qena	131	0.0	100.0
17	Asyut	0.0	0.0	100.0
18	Sohag	0.0	0.0	100.0
19	Aswan	0.0	0.0	100.0
Total		995302	100.0	1708.6 Approx. total (1709)

Table 9.b Continued

Maize				
Rank	Governorate	Area under crop in feddan	% of total	Cumulative %
1	Sharqiya	194432	14.9	14.9
2	Minufiya	178351	13.7	28.6
3	Buheira	174398	13.4	42.0
4	Minya	157942	12.1	54.1
5	Gharbiya	116622	8.9	63.0
6	Qalyubiya	91026	7.0	70.0
7	Kafr ash Shaykh	75926	5.8	75.8
8	Daqahliya	70260	5.4	81.2
9	Giza	64995	5.0	86.2
10	Beni Suef	46742	3.6	89.8
11	Asyut	32927	2.5	92.3
12	Sohag	30147	2.3	94.6
13	Qena	28925	2.2	96.8
14	Fayum	11061	0.8	97.6
15	Ismailia	10172	0.8	98.4
16	Alexandria	9156	0.7	99.1
17	Damietta	6555	0.5	99.6
18	Aswan	2267	0.3	99.9
19	Suez	1176	0.1	100.0
Total		1303079	100.0	1483.9 Approx. total (1484)

Table 9.b Continued

Sugar Cane				
Rank	Governorate	Area under crop in feddan	% of total	Cumulative %
1	Qena	116113	57.6	57.6
2	Aswan	47528	23.4	81.0
3	Minya	22384	11.1	92.1
4	Giza	2219	1.1	93.2
5	Sohag	2208	1.1	94.3
6	Asyut	1854	0.9	95.2
7	Buheira	1767	0.9	96.1
8	Minufiya	1334	0.7	96.8
9	Daqahliya	1143	0.6	97.4
10	Kafr ash Shaykh	1112	0.6	98.0
11	Damietta	823	0.4	98.4
12	Beni Suef	760	0.4	98.8
13	Qalyubiya	695	0.3	99.1
14	Gharbiya	593	0.3	99.4
15	Alexandria	417	0.2	99.6
16	Fayum	387	0.2	99.8
17	Sharqiya	328	0.2	100.0
18	Ismailia	31	0.0	100.0
19	Suez	23	0.0	100.0
Total		201717	100.0	1796.8 Approx. total (1797)

Table 9.b. Continued

Wheat				
Rank	Governorate	Area under crop in feddan	% of total	Cumulative %
1	Sharqiya	141763	11.4	11.4
2	Daqahliya	134663	10.8	22.2
3	Buheira	125836	10.1	32.3
4	Sohag	105938	8.5	40.8
5	Qena	93245	7.5	48.3
6	Kafr ash Shaykh	92634	7.4	55.7
7	Gharbiya	91053	7.3	63.0
8	Minufiya	79340	6.4	69.4
9	Minya	79092	6.3	75.7
10	Asyut	74359	5.9	81.6
11	Fayum	73899	5.9	87.5
12	Beni Suef	45612	3.7	91.2
13	Qalyubiya	34066	2.7	93.9
14	Aswan	28638	2.2	96.1
15	Giza	20012	1.6	97.7
16	Damietta	13584	1.1	98.8
17	Ismailia	9547	0.8	99.6
18	Alexandria	3279	0.3	99.9
19	Suez	1018	0.1	100.0
Total		1247578	100.0	1365.1 Approx. total (1365)

Table 9.b Continued

Total Crops Area				
Rank	Governorate	Total area under crops in feddans	% of total	Cumulative %
1	Buheira	1345934	12.3	12.3
2	Sharqiya	1240959	11.3	23.6
3	Daqahliya	1216262	11.1	34.7
4	Kafr ash Shaykh	888158	8.1	42.8
5	Gharbiya	784489	7.2	50.0
6	Minya	720440	6.6	56.6
7	Minufiya	644780	5.9	62.5
8	Sohag	570454	5.3	67.8
9	Fayum	569698	5.3	73.1
10	Asyut	566379	5.3	78.4
11	Qena	541131	4.9	83.3
12	Beni Suef	488747	4.5	87.8
13	Qalyubiya	429374	3.9	91.7
14	Giza	411417	3.8	95.5
15	Damietta	187944	1.7	97.2
16	Aswan	143197	1.4	98.6
17	Ismailia	96260	0.9	99.5
18	Alexandria	90793	0.4	99.9
19	Suez	10944	0.1	100.0
Total		10947360	100.0	1355.3 Approx. total (1355)

9.4 - Agricultural regions in Egypt :-

It is not easy to define distinct and clear-cut land use regions in the Nile Valley and Delta areas. This is because it may be all regarded as one vast single region of mixed agriculture. However, the Delta and the Nile Valley can be classified into three main regions (Fig. 9.13). These are :-

1 - Lower Egypt :-

This region consists of the Delta proper from Cairo northward to the Mediterranean Sea. It can also be divided into two sub-regions :-

A - Northland :- This area includes the governorates of Buheira, Alexandria, Kafr ash Shaykh, Gharbiya, Daqahliya and Sharqiya (Fig. 9.13). It comprises the Berari and the rice belts in their entirety, as well as the sandy east and west margins of the Delta. Clover, cotton, maize, wheat and rice are the main crops produced in this area.

B - South of the Delta area :- This zone comprises Minufiya and Qalyubiya governorates in the south of the Delta together with Giza at the head of the Valley (Fig. 9.13). This old, settled, very densely populated region further differs from Northland by its higher elevations and more sandy soils. Agriculturally intensive, this zone is primarily one of food production, the pressure of population being of paramount importance.
In contrast to Northland, the area occupied by the five main crops are in the following order, maize, wheat, cotton, rice, and clover.

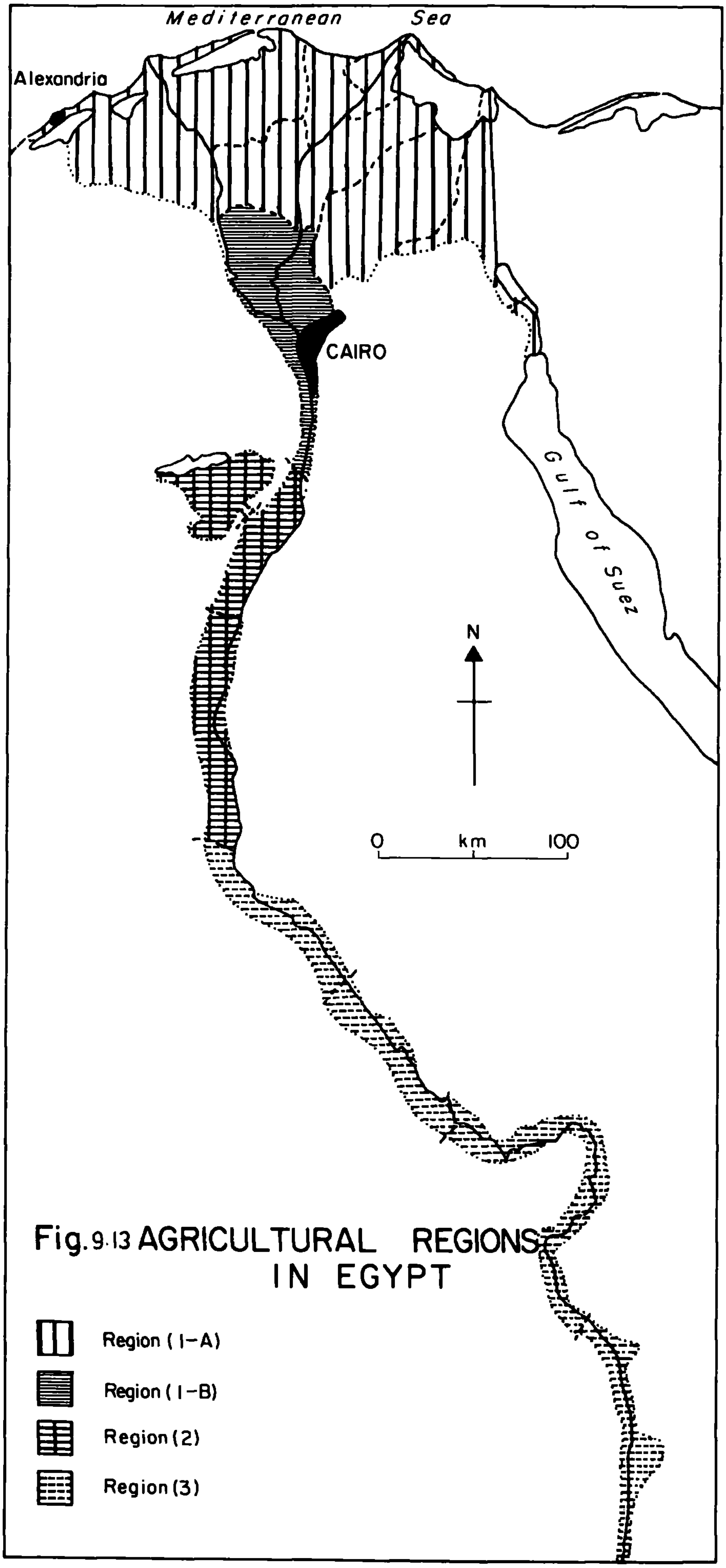


Fig.9.13 AGRICULTURAL REGIONS IN EGYPT

2 - Middle Egypt :-

This region includes the narrow cultivated strip along the Nile from Cairo to Asyut (Fig. 9.13). It is a region of traditional agriculture with the usual base crops and a special development of pulses. Maize is the first crop in this region. This fact is explained by the very high population density. Wheat finds propitious conditions in the mild, almost warm, winter of Middle Egypt. Rice is the second most important crop in this region. However, rice and fruit in the Fayum area are historically famous crops, while Minya features the more commercial sugar cane and onions.

3 - Upper Egypt :-

Like Northland, this is a very distinctive region. As in Northland, the explanation lies in a marginal position, very high temperatures, sandy soils as well as difficult human conditions. This region includes the narrow cultivated strip along the Nile from Asyut southwards to the Sudanese border (Fig. 9.13). Sugar cane and lentils reach their highest importance in this region. Sorghum, cotton, clover, and wheat occupy important places in crop rotation.

CHAPTER 10

Irrigation and Drainage in Egypt

10.1 - Irrigation in Egypt :-

Irrigation has always played a large part in the production of crops in the hot arid zone, but its importance is increasing rapidly as new dams and barrages make it possible to grow crops in huge areas that could not previously be irrigated (see for example, Willcocks, 1913; Hudson, 1965; Rosenbery, 1966; Abdel-Rahman, 1965; Sirinada, 1970; Beaumont, 1974 and 1977; Smith, 1966 and 1970 and others).

Agriculture in Egypt depends on artificial irrigation using water from the Nile, as the country is practically rainless (see precipitation chapter). Two systems of irrigation were in use. The older system is known as "basin irrigation", where the land is divided into basins of variable dimensions surrounded by embankments to prevent water from draining back into the river for a period ranging from thirty to forty days. Upon the rich sediment deposited by the flood, one winter crop can be grown. The land then remains fallow throughout the summer waiting for the next flood (Marei, 1960 and Abd el-Llah, 1965).

After the High Dam was built, all basin lands were converted to perennial irrigation. Many new canals were dug throughout the country, several banks were constructed and numerous regulators built. These canals carry the water to the fields giving each farmer a fixed water share on a rotation of watering days and closing days in order to have irrigation water judiciously distributed among the various canal systems.

The area under the two systems of irrigation before the High Dam was built are illustrated (Tables 10.a and 10.b). The total area under perennial irrigation was 4,285,479 feddans in Lower Egypt and 2,053,891 feddans in Middle and Upper Egypt. Basin irrigation was concentrated in Middle and Upper Egypt. The total area under basin irrigation was 458,273 feddans (Table 10.b). It was found that 335,129 feddans was irrigated without pumps and 123,144 feddans was irrigated with pumps in Middle and Upper Egypt respectively.

The Nile River :-

The Nile River ranks among the great rivers of the world. The sources of the Nile, long unknown to many who made use of its waters, are found in the Atbara River in Ethiopia, the Blue Nile with its origin in Lake Tana in Ethiopia, and the White Nile within the lake plateau region of Lake Victoria, Lake Albert, Lake Edward and Lake Kyoga (Awad, 1947; Abu Al-Izz, 1971).

The width of the Nile Valley in Egypt increases gradually northward until it reaches its maximum width of 23 Km at Bani Suef (Table 10.c), near the mouth of Bahr Yusuf where it enters the Fayum Depression through the Al-Haware (Lahun) Gap. Upon reaching Giza province, the flood plain narrows to a maximum width of only 12 Km and its mean width is 8.3 km. This is due to the narrowing of the valley before the branching of the Delta. To the east, Mount Muqattam is close to the valley, and to the west, there is the Abu Rawash Block. North of these two

Table 10.a

Irrigation in Lower Egypt

Governorate	Area irrigated without pumps (Feddans)	Area irrigated with pumps (Feddans)
Cairo	9800	1200
Alexandria	-	22000
Port Said	400	-
Ismailia	15000	33075
Suez	7000	15060
Damietta	-	127877
Daqahliya	-	836013
Sharqiya	49300	727340
Qulyubiya	106395	130825
Kafr ash Shaykh	-	539844
Gharbiya	23000	421318
Minufiya	39700	317600
Buheira	34205	828527
Total	284800	4000679

Source :- Ministry of Irrigation, Census 1961, Cairo, Egypt.

Table 10.b

Irrigation in Middle and Upper Egypt

Governorate	Area irrigated without pumps (Feddans)	Area irrigated with pumps (Feddans)	Area of basin irrigated without pumps (Feddans)	Area of basin irrigated with pumps dry summer (Feddans)
Giza	180456	42927	-	-
Beni Suef	59843	261481	6755	50603
Fayum	348083	13151	-	-
Minya	271018	92329	95407	68341
Asyut	45690	208635	17500	-
Sohag	90000	246384	-	-
Qena	-	91830	215467	4200
Aswan	-	102164	-	-
Total	995090	1058801	335129	123144

Source :- Ministry of Irrigation, Census 1961, Cairo, Egypt.

Table 10.c

Valley Width and River Length by Provinces (metres).

Province	mean valley width	maximum valley width	minimum valley width	length of the river (km)
Aswan	2,800	7,500	200	318
Qena	5,300	18,000	2,600	207
Suhag	15,000	19,000	9,500	100
Asyut	14,700	20,000	9,000	140
Minya	15,300	20,000	11,000	113
Bani Suef	17,200	23,000	10,000	70
Giza	8,300	12,000	5,000	70.

blocks, the land is very flat so permitting the deposits of the Nile to be spread over a broad area. The minimum width of the valley occurs in Aswan province where it is less than 200 m at Kalabsha Gorge and 320 m at the Silsila Gorge. There is no flood plain in either of these localities. This is a result of the nature of the bed rock in the two areas.

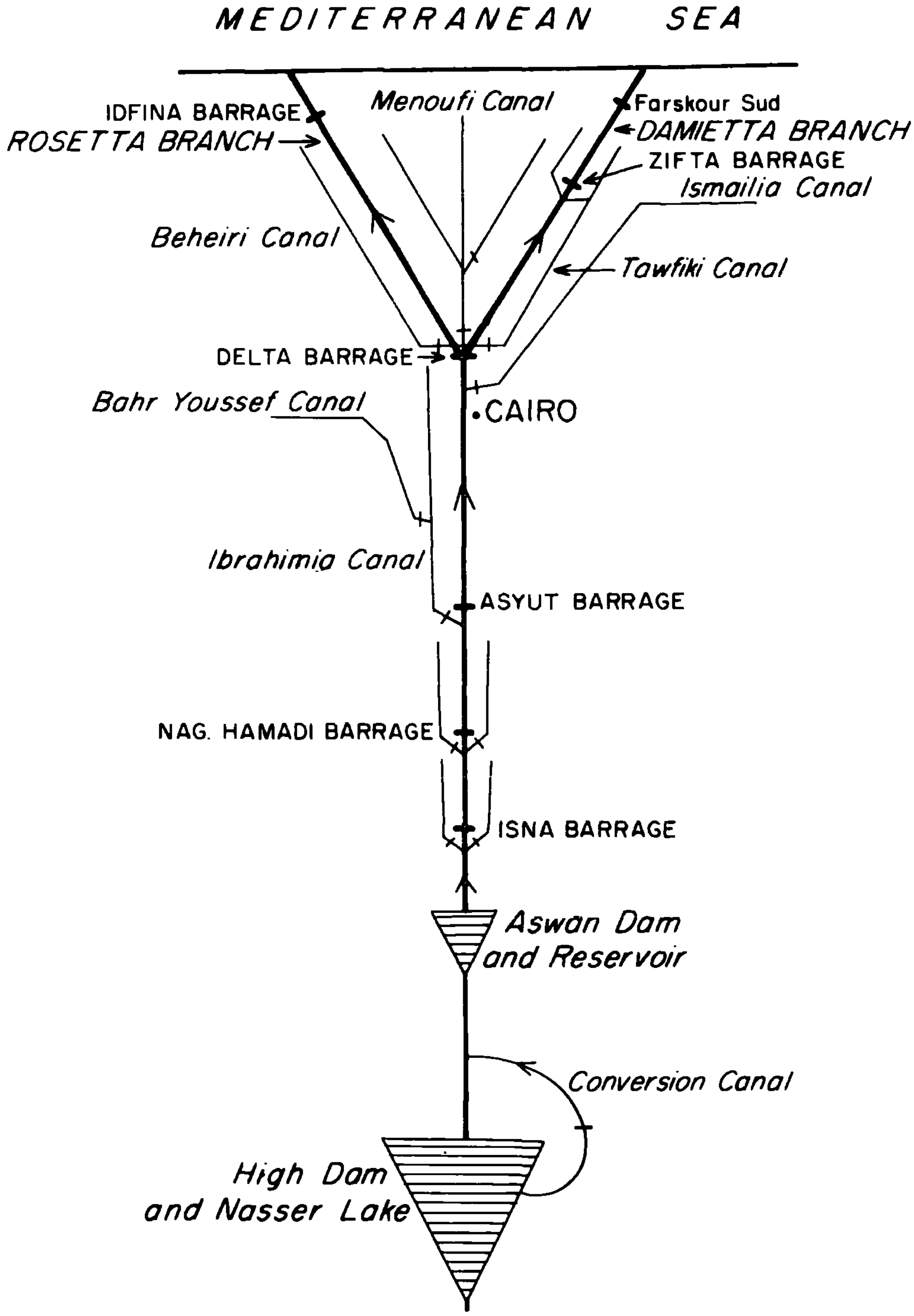
Two kinds of barrages have been constructed in Egypt during the twentieth century. These are elevation barrages and reservoir dams.

The function of elevation barrages is to raise the level of the water behind them so that it will flow into the canals through entrance gates which are situated upstream from the barrages. The barrages consist of large platforms of concrete extending from one bank to the other with gates which can be opened and closed to control the flow.

There are six barrages along the course of the Nile from Aswan in the south to Alexandria in the north. These are the Isna Barrage, the Nag-Hamadi Barrage, the Asyut Barrage, the Delta Barrage, the Zifta Barrage and the Idfina Barrage (Fig. 10.1).

Reservoir dams store excessive water in periods of flood so that it can be utilized in months of low discharge. The Aswan Dam located 7 km north of the High Dam, was constructed in 1902. Its original capacity was 1,000 million cubic metres. In 1912, the storage volume was raised to 2,500 million cubic metres and in 1933 to

Fig.10. 1 'A DIAGRAM OF THE IRRIGATION SYSTEM'
After Hurst (with High Dam and Nasser's Lake added)



5,000 million cubic metres (Shibl, 1971).

The construction of the Aswan Dam was the first step in the conversion of the basin irrigation into perennial irrigation. Consequently a network of canals, the total length of which is estimated as 23,000 kilometres, was developed. The efficiency of the canal system is measured by the area irrigated by a given quantity of water called "water duty" which represents the optimum amount of water to be used by various crops.

The High Dam :-

The High Dam is the second largest dam in the world as far as the volume of its reservoir and the eighth largest as far as its power capacity is concerned (Shibl, 1971, p. 57). The High Dam is located 7 km upstream from the old Aswan Dam and 650 km south of Cairo. This site was chosen as a result of extensive geological studies and investigations. It has the advantage that both banks of the Nile rise steeply from the river bed and a very deep wide valley upstream provides excellent storage capacity.

The height of the dam above the river bed is 111 metres and the river at the dam site is about 550 metres from bank to bank. The crest extends to 3,600 metres. At the river bed level the dam measures 980 metres (Ministry of the High Dam, Aswan High Dam, Cairo, Egypt, 1966, p. 12).

The storage capacity created by Lake Nasser is 164,000 million m^3, or approximately thirty times larger than the storage of the heightened Aswan Dam. The High

Dam provides a controlled mean annual discharge of 84,000 million m^3 downstream from Aswan, which is considered equivalent to the mean flow of the Nile over a 60 year period (U.A.R., the High Dam, Cairo, 1963, p. 6). Lake Nasser extends 350 km in Egyptian territory and 150 km into the Sudan. The width of the lake ranges between 3 and 25 km (Shibl, 1971).

The High Dam project has expanded the agricultural area by 1.2 million feddans which represents a 20% increase over the previous area of 6.2 million feddans. It has also increased agricultural production by approximately 10% owing to the regulation of water supply during the whole year. 850,000 feddans in Upper Egypt have been converted from basin into perennial irrigation. This will make it possible to produce three crops per year instead of one.

The dam has reduced flood damage by eliminating excess water from the cultivated area. This increase of productivity has facilitated earlier planting, has lengthened the crop growing season, has improved soil ventilation and has leached excess salts from the soil. As a result of controlling the river flow downstream from the Aswan High Dam navigation conditions have been improved. The power units at the dam will produce 10 billion K.W.H. of electricity annually which will supply cheap power to industry equivalent to twice the total energy created by the old Aswan Dam and all the thermal stations operating in Egypt.

Finally it has permitted the development of a fishery industry on a small scale in Lake Nasser which will reach a production level of 40 tonnes/day (Little, 1965; Shibl, 1971; Beaumont et al., 1976).

The construction of the High Dam has given rise to a number of problems. The course of the Nile was blocked in May, 1964 and since that time the silt has been deposited in the Dam's reservoir. As a result soil fertility in Egypt has declined. However this problem has been obscured so far by a rising total production of certain crops, owing to the growth of more than one crop in the old basin irrigation areas and the introduction of a better drainage system which has provided better conditions for plant roots growth. The absence of the silt in the lower Nile valley has also damaged the Nile fishing industry by reducing the supply of nutrients, and consequently the number of plants and animals on which the fish feed. Thus a decline in sardine landings in the eastern Mediterranean over the last few years has been attributed to this cause.

The potential loss of water by seepage from Lake Nasser was considered by some engineers to be so serious as to make the whole project a failure. However, an extensive investigation made by a German consulting firm concluded that at a water level of 120 m no serious loss of water will occur, while at a level of 150 m the loss is estimated at 600 million m^3/year rising to 2000 million m^3 at a water level of 180 m. Since the last level is rarely attained except in unusually high flood years, seepage losses on average will not exceed 1000 million m^3/year in normal years (Ministry of High Dam, the High Dam, Cairo, 1967, p. 326). The loss of water by evaporation from Lake Nasser has been estimated at 8.0 mm/day (Omar and El-Bakery, 1970). This means that when the lake is full the annual water loss will be 15,324 million m^3/year.

The spread of Bilharzia is being blamed on the High Dam. This disease is carried by parasites living on freshwater snails in irrigation canals. It is claimed to have increased in incidence with the spread of perennial irrigation and the construction of new canal systems (Ministry of the High Dam, 1963, 1966 and 1967; Shibl, 1971).

The River Flow :-

The flow of the River Nile has been measured for many years at a number of locations. The measurements at Aswan provide an excellent basis for determining the amount of water flow into Egypt. The gauge is located at the Aswan Dam, which is 7 kilometres downstream from the new High Aswan Dam (Sadd El-Aali). A record of these measurements is reported by Hurst, Black and Simaika for the years 1871-1945; 1945-1958 and 1959-1965 (Table 10.d). It is noticed that the highest annual total discharge of the River Nile at Aswan was recorded in 1879. At this time the total flow was 137,000 million m^3. The lowest

Table 10.d

Discharge of Nile River at Aswan, 1871-1965

Milliards (Billions) of Cubic Meters, Rounded to Three Significant Figures

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual total
1871	6.98	4.82	3.98	2.42	1.96	1.97	6.63	24.00	25.80	17.60	9.13	6.48	112.0
1872	4.48	2.59	1.95	1.57	1.50	2.28	8.36	23.60	27.30	21.30	12.90	8.31	116.0
1873	5.86	4.48	3.31	1.96	1.49	3.61	6.15	19.00	21.80	15.20	7.96	5.49	96.3
1874	3.59	2.05	1.78	1.34	1.25	2.50	8.20	28.90	30.60	21.60	11.10	7.78	121.0
1875	5.92	4.08	2.84	2.00	1.71	1.81	6.42	24.80	27.10	20.60	11.50	7.58	116.0
1876	5.67	4.49	3.86	2.45	1.94	2.30	8.32	23.60	28.70	18.10	9.82	6.76	116.0
1877	4.91	3.06	2.53	1.99	1.94	2.52	7.07	15.80	16.70	12.60	7.39	4.87	81.3
1878	3.68	2.29	1.82	1.41	1.25	1.32	5.72	22.10	32.00	27.40	14.40	10.10	123.0
1879	7.70	5.81	5.72	4.79	4.55	5.16	10.60	25.50	27.70	19.40	11.30	8.60	137.0
1880	7.03	5.68	4.87	3.45	2.86	2.96	9.50	22.50	23.30	16.80	8.46	6.35	114.0
1881	4.78	3.20	2.66	1.96	1.85	1.98	4.96	18.00	26.30	17.60	9.67	6.54	99.5
1882	4.90	3.25	2.37	1.70	1.48	1.39	4.08	18.20	22.60	15.50	11.00	6.92	93.5
1883	5.02	3.69	3.36	2.25	1.79	1.84	7.26	24.30	26.50	17.40	9.99	7.31	111.0
1884	5.58	4.40	3.87	2.67	2.28	2.28	4.75	17.80	21.20	17.00	10.70	6.94	99.4
1885	5.18	3.55	2.54	1.82	1.50	1.48	8.20	24.80	23.00	15.80	8.21	5.70	102.0
1886	4.02	2.47	2.18	1.80	1.79	2.00	5.07	20.20	25.30	15.80	8.51	6.91	96.0
1887	4.98	3.22	2.44	1.75	1.87	2.51	8.21	28.70	29.30	18.20	10.00	7.23	118.0
1888	5.53	3.38	2.54	1.96	1.77	1.84	4.23	17.80	18.90	11.70	5.88	4.35	79.9
1889	3.04	1.88	1.66	1.36	1.28	1.34	5.02	22.30	25.90	17.60	8.63	5.74	95.8
1890	4.39	2.56	1.96	1.43	1.27	1.60	5.87	25.80	27.40	21.40	12.30	7.86	114.0
1891	5.67	3.40	2.33	1.71	1.62	3.12	5.71	21.80	25.60	19.70	12.30	7.56	110.0
1892	5.20	3.37	2.31	1.59	1.34	1.38	5.64	23.80	31.60	23.70	12.40	8.36	121.0
1893	6.60	5.20	5.04	4.37	2.68	2.11	4.93	22.40	23.80	19.90	10.80	7.05	115.0
1894	5.39	3.51	2.46	1.85	1.85	2.15	7.65	26.10	28.70	24.20	12.40	8.72	125.0
1895	6.78	5.05	4.71	3.41	2.82	2.60	7.75	29.10	27.10	17.50	10.60	8.46	126.0
1896	6.42	4.83	3.77	2.67	2.38	2.32	7.10	21.90	27.90	18.80	13.00	11.00	122.0
1897	7.00	4.89	4.04	2.76	2.42	2.70	5.76	19.00	23.60	16.40	8.25	5.83	103.0
1898	4.65	3.29	2.43	1.80	1.59	1.52	4.00	24.30	27.00	20.10	11.30	8.14	110.0
1899	6.04	4.65	4.32	2.99	2.22	2.10	4.81	14.80	16.90	10.30	4.97	3.36	77.4
1900	2.14	1.47	1.25	1.02	1.06	1.41	3.86	22.20	21.50	15.80	7.22	5.04	84.0
1901	3.75	2.35	1.93	1.45	1.51	1.62	5.32	20.60	23.50	13.30	7.23	4.94	87.4
1902	3.30	1.98	1.67	1.40	1.33	1.46	3.42	11.10	18.40	14.20	6.81	4.40	69.4
1903	3.47	2.16	1.67	1.24	1.25	2.37	4.96	17.50	24.00	18.10	10.20	5.62	92.6
1904	4.19	3.23	2.38	1.67	1.79	2.92	5.11	18.90	19.00	13.00	6.10	4.51	82.7
1905	3.78	2.44	1.92	1.35	1.44	1.59	2.96	12.40	19.60	13.20	5.29	4.19	70.1
1906	3.60	2.63	2.09	1.86	1.80	1.97	3.83	17.80	24.80	17.50	8.68	5.17	91.7
1907	4.05	2.86	2.04	1.79	1.83	1.87	3.63	11.70	17.60	11.20	6.26	4.12	69.0
1908	3.52	2.17	1.77	1.55	1.48	1.52	3.47	21.60	27.90	20.20	9.32	5.32	99.9
1909	4.39	3.40	2.49	1.77	1.99	3.60	5.74	20.70	25.80	19.40	9.52	6.42	105.0
1910	4.26	3.79	3.12	1.83	1.71	2.20	3.55	16.30	24.50	18.90	10.70	5.91	96.8
1911	4.32	2.56	2.13	1.40	1.55	2.08	3.50	15.00	23.30	14.50	7.40	4.92	82.7
1912	3.38	2.34	1.78	1.48	1.48	1.53	3.44	18.60	18.20	10.30	4.43	4.03	70.9
1913	3.16	1.93	1.56	1.64	1.87	1.96	2.48	6.55	12.20	7.52	2.65	2.00	45.5
1914	1.51	1.14	1.61	1.43	1.49	1.69	2.29	19.40	20.00	16.50	10.70	6.31	84.1
1915	3.36	2.57	2.05	1.71	1.79	2.26	3.44	10.70	14.90	14.70	7.75	4.07	69.2
1916	3.23	2.10	1.71	1.50	1.89	2.25	5.34	25.00	26.60	22.40	13.30	7.85	113.0
1917	4.13	3.03	3.34	2.22	2.20	3.20	5.47	17.50	27.80	22.80	11.60	7.34	111.0
1918	3.98	3.29	4.23	4.19	4.00	4.62	5.87	13.60	17.70	11.10	5.38	3.07	81.0
1919	3.34	2.09	2.01	2.10	2.21	2.31	4.10	16.60	20.80	12.60	5.83	3.00	77.1
1920	2.64	1.89	1.66	1.61	1.88	3.02	5.76	18.20	17.80	15.00	8.94	3.82	82.2
1921	3.00	2.14	1.91	1.79	1.89	2.11	3.44	15.40	19.60	14.80	7.09	3.22	76.5
1922	2.99	1.98	1.54	1.44	1.51	1.84	3.73	18.80	23.60	15.90	8.15	3.41	84.9
1923	2.71	2.22	1.58	1.52	2.08	3.30	4.41	20.10	21.40	16.20	7.14	3.86	86.5
1924	3.02	2.43	1.91	1.76	2.11	2.52	5.60	18.00	22.30	14.30	7.98	4.49	86.4
1925	2.49	2.40	1.89	1.72	2.07	2.60	4.14	13.30	16.50	12.40	4.63	3.49	67.7
1926	3.10	2.19	1.65	1.71	2.34	3.15	4.99	18.80	20.50	14.40	8.00	3.52	84.4
1927	2.80	2.75	1.96	1.80	2.25	2.64	4.51	15.30	18.30	13.30	4.42	2.91	72.9
1928	2.18	1.76	1.61	1.67	2.37	2.96	6.65	17.90	19.90	12.30	6.39	3.38	79.0
1929	2.77	2.23	1.97	1.87	2.45	3.72	9.42	22.90	24.40	17.80	9.59	3.51	103.0
1930	3.31	2.74	2.13	1.96	2.52	2.81	4.71	17.80	17.50	11.70	3.52	3.19	77.1
1931	2.37	1.76	1.94	1.71	1.78	2.02	3.08	15.50	21.20	14.80	7.84	3.10	77.1
1932	2.73	2.02	2.07	1.65	2.19	2.80	4.37	18.50	22.80	15.70	7.06	3.08	85.0
1933	3.51	3.29	2.70	1.99	2.58	3.03	3.69	12.70	22.10	15.10	7.34	4.31	82.4
1934	3.49	2.73	2.37	2.05	2.61	3.21	6.46	20.20	23.70	15.40	6.04	3.38	91.6
1935	3.51	2.73	2.41	2.19	3.04	4.19	7.87	21.00	23.90	17.40	5.00	3.58	96.9
1936	3.42	2.68	2.40	2.19	3.10	3.65	6.00	18.70	23.80	14.30	4.50	3.49	88.2
1937	2.95	2.25	2.28	1.99	2.43	3.17	4.67	19.50	22.10	12.40	3.19	3.62	80.6
1938	3.23	2.29	2.32	2.02	2.77	3.39	4.63	22.50	28.10	19.30	6.42	3.58	101.0
1939	3.45	3.05	2.51	2.21	3.26	4.11	5.11	13.20	18.20	10.50	5.30	4.15	75.0
1940	3.15	2.35	2.31	2.07	2.98	3.39	3.96	15.00	17.90	7.70	2.87	2.40	66.1
1941	2.19	2.13	2.08	1.95	2.64	3.61	4.69	11.90	14.20	8.56	5.41	4.09	63.4
1942	2.66	2.45	2.37	2.48	3.34	4.04	5.63	20.10	20.10	13.90	3.26	2.95	83.3
1943	2.50	2.49	2.21	2.38	3.10	3.38	3.96	14.60	24.40	12.00	4.60	3.70	79.3
1944	2.80	2.69	2.49	2.28	3.17	4.04	5.09	16.50	17.90	9.47	3.01	3.26	72.7
1945	2.36	2.56	2.12	2.22	2.79	3.96	4.55	14.80	18.80	14.80	4.82	4.70	78.5
1946	3.66	2.84	2.27	2.27	2.99	4.15	7.25	23.80	26.90	14.90	7.31	4.85	103.0
1947	3.89	3.58	2.92	2.66	3.91	4.66	5.01	14.80	22.30	12.10	4.07	4.18	84.1
1948	3.36	2.99	2.47	2.35	3.21	4.51	5.65	17.20	19.10	13.70	8.07	3.89	86.6
1949	2.50	3.06	2.45	2.48	3.19	4.49	5.47	17.80	20.10	12.20	4.76	4.23	82.8
1950	3.11	3.05	2.47	2.51	3.45	4.63	5.38	21.30	22.30	12.90	3.28	3.88	88.3
1951	2.75	2.92	2.41	2.43	2.92	3.66	3.83	14.90	17.50	10.10	4.35	4.30	72.3
1952	2.95	2.77	2.32	2.30	2.89	3.67	4.49	14.50	20.90	10.40	3.20	2.98	73.4
1953	2.21	2.45	2.22	2.20	2.70	3.91	5.23	21.50	20.60	12.20	2.85	3.28	81.3
1954	2.55	2.40	2.24	2.30	2.76	4.04	6.79	23.20	27.00	19.70	6.87	3.82	104.0
1955	3.39	2.59	2.47	2.48	3.29	4.80	5.70	18.80	22.50	16.50	4.03	3.70	90.2
1956	2.88	2.65	2.46	2.56	3.38	4.92	7.50	19.30	20.50	16.00	10.20	4.04	96.5
1957	3.51	2.98	2.50	2.90	3.82	5.30	6.21	17.20	21.10	7.44	2.18	2.23	77.4
1958	2.11	2.32	2.34	2.25	2.72	3.93	5.79	23.20	24.90	12.90	6.32	3.51	92.2
1959	2.87	2.40	2.34	2.42	3.22	4.46	4.88	18.10	27.90	15.30	6.62	3.78	94.3
1960	3.14	2.60	2.37	2.35	3.17	4.48	4.97	16.50	20.20	12.90	3.14	2.18	78.0
1961	2.24	2.17	2.32	2.40	3.08	4.22	6.50	21.90	26.10	17.90	5.91	4.59	98.4
1962	3.56	2.78	2.75	2.95	3.67	5.32	6.67	15.40	22.20	15.40	3.42	3.30	87.5
1963	2.90	2.71	2.77	2.59	3.86	5.42	7.04	19.80	21.30	9.42	3.80	4.42	86.0
1964	4.16	3.33	2.95	2.68	3.76	5.18	8.11	22.80	25.30	15.40	10.30	5.38	109.0
1965	5.07	5.31	4.63	4.26	5.57	6.36	6.38	9.35	12.60	10.80	7.76	4.68	82.7

Source: H. E. Hurst, R. P. Black, and Y. M. Simaika, *The Nile Basin* (Cairo: Ministry of Public Works, 1946, 1959, and 1966), Vols VII, IX, and X. No information is available to verify the accuracy of the measurements implied by the figures given.

annual discharge during these 95 years of investigation was 45,500 million m^3 in 1913 (Table 10.d). In general the months of August, September and October (flood period) used to have the highest monthly discharge, while minimum flows occurred in April, May and June. After 1964 the pattern of water discharges at Aswan was changed as a result of the construction of the High Dam (Fig. 10.2).

An attempt has been made by the author to show the complete discharge picture of the River Nile before and after the construction of the High Dam (Figs. 10.3 and 10.4). It can be seen that the completion of the High Dam changed the picture and it is unlikely, assuming efficient flood control operation of the reservoir, that the Delta will ever again be in danger of serious flooding. The waters are now being retained in Lake Nasser and the flood control features of the project are already a reality.

The daily water discharge of the River Nile at Aswan, Cairo, Damietta and Rosetta are graphed for the three year period before the High Dam (1960-1962) and for three years after the filling of Lake Nasser (1973-1975). The data for the period 1960-1962 show flood peaks between August and October for the four stations. The daily water discharge for the period 1973-1975 show a different picture with three much smaller peaks. These peaks are not the result of flood conditions but represent the high demand of water for the irrigation of summer crops. This high irrigation demand for water reaches a maximum between June and August (Figs. 10.3 and 10.4).

Fig. 10. 2 DISCHARGE OF THE NILE RIVER AT ASWAN (1871-1975) IN AUGUST

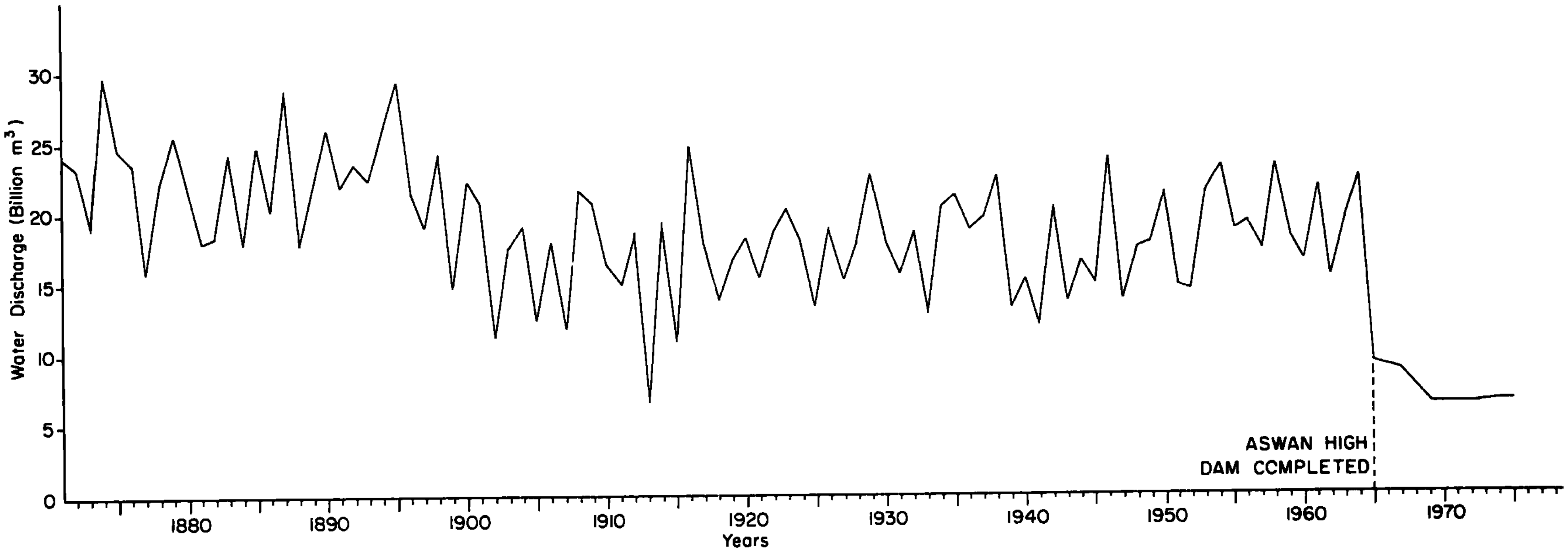


Fig. 10.3

DISCHARGE FROM RIVER NILE AT
· DAMIETTA
" ASWAN
' CAIRO
• ROSETTA

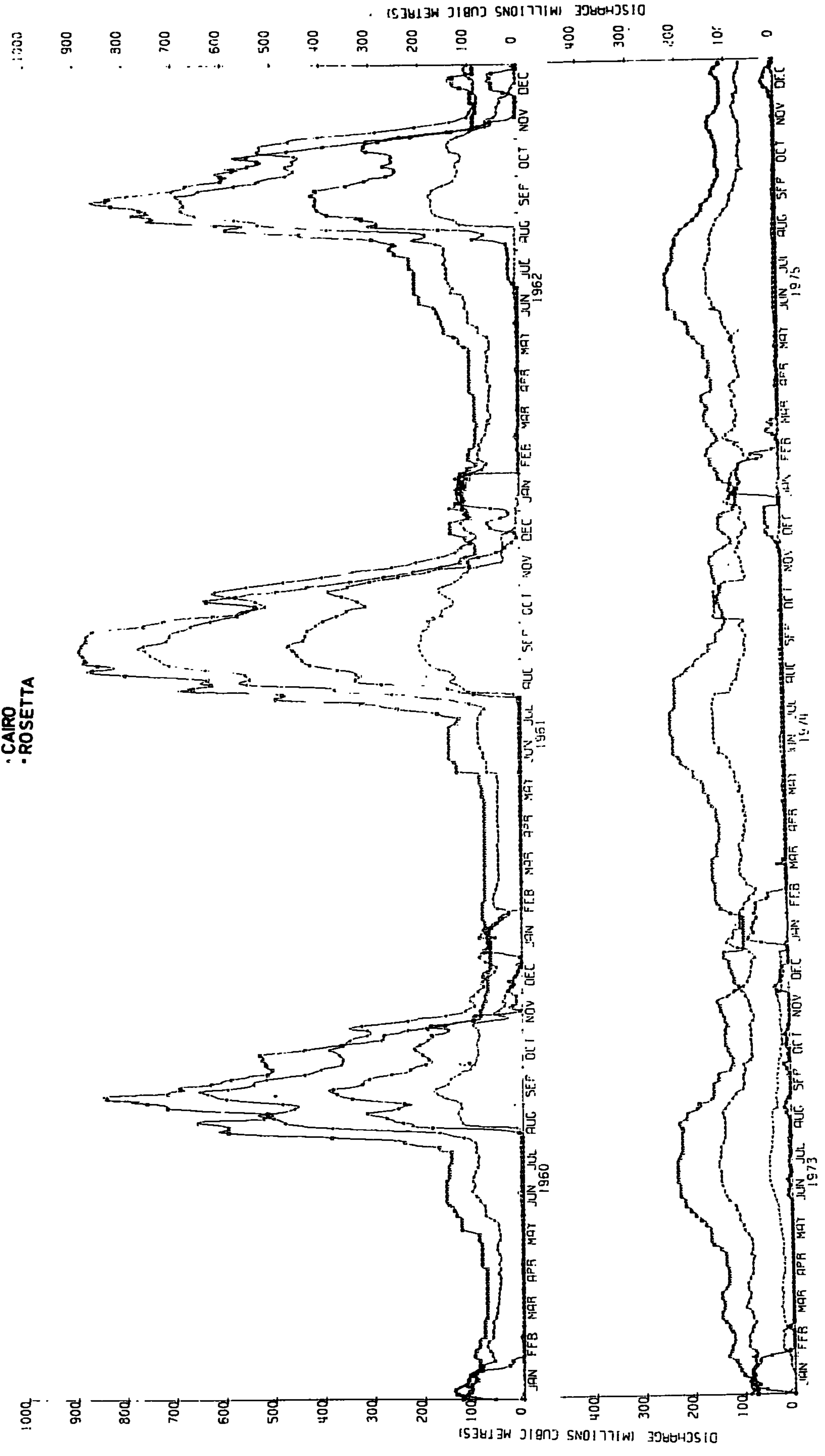
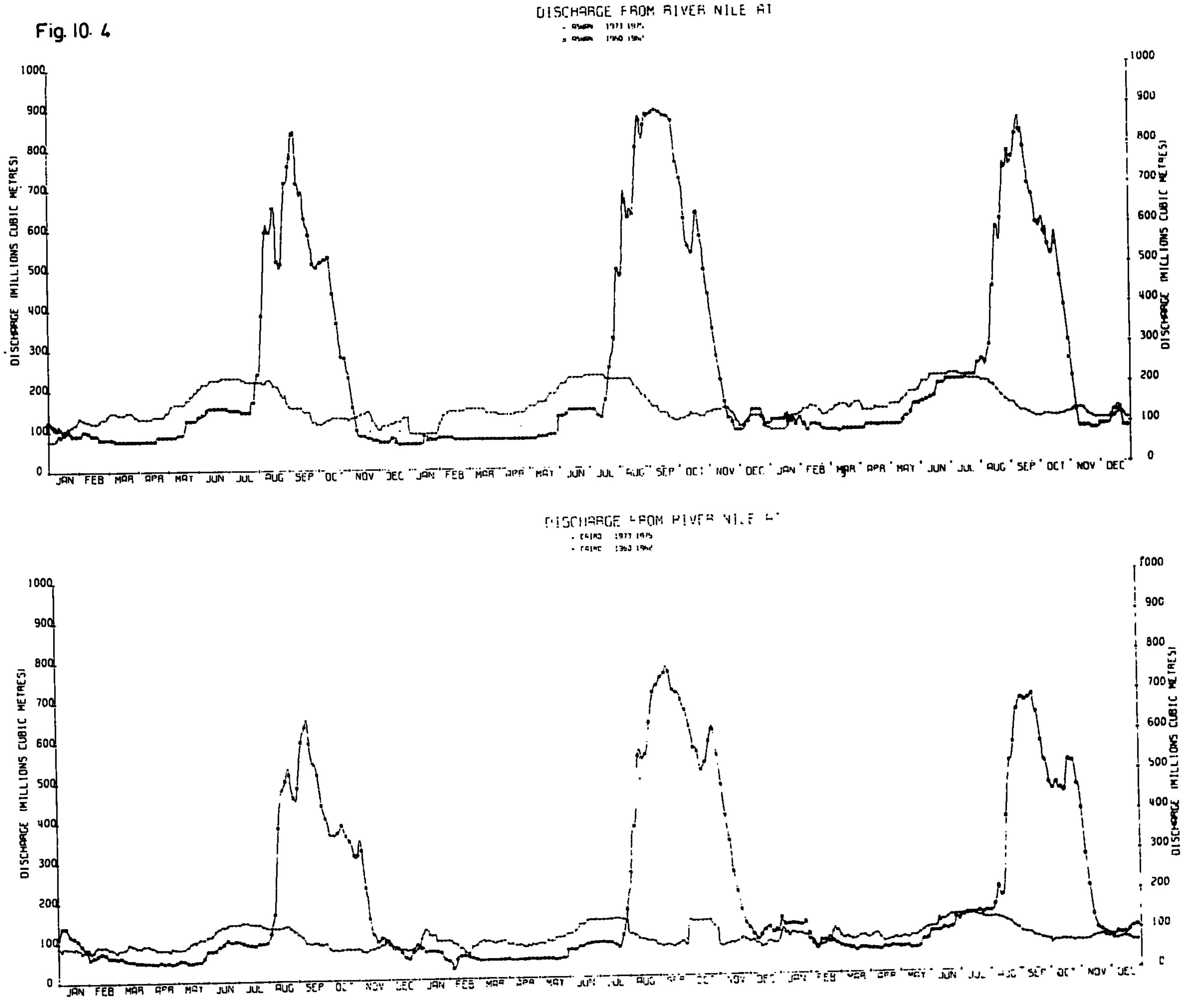


Fig. 10. 4


DISCHARGE FROM RIVER NILE AT
- ASWAN 1973 1975
x ASWAN 1960 1962
DISCHARGE (MILLIONS CUBIC METRES)
0
100
200
300
400
500
600
700
800
900
1000
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
DISCHARGE FROM RIVER NILE AT
. CAIRO 1973 1975
. CAIRO 1960 1962
DISCHARGE (MILLIONS CUBIC METRES)
0
100
200
300
400
500
600
700
800
900
1000
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

Consumptive use of water :-

The consumptive use of water is defined by Blaney and Criddle as "the sum of the volumes of water used by the vegetative growth of a given area in transpiration and building of plant tissue and that evaporated from adjacent soil, snow or intercepted precipitation on the area in any specified time, divided by the given area..." (Blaney and Criddle, 1950, p. 3). By this definition and Penman's (1956) definition for potential evapotranspiration (see Evapotranspiration chapter), the effect of soil and plant factors on evapotranspiration are removed and climatic factors are considered to be the main variables upon which evapotranspiration depends. The water requirements of crops can be quickly estimated for any area where the necessary climatological and water needs data for each crop are available (Blaney and Criddle, 1950; Stamm, 1967; Oliver, 1972).

The consumptive water use of any crop may be estimated from the total consumptive use factor for the growing or irrigation season and the coefficient for the crop, with allowance made for abnormal conditions. As indicated by studies made in Lower, Middle and Upper Egypt, the use of water varies for different crops, not only in terms of the total amount, but also in its seasonal distribution (Hashemi & Decker, 1968; Bavel et al., 1967; Stamm, 1967).

Estimates have been made of the irrigation requirements of the main crops in Egypt at the point of water delivery to the field. This has been accomplished by dividing consumptive use minus rainfall by field irrigation efficiency (Tables 10.e, 10.f, 10.g).

The irrigation water required to satisfy consumptive use by each crop, growing or to be grown on a farm, is obtained by subtracting the effective rainfall from the consumptive use of water during the growing season. This net consumptive use requirement (consumptive use minus rainfall) of the crop when divided by the farm irrigation efficiency gives the seasonal amount of water required at the farm headgate for each feddan of the crop (I).

The summation of the head gate requirements for each crop times its area, gives the total amount of water that must be delivered to the farm headgate for satisfactory crop production. To this total must be added the amount of water needed for incidental farm operation (Rijks, 1965; Hashemi and Decker, 1968).

The consumptive use of water or potential evapotranspiration (Et) may also be calculated by the Penman formula (1956). For the Penman formula; the calculation was facilitated by the application of a Computer program supplied by the Institute of Hydrology, see Chapter 5. The potential evapotranspiration (Et) has been computed for Tanta (Lower Egypt); Minya (Middle Egypt) and Aswan (Upper Egypt) for each crop during the growing season period (Tables 10.e - 10.g).

Table 10.e

Computations of Seasonal Consumptive Use of Water and Irrigation Requirements for Crops in Lower Egypt

Crop	Growing season	Consumptive use factor "F"	Consumptive use coefficient "K"	Blaney & Criddle consumptive use "U" metres	Penman consumptive use (ET) metres	"U" minus "R" metres	Field irrigation efficiency "E" %	Blaney & Criddle irrigation requirements (I) metres	Penman irrigation requirements EI metres
Cotton	March 1st-Sep. 1st	40.43	0.70	0.73	0.70	0.72	65	1.11	1.08
Sugar cane	Feb. 1st-Jan. 31st	69.42	0.80	1.42	1.14	1.41	70	2.02	1.63
Rice	May 1st-Sep. 30th	35.94	1.25	1.15	0.59	1.15	60	1.92	0.98
Maize	Apr. 15th-Aug. 8th	26.99	0.85	0.59	0.49	0.58	65	0.89	0.75
Wheat	Nov. 10th-May 10th	28.28	0.75	0.54	0.35	0.53	65	0.81	0.54
Clover (catch crop)	Oct. 1st-May 31st	40.51	0.85	0.88	0.59	0.87	70	1.24	0.84
Clover	Oct. 1st-Jan. 15th	16.68	0.85	0.36	0.20	0.34	70	0.49	0.29

U = Consumptive use for growing or irrigation season
K = Empirical consumptive, use coefficient determined experimentally
F = Sum of monthly consumptive - use factors, (F), for the growing irrigation season
R = Sum of monthly precipitation for growing or irrigation season
$I = \frac{U-R}{E}$ = Irrigation requirement at head of the field

Et = Penman potential evapotranspiration for Tanta (Lower Egypt), Minya (Middle Egypt) and Aswan (Upper Egypt) for year 1973.
K & E = Obtained from Agriculture Res. Rev., Cairo, Egypt, Vol. 44, part 1, 1966, pp. 133-135 (in Arabic).

Table 10.f

Computations of Seasonal Consumptive Use and Irrigation Requirements for Main Crops in Middle Egypt

Crop	Growing season	Consumptive use factor "F"	Consumptive use coefficient (K)	Blaney & Criddle consumptive use "U" metre	Penman consumptive use ET metre	"U" minus "R" metre	Field irrigation efficiency "E" %	Blaney & Criddle irrigation requirements (I) metre	Penman irrigation requirements (EI) metre
Cotton	Mar. 1st- Sep. 31st	42.03	0.70	0.75	0.73	0.75	65	1.16	1.12
Sugar cane	Feb. 1st- Jan. 31st	71.63	0.80	1.47	1.24	1.47	70	2.10	1.77
Rice	May 1st- Sep. 30th	37.19	1.25	1.19	0.64	1.19	60	1.99	1.07
Maize	Apr. 15th- Aug. 8th	28.06	0.85	0.61	0.53	0.61	65	0.94	0.82
Wheat	Nov. 10th- May 10th	29.26	0.75	0.56	0.38	0.56	65	0.87	0.58
Clover (catch crop)	Oct. 1st- May 31st	41.80	0.85	0.91	0.65	0.91	70	1.30	0.93
Clover	Oct. 1st- Jan. 1st	17.07	0.85	0.37	0.22	0.37	70	0.53	0.31

Table 10.g

Computation of Seasonal Consumptive Use of Irrigation Requirements for Main Crops in Upper Egypt

Crop	Growing season	Consumptive use factor "F"	Consumptive use coefficient "K"	Blaney & Criddle consumptive use "U" metre	Penman consumptive use (ET) metre	"U" minus "R" metre	Field irrigation efficiency "E" %	Blaney & Criddle irrigation requirements (I) metre	Penman irrigation requirements (EI) metre
Cotton	Mar. 1st- Sep. 1st	45.21	0.70	0.81	0.78	0.81	65	1.25	1.20
Sugar cane	Feb. 1st- Jan. 31st	77.00	0.80	1.58	1.33	1.58	70	2.26	1.90
Rice	May 1st- Sep. 30th	39.92	1.25	1.28	0.73	1.28	60	2.13	1.22
Maize	Apr. 15th- Aug. 8th	30.13	0.85	0.66	0.55	0.66	65	1.02	0.85
Wheat	Nov. 10th- May 10th	31.54	0.75	0.61	0.41	0.61	65	0.94	0.63
Clover (catch crop)	Oct. 1st- May 31st	45.14	0.85	0.98	0.69	0.98	70	1.40	0.99
Clover	Oct. 1st Jan. 15th	18.27	0.85	0.40	0.24	0.40	70	0.57	0.34

Evaluation of effects of irrigation water use on main crop yields such as cotton, wheat, maize, sugar cane and rice :-

A number of aspects discussed in the preceding pages will be considered in relation to some experimental data derived from the available literature in Egypt. The early work (before 1946) was mainly of the survey type, in which water flow measurements at weirs to crop fields were performed. This was followed by a series of simple experiments with three irrigation treatments classified as "light", "medium" and "heavy". This traditional fixed irrigation schedule, producing the highest yields over a number of years, was considered to give the "optimum" water requirement. In the fifties, five water treatments instead of three were adopted (Ministry of Irrigation, 1972).

Systematic studies on irrigation intervals for main crops by the Ministry of Irrigation in collaboration with the Ministry of Agriculture started in 1962. As a result of all these sequential studies, two reports were issued (1972) by the water studies section of the Ministry of Irrigation, Cairo, Egypt. The consumptive use and water requirements for main crops are given in cubic metres/ feddan (1 feddan = 4200 m^2). Water requirements of cotton, wheat, sugar cane, maize and rice are discussed in the following pages.

Cotton is the crop most studied in Egypt with respect to irrigation requirements. Systematic studies of irrigation intervals for cotton by the Ministry of

Irrigation and Agriculture stated in 1962. Out of five irrigation intervals ranging between 10 and 21 days, in general the 15 day interval for irrigation was considered the best. In the early sixties, irrigation treatments were based more on the hydrophysical properties of the soils and the appearance of wilting symptoms of the crop. Experiments of the type which replenished soil water requirements and provided a 5, 10, 15 and 20% extra amount were performed as well as irrigation at different intervals in relation to the appearance of wilting. Thus for cotton, water uses of 2600, 3200 and 4500 m^3/feddan are given for Lower Egypt (Delta), Middle and Upper Egypt respectively (Table 10.h). The actual irrigation water requirements of cotton have been suggested by the Ministry of Irrigation (1972) as 3300, 3950 and 5300 m^3/fed. respectively for Lower, Middle and Upper Egypt. Similar results have been obtained using Blaney and Criddle formula and the Penman equation (Tables 10.h and 10.i). The estimated cotton water use by the Blaney and Criddle formula in Lower, Middle and Upper Egypt is 3066, 3150 and 3402 m^3/fed. respectively. The cotton consumptive water use estimated by the Penman equation is 2940 m^3/fed. (Lower Egypt), 3066 m^3/fed. (Middle Egypt), and 3276 m^3/fed. (Upper Egypt).

Adopted irrigation water use figures for wheat in Egypt range from 260 to 600 mm in depth (Ministry of Irrigation,1972). The consumptive use of water for wheat in the Delta, Middle and Upper Egypt is 1100, 1300 and 1700 m^3/fed. respectively (Table 10.h). The Blaney and

Table 10.h

Measured and Estimated Consumptive Water Use for the Main Crops in Lower, Middle and Upper Egypt (m^3/Feddan)

Crop	Lower Egypt			Middle Egypt			Upper Egypt		
	Measured consumptive water use [1]	Estimated consumptive water use		Measured consumptive water use [1]	Estimated consumptive water use		Measured consumptive water use [1]	Estimated consumptive water use	
		Blaney & Criddle (U)	Penman (Et)		Blaney & Criddle (U)	Penman (Et)		Blaney & Criddle (U)	Penman (Et)
Cotton	2600	3066	2940	3200	3150	3066	4500	3402	3276
Sugar cane	10500	5964	4788	14000	6174	5208	15800	6636	5586
Rice	7200	4830	2478	-	4998	2688	-	5376	3066
Maize	1800	2478	2058	2300	2562	2226	2500	2772	2310
Wheat	1100	2268	1470	1300	2352	1596	1700	2562	1722
Clover (catch crop)	2600	2696	2478	3100	3822	2730	3100	4116	2898
Clover	1200	1512	840	1700	1554	924	2100	1680	1008

1 - Measured consumptive water use have been obtained from Ministry of Irrigation reports (Vol. 1), 1972, p. 151. Cairo, Egypt.

Table 10.i

Measured and Estimated Irrigation Requirements for the Main Crops in Lower, Middle and Upper Egypt

(m^3/Feddan)

Crop	Lower Egypt			Middle Egypt			Upper Egypt		
	Ministry of irrigation requirements (MI)	Estimated irrigation requirements		Ministry of irrigation requirements (MI)	Estimated irrigation requirements		Ministry of irrigation requirements (MI)	Estimated irrigation requirements	
		Blaney & Criddle (I)	Penman (EI)		Blaney & Criddle (I)	Penman (EI)		Blaney & Criddle (I)	Penman (EI)
Cotton	3300	4662	4536	3950	4872	4704	5300	5250	5040
Sugar cane	11300	8484	6846	14800	8820	7434	16800	9492	7980
Rice	8000	8064	4116	-	8358	4494	-	8946	5124
Maize	2500	3738	3150	3050	3948	3444	3300	4284	3570
Wheat	1500	3402	2268	1750	3654	2436	2200	3948	2646
Clover (catch crop)	3000	5208	3528	3550	5460	3906	3600	5880	4158
Clover	1600	2058	1218	2150	2226	1302	2600	2394	1428

MI = Irrigation requirements have been suggested by the Ministry of Irrigation and published in :

Ministry of Irrigation reports, (Vol. 1), Cairo, Egypt, p. 151, 1972.

Criddle consumptive water use figures (U) are 2268, 2352 and 2562 m^3/fed. respectively in Lower, Middle and Upper Egypt. Lower values have been obtained by the Penman equation. These are 1470 m^3/fed. (Delta), 1596 m^3/fed. (Middle Egypt) and 1722 m^3/fed. (Upper Egypt).

The total water use of maize is given as 1800, 2300 and 2500 m^3/fed. for Lower, Middle and Upper Egypt respectively (Ministry of Irrigation, 1972). The estimated figures for consumptive water use for maize by Blaney and Criddle are 2478 (Delta), 2562 (Middle Egypt) and 2772 (Upper Egypt) m^3/fed., while Penman estimated values are 2058, 2226 and 2310 m^3/fed. respectively (Table 10.h).

The consumptive water use of rice and the actual irrigation requirements for Lower, Middle and Upper Egypt are given in Tables 10.h and 10.i. The estimated consumptive water use values using the Blaney and Criddle formula are 4830, 4998 and 5376 m^3/fed. for Lower, Middle and Upper Egypt respectively (Table 10.h). No experimental data are available for Middle and Upper Egypt. The Penman estimated values for rice water use are 2478 m^3/fed. (Delta), 2688 m^3/fed. (Middle Egypt) and 3066 m^3/fed. (Upper Egypt).

Very few experiments have been carried out on the water use of sugar cane. However, the results which are available for Lower, Middle and Upper Egypt suggest values 10500, 14000 and 15800 m^3/fed. respectively (Table 10.h). Consumptive water use and actual irrigation requirements for the sugar cane crop have been estimated by the Blaney and Criddle formula and the Penman equation

(Tables 10.h and 10.i).

The results above show clearly that the consumptive water use and irrigation requirements calculated by the Blaney and Criddle method in all the crops are greater than Penman's (Et) potential evapotranspiration. The main reason for this is the fact that the Blaney and Criddle method depends on an empirical coefficient (K) which tends to overestimate crop water requirements. It is noticed that the actual irrigation requirements are much higher for both the sugar cane and rice crops than the estimated values obtained by use of the Blaney and Criddle formula and the Penman equation in Lower, Middle and Upper Egypt (Tables 10.h and 10.i). This is to be expected because the estimated results are obtained from climatological variables, whilst the measured ones usually give the actual optimum water volumes which should be delivered to the field.

10.2 - Drainage in Egypt :-

Drainage in Egypt is in no way less important than irrigation. In Lower Egypt there are two systems of drainage; the first is by free flow gravity channels discharging into the sea or lakes, and the second is by lifting. In Middle and Upper Egypt also, these two systems are in use (Table 10.j).

Investigations carried out in Egypt on drainage date back to 1930, when it was found that the underground water level was becoming very high owing to the conversion

Table 10.j

Drainage Systems in Lower, Middle and Upper Egypt (Feddans)

Governorate	Lower Egypt	
	Area drained without pumps	Area drained with pumps
Cairo	-	3,750
Alexandria	-	22,000
Port Said	-	400
Ismailia	23,000	13,000
Suez	4,750	-
Damietta	12,932	114,945
Daqahliya	255,096	480,917
Sharqiya	5 6,590	222,300
Qalyubiya	156,340	4,500
Kafr ash Shaykh	176,600	363,244
Gharbiya	398,855	100,863
Minufiya	249,600	326,600
Buheira	485,202	477,530
Total	2,288,965	2,130,049

Source:- Ministry of Irrigation, Census, 1961, Cairo

Table 10.j. Continued

Middle and Upper Egypt		
Governorate	Area drained without pumps	Area drained with pumps
Giza	218983, all the year, except during the period 15/8 to 15/11 the area decreased to 8000 Fed. only	209183 during the period from 15/8 to 15/11 only
Beni Suef	181354	102850
Fayum	342014	19220
Minya	313504	31950
Asyut	27787 Fed. including 26387 Fed. drained with pumps during flood season	20980
Sohag	27620	27620 Fed. during flood season
Qena	-	54100
Aswan	87454	14710 Fed. during flood season
Total	1198716 Fed. increases to 237370 Fed. drained with pumps during flood season.	480613 Fed. increases to 251513 Fed. drained with pumps during dry period

of most of the cultivated areas to perennial irrigation and the non-existence of drainage systems. This has resulted in the deterioration of the land and to a decrease in its productivity (Amer and Gabaly, 1962). Recent studies were based on the assumption that the most effective drainage is attained with a minimum difference of 1.5 metres between the maximum water level in the public drain and the surface of the land to be drained. This allowed the depth of private field drains to be between 0.60 and 0.80 metres in depth with their water levels from 0.50 to 0.79 metres below the ground surface. However, later research found that this depth was not adequate for satisfactory drainage, and a depth of 2.5 metres was adopted for the public drains (Marei, 1960).

Present and planned drainage :-

Before 1960 only 50,000 feddans were provided with tile drainage in the whole country, whilst during the country's five-year plan (1960-1965) about 250,000 feddans were provided with tile drains. (Arar and Bishay, 1975). By the end of 1972 the total area tiled amounted to about 675,000 feddans. In the five-year plan (1973-1978) it is hoped to install covered drains in about 770,000 feddans in the Delta alone (Amer and Gabaly, 1962; Arar and Bishay, 1975). There are three main drainage projects in the Delta region and the Nile Valley area. These are :-

1. The Tile Drainage Project of the Delta (Lower Egypt) of about 4.5 million feddans.

2. The Tile Drainage Project of the Nile Valley (Upper and Middle Egypt), 2.3 million feddans.

3. The National Project for land Improvement and Soil Conservation. This will be complementary to the above - mentioned two projects.

To be able to implement the above mentioned projects, the government of the Arab Republic of Egypt has established two semi-autonomous bodies, which are attached to the Ministry of Irrigation. These are the Nile Delta Drainage Authority and the Authority for tile drainage in Middle and Upper Egypt. They are responsible for the planning and execution of drainage works in the Delta area, and Upper and Middle Egypt respectively. Steps now are being taken to merge these two authorities. It is planned to establish another authority in the Ministry of Agriculture to be responsible for the third project mentioned above (Aboukhaled et al., 1975).

Economics of drainage systems :-

The average increase in yield for the various crops to be expected after drainage is not known accurately because of the strongly varying conditions in the different parts of the cultivated area. Moreover, the yields of crops vary greatly from year to year as a result of meteorological conditions and special management inputs. It is no wonder that the data on yield increase due to drainage very greatly; cotton 0 to 50%, wheat 20 to 32%, maize 17 to 48% (Arar and Bishay, 1975). Measurements of wheat yields in pilot areas indicate that in the first one or two years after drainage, a yield increase of about 10% can be expected to occur. This percentage may increase to 20% after some years.

Drainage gives many indirect benefits of an agroeconomic and a socio-economic nature, as the available labour on the land is more efficiently used and the higher production increases the crop volume which has to be marketed and processed. The increased export value of the produce or the decreased import requirement of certain foodstuffs is of national economic importance. It is almost impossible to express the value of the indirect benefits quantitatively within the scope of a given project (see Balba et al., 1975; Arar and Bishay, 1975).

SECTION 3

Chapter 11 - Introduction

Chapter 12 - The Contribution of Climatic Elements in Predicting Cotton Yields in Egypt.

Chapter 13 - The Contribution of Climatic Elements in Predicting Wheat Yields in Egypt.

Chapter 14 - Actual and Predicted Maize, Rice and Sugar Cane Yields in Egypt.

The Relationship between Climatic Variables and Crop Yields in Egypt

Introduction

Climate is a factor of great importance in determining the yields and water losses from agricultural crops. Damage caused by the attack of various pests and diseases, and the success of the various measures which may be adopted to control such attacks must also be considered (Stanhill and Fuchs, 1968 and Fuller, 1972).

The problem of estimating the integrated effect of meteorological parameters on crop yield is one of considerable complexity. The methods available for the solution of this problem continue to be statistical methods such as correlation analysis, multiple regression and crop - climate analysis models. These methods enable one to discover the quantitatively integrated influences of the meteorological elements, occurring during the various stages of the growth of a crop, on the final yields (Robertson, 1968 and Mather, 1974).

Questions involving the relationships between yields and meteorological conditions are among the most complex in applied climatology. For example, average meteorological conditions over the whole crop-growing season may be less important for ultimate yields, than the weather of a particular period during the development of the crop (Huda et al., 1975 and 1976). Monthly or seasonal data may, therefore, obscure the real relationships (Mather, 1974).

The purpose of the present section is to examine the variations in relationships between crop yields and climatological variables around Alexandria, Tanta, Minya and Aswan (Fig. 11.1) and to discuss the problems and uses of yield-climate relationship analysis. The major crops discussed in this section are cotton, wheat, maize, rice and sugar cane. These five crops have been chosen to explain the relationships between climatic conditions and crop yields in Egypt.

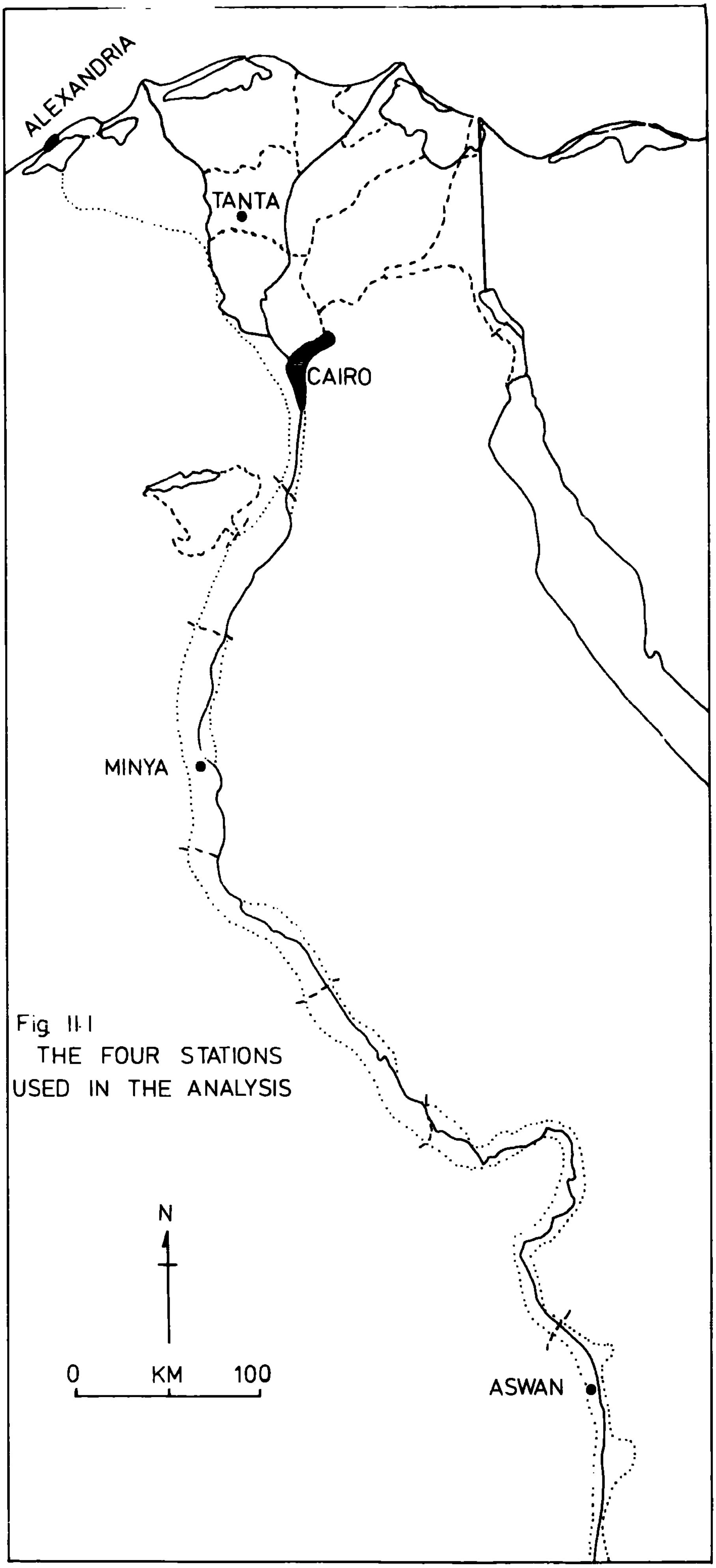


Fig. II.1
THE FOUR STATIONS USED IN THE ANALYSIS

CHAPTER 12

The Contribution of Climatic Elements in Predicting Cotton Yields in Egypt

12.1 - Cotton yields :-

The cotton yields around Alexandria, Tanta, Minya and Aswan, and for the whole country during the period 1960 to 1974 are shown in Table 12.a. These fifteen years have been used for statistical analysis to explain the relationships between cotton yields and weather conditions.

The object of the present chapter is to study the influence of temperature, evaporation, precipitation, relative humidity, sunshine and wind speed on cotton yields around Alexandria, Tanta, Miny and Aswan, using seasonal, monthly and daily climatic data for the period 1960 to 1974.

12.2 - Current varieties of cotton used in Egypt :-

The current varieties of cotton being grown in Egypt are the result of years of research work and studies aimed at satisfying the different needs of spinners and the varying climatic conditions existing throughout the country. Following is a brief description of the most important characteristics of the various varieties (Fig. 12.1).

A - Extra long staples over 3.5 cm :-

1 - Giza 45 :-

This is a hybrid of Giza 28 x Giza 7. It is an excellent quality cotton which is indeed considered as the most luxurious variety of cotton in the world. It is used in the production of luxury textiles and embroidery

Table 12.a

Cotton Yield Data

(Kg/Feddan)*

Place / Year	Alexandria	Tanta	Minya	Aswan	Egypt
1960	552.8	896.2	1011.2	596.9	819.0
1961	418.9	483.5	719.8	496.1	505.6
1962	680.4	949.7	845.8	801.7	806.4
1963	689.9	1009.6	1053.7	474.1	855.2
1964	781.2	1078.9	1058.4	15.8	985.9
1965	746.6	853.7	943.4	387.5	863.1
1966	834.8	680.4	941.9	667.8	770.2
1967	103.9	711.9	929.3	978.1	743.4
1968	269.3	795.4	930.8	475.7	826.9
1969	425.3	910.4	951.3	160.7	911.9
1970	598.5	979.7	804.8	1116.7	863.1
1971	511.9	962.3	1023.8	967.1	929.3
1972	508.7	1014.3	1034.8	859.9	916.7
1973	382.7	968.6	825.3	1134.0	855.2
1974	732.4	945.0	751.3	1122.9	828.5
Mean	549.2	882.6	921.7	683.7	832.0

Source : Ministry of Agriculture, Agricultural Censuses for years 1960 to 1974, Cairo, Egypt.

* Feddan = 4200 m^2 = 0.4200 ha.

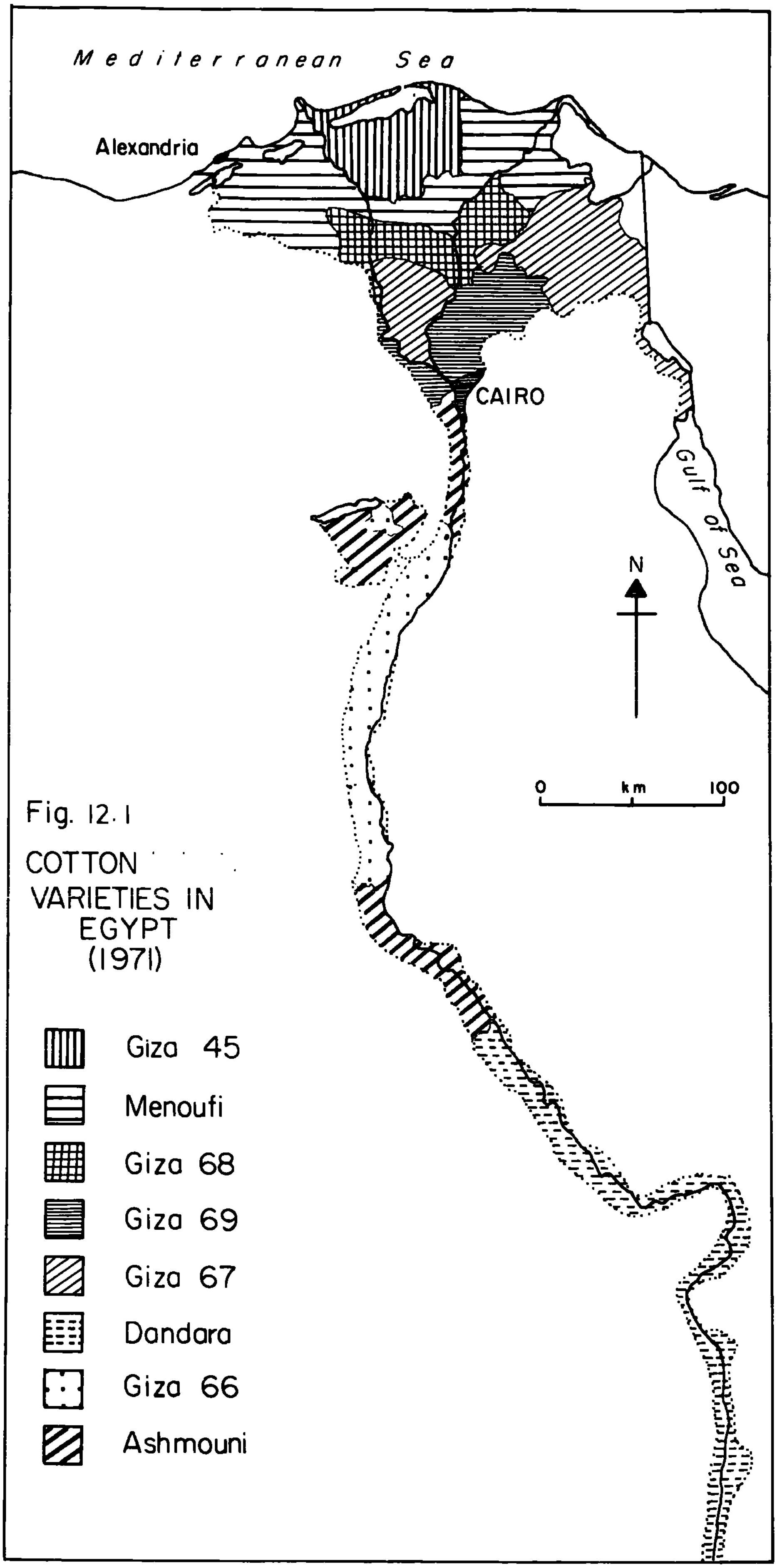


Fig. 12.1

COTTON VARIETIES IN EGYPT (1971)

threads, and in specialities which require fibres with exceptional length and strength. This is mainly cultivated in Kafr ash Shaykh governorate in the north delta region. In this area relative humidities are high and temperatures are not too extreme.

2 - Menoufi :-

This is a hybrid of Wafir x Sakha 3. It is an extra long staple cotton used for most purposes, such as the manufacture of sewing threads, trecholine, the organdies and good quality textiles generally. This variety is mainly found in the northern and central areas of the Delta (Fig. 12.1).

3 - Giza 68 :-

This is a hybrid of Menoufi x Giza 56. It is one of the new extra long staple varieties which was released for growing commercially in 1963. It was originally introduced in the Tanta region but its area has since been extended throughout the Delta. In 1969 it covered an area of 228,396 feddans (Ministry of Agriculture, Cairo, 1971). It produces a crop yield exceeding that of the Menoufi variety by 17.4%. Figure 12.1 indicates that this variety is concentrated in the central Delta region.

B - Long staples over 3.0 cm :-

1 - Giza 67 :-

This is a hybrid of Giza 53 x Giza 30

and is one of the new long staple varieties. It was released for growing commercially in 1963 and it has since gained widespread popularity in the southern part of the centre of the Delta (Fig. 12.1). In 1969 it was cultivated over an area of 213,858 feddans (Ministry of Agriculture, Cairo, 1969). It gives the best crop among all the Delta varieties and it is considered as one of the best Egyptian cottons.

2 - Giza 69 :-

This is a hybrid of Giza 51 x 30 and is also one of the new long staple varieties. It was introduced for cultivation on a commercial scale in 1966. Since then it gained popularity in the southern part of the Delta. It is principally cultivated in Giza and Qalyubiya governorates. By 1969 it was already cultivated over an area of 119,156 feddans (Ministry of Agriculture, Cairo, 1969). It completes with Giza 67 in producing a high yield.

3 - Dandara :-

This was selected from Giza 3 which had been originally derived from the Ashmouni. It is one of the old long staple varieties, cultivated in the southern part of Upper Egypt since it is resistant to the high temperatures of that area (Fig. 12.1). It is used for the manufacture of underclothes, vests, tricot threads and sports wear.

C - Long medium staples over 2.8 cm :-

1 - Ashmouni :-

This is the oldest Egyptian cotton as it was first introduced in 1860. Ashmouni is unique among all other Egyptian varieties for its almost complete freedom from neps. It is, therefore, characterized by its easy handling in spinning. It is used in the production of ordinary textiles such as socks and vests. The greater part of the crop is consumed locally. This variety is located immediately south of Cairo and in the Nile valley governorates of Fayum and Minya, (Fig. 12.1).

2 - Giza 66 :-

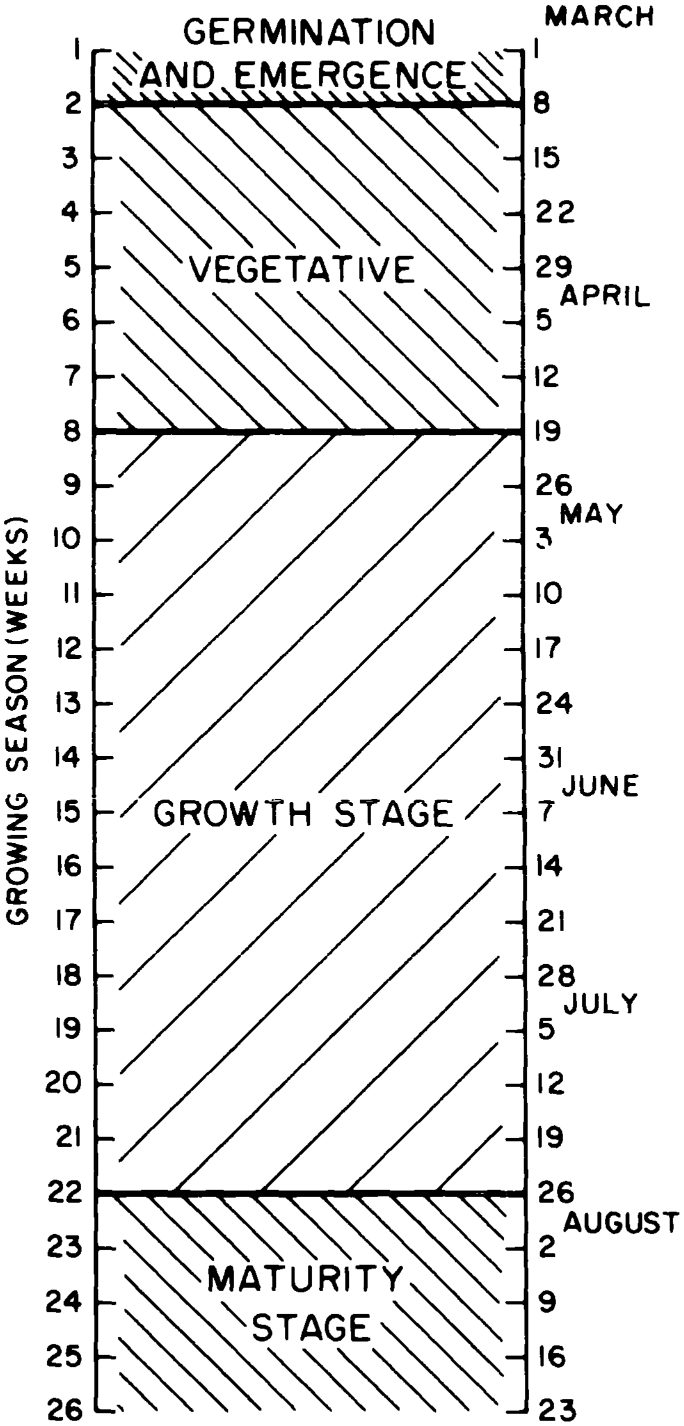
This is a hybrid of Giza 46 A x Giza 47 and is one of the new long/medium staple varieties, which was released for cultivation on a commercial scale in 1962. Since then it has come to occupy a large area in Middle Egypt; and in 1969 it was cultivated over an area of 271,897 feddans (Ministry of Agriculture, Cairo, 1969).

The Cotton Research Control Board is always keen on developing new varieties which give better yields and have better qualities than the present ones. Some new varieties have been recently developed and they are now in the advanced stage of multiplication.

12.3 - Cotton growing season :-

The cotton growing season covers an approximate period of 182 days from March 1st to September 1st (Fig. 12.2). For analytical purposes this period was divided into 26 7-day periods. The crop-growing season can be divided broadly into the following physiologically distinct

Fig.12.2 TYPICAL GROWTH STAGES OF THE COTTON CROP



stages (see, Arnon, 1972, Huda et al., 1975 and 1976 and Agricultural Research Review, 1966).

1 - Germination and emergence stages :-

The first week of the growing season is normally from March 1st, when the seed is planted, to March 7th by which time emergence of the seedling will have taken place. This period is usually characterized by Khamsin conditions, which increase maximum and minimum daily temperatures and decrease daily relative humidities.

2 - Vegetative stage :-

After emergence, the period from March 8th to April 18th is known as the vegetative stage, which is also characterized by Khamsin conditions.

3 - Growth stage :-

This stage includes the active, the lag vegetative and the reproductive growth periods. The critical stages of this period appears to be maximum tillering, boll initiation and flowering. This period lasts from about April 19th to July 25th and climatologically includes both the Khamsin period and the dry season.

4 - Maturity stage :-

This stage, including the ripening stage of the crop, covers the period from July 26th to September 1st. During this stage the shedding of the bolls ceases almost completely after they have reached their full size (Arnon, 1972). This period is normally characterized by high daily maximum temperatures and high daily relative humidities.

Statistical analysis :-

In the following paragraphs attempts have been made to understand how the intensity and distribution of different climatic variables affect cotton yields at different stages of growth. Statistical analysis based on seasonal, monthly and daily climatological data have been utilised.

12.4 - Correlation coefficient techniques :-

A - Correlation coefficients between cotton yields and climatic variables using seasonal data :-

Correlation coefficients were calculated between the climatic variables, such as mean, maximum and minimum temperatures, evaporation, relative humidity, sunshine and wind speed data averaged over the growing season from March 1st to September 1st, and cotton yields around Alexandria, Tanta, Minya and Aswan. The individual observations were the growing seasons for each year from 1960 to 1974, giving a sample of 15 years.

According to the results, which are shown in Table 12.b, there are no highly significant correlations between the climatic variables and the cotton yields. It

Table 12.b

Correlation Coefficients Between Climatic Variables and Cotton Yield at Alexandria, Tanta, Minya and Aswan (Seasonal Data for Period 1960-1974)

Variable / Place	Mean temp.	Maximum temp.	Minimum temp.	Evaporation	Relative humidity	Sunshine	Wind speed	Rainfall
Alexandria	0.1855	0.3100	0.1416	-0.1651	-0.3230	0.0831	0.4601	-0.3943
Tanta	-0.3143	-0.2627	-0.3500	-0.4158	0.4286	0.1084	0.3591	-0.3723
Minya	0.4173	0.5535	0.3959	-0.2281	0.1870	-0.2263	0.0522	-
Aswan	-0.2510	-0.3015	-0.1980	0.0168	0.5246	-	0.3173	-

(N = 15) Level of significance:-

5% = 0.514 2% = 0.592 1% = 0.641

can be seen that there is only a moderately high correlation between maximum temperature and crop yields at Minya and between relative humidity and crop yields at Aswan. These values are 0.554 and 0.525 respectively. Much lower correlation coefficients are recorded between the other climatic parameters and crop yields.

B - Correlation coefficients between climatic elements and cotton yields using monthly data :-

The correlation coefficients between cotton yield and climatic variables at Alexandria, Tanta, Minya and Aswan, using monthly climatic data during the period 1960 to 1974 are discussed.

Temperature :-

The results of the correlation analyses between the monthly mean, minimum and maximum air temperatures and the average yield of cotton around Alexandria, Tanta, Minya and Aswan are shown in Table 12.c.

At Alexandria, the mean and maximum temperatures have a moderate correlation with cotton yield. The correlation coefficient between mean temperature and cotton yield is equal to 0.522 in March; for maximum temperature it is equal to 0.675 in March, and for minimum temperature it is equal to -0.549 in May. This indicates that the March mean, May minimum and March maximum temperatures are moderately correlated with cotton yield (positively correlated in March and negatively correlated in May). These correlation coefficients are statistically signific-

Table 12.c

Correlation Coefficients between Climatological Elements and Cotton Yields at Alexandria, Tanta, Minya and Aswan (1960-1974)

1 - Alexandria

Variable \ Month	March	April	May	June	July	August
Mean temperature	0.522	0.336	-0.373	-0.141	-0.455	-0.139
Minimum temperature	0.264	0.275	-0.549	-0.033	-0.509	-0.149
Maximum temperature	0.675	0.289	0.104	-0.157	-0.252	-0.325
Evaporation	0.092	0.584	0.545	0.125	-0.507	0.028
Rainfall	0.433	0.023	0.539	-	-	-
Relative humidity	-0.075	0.559	-0.439	0.362	0.186	0.112
Sunshine	0.292	-0.074	-0.333	-0.663	0.432	-0.381
Wind speed	0.392	-0.079	0.298	0.681	0.213	0.149

N = 15 : Level of significance :-

5% = 0.514 2% = 0.592 1% = 0.641

≥5% level of significance underlined

Table 12.c Continued

2 - Tanta

Month Variable	March	April	May	June	July	August
Mean temperature	0.209	-0.518	-0.314	-0.439	-0.627	-0.722
Minimum temperature	0.119	-0.415	-0.452	-0.462	-0.373	-0.781
Maximum temperature	0.365	-0.503	-0.017	-0.431	-0.565	-0.614
Evaporation	-0.182	-0.719	0.105	-0.469	-0.661	-0.687
Rainfall	0.019	0.508	0.409	-	-	-
Relative humidity	0.172	0.627	-0.136	0.052	0.712	0.495
Sunshine	-0.271	-0.569	-0.019	-0.465	0.004	-0.203
Wind speed	0.312	-0.291	0.037	0.456	0.123	0.247

N = 15 : Level of significance :-

5% = 0.514 2% = 0.592 1% = 0.641

⩾ 5% level of significance underlined

Table 12.c Continued

3 - Minya

Month / Variable	March	April	May	June	July	August
Mean temperature	0.138	-0.089	-0.189	0.204	-0.304	-0.589
Minimum temperature	0.227	0.182	0.164	0.171	-0.225	-0.450
Maximum temperature	-0.009	-0.188	-0.283	0.216	-0.399	-0.405
Evaporation	-0.112	-0.212	-0.422	-0.214	-0.054	-0.038
Relative humidity	0.327	0.045	0.106	-0.277	0.179	-0.358
Sunshine	-0.547	-0.537	-0.419	-0.175	-0.366	-0.313
Wind speed	0.039	-0.219	0.396	0.567	-0.246	0.231

Level of significance :-

5% = 0.514 2% = 0.592 1% = 0.641

⩾5% level of significance underlined

Table 12.c Continued

4 - Aswan

Month / Variable	March	April	May	June	July	August
Mean temperature	-0.473	-0.578	-0.268	-0.752	-0.069	-0.391
Minimum temperature	-0.435	0.175	0.121	-0.388	-0.131	-0.002
Maximum temperature	-0.485	-0.420	-0.448	-0.799	-0.082	-0.564
Evaporation	-0.073	0.072	0.102	-0.138	-0.109	-0.291
Relative humidity	0.414	0.026	0.524	0.554	0.442	0.458
Wind speed	-0.029	0.462	0.316	0.620	-0.123	0.196

Level of significance :-

5% = 0.514 2% = 0.592 1% = 0.641

⩾5% level of significance underlined

ant at the 5%, 1% and 5% levels for mean, maximum and minimum temperatures respectively.

The relationships between cotton yield and mean, minimum and maximum temperatures at Tanta are not highly significant except for the month of August. At this time a correlation coefficient of -0.722 for mean; -0.781 for minimum and -0.614 for maximum temperatures were obtained. These indicate that the mean, minimum and maximum temperatures in August are negatively correlated with cotton yield at Tanta.

The mean, minimum and maximum temperatures have low correlation coefficients with cotton yields at Minya. The highest values recorded are -0.589 for mean, -0.450 for minimum and -0.405 for maximum temperatures. These values are experienced during August. Such correlation coefficients are not significant statistically and, therefore, are unreliable.

The strongest monthly correlations between cotton yield and maximum and mean temperatures at Aswan are equal to -0.799 and -0.752 respectively. Both of these occurred in June (Table 12.c).

Evaporation :-

The strongest monthly correlation coefficients between evaporation and cotton yield are equal to -0.719, -0.661 and -0.687 during April, July and August respectively at Tanta. These are highly significant at the 1% level. At

Alexandria there are moderately high correlations between cotton yield and evaporation. These values are 0.584 and 0.545 and occur in April and May respectively (Table 12.c).

Rainfall :-

Rainfall is of no importance in Upper and Middle Egypt and therefore correlation coefficients cannot be calculated because most values are zero. In Lower Egypt the effect of precipitation can be significant, especially during the early period of crop growth. Table 12.c shows that rainfall has a weak correlation with cotton yields at Alexandria. This correlation coefficient is equal to 0.433 during March and 0.539 during May. At Tanta the correlation coefficients in April and May are equal to 0.508 and 0.409 respectively. These correlation coefficients fail to reach the 5% level of significance.

Relative humidity :-

The correlation coefficients between relative humidity and cotton yields are generally similar to those described for the previous variables. The strongest monthly correlation coefficient between relative humidity and cotton yield is equal to 0.712 and this occurs during July at Tanta. It is highly significant at the 1% level. A moderately high monthly correlation coefficient equal to 0.627 was experienced during April at Tanta. The moderately high correlation coefficient of 0.559 in April at Alexandria and 0.524 and 0.554 for May and June respectively at Aswan have been computed.

Sunshine :-

The sunshine regime is also of significance to the cotton yield. It may be seen from Table 12.c that the strongest correlation coefficient between sunshine and cotton yields is equal to -0.663, and is experienced during June at Alexandria. A moderately high correlation coefficient equal to -0.569 characterises Tanta in April. In Minya, results for March and April produced moderately high correlation coefficients of -0.547 and -0.537 respectively.

Wind speed :-

The strongest monthly correlation coefficient between wind speed and cotton yield is equal to 0.681, occuring during June at Alexandria. A moderately high correlation coefficient, equal to 0.620, was found for June at Aswan. At Minya a moderately high correlation coefficient, equal to 0.567, also occurs in June (Table 12.c).

The correlation coefficients outlined above between cotton yields and selected climatic elements are not as fruitful as might be hoped. The negative relationship between yield and maximum as well as minimum temperatures could be interpreted as temperature cannot be stored (in the sense that rainfall is stored in the soil), its influence on crop growth is of an immediate nature. These correlation results also prove that average meteorological conditions over the whole crop-growing season are not very useful for predicting ultimate yields. To improve upon this situation daily data have been used to analyse the relationships between cotton yields and selected climatic variables using a multiple regression technique.

12.5 - Multiple regression equations :-

The objective of this study was to show how the average weekly, minimum and maximum temperatures, relative humidity and wind speed interact at various times during the growing season and effect crop yield. A second degree multiple regression equation between crop yield and each climatic variable has been used by Huda et al., (1975 and 1976) and Runge (1968) in an attempt to study the relationships between maize and rice yields and weather parameters. This technique was developed originally by Fisher (1924), modified by Henrick and Scholl (1943), and later adapted by Stacy et al., (1957). The average weekly maximum and minimum temperatures, relative humidities and wind speeds for the 26 weeks of the cotton growing season and the cotton yields for the 15 years (from 1960 - 1974), at Alexandria, Tanta, Minya and Aswan were analysed.

The multiple regression techniques used in the present chapter are similar to those used by Runge (1968) and Huda et al., (1975 and 1976). The second degree multiple regression equation between cotton yield and selected climatic variables is :-

$$y = Ao + a_1 \sum_{i=1}^{n} (t^o{}_i \; x_i) + a_2 \sum_{i=1}^{n} (t^1{}_i \; x_i)$$

$$+ a_3 \sum_{i=1}^{n} (t^2{}_i \; x_i) + MT$$

Where Y = Crop yield (Quintar/feddan) (Quintar = 157.5 Kg); A_o, a_1, a_2, a_3 and M = Constants; X = any climatic variable within each 7-day period; t_i = the number of each of the 7-day periods (it is 1 for the period from March 1 - 7 and 26 for the period August 23 - 29), n = 26 7-day periods in the growing season; T = year number (beginning with one in 1960 and ending with fifteen in 1974).

Since the data on relative humidity were in percentages and were not normally distributed, the data were, therefore, transformed using the arc-sine root proportion and then subjected to analysis (Fisher and Yates, 1974).

Results and discussion :-

Effect of climatic variables on cotton yields :-

The average data for the 15 years from 1960 to 1974 for the 26 weeks of the cotton growing season concerning maximum and minimum daily temperatures, mean daily relative humidities and mean daily wind speeds are included (Fig. 12.3 and Appendix 2A). These data, along with the cotton yields for the 15 years were analysed using multiple - regression techniques. The effect of the selected climatic variables on cotton yield during each stage of the growing season is discussed separately :-

Distribution of climatic variables :-

The distribution of climatic variables during the cotton growing season is discussed first and then their effect on cotton yield is considered.

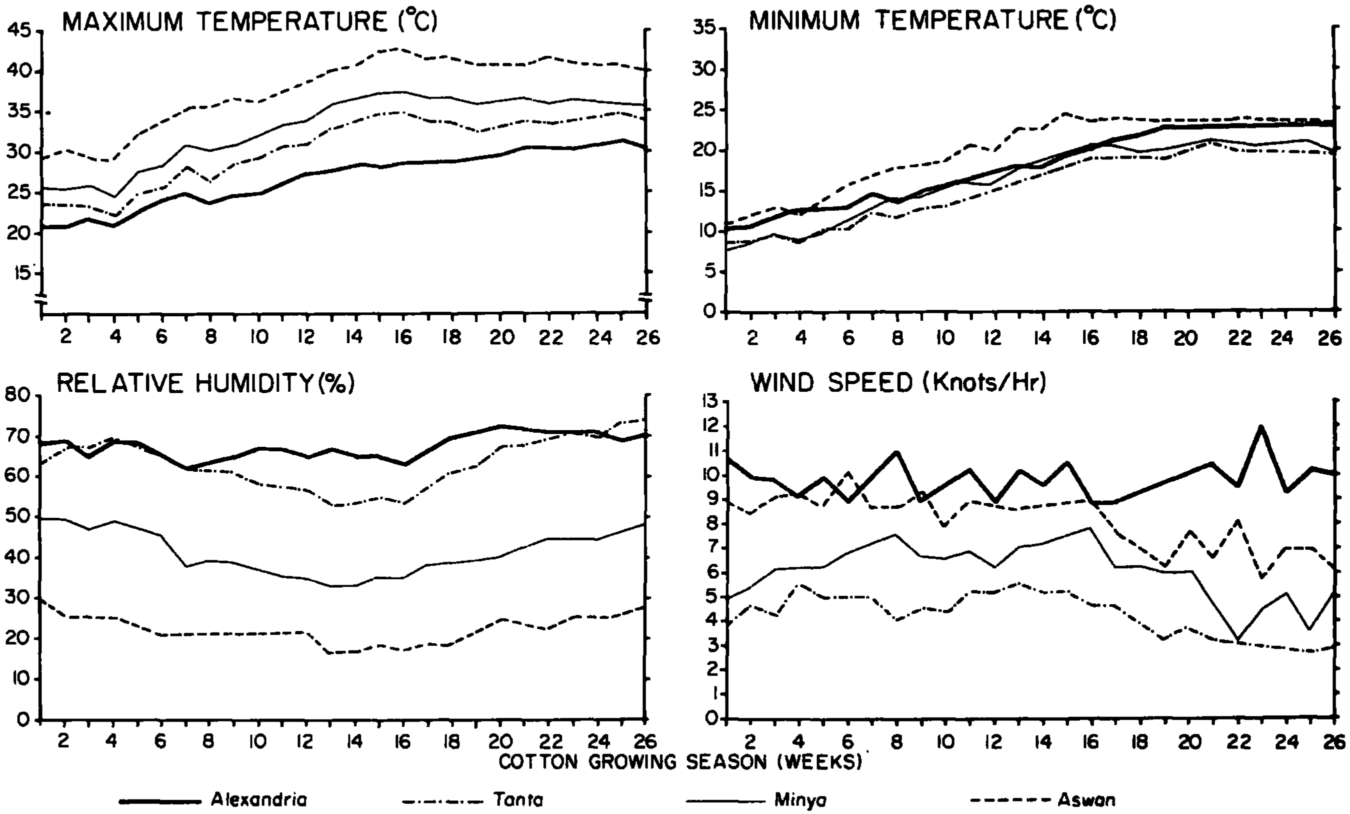
Average maximum daily temperatures :-

The average maximum daily temperatures during the cotton growing season varied from 20.4 to 31.1°C at Alexandria; from 22.1 to 34.5°C at Tanta; from 24.8 to 37.5°C at Minya and from 29.0 to 42.4°C at Aswan. The distribution of average maximum daily temperatures for each 7-day period during the cotton growing season are shown in Figures 12.3 and 12.4. It can be seen that up to week 3 there is a slight tendency for temperatures to increase at Alexandria and Minya, whereas at Tanta there is no change. At Aswan there is an increase from week 1 to week 2 followed by a decline to the original level. Between week 3 and week 4 temperatures fall at all stations except at Aswan. From week 4 to week 7 a sharp temperature rise occurs at all stations, followed by a second slight drop everywhere except at Aswan. After week 8 there is a general increase, steady and prolonged, continuing until week 16. Then, between week 16 and 19 a slight decline takes place at Tanta; Minya and Aswan, while at Alexandria, there is a continued increase. During the period after week 19 temperatures are largely stable, though with small fluctuations until week 25 when a general decline begins.

Average minimum daily temperatures :-

The average minimum daily temperatures during the cotton growing season varied from 10.2 to 22.9°C at

Fig. 12.3 CLIMATIC CONDITIONS FOR EACH 7 DAY PERIOD (MARCH 1st.-SEPT. 1st.) DURING THE COTTON GROWING SEASON



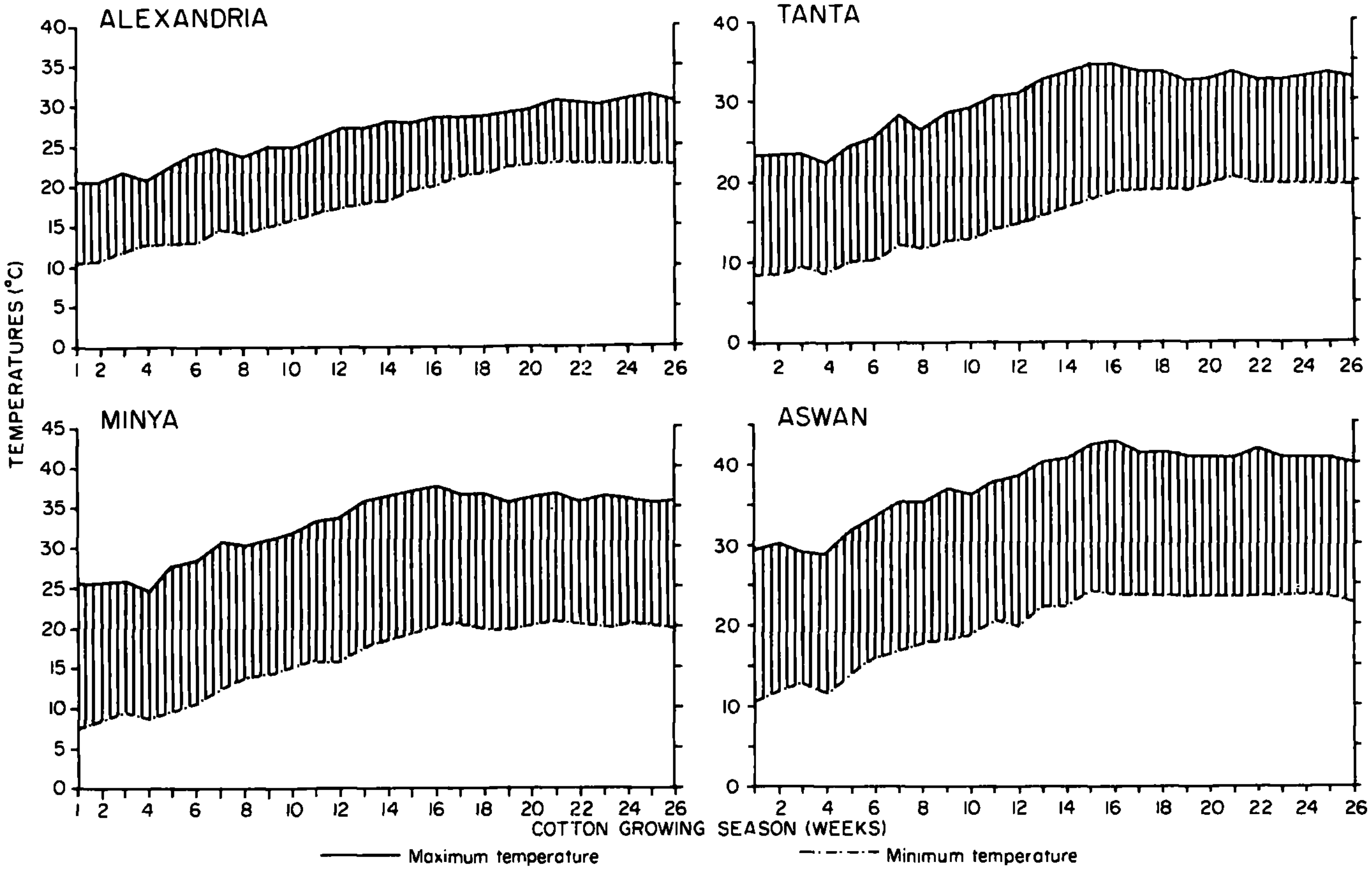
MAXIMUM TEMPERATURE (°C)

MINIMUM TEMPERATURE (°C)

RELATIVE HUMIDITY (%)

WIND SPEED (Knots/Hr)

Fig.12.4 WEEKLY AVERAGE MAXIMUM AND MINIMUM TEMPERATURES DURING THE COTTON GROWING SEASON (1960-1974)



Alexandria; from 8.5 to 20.3°C at Tanta; from 7.8 to 20.8°C at Minya and from 10.9 to 24.1°C at Aswan. It can be seen from Figures 12.3 and 12.4 that up to week 3 there is a slight increase at all stations, followed by a fall in week 4 except at Alexandria. From week 4 to week 15 the trend is for a general increase, similar to that for maximum temperatures after week 8. After week 15 increases continue at Alexandria, again paralleling the changes in maximum temperature, whereas elsewhere there is stability with only small fluctuations.

Average daily relative humidities :-

The average daily relative humidities during the cotton growing season varied from 62.8 to 72.1% at Alexandria; from 52.7 to 73.2% at Tanta; from 32.3 to 49.9% at Minya and from 17.1 to 29.5% at Aswan. Figure 12.3 shows that from week 1 to week 14 a decline in relative humidities occurred at Tanta, Minya and Aswan, which are usually the result of the onset of Khamsin conditions. At Alexandria there is little change owing to the sea-breeze effect. After week 14 there is a slow return to high relative humididy levels as the Khamsin declines. Alexandria is again little affected.

Average mean daily wind speeds :-

The average daily wind speeds for the cotton growing season varied from 8.6 to 11.0 knots at Alexandria; from 2.6 to 5.5 knots at Tanta; from 3.2 to 7.7 knots at

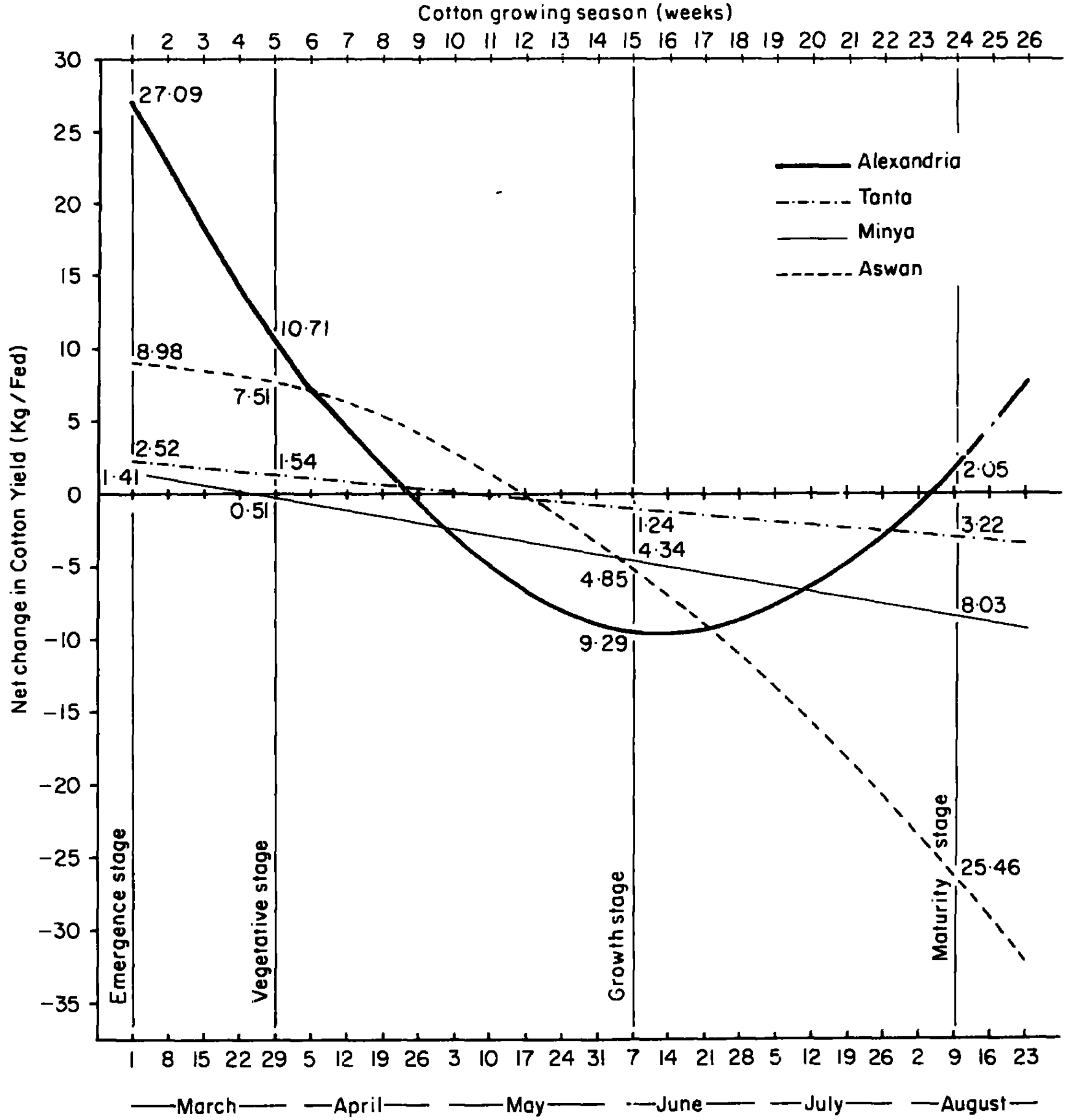
Minya and from 5.6 to 10.2 knots at Aswan. Average daily wind speeds are shown in Figure 12.3. It can be seen that up to week 15 there is general trend towards an increase in velocity at Minya. This contrasts with the strong fluctuations at Alexandria due to Khamsin conditions, while at Aswan the increase in velocities is mainly related to the frequency of duststorms (see Khamsin chapter). At Tanta wind velocities remain relatively constant. After week 16 a decline in velocities takes place everywhere except at Alexandria, which shows an increase, though with marked fluctuations between weeks 22 and 24 (Fig. 12.3).

The effect of maximum daily temperature :-

The multiple - regression equations were obtained for maximum daily temperature at Alexandria, Tanta, Minya and Aswan. The constant values for these equations are shown in Appendix 2B. The effect of maximum temperatures on cotton yields during each period of the growing season is discussed separately. The net change in cotton yields for different weeks of the growing season, when the temperature was 1°C above the average maximum daily temperature is presented in Figure 12.5. These results have been computed using the multiple regression equation which was discussed in the preceding pages (for more details about the technique used, see Appendix 3, where a complete example for the maximum temperature calculation at Alexandria is included).

During the emergence period of the cotton (week 1), the average maximum daily temperature was 20.4°C at

Fig 12·5 EFFECT OF ONE DEGREE OF TEMPERATURE (°C) ABOVE AVERAGE VALUE OF MAXIMUM DAILY TEMPERATURE ON COTTON YIELDS FOR EACH SEVEN DAY PERIOD - MARCH 1st to SEPTEMBER 1st



Alexandria, 23.2°C at Tanta, 25.4°C at Minya and 29.1°C at Aswan. An increase of 1°C in the average maximum daily temperature during this period, resulted in a predicted increase of cotton yield of 27.09 Kg/fed. at Alexandria, 2.52 Kg/fed. at Tanta, 1.41 Kg/fed. at Minya and 8.98 Kg/fed. at Aswan (Fig. 12.5).

The average maximum daily temperature during the vegetative stage (weeks 2-8) varied from 20.4°C to 24.6°C at Alexandria, from 22.1°C to 28.1°C at Tanta, from 24.8°C to 30.9°C at Minya and from 29.0°C to 35.3°C at Aswan. An increase in maximum daily temperature of 1°C during the 5th week (the middle week of the vegetative stage) had a beneficial effect on yield of the order of 10.71 Kg/fed. at Alexandria, 1.54 Kg/fed. Tanta, and 7.51 Kg/fed. at Aswan. In contrast a reduction in yield of 0.51 kg/fed. at Minya was predicted (Fig. 12.5).

During the growth stage (weeks 8-22), the average maximum daily temperature increased from 23.4°C to 30.7°C at Alexandria, from 26.3°C to 34.5 at Tanta, from 30.0°C to 37.5°C at Minya, and from 35.3°C to 42.4°C at Aswan. During the 15th week (the middle week of the growth stage), an increase of 1°C above the average maximum daily temperature suggested a reduction in yield of 9.29 kg/fed. at Alexandria, 1.24 kg/fed. at Tanta, 4.34 kg/fed. at Minya and 4.85 kg/fed. at Aswan (Fig. 12.5).

The average maximum daily temperature during the maturation period (weeks 22-26) varied from 30.1°C to 31.1°C at Alexandria, from 32.8°C to 33.4°C at Tanta, from

35.6°C to 36.2°C at Minya, and from 40.0°C to 41.9°C at Aswan. If the maximum daily temperature during the 24th week (the middle week of the maturation period) was 1°C more than the average value, the predicted cotton yield would be reduced by 3.22 kg/fed. at Tanta, 8.03 kg/fed. at Minya and 25.46 kg/fed. at Aswan. In contrast a beneficial effect on cotton yield of 2.05 kg/fed. was recorded at Alexandria (Fig. 12.5). In contrast, if there was a 1°C decrease in the average maximum daily temperature during any period of the growing season, the opposite effect on yield of the same order to those outlined above is predicted.

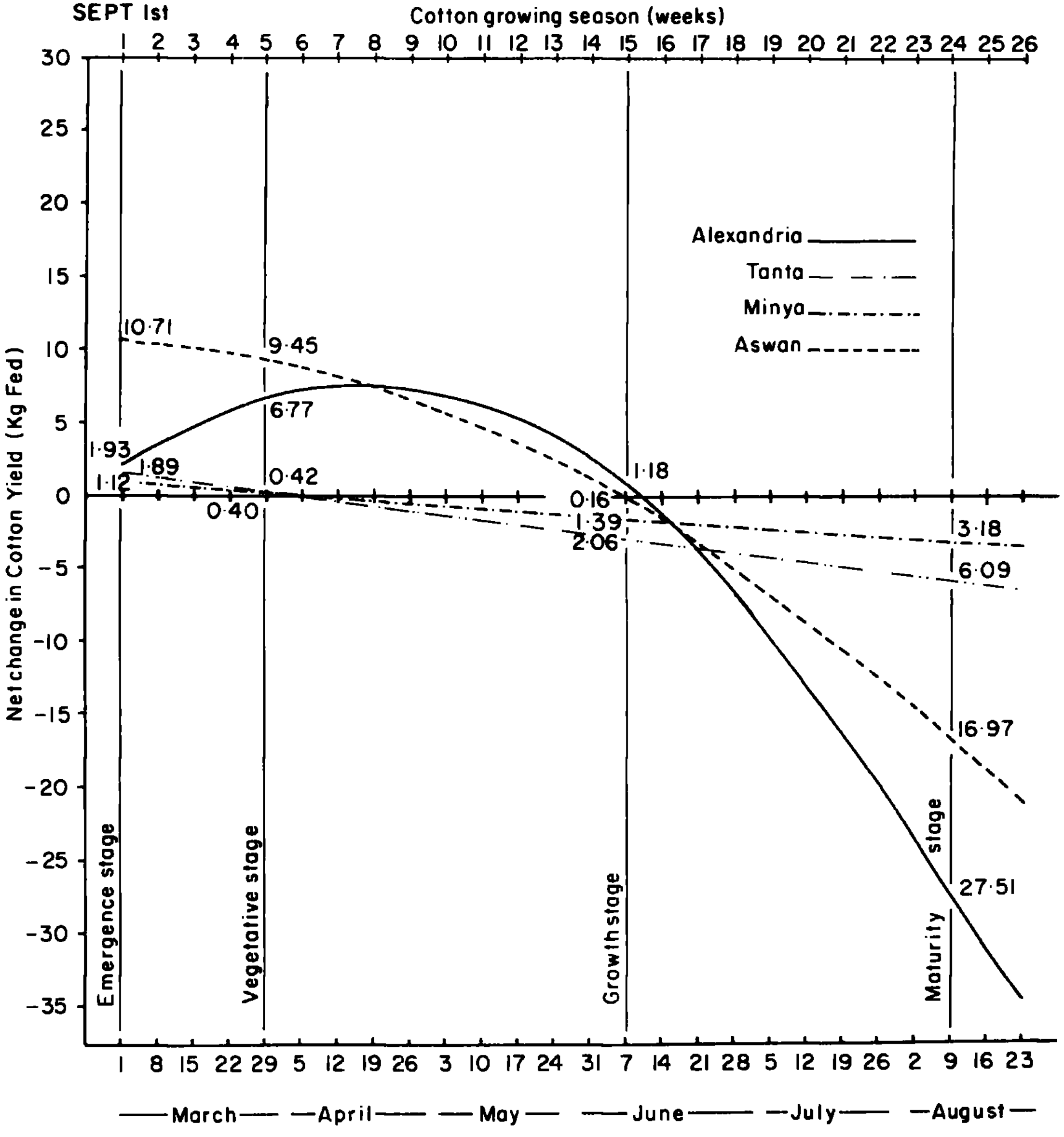
The effect of minimum daily temperature :-

The multiple - regression equations obtained for minimum daily temperature, for Alexandria, Tanta, Minya and Aswan are shown in Appendix 2B.

During the emergence stage (week 1), the average minimum daily temperature was 10.2°C at Alexandria, 8.5°C at Tanta, 7.8°C at Minya and 10.9°C at Aswan. If the average minimum daily temperatures during this period were 1°C more than the average, beneficial effects on cotton yields would be observed. These were of the order of 1.93 kg/fed. at Alexandria, 1.89 kg/fed. at Tanta, 1.12 kg/fed. at Minya and 10.71 kg/fed. at Aswan (Fig. 12.6).

The average daily minimum temperature during the vegetative stage (weeks 2-8), varied from 10.7°C to 14.3°C at Alexandria, from 8.9°C to 12.0°C at Tanta, from 8.3°C to 13.9°C at Minya and from 12.0°C to 17.8°C at Aswan. If

Fig 12·6 EFFECT OF ONE DEGREE OF TEMPERATURE (°C) ABOVE AVERAVE VALUE OF MINIMUM DAILY TEMPERATURE ON COTTON YIELDS FOR EACH SEVEN DAY PERIOD — MARCH 1st to SEPT 1st



there was an increase in the minimum daily temperature of 1°C above the average value during the 5th week (the middle of the vegetative stage) a beneficial effect on cotton yield of 6.77 kg/fed. at Alexandria, 9.45 kg/fed. at Aswan 0.42 kg/fed. at Minya and 0.40 kg/fed. at Tanta was predicted (Fig. 12.6).

During the growth stage (weeks 8-22), the average minimum daily temperature varied from 13.8°C to 22.8°C at Alexandria, from 11.5°C to 20.3°C at Tanta, from 13.9°C to 20.4°C at Minya and from 17.8°C to 24.1°C at Aswan. An increase in minimum daily temperature during the 15th week (the middle of the growth stage) of 1°C above the average value, predicted an adverse effect on yield of 1.39 kg/fed. at Minya, and 2.06 kg/fed. at Tanta. In contrast a beneficial effect on yield of 0.16 kg/fed. at Aswan and 1.18 kg/fed. at Alexandria was predicted (Fig. 12.6).

During the maturity stage (weeks 22-26), the average minimum daily temperature varied from 22.8°C to 22.9°C at Alexandria, from 19.4°C to 19.9°C at Tanta, from 19.9°C to 20.8°C at Minya and from 22.8°C to 23.8°C at Aswan. An increase in minimum daily temperature during this period of 1°C above the average value predicted an adverse effect on yield. During the 24th week (the middle of the maturity stage), the results showed that the adverse effect due to an increase in the minimum daily temperature was 27.51 kg/fed. at Alexandria, 16.97 kg/fed. at Aswan, 6.09 kg/fed. at Tanta and 3.18 kg/fed. at Minya (Fig. 12.6).

The effect of mean daily relative humidity :-

The multiple regression equations obtained for mean daily relative humidity for Alexandria, Tanta, Minya and Aswan are shown in Appendix 2B.

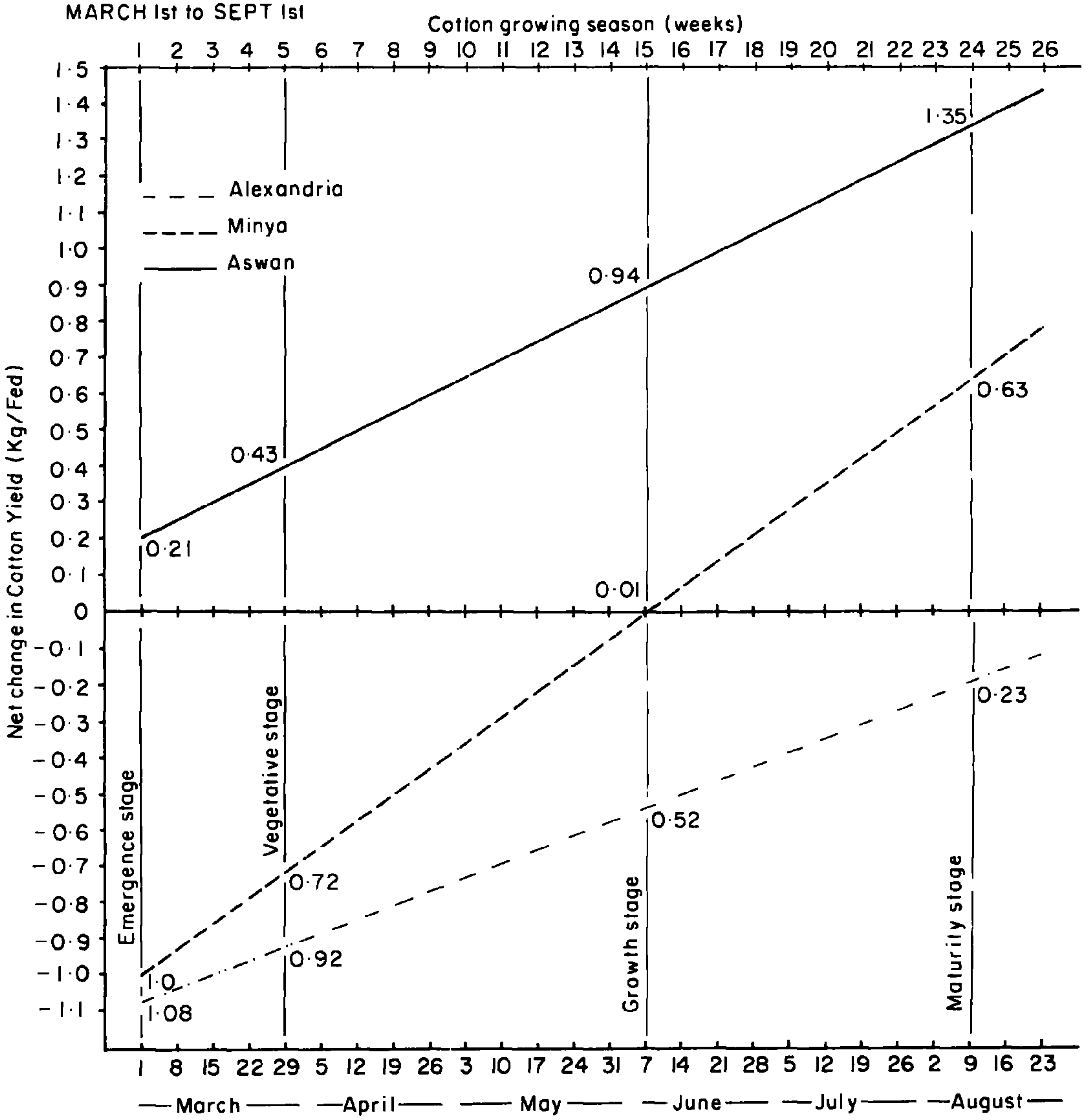
Figure 12.7 show clearly the net change in cotton yield due to a 1% increase in relative humidity at Alexandria, Minya and Aswan. At Tanta the effect of relative humidity on cotton yield is not significant.

During the emergence period (week 1), the average daily relative humidity was 68.1% at Alexandria, 49.9% at Minya and 29.5% at Aswan. An increase of 1% relative humidity had an adverse effect on cotton yield of 1.08 kg/fed. at Alexandria, and 1.0 kg/fed. at Minya. At Aswan a beneficial effect on yield of 0.21 kg/fed. was predicted (Fig. 12.7).

During the vegetative stage (weeks 2-8) the relative humidity varied from 62.8% to 69.3% at Alexandria, from 38.0% to 49.3% at Minya and from 21.1% to 25.9% at Aswan. If the average daily relative humidity during the 5th week (the middle of the vegetative stage) was increased by 1% an adverse effect on cotton yield is predicted of the order of 0.92 kg/fed. at Alexandria and 0.72 kg/fed. at Minya. A beneficial effect on cotton yields of 0.43 kg/fed. was predicted for Aswan (Fig. 12.7).

The average daily relative humidity during the growth stage (weeks 8-22), varied from 63.7% to 72.1% at Alexandria, from 32.3% to 44.3% at Minya and from 17.1%

Fig 12·7 EFFECT OF ONE PER CENT OF RELATIVE HUMIDITY ABOVE AVERAGE VALUE OF MEAN DAILY RELATIVE HUMIDITY ON COTTON YIELDS FOR EACH SEVEN DAY PERIOD — MARCH 1st to SEPT 1st



to 24.4% at Aswan. If the average daily relative humidity increased by 1% during the 15th week (the middle of the growth stage), a beneficial effect on cotton yield of 0.94 kg/fed. at Aswan and 0.01 kg/fed. at Minya was predicted. In contrast a reduction in yield of 0.52 kg/fed. was predicted at Alexandria.

The average daily relative humidity during the maturation period (weeks 22-26), varied from 68.8% to 70.4% at Alexandria, from 44.0% to 47.9% at Minya and from 22.7% to 26.9% at Aswan. If the average daily relative humidity increased by 1% during the 24th week (the middle of the maturation period), a beneficial effect on yield of 1.35 kg/fed. at Aswan, and 0.63 kg/fed. at Minya was recorded. In contrast, an adverse effect on yield of 0.23 kg/fed. was predicted at Alexandria (Fig. 12.7).

<u>The effect of daily wind speed</u> :-

The multiple regression equations for daily wind speed obtained for Alexandria, Tanta, Minya and Aswan are shown in Appendix 2B. The effect of daily wind speed on cotton yields is highly significant for Tanta and Minya, but not at Alexandria and Aswan.

The net change in cotton yield due to a 1 knot increase in wind speed was calculated for Tanta and Minya. The results are shown in Figure 12.8.

During the emergence period (week 1), the average wind speed was 3.8 knots at Tanta and 5.0 knots at Minya. An increase of 1 knot above the average daily wind speed

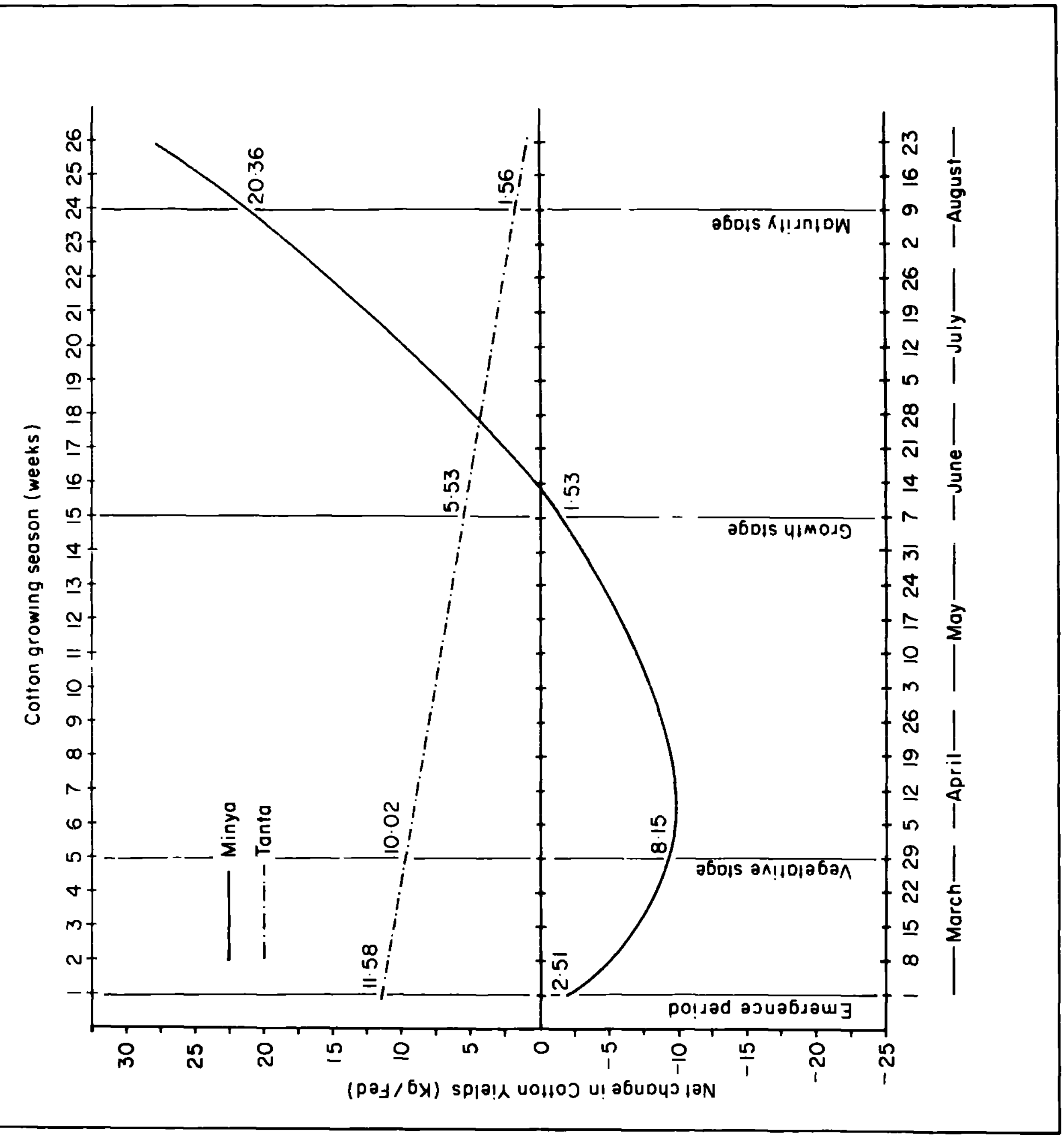


Fig 12.8 EFFECT OF ONE KNOT OF WIND SPEED ABOVE AVERAGE VALUES OF DAILY WIND SPEED ON COTTON YIELDS FOR EACH SEVEN DAY PERIOD - MARCH 1st to SEPTEMBER 1st

had a beneficial effect on cotton yield of 11.58 kg/fed. at Tanta. In contrast an adverse effect on yields of 2.51 kg/fed. at Minya was predicted (Fig. 12.8).

During the vegetative stage (weeks 2-8), the daily wind speed varied from 4.0 to 5.5 knots at Tanta and from 5.4 to 7.5 knots at Minya. If the average daily wind speed increased by 1 knot during the 5th week (the middle of the vegetative stage), an adverse effect on cotton yield of 8.15 kg/fed. at Minya was predicted. At Tanta a beneficial effect on yield of 10.02 kg/fed. was suggested (Fig. 12.8).

During the growth stage (weeks 8-22), the average daily wind speed varied from 2.9 to 5.4 knots at Tanta and from 3.2 to 8.7 knots at Minya. If the average daily wind speed was increased by 1 knot during the 15th week (the middle of the growth stage), a beneficial effect on cotton yield of 5.53 kg/fed. at Tanta was recorded. In contrast an adverse effect on yield of 1.53 kg/fed. at Minya was predicted (Fig. 12.8).

The average daily wind speed during the maturation period (weeks 22-26), varied from 2.6 to 2.9 knots at Tanta, and from 3.2 to 5.1 knots at Minya. If the average daily wind speed increased by 1 knot during the 24th week (the middle of the maturation period) a beneficial effect on cotton yield was predicted for both of the stations. The increase in yield was 1.56 kg/fed. at Tanta and 20.36 kg/fed at Minya (Fig. 12.8).

12.6 - Actual and predicted cotton yields :-

The aim of this part of the study was to predict cotton yields from the selected climatological variables and to explain the effect of different climatic elements on crop response measured by yield statistics (Robertson, 1968; and Baier, 1973).

The predicted cotton yields around Alexandria, Tanta, Minya and Aswan were calculated for a period of 15 years from 1960 to 1974 inclusive. These results were obtained by using multiple regression equations for maximum and minimum temperatures, mean relative humidities, and mean daily wind speeds. These equations have been discussed in the preceding pages. The results of the calculations are shown in Figure 12.9. It can be seen from this figure that in 1967 the actual cotton yields were particularly low at Alexandria. One of the reasons for this was the 1967 June War which had far reaching detrimental effects on agriculture output in Lower Egypt. At Aswan, the actual cotton yields were very low in 1964 and in 1969. This was partly as the result of the completion of the first and last stages of the High Aswan Dam in 1964 and 1969 respectively, which caused flooding in parts of the area in question (Shibl, 1971).

Table 12.d shows clearly that there is a highly significant correlation between the actual and predicted cotton yields at Alexandria, Tanta, Minya and Aswan. The strongest correlation coefficient between actual and predicted cotton yields is equal to 0.765 in Aswan for maximum temperature. This was found to be significant at the 1% level. This indicates that the cotton yields predicted by use the regression equation for maximum temperature

Fig.129 ACTUAL AND PREDICTED COTTON YIELD USING MULTIPLE REGRESSION EQUATIONS FOR CLIMATIC VARIABLES

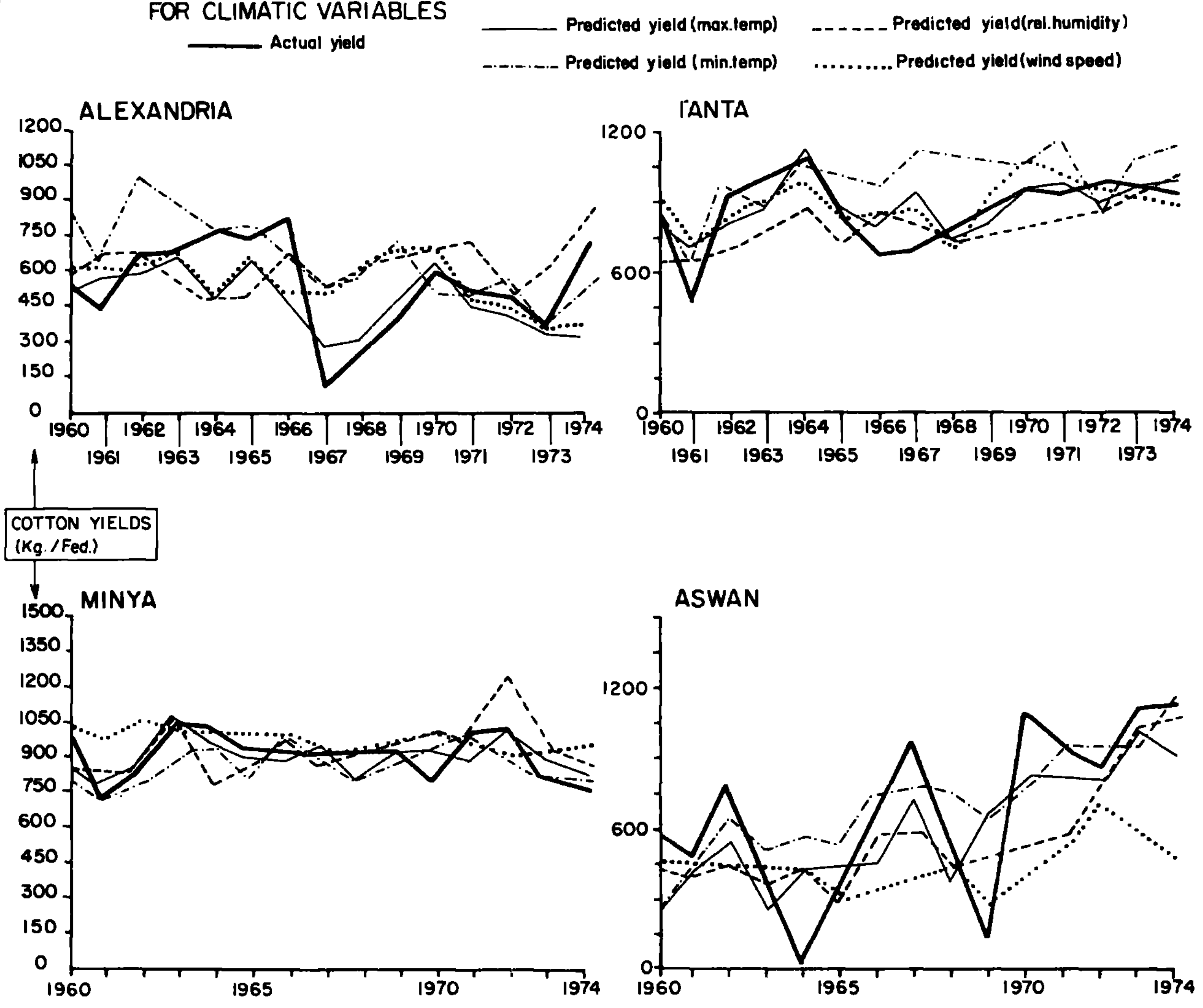


Table 12.d

Correlation Coefficients between Actual and Predicted Cotton Yields for Alexandria, Tanta, Minya and Aswan for the Period 1960-1974

Place / Climatic variable equations	Alexandria	Tanta	Minya	Aswan
Maximum temperature	0.649	0.670	0.583	0.765
Minimum temperature	0.611	0.591	0.740	0.754
Relative humidity	0.522	0.320	0.601	0.650
Wind speed	0.321	0.636	0.529	0.401

N = 15   Significance level :-

5% = 0.514   2% = 0.592   1% = 0.641

are highly correlated with actual cotton yields. The weakest correlation coefficient is equal to 0.320 at Tanta for relative humidity. This is insignificant, as is also the correlation coefficient for wind speeds at Alexandria (0.321) and at Aswan (0.401), (Table 12.d).

12.7 - Discussion :-

The cotton growing season was divided into four different stages (the emergence, the vegetative, the growth and the maturity stages) according to the intensity and distribution of climatic factors, of which temperature is probably the most important. The importance of temperature is clearly shown in the experiments of numerous researchers in this field (Powell, 1969; Arndt, 1945; McMichael and Powell, 1971; Powell and Amin, 1969; Gipson and Joham, 1968; Anderson, 1971; Noggle, 1973 and others).

The temperature requirements for the emergence period (week 1) of the cotton plant are high. A maximum temperature of 35°C gives a slightly more rapid germination than does 30°C, which in turn produces considerably more rapid germination than does 25°C (McMichael and Powell, 1971 and Arnon, 1972). The beneficial effect on yield observed with an increase in maximum daily temperature during this period at Alexandria, Tanta, Minya and Aswan was consistent with the foregoing generalisation. In particular it was noted that thelargest predicted increase in yield occurred at Alexandria, which had the lowest maximum temperatures. However, it must be remembered that different cotton varieties are grown in the Alexandria area which makes it difficult to isolate climatic from plant effects as far as their influence on yields is concerned.

Arndt (1945) who studies temperature-growth relations of root and hypocotyl development of cotton seedlings in south Carolina concluded that low minimum temperatures below (15-18°C) shortly after sowing, may cause the decay of a large proportion of the seed; delay emergence; retard seedling development and encourage diseases causing seedling mortality. He also found that the optimal maximum temperatures during the emergence stage are between 27°C and 33°C. The author's results showed that an increase in daily minimum temperature during the emergence stage causes a beneficial effect on cotton yields at all stations. This suggests that the optimum minimum temperatures are probably in excess of 11°C. These results, therefore, tend to agree in a general way with the values found by Arndt (1945).

It is generally believed that in a season of high mean relative humidity (above 55%), the cotton may suffer. Hoffman's research (1973) in California revealed a poor correlation between relative humidity and the growth rate of the cotton plant. With an increase of daily relative humidities during the emergence period a decrease in cotton yield was predicted at Alexandria and Minya, where the average daily relative humidities prevailing during this period are already quite high (Fig. 12.3). At Aswan, where relative humidities are low an increase in relative humidity predicted an increase in yield. This indicates that the optimum relative humidity is about 30% during the emergence stage. Similar results to these were obtained by Hoffman (1973).

The average daily wind speed does not have a significant effect on yields at Alexandria and Aswan, but does at Tanta and Minya. The present results show that a beneficial effect on cotton yield due to an increase in wind speed was obtained at Tanta. In contrast an adverse effect on cotton yield was predicted at Minya. This is because the average daily wind speed recorded during this period at Tanta was quite low in contrast with Minya. This suggests that the optimum wind speeds are between 3.5 and 4 knots.

The period from March 8th to April 19th (weeks 2-8) includes the vegetative stage. McMichael and Powell (1971) showed in their experimental work in Texas that the optimum temperatures during the vegetative stage are 24°C and 10°C for maximum and minimum temperatures respectively. Similar results have been calculated by the present author. These indicate that an increase in maximum temperature above the average values during the vegetative period has a beneficial effect on cotton yields at Alexandria, Tanta and Aswan, whilst at Minya a slight detrimental effect on yield was suggested. Beneficial effects on cotton yields due to an increase in minimum weekly temperatures were obtained at all stations during the vegetative period. However, the reason for these yield differences are most likely the result of the use of different varieties of seed.

An increase in relative humidities above the average values resulted in a beneficial effect on cotton yield at Aswan. This is because the average daily relative humidity at Aswan was quite low (Fig. 12.3). In contrast a reduction in yield was observed at Minya and Alexandria, which is in general to be expected because the daily relative humidities at these two stations are quite high during this period in contrast with the optimum values of about 20 - 30%.

An adverse effect on cotton yield due to an increase in daily wind speed was predicted at Minya, while the reverse was the case for Tanta. This is also because the average wind speed prevailing during this period is quite high at Minya in comparison with Tanta (Fig. 12.3). This suggests that the optimum wind speeds are between 3.5 and 5.5 knots.

During <u>the growth stage</u>, April 19th to July 26th (weeks 8-22), higher maximum temperatures during this period were not beneficial at any of the stations. The optimal maximum temperatures for the growth stage of the cotton plant are between 25°C and 30°C, according to the work of Sikka and Dastur (1960) in India, McMichael and Powell (1971) showed in their experimental work in Texas that the optimal maximum and minimum temperatures for the growth stage of the cotton plant are 29°C and 16°C respectively.

Tharp (1960) found that during the growth stage, maximum temperatures of 26°C - 32°C are best. In general maximum temperatures above 35°C are not desirable. However, when the moisture supply is favourable, the cotton plant is capable of enduring, without permanent injury, very high maximum temperatures (up to 43°C - 45°C) for short periods (Sikka and Dastur, 1960). If these high temperatures persist for several days, however, yields will be adversely affected. Hoffman (1973) showed in his experimental work in California that maximum and minimum temperatures during the cotton growth period are 38°C and 26°C respectively, with a relative humidity of about 55%.

The present results show that an increase in maximum daily temperature caused a reduction in yields at all stations during the growth stage (Fig. 12.5). This suggests that the optimum maximum temperatures are less than 27°C. Similar results have been recorded by Sikka and Dastur (1960), and McMichael and Powell (1971). The results obtained by Tharp (1960) and Hoffman (1973) were much higher in contrast to the ones suggested by the present author.

An increase in average daily minimum temperature caused a reduction in yields at all stations, with the exception of the first half of the growth stage for Aswan and Alexandria (Fig. 12.6). This is probably mainly due to the different plant varieties used. However, it suggests that the optimum minimum temperatures lie between 10°C and 15°C. Similar results have been suggested by McMichael and Powell (1971).

A beneficial effect on cotton yield was predicted with an increase in mean daily relative humidities above the average values, especially at Aswan and Minya during the second half of the growth period. At Alexandria, the reverse was obtained. This is in general to be expected because the mean relative humidity at Alexandria during this period is higher than the optimum value suggested by Hoffman (1973).

An adverse effect on cotton yield was recorded by an increase in wind speed at Minya, whilst a beneficial effect was predicted at Tanta. This is in general to be expected because the average daily wind speed registered at Tanta is quite low in contrast with that prevailing at Minya (Fig. 12.3). This suggests that the optimum wind speeds during the growth stage are between 3 and 5.5 knots.

During <u>the maturation period</u>, July 26th to August 30th (weeks 22-26), the results outlined above suggest that cotton yields are decreased when the maximum temperature during the maturity period rises above 32°C and when minimum temperature rises above 19°C. An increase in weekly maximum temperature had a detrimental effect on cotton yields at all stations except Alexandria. At Alexandria, this is probably because the average daily maximum temperature at this period is below the optimum value. McMichael and Powell (1971) in Texas, also showed that the optimal maximum temperature for the maturity stage lies between 21°C and 35°C. Hesketh and Low (1968) reported in their research in Australia that the optimal maximum temperatures for this stage are between 28°C and 33°C. Arnon (1972) found in his research in Israel that when the average maximum daily temperature approaches 38°C, the period of maturation is shortened, the bolls are smaller, the fibres do not develop fully, and yields are reduced.

In this study it was seen that higher minimum temperatures had an unfavourable effect on cotton yields at all stations and especially at Alexandria and Aswan which recorded the highest reduction in yield. During the maturity stage the average minimum daily temperatures in these areas were apparantly higher than the optimum values. This suggests that the optimum values during this period are below 19°C.

An increase in average daily relative humidity increased yields especially at Aswan and Minya, while the reverse was the case at Alexandria. This is in general to be expected because the average daily relative humidity recorded during this period at Alexandria was higher than the optimum values, which are between 20-50%

An increase in cotton yield was suggested at Tanta and Minya during this period due to an increase in average daily wind speeds. This indicates that the optimum wind speeds are between 2.5 and 5.5 knots (Fig. 12.3).

CHAPTER 13

The Contribution of Climatic Variables in Predicting Wheat Yields in Egypt

13.1 - Wheat yield :-

Wheat is the principal winter crop in Egypt and is grown in Egypt on about 1,300,000 feddans of land each year. Seeding is usually done in November following cotton, corn, or dry summer fallow. Harvesting by hand sickles occurs in May. Threshing is normally done by a norage which consists of a series of metal discs mounted under a carriage on which a man sits. It is pulled by a buffalo or bullock team over the harvested wheat which is scattered in a circle. The norage discs cause the wheat kernels to separate from the heads. Following the action of the norage the crushed straw and chaff are winnowed with a fork, and the chaff is blown away. The straw is saved for animal feed, and the grain is further cleaned by throwing it into the air.

Wheat yield data for Alexandria, Tanta, Minya and Aswan and for the whole of the country during the period 1960 - 1974 are given in Table 13.a. These data have been used to explain the relationships between wheat yields and climatic conditions.

The purpose of the present chapter is to examine the variation in the relationships between wheat yields and climatological variables around Alexandria, Tanta, Minya and Aswan and to discuss some of the problems and uses of yield climate relationship analysis.

13.2 - Wheat growing season :-

The wheat growing season lasts approximately 182

Table 13.a

Wheat Yield Data

(Kg/Feddan)*

Place / Year	Alexandria	Tanta	Minya	Aswan	Egypt
1960	769.5	1087.5	1335.0	825.0	1029.0
1961	784.5	1140.0	1338.0	808.5	1038.0
1962	982.5	1135.5	1369.5	882.0	1095.0
1963	966.0	1257.0	1296.0	915.0	1110.0
1964	1012.5	1311.0	1342.5	867.0	1158.0
1965	717.0	1234.5	1347.0	877.5	1110.0
1966	921.0	1290.0	1368.0	712.5	1135.5
1967	502.5	1185.0	1414.5	820.5	1036.5
1968	312.0	1147.5	1363.5	727.5	1074.0
1969	532.5	1074.0	1300.5	768.0	1018.5
1970	576.0	1206.0	1521.0	769.5	1161.0
1971	607.5	1440.0	1498.5	871.5	1282.5
1972	748.5	1464.0	1413.0	897.0	1303.5
1973	835.5	1632.0	1573.5	963.0	1473.0
1974	921.0	1512.0	1548.0	1053.0	1375.5
Mean	745.5	1275.0	1402.5	850.5	1159.5

Source :- Ministry of Agriculture, Agricultural Censuses for years 1960 to 1974, Cairo, Egypt.

* Feddan = 4200 m^2 = 0.4200 ha.

days, from November 10th to May 10th; a period of 26 weeks. The crop-growing season can broadly be grouped into the three following periods (Fig. 13.1) :-

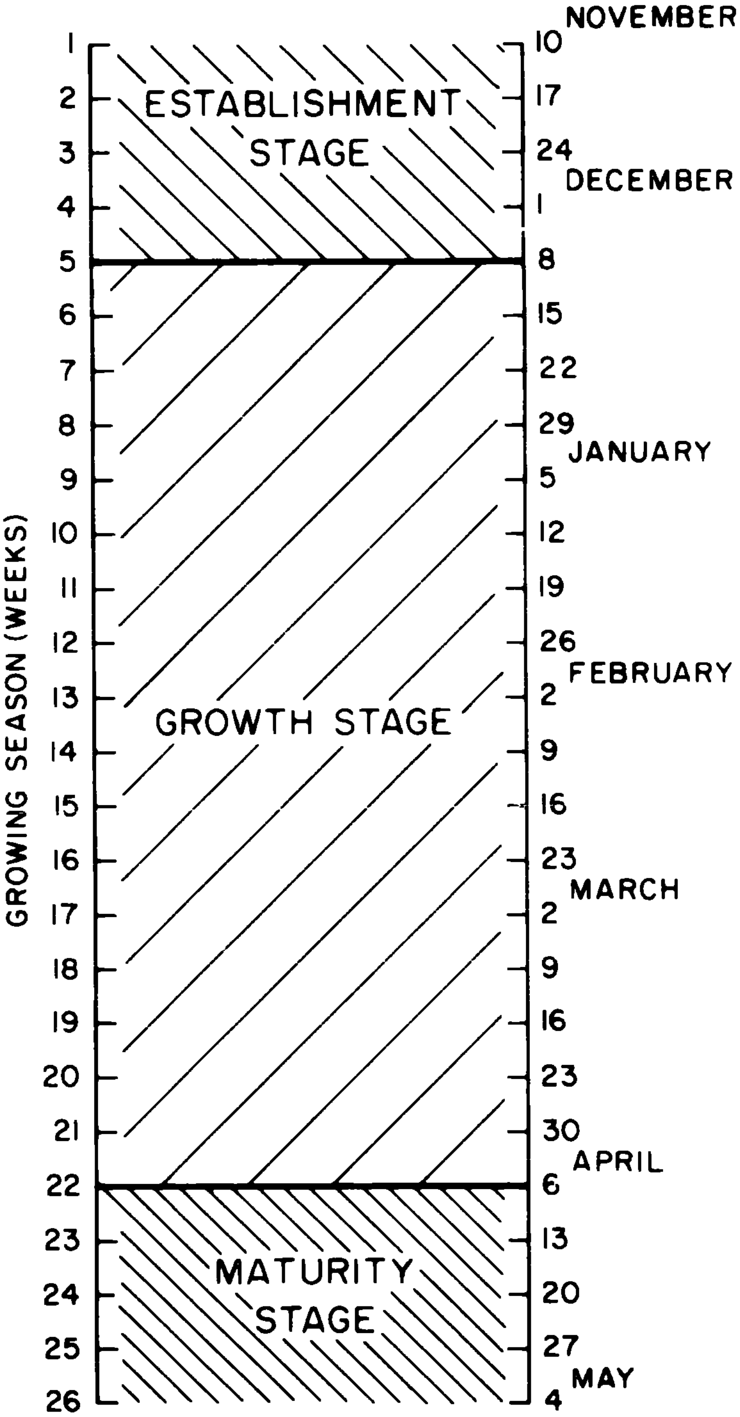
1 - Establishment period :-

The phase from November 10th - December 7th usually includes the period from sowing to emergence. On the basis of the climatic parameters this is termed the Autumn season. The autumn season is usually characterized by average maximum temperatures of 22.0°C and 25.0°C, and minimum temperatures of 11.0°C and 10°C in Lower and Upper Egypt respectively. The relative humidities levels are 72% and 50% and the wind speeds of 6.0 and 7.5 knots respectively in Lower and Upper Egypt.

2 - Growth period :-

This period includes the active, the vegetative and reproductive growth stages. The critical parts of this period appear to be maximum tillering (weeks 5 - 14), ear-initiation (weeks 14-19) and flowering (weeks 19-22). The growth period usually lasts from December 8th to April 5th (weeks 5-22) and is normally termed climatologically as the winter and spring seasons. The former season is usually characterized by average maximum daily temperatures of 17.5°C and 21.0°C and minimum temperatures of 8.5°C and 7.0°C in Lower and Upper Egypt respectively. Relative humidities during this season reach 75% in Lower Egypt and 56% in Upper Egypt. Average wind speeds of 8.5 and 6.0 knots respectively are also experienced. The

Fig.13.1TYPICAL GROWTH STAGES OF THE WHEAT CROP



spring season is usally characterized by Khamsin weather conditions; normally associated with maximum temperatures of about 26°C and 30°C and mimimum temperatures of 12°C and 13.5°C in Lower and Upper Egypt respectively. The corresponding relative humidity levels for these two areas are 62% and 30%, whilst wind speeds reach 9 and 6 knots respectively.

3 - Maturity period :-

The period April 6th to May 10th (weeks 22-26) usually includes the ripening stage of the wheat. It is normally associated with Khamsin conditions, which produce an increase in maximum and minimum daily temperatures and wind speeds, and a decrease in daily relative humidities.

13.3 - Statistical analysis :-

The multiple regression technique used here is similar to that which has been used in the preceding chapter (cotton chapter). The second-degree multiple regression equation between wheat yields and each climatic variables is :-

$$Y = Ao + a_1 \sum_{i=1}^{n} (t^o_i \; x_i) + a_2 \sum_{i=1}^{n} (t^1_i \; x_i) + a_3 \sum_{i=1}^{n} (t^2_i \; x_i) + MT$$

Where y = crop yield (Ardab/fed.), (Ardab = 150 kg), Ao, a_1, a_2, a_3, and M are constants; x = any climatic variable within any given 7-day period; t_i = the number of each

7-day period (it is 1 for the period from November 10th-16th and 26 for the period from May 4th - 10th); T = the year number (beginning with 1 in 1960 and ending with 15 in 1974).

Distribution of climatic variables during the wheat growing season :-

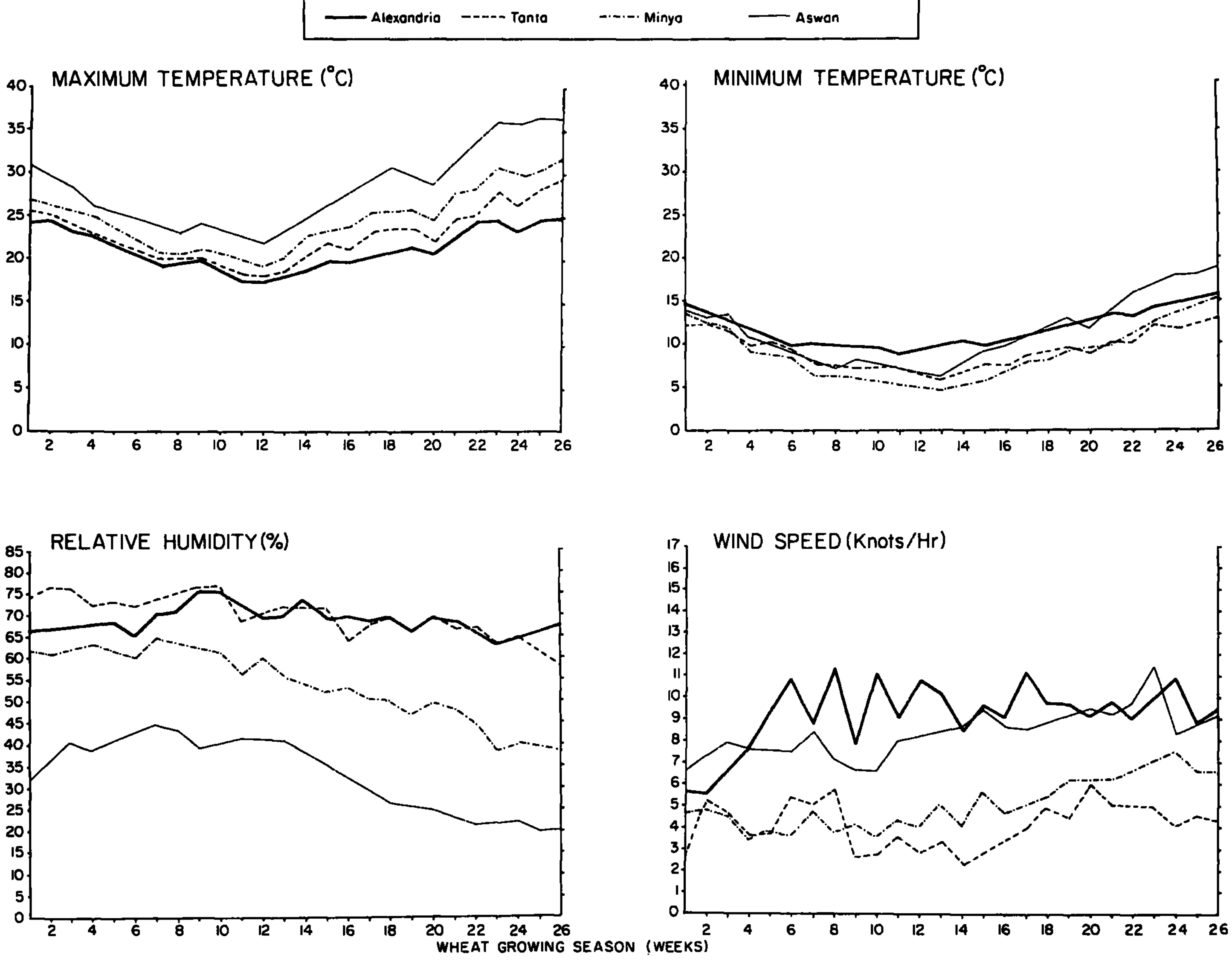
1 - Average maximum daily temperatures :-

The average maximum daily temperatures during the wheat growing season varied from 17.3°C to 24.7°C at Alexandria; from 17.9°C to 29.0°C at Tanta; from 18.9°C to 32.0°C at Minya and from 22.1°C to 36.7°C at Aswan (Appendix 2C). The distribution of average maximum daily temperatures from each 7-day period during the wheat growing season shows a rapid decrease from week 1 to week 12 with the exception of a slight increase in week 9 at all stations. This period is the winter season, which is usually characterized by low maximum temperatures. The average maximum daily temperatures then increase from week 13 to week 26 with slight decreases being registered in weeks 20 and 24 at all stations (Fig. 13.2). Khamsin weather conditions are generally experienced during this period.

2 - The average minimum daily temperatures :-

The average minimum daily temperatures during the wheat growing season varied from 8.9°C to 15.6°C at Alexandria; from 5.8°C to 12.8°C at Tanta; from 4.5°C to 15.1°C at Minya and from 6.2°C to 18.9°C at Aswan. Figure

Fig.13.2 CLIMATIC CONDITIONS FOR EACH 7 DAY PERIOD (NOV 10th - MAY 10th) DURING THE WHEAT GROWING SEASON



13.2 shows the distributions of average minimum daily temperatures for each 7-day period during the wheat growing season. It can be seen that the average minimum daily temperature decreases during the period from week 1 to week 13 with slight rises in weeks 3 and 9 at Aswan. From weeks 13 to 26 the minimum temperature increases quite rapidly, though with a slight decrease in week 20 at Aswan and Tanta (Fig. 13.2).

3 - The average daily relative humidities :-

The average daily relative humidities during the wheat growing season varied from 62.8% to 75.2% at Alexandria; from 58.4% to 76.9% at Tanta; from 38.1%to 64.5% at Minya and from 19.5% to 44.6% at Aswan. The distributions of average daily relative humidities are similar at Alexandria and Tanta and at both these stations there is little change during the whole growing season, with the exception of slight changes from week to week (Fig. 13.2). The distribution of average daily relative humidity at Minya and Aswan are also similar. From week 3 to week 13 at Aswan and from week 1 to week 12 at Minya, there are relatively stable daily relative humidites, followed by a rapid decrease between week 12 and week 26 at both stations.

4 - The average daily wind speeds :-

The average daily wind speeds during the wheat growing season varied from 5.5 to 11.3 knots at Alexandria; from 2.2 to 5.9 knots at Tanta; from 3.3 to 7.5 knots at Minya and from 6.4 to 11.4 knots at Aswan (Fig. 13.2). It can be seen that the distributions of average daily wind speed shows little variation at all stations. In general the trend indicates that there is a slight increase in average daily wind speed during the wheat growing season especially at Aswan and Minya.

Effect of climatic variables on wheat yields :-

The weekly maximum and mimimum daily temperatures, average daily relative humidities and average daily wind speeds throughout the 26 weeks of the wheat growing season and the wheat yields for 15 years (1960 - 1974) were analysed. The effect of these climatic variables on wheat yield during different stages of the wheat growing season is discussed.

1 - Effect of maximum daily temperatures :-

The multiple regression equations obtained for maximum daily temperatures at Alexandria, Tanta, Minya and Aswan are shown in Appendix 2D.

During the establishment stage (weeks 1 - 5), the average maximum daily temperatures decreased from 24.3°C to 21.3°C at Alexandria; from 25.4°C to 21.3°C at Tanta; from 26.7°C to 23.0°C at Minya and from 30.8°C to 25.6°C at Aswan. An increase of 1°C above the average maximum daily temperature during the 3rd week (the middle of the establishment stage) resulted in a predicted beneficial effect on yield of 1.42 kg/fed. at Alexandria and

2.63 kg/fed. at Tanta. In contrast a decline in wheat yields of 1.51 kg/fed. at Minya and 5.19 kg/fed. at Aswan was predicted.

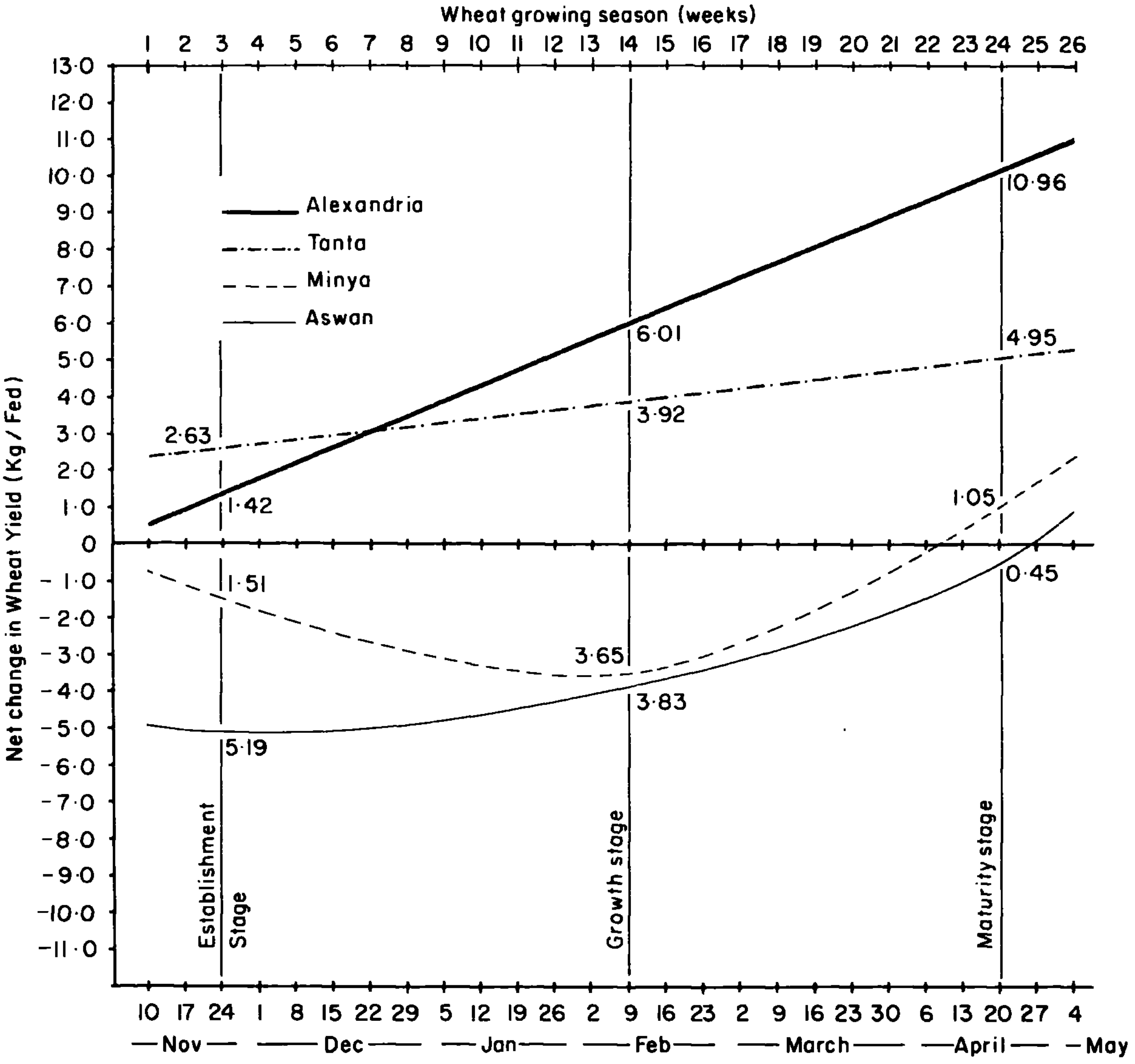
During the growth stage (weeks 5-22) the average maximum daily temperatures varied from 17.3°C to 23.9°C at Alexandria; from 17.9°C to 25.2°C at Tanta; from 18.9°C to 28.1°C at Minya and from 22.1°C to 34.1°C at Aswan. An increase in average maximum daily temperatures during the 14th week (the middle of the growth period) by 1°C more than the average, had an adverse effect on wheat yields of the order of 3.65 kg/fed. at Minya and 3.83 kg/fed. at Aswan. In contrast, an increase in yield of 3.92 kg/fed. at Tanta and 6.01 kg/fed. at Alexandria was obtained (Fig. 13.3).

During the maturity stage (weeks 22-26) the average maximum daily temperatures increased from 23.9°C to 24.7°C at Alexandria; from 25.2°C to 29.0°C at Tanta; from 28.1°C to 32.0°C at Minya and from 34.1°C to 36.7°C at Aswan. If the maximum daily temperature was 1°C more than the average value during the 24th week (the middle of the maturity stage), beneficial effects on yields were predicted for Alexandria (10.96 kg/fed.); Tanta (4.95 kg/fed.) and Minya (1.05 kg/fed.). At Aswan an adverse effect on yield of 0.45 kg/fed. was suggested (Fig. 13.3).

2 - Effect of minimum daily temperatures :-

The multiple regression equations obtained for minimum daily temperatures at Alexandria, Tanta, Minya

Fig 13·3 EFFECT OF ONE DEGREE OF TEMPERATURE (°C) ABOVE AVERAGE MAXIMUM DAILY TEMPERATURE ON WHEAT YIELD FOR EACH SEVEN DAY PERIOD - NOVEMBER 10th to MAY 10th



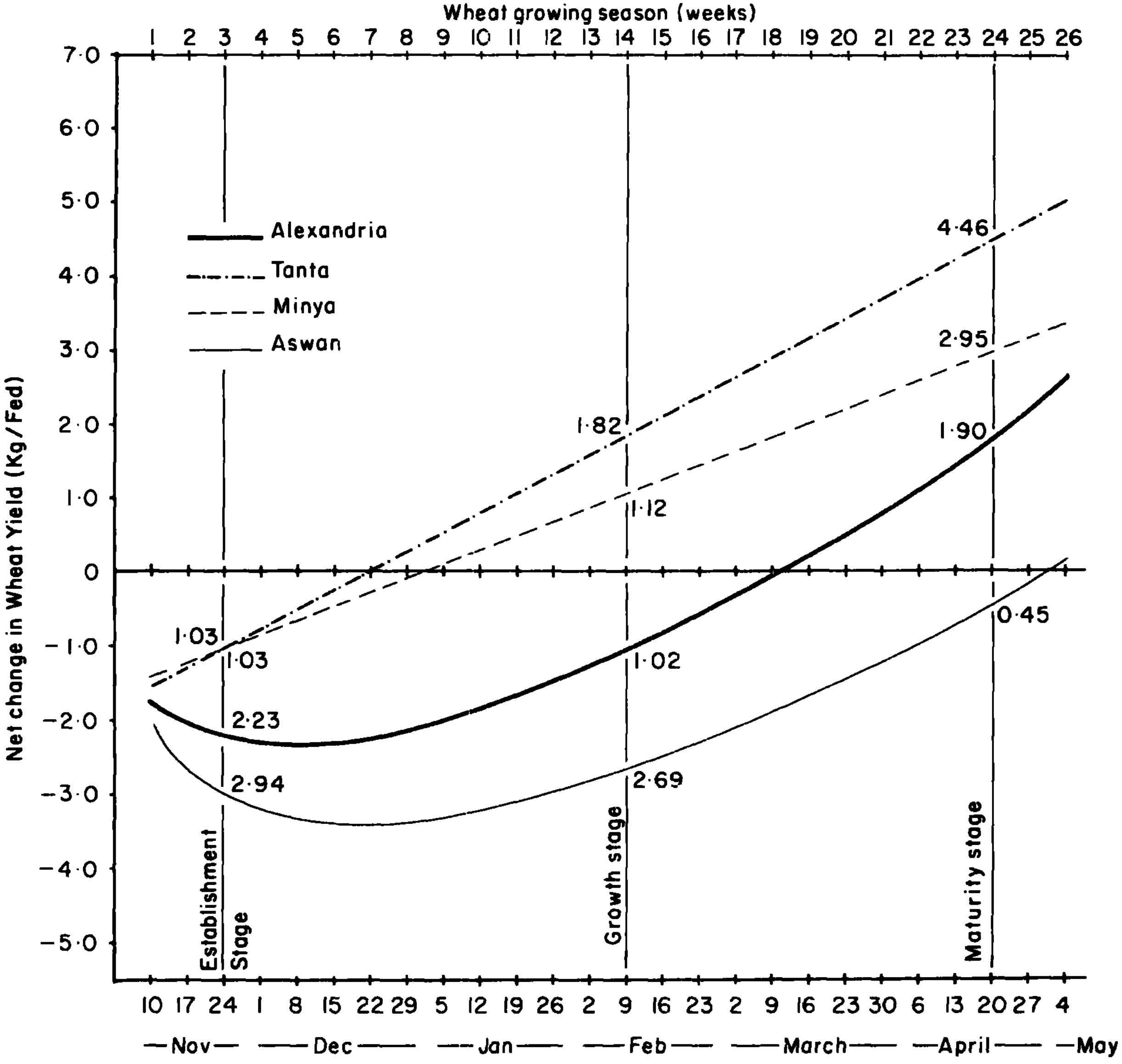
and Aswan are shown in Appendix 2D.

During the establishment stage (weeks 1-5) the average minimum daily temperatures decreased from 14.2°C to 10.7°C at Alexandria; from 12.2°C to 9.9°C at Tanta; from 13.4°C to 8.6°C at Minya and from 13.6°C to 10.3°C at Aswan. During the 3rd week (the middle of the establishment stage), if the minimum daily temperature was 1°C above the average value, adverse effects on yields were predicted at all stations; these were of the order of 1.03 kg/fed. at Tanta and Minya; 2.23 kg/fed. at Alexandria and 2.94 kg/fed. at Aswan (Fig. 13.4).

During the growth stage (weeks 5-22) the average minimum daily temperatures varied from 8.9°C to 13.6°C at Alexandria; from 5.8°C to 10.1°C at Tanta; from 4.5°C to 10.9°C at Minya and from 6.2°C to 15.7°C at Aswan. If there was an increase in minimum daily temperature during the 14th week (the middle of the growth stage) by 1°C more than the average value, beneficial effects on yields of 1.82 kg/fed. at Tanta and 1.12 kg/fed. at Minya were suggested. In contrast, adverse effects on yields of 1.02 kg/fed. and 2.69 were predicted at Alexandria and Aswan respectively (Fig. 13.4).

During the maturity stage (weeks 22-26), the average minimum daily temperatures increased from 13.2°C to 15.6°C at Alexandria; from 10.1°C to 12.8°C at Tanta; from 10.9°C to 15.1°C at Minya and from 15.7°C to 18.9°C at Aswan. The results in Figure 13.4 showed that increases in yields due to a rise in the minimum daily temperature

Fig 13·4 EFFECT OF ONE DEGREE OF TEMPERATURE (°C) ABOVE AVERAGE MINIMUM DAILY TEMPERATURE ON WHEAT YIELD FOR EACH SEVEN DAY PERIOD – NOVEMBER 10th to MAY 10th



during the 24th week (the middle of the maturity stage) were 4.46 kg/fed. at Tanta; 2.95 kg/fed. at Minya and 1.90 kg/fed at Alexandria. In contrast a slight decline in yield of 0.45 kg/fed. was predicted at Aswan.

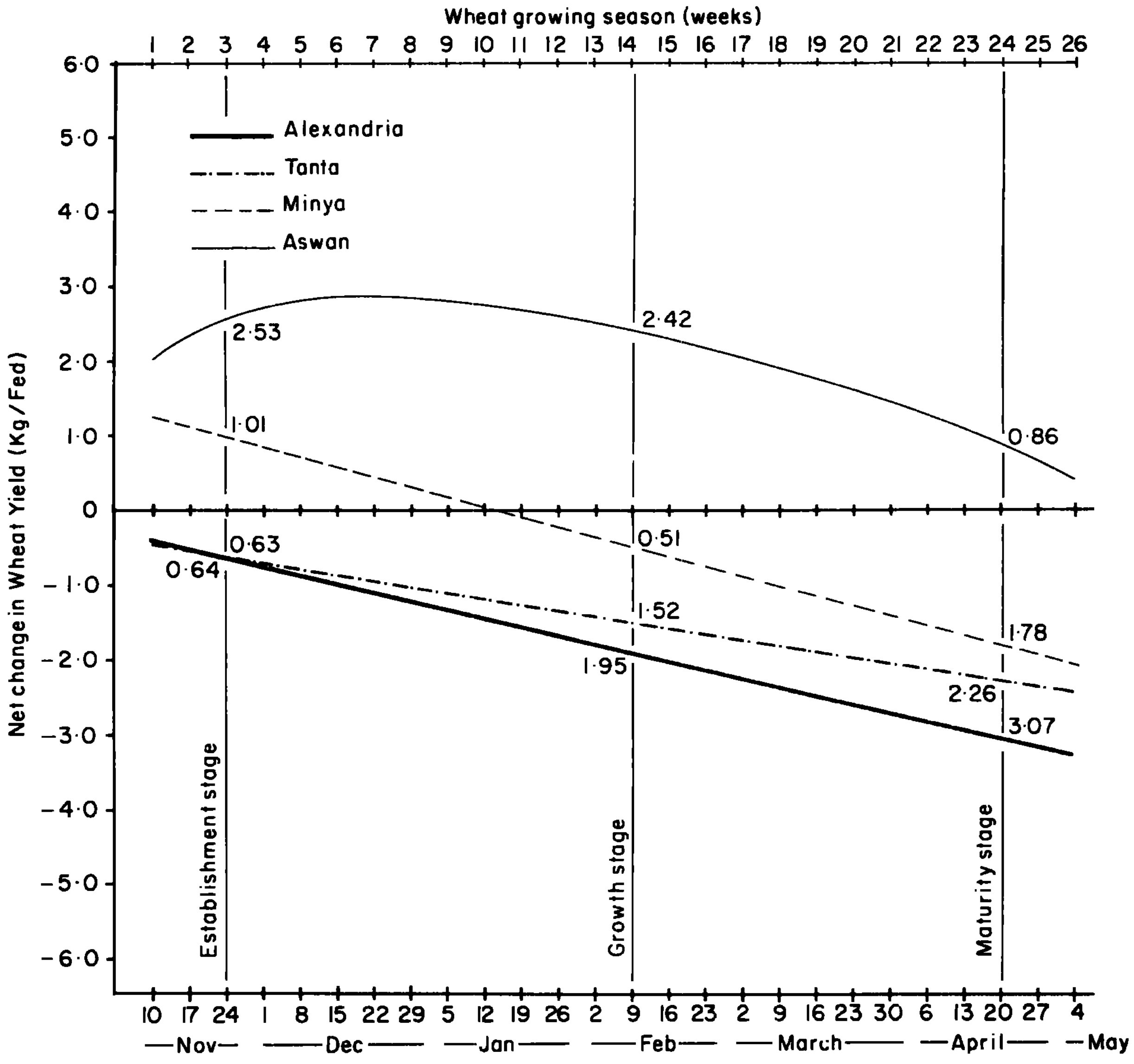
3 - Effect of daily relative humidities :-

The multiple regression equations obtained for daily relative humidities for Alexandria, Tanta, Minya and Aswan are shown in Appendix 2D. Figure 13.5 shows clearly the net change in wheat yield due to a 1% increase in relative humidity at Alexandria, Tanta, Minya and Aswan.

During the establishment stage (weeks 1-5) the average daily relative humidities varied from 66.0% to 68.5% at Alexandria; from 72.3 to 76.9% at Tanta; from 55.4% to 62.9% at Minya and from 31.6% to 41.0% at Aswan. During the 3rd week (the middle of the establishment stage), if the daily relative humidity was 1% more than the average value, beneficial effects on yields were obtained at some stations. Increases were 2.53 kg/fed. at Aswan, and 1.01 kg/fed. at Minya. In contrast, decreases in yields of 0.63 kg/fed. at Tanta and 0.64 kg/fed. at Alexandria were predicted (Fig. 13.5).

During the growth stage (weeks 5-22), the average daily relative humidities varied from 65.0 to 75.2 at Alexandria; from 64.7 to 75.0% at Tanta; from 44.9% to 64.5% at Minya and from 21.5% to 44.6% at Aswan. If there was an increase in daily relative humidity during the 14th week (the middle of the growth period) by 1% above the

Fig 13·5 EFFECT OF ONE PER CENT OF RELATIVE HUMIDITY ABOVE AVERAGE DAILY RELATIVE HUMIDITY ON WHEAT YIELD FOR EACH SEVEN DAY PERIOD - NOVEMBER 10th to MAY 10th



average value, reductions in wheat yields were suggested for three of the stations. These were 0.51 kg/fed. at Minya; 1.52 kg/fed. at Tanta and 1.95 kg/fed. at Alexandria. At Aswan a rise in yield of 2.42 kg/fed. was predicted (Fig. 13.5).

During the maturity stage (weeks 22-26) the average daily relative humidities varied from 62.8% to 67.3% at Alexandria; from 58.4% to 66.5% at Tanta; from 38.0% to 44.9% at Minya and from 19.5% to 22.3% at Aswan. With an increase in average daily relative humidity during the 24th week (the middle of the maturity period) by 1% more than the average value; decreases in yields were obtained at three stations. These were 1.78 kg/fed. at Minya, 2.26 kg/fed. at Tanta and 3.07 kg/fed. at Alexandria. In contrast, an increase in yield of 0.86 kg/fed. was predicted at Aswan (Fig. 13.5).

4 - Effect of daily wind speed :-

The multiple regression equations obtained for daily wind speed for Alexandria, Tanta, Minya and Aswan are shown in Appendix 2D.

During the establishment stage (weeks 1-5) the average daily wind speed varied from 5.5 to 9.4 knots at Alexandria; from 2.4 to 5.2 knots at Tanta; from 3.3 to 4.8 knots at Minya and from 6.4 to 7.8 knots at Aswan. An increase in average daily wind speed of 1 knot during the 3rd week (the middle of the establishment stage) had a predicted beneficial effect on yields of 1.61 kg/fed. at Aswan; 1.28 kg/fed. at Alexandria; 0.82 kg/fed. at

Minya and 0.33 kg/fed. at Tanta (Fig. 13.6).

During the growth stage (weeks 5-22), the average daily wind speeds varied from 7.8 to 11.3 knots at Alexandria; from 2.2 to 5.9 knots at Tanta; from 3.5 to 6.6 knots at Minya and from 6.6 to 9.7 knots at Aswan. An increase in daily wind speed during the 14th week (the middle of the growth period) suggested a slight beneficial effect on yield of 0.26 kg/fed. at Aswan; 0.13 kg/fed. at Alexandria and a larger predicted effect of 1.08 kg/fed at Tanta and 1.91 kg/fed. at Minya (Fig. 13.6).

During the maturity period (weeks 22-26), the average daily wind speeds varied from 8.8 to 10.9 knots at Alexandria; from 4.1 to 5.1 knots at Tanta; from 6.5 to 7.5 knots at Minya and from 8.3 to 11.4 knots at Aswan. If the daily wind speed during the 24th week (the middle of the maturity stage) was 1 knot more than the average, reductions in yields of 0.92 kg/fed. at Aswan and 2.35 kg/fed. at Alexandria were predicted. At Tanta and Minya beneficial effects of 1.74 kg/fed. and 2.83 kg/fed. respectively were obtained (Fig. 13.6).

13.4 - Actual and predicted wheat yields :-

Using the regression equations given in the preceding pages, wheat yields were predicted for Alexandria, Tanta, Minya and Aswan for the 15 year period from 1960 to 1974. These predicted data were plotted together with the actual yields and their trend is shown in Figure 13.7.

The correlation coefficients between actual and

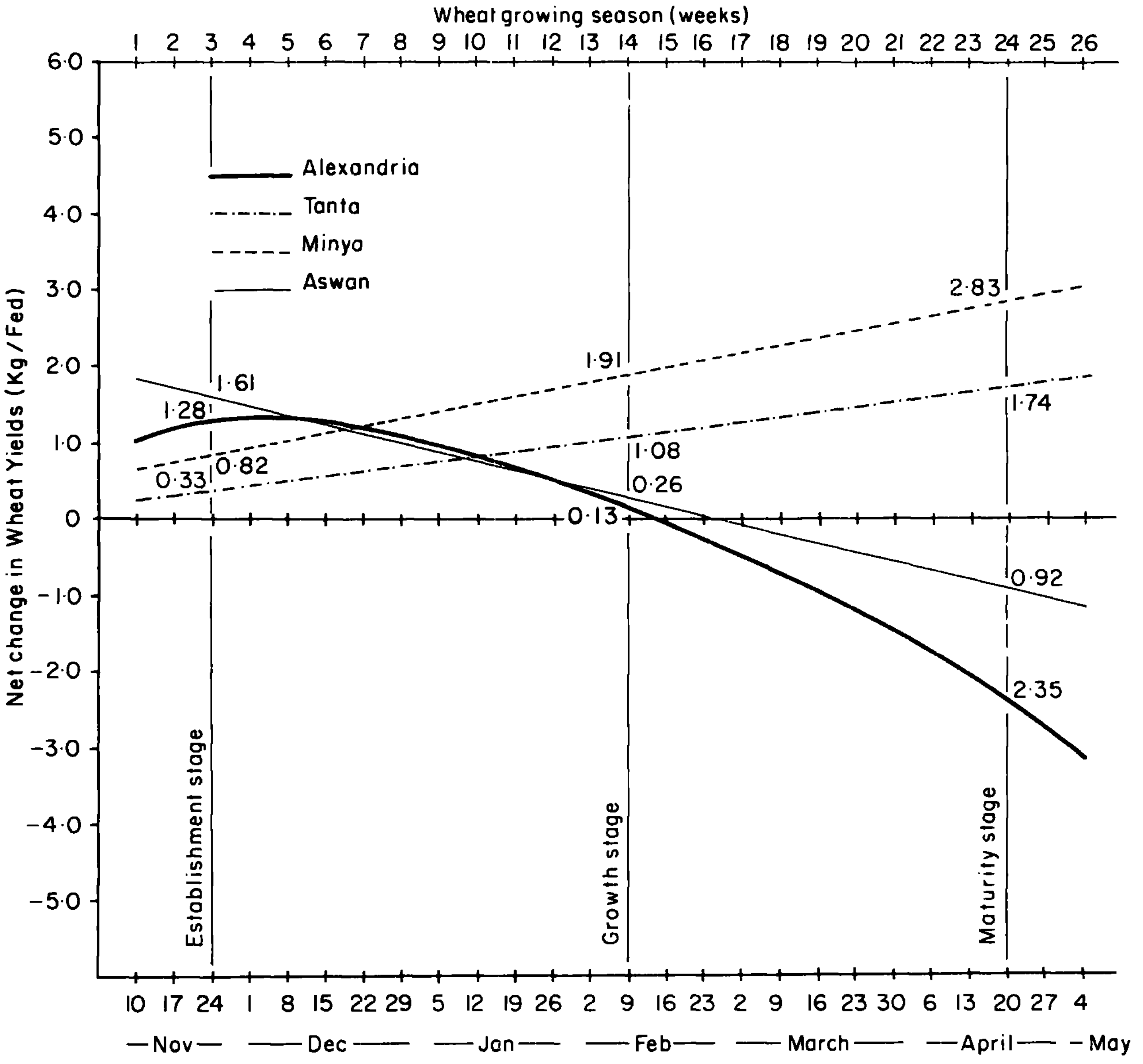


Fig13·6 EFFECT OF ONE KNOT OF WIND SPEED ABOVE AVERAGE DAILY WIND SPEED ON WHEAT YIELDS FOR EACH SEVEN DAY PERIOD — NOVEMBER 10th to MAY 10th

Table 13.b

Correlation Coefficients between Actual and Predicted Wheat Yields

Place Variables	Alexandria	Tanta	Minya	Aswan
Maximum temperature	0.7263	0.8682	0.8561	0.8415
Minimum temperature	0.8627	0.8206	0.6461	0.8513
Relative humidity	0.7307	0.6682	0.5870	0.8608
Wind speed	0.7331	0.6748	0.8039	0.6467

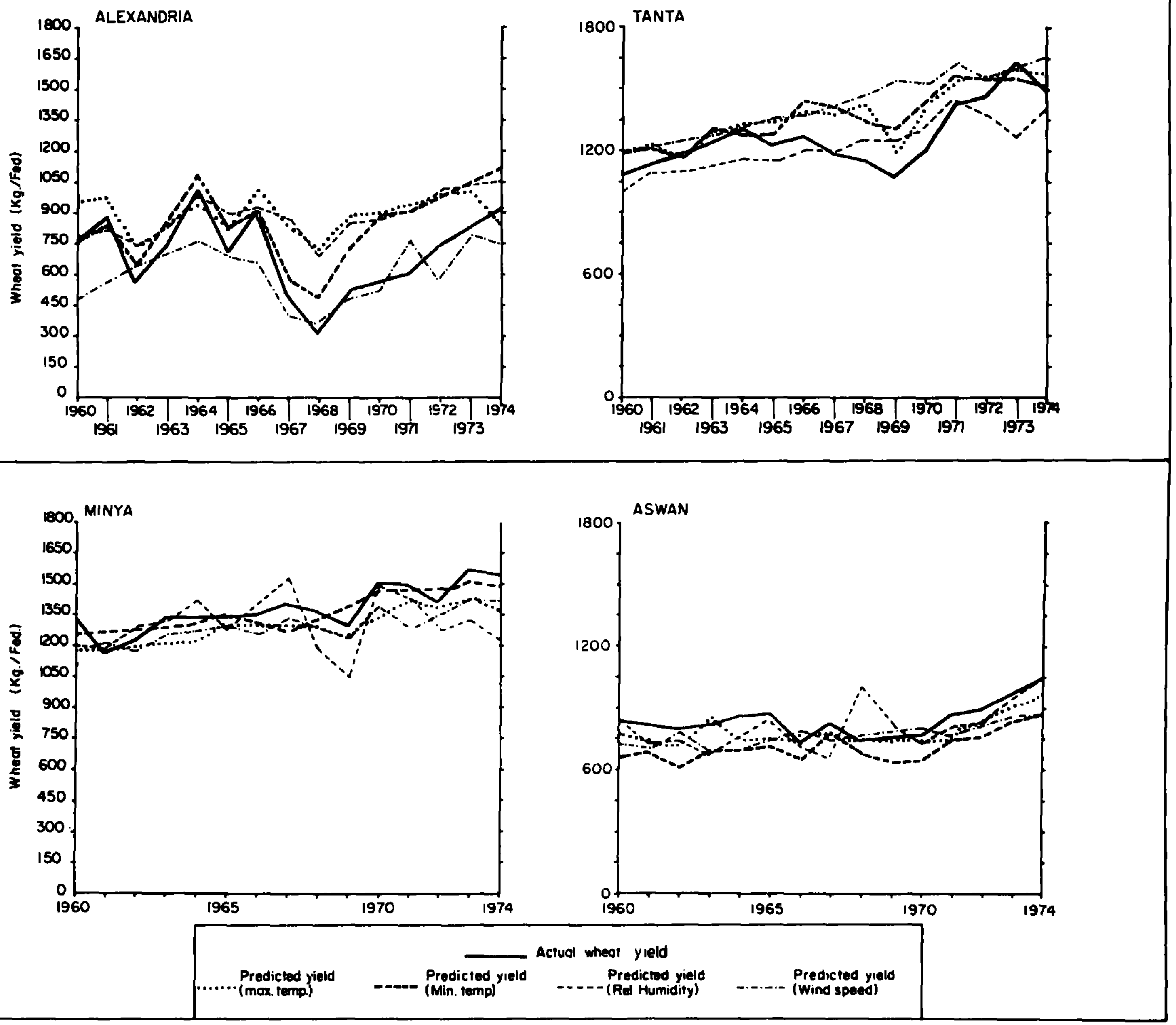
N = 15 Significance level :-

5% = 0.514 2% = 0.592 1% = 0.641

predicted wheat yields are high and highly significant (Table 13.b). These correlation coefficients are found to be significant at the 1% level, with the exception of the correlation coefficients between actual and predicted wheat yields from the relative humidity equations at Minya. This correlation coefficient is 0.5870 and found to be significant at 5% level (Table 13.b).

At each individual station the actual and predicted wheat yields are very similar (Fig. 13.7). However, there are slight variations resulting from the different effects of climatic variables on what yields. In 1967 and 1968 at Alexandria, the actual yield was very low in contrast with other years. The reason for this was mainly the results of the 1967 War (see cotton chapter), while in 1968 the wheat crop at Alexandria was attacked by rust diseases, which are the most destructive and widespread diseases affecting wheat (Mann, 1946; and Arnon, 1972). At Tanta, Minya and Aswan there are slight variations in the actual yields from year to year. In general, the actual and the predicted wheat yields at all stations are similar in their annual fluctuations (Fig. 13.7). However, overall it can be seen that the most important climatic variable appears to be minimum temperature. At Tanta and Minya maximum temperatures have the greatest effect on yields, while at Aswan relative humidity and minimum temperature are the most highly significant variables (Tables 13.b and Fig. 13.7).

Fig.13.7 ACTUAL AND PREDICTED WHEAT YIELDS, USING MULTIPLE REGRESSION EQUATIONS FOR SELECTED CLIMATIC VARIABLES



13.5 - Discussion :-

The wheat growing season is divided into three different periods (establishment, growth and maturity stages), according to the intensity and distribution of the climatic variables.

During the establishment stage, November 10th - December 8th (weeks 1-5), the seeds of wheat begin to germinate under suitable temperature conditions. Arnon (1972) showed in his research in Israel that the optimum maximum temperatures for wheat during the establishment stage are between 20°C and 22°C. He also showed that the lower the temperature is, the slower will be the rate of germination, ceasing almost completely when minimum temperatures fall below 4°C. With maximum temperatures above 22°C germination becomes irregular and the germinating seeds are readily attacked by disease (Arnon, 1972). Baier (1973) reported in his research in Canada that the optimum maximum daily temperatures during the establishment period are between 18.1°C and 20.0°C, with minimum temperatures between 6.3°C and 10.6°C. He also showed that the highest maximum temperature was 33.9°C and the highest minimum temperature was not above 21.4°C. Baier and Robertson (1968) showed that there are highly significant multiple correlations between wheat yields and mean daily maximum and minimum temperatures. These correlations were 0.68 and 0.74 respectively for maximum and minimum temperatures during the establishment stage.

In the present work the results indicate that an increase in daily maximum temperatures above the average during the establishment stage (weeks 1-5) resulted in higher yields at Alexandria and Tanta and lower yields at Minya and Aswan (Fig. 13.3). This suggests that the optimum maximum temperatures during this stage are between 22°C and 25°C. These temperatures are similar to the ones outlined above, which have been recorded by Arnon (1972) and Baier (1973).

A reduction in wheat yield at all stations was predicted if minimum temperatures were increased. This indicates that the optimum minimum temperatures during this period are less than 12°C. The nature of the data do not permit any more precise indication of what the optimum temperatures are. However, similar results for minimum temperatures have been recorded by Baier (1973).

The present results show that an increase in weekly average relative humidity had a beneficial effect on yield at Minya and Aswan and an adverse effect on yield at Tanta and Alexandria. This suggests that the optimum relative humidities during this period are about 65%.

An increase in daily wind speed during the establishment period had a favourable effect on yield at Alexandria, Tanta, Minya and Aswan. This suggests that the optimum wind speed during this period is in excess of 8 knots. There does not appear to be any information in the literature analysing the relationship between wheat yields and wind speeds.

The period from December 8th to April 6th includes the growth stage (weeks 5-22). Baier (1973) showed that the optimum daily maximum temperature was 23.2°C and the mean minimum daily temperature was 10.6°C for this period. Baier and Robertson (1968) found in their research that there are highly significant multiple correlations between wheat yields and mean maximum and mean minimum daily temperatures during the growth stage of 0.69 and 0.76 respectively. Arnon (1972) showed in his research in Israel that the optimum mean temperature is 25°C and the optimum maximum temperature is approximately 30°C - 32°C during the growth period. Hoffman (1973) reported in his experimental research in California that the optimum maximum temperatures during the wheat growth period are about 26°C, with minimum temperatures of 10°C, while the mean daily relative humidities are 65%.

The present results show that an increase in average maximum daily temperatures resulted in adverse effects on yields at Minya and Aswan and beneficial effects at Alexandria and Tanta. This suggests that the optimum maximum temperatures during this period are between 20°C and 22°C in the first half (weeks 5-13) and between 20°C and 25°C in the second half of the growing season (weeks 13-22). These results found by the present author are similar to the results outlined above obtained by Baier (1973) and Hoffman (1973), but well below the optimum values suggested by Arnon (1972).

An increase in minimum daily temperatures during the growth stage (weeks 5-22) resulted in adverse effects on yields at Alexandria and Aswan, while the reverse was the case at Tanta and Minya (Fig. 13.4). This indicates that the optimum minimum daily temperatures during this period lie between 6.5°C and 11°C. Similar results have been suggested by Baier (1973) and Hoffman (1973).

An adverse effect on yield due to an increase in daily relative humidities was predicted at Alexandria, Tanta and Minya, while at Aswan a beneficial effect on yield was obtained. This suggests that the average daily relative humidities prevailing during this period were higher at Alexandria, Tanta and Minya than the optimum values. Optimum values are believed to lie between 25% and 45%. These results are well below the optimum values found by Hoffman (1973).

An increase in yields due to a rise in average daily wind speeds was predicted at Tanta, Minya, Alexandria and Aswan. This was especially well marked in the first half of the growth stage for Alexandria and Aswan (Fig. 13.6). This indicates that the optimum daily wind speeds during this stage are between 2.5 - 10.5 knots in the first half of this stage (weeks 5-13), and between 6.0 and 9.0 knots in the second half of the growth stage (weeks 13-22).

The period from April 6th to May 10th (weeks 22-26) includes <u>the maturity stage</u> of the wheat crop. Field observations in India have shown mean maximum/minimum temperatures of about 25°C/12°C and relative humidities well below 40% to be optimal during the maturity stage (Asana and Williams, 1965). Baier (1973) showed that the highest maximum temperature for the maturity stage of the wheat plant should not be above 37.2°C with minimum temperatures not below 23.6°C. Baier and Robertson (1968) reported that there are highly significant multiple correlation values between wheat yields and mean daily maximum and minimum temperatures. These correlations were 0.68 and 0.76 respectively for maximum and minimum daily temperatures.

The present results show that an increase in maximum daily temperature above the average value had a beneficial effect on yield at Alexandria, Tanta and Minya. The reverse was the case for Aswan. This suggests that the optimum maximum temperatures during the maturity stage might well be as high as 30°C - 33°C. These results are much higher than the results obtained by Asana and Williams (1965), and similar to the results suggested by Baier (1973).

An increase in yield was obtained by increasing the average minimum daily temperatures at Alexandria, Tanta and Minya. At Aswan a slight decrease in yield was predicted. This indicates that the optimum minimum temperatures during this stage are probably as high as 16°C - 17°C. These results are higher than the results outlined above by Asana and Williams (1965) and well below the results suggested by Baier (1973).

An adverse effect on yield during the maturity stage occurred at Alexandria, Tanta and Minya, due to an increase in average daily relative humidities. In contrast a beneficial effect on yield was predicted at Aswan. This suggests that the optimum relative humidities during this period are between 20% and 40%. Similar results were obtained by Asana and Williams (1965).

Adverse effects on yields were obtained at Alexandria, and Aswan, when average daily wind speeds were increased. At Tanta and Minya beneficial effects on yields were predicted. This suggests that the optimum wind speeds during the maturity stage are between 7 and 9 knots (Fig. 13.2).

CHAPTER 14

Actual and Predicted Maize, Rice and Sugar Cane Yields in Egypt

The multiple regression techniques which have been used in the preceding chapters dealing with climatic variables and cotton and wheat yields, are also used in the present chapter to predict maize, rice and sugar cane yields around Alexandria, Tanta, Minya and Aswan for the 15 year period from 1960 to 1974. The equation used in this analysis is :-

$$Y = Ao + a_1 \sum_{i=1}^{n} (t^o_i \ x_i) + a_2 \sum_{i=1}^{n} (t^1_i \ x_i)$$
$$+ a_3 \sum_{i=1}^{n} (t^2_i \ x_i) + MT$$

Where Y = crop yield (1), Ao, a_1, a_2, a_3, and M are constants; x_i = any climatic variable within any given 7-day period; t_i = the number of each 7-day period (it is 1 for the first week of the growing season and 17, 22 and 54 for the last week of maize, rice and sugar cane growing seasons respectively); T = the year number (beginning with 1 in 1960 and ending with 15 in 1974).

The multiple regression equations for maximum and minimum temperatures, relative humidities and wind speeds have been obtained and used to predict maize, rice and sugar cane yields. These equations used in this analysis are included in Appendix 2E.

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(1) Maize yield (Ardab/fed.; Ardab = 140 kg),
rice yield (Dariba/fed.; Dariba = 945 kg) and
sugar cane yield (Quintar/fed.; Quintar = 50 kg).

14.1-Actual and predicted maize yields :-

The correlation coefficients between the actual and predicted maize yields around Alexandria, Tanta, Minya and Aswan are calculated and the results are shown in Table 14.a . This table indicates that the correlation coefficients between the actual and predicted maize yields are very high and highly significant in general. The highest correlation coefficients are 0.909 and 0.871. These occurred at Aswan with regard to the maximum and minimum temperatures equations respectively (Table 14.a). The lowest correlation coefficients between actual and predicted maize yields are recorded at Alexandria (0.413) and Minya (0.427), using the relative humidity equation. These latter correlation coefficients fail to reach the 5% level of significance.

The predicted data and the actual maize yields for Alexandria, Tanta, Minya and Aswan are illustrated (Fig. 14.1). This figure shows clearly that the actual and predicted maize yields are similar in their fluctuations at each station. However, there are slight variations resulting from the different effects of climatic variables on maize yields in Egypt. It can also be seen that the actual maize yield at Alexandria in 1968 was low in contrast with other years (Fig. 14.1). One of the main reasons was that the 1968 Alexandria maize crop had been attacked by rust diseases (Arnon, 1972). Overall it can be seen that the estimated yields closely approximate the observed values at all four stations.

Table 14.a

Correlation Coefficients between the Actual and Predicted Maize Yields

Place / Climatic variable	Alexandria	Tanta	Minya	Aswan
Maximum temperature	0.584	0.569	0.569	0.909
Minimum temperature	0.658	0.542	0.623	0.871
Relative humidity	0.413	0.605	0.427	0.621
Wind speed	0.522	0.655	0.527	0.806

N = 15 Significance level :-

5% = 0.514 2% = 0.592 1% = 0.641

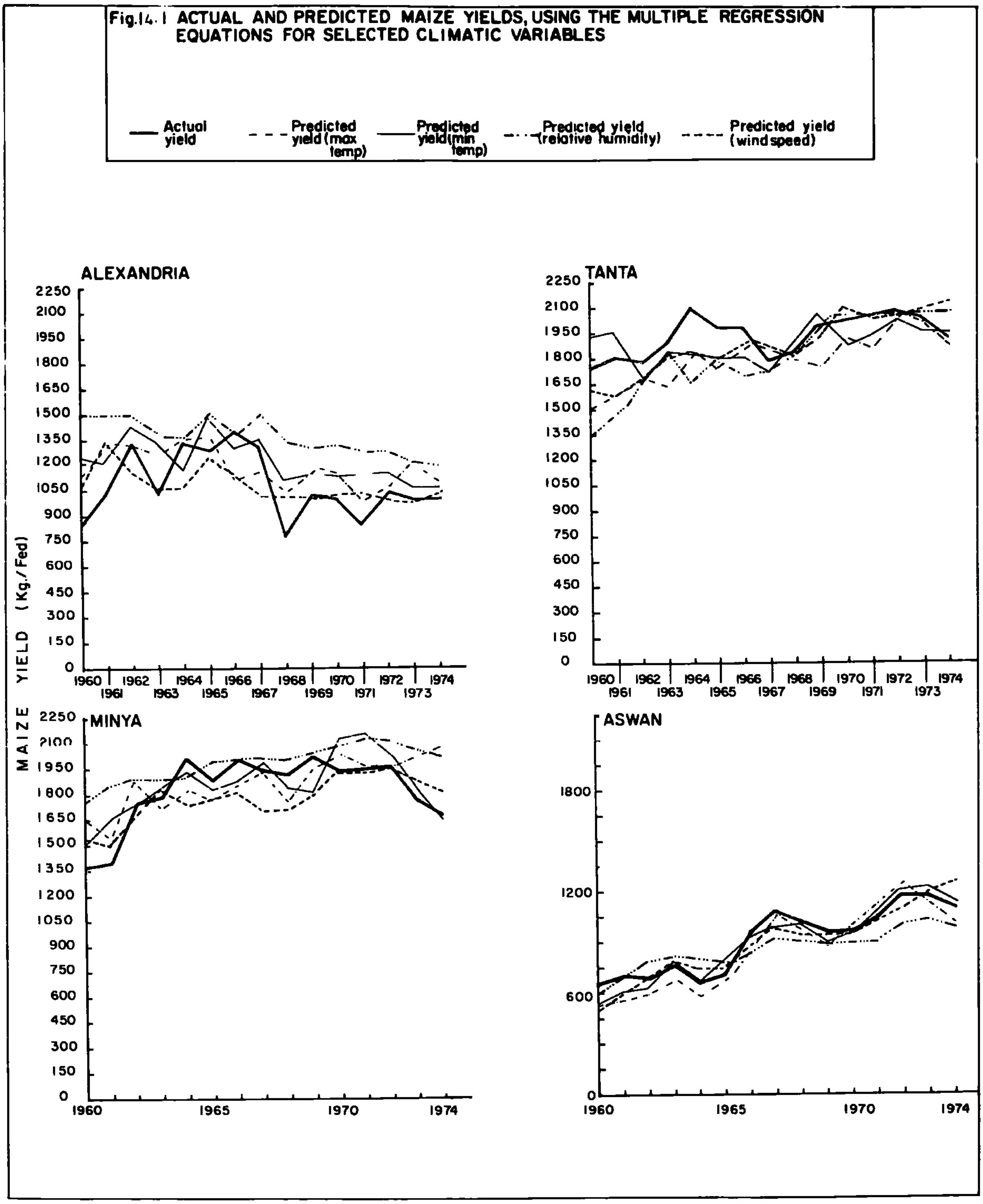


Fig.14.1 ACTUAL AND PREDICTED MAIZE YIELDS, USING THE MULTIPLE REGRESSION EQUATIONS FOR SELECTED CLIMATIC VARIABLES

14.2-Actual and predicted rice yields :-

The correlation coefficients between the actual and predicted rice yields are high and highly significant especially for the values obtained by using the maximum temperature and relative humidity equations (Table 14.b).

The highest correlation coefficients between the actual and predicted rice yields are 0.789 for maximum temperature at Alexandria, and 0.788, 0.782 and 0.708 for relative humidity at Alexandria, Tanta and Minya respectively. These correlation coefficients are found to be significant at the 1% level (Table 14.b). In contrast, the lowest correlation coefficients obtained between the actual and predicted rice yields are 0.516 and 0.526 for wind speed at Alexandria and Minya respectively. These latter correlation coefficients just reach the 5% level of significance.

Figure 14.2 shows clearly that the actual and predicted rice yields at Alexandria are very similar in their fluctuations. Similar results are seen in Tanta, while at Minya, there are some variations, such as in 1969 and 1973 when the predicted rice yields were higher than the actual ones. A major reason for this was that the rice crop in both years suffered from blast, which for rice is a most damaging disease (Arnon, 1972).

14.3-The actual and predicted sugar cane yields :-

The simple correlation analysis (Table 14.c) indicates that the best estimators of sugar cane yields

Table 14.b

Correlation Coefficients between the Actual and Predicted Rice Yields

Place / Climatic variable	Alexandria	Tanta	Minya
Maximum temperature	0.789	0.644	0.642
Minimum temperature	0.647	0.598	0.563
Relative humidity	0.788	0.782	0.708
Wind speed	0.516	0.562	0.526

N = 15 Significance level :-

5% = 0.514 2% = 0.592 1% = 0.641

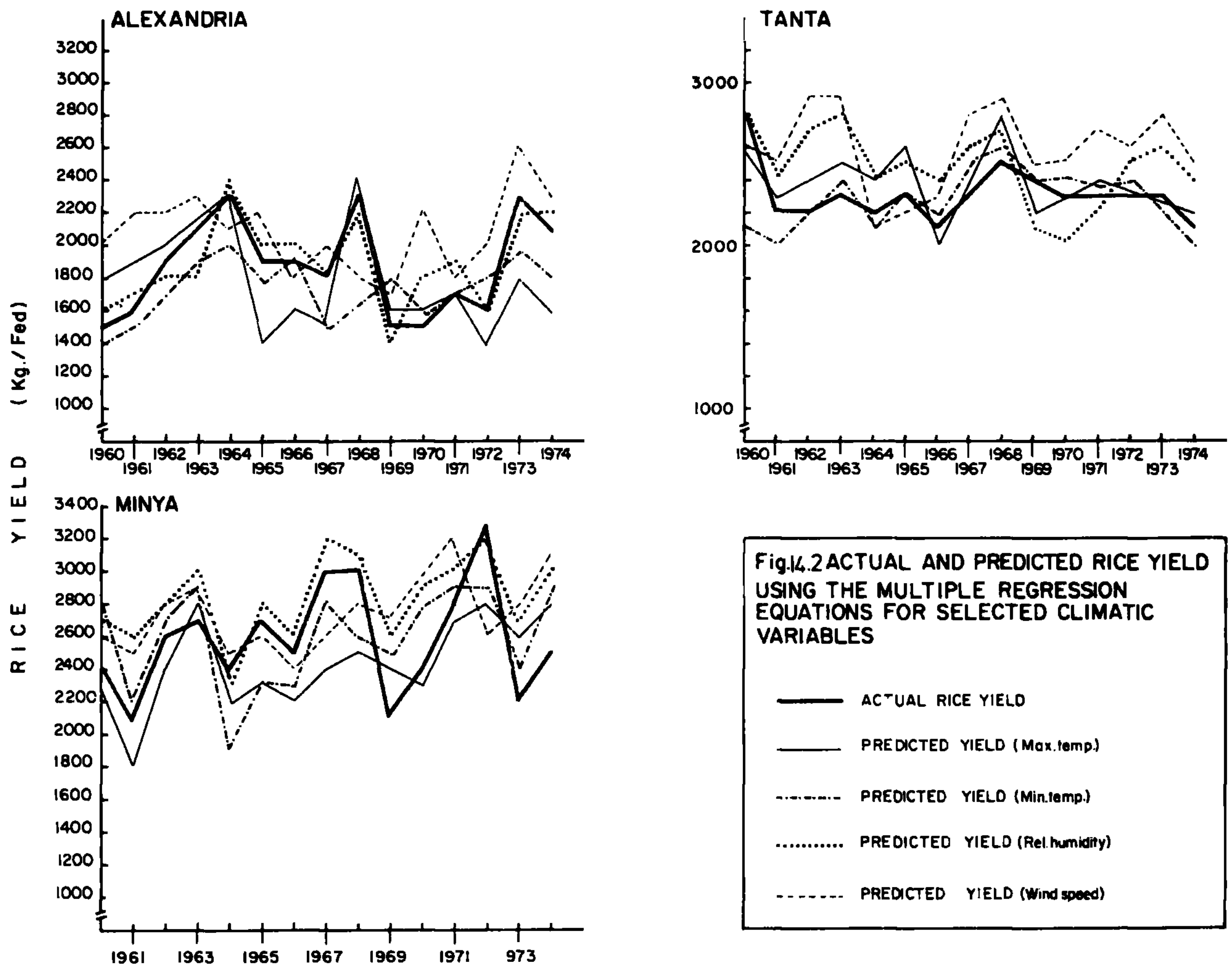


Fig.14.2 ACTUAL AND PREDICTED RICE YIELD USING THE MULTIPLE REGRESSION EQUATIONS FOR SELECTED CLIMATIC VARIABLES

are maximum and minimum temperatures, and relative humidity. The highest correlation coefficients between the actual and the predicted sugar cane yields are 0.883 and 0.879 for maximum temperatures at Aswan and Minya respectively (Table 14.c). These correlation coefficients are found to be significant at the 1% level. The lowest correlation coefficients between the actual and predicted sugar cane yields are 0.476, for relative humidity at Tanta and 0.501 and 0.429 for wind speed at Alexandria and Minya respectively. These low correlation coefficients do not reach the 5% level of significance (Table 14.c).

The predicted sugar cane yields are plotted with the actual yields (Fig. 14.3). This figure indicates that the actual and predicted sugar cane yields are high at Minya and Aswan, in comparison with Alexandria and Tanta. This can be explained by the favourable climatic conditions at Aswan and Minya, especially the high temperatures and low relative humidities. It can also be seen that the actual and predicted sugar cane yields are very similar in their fluctuations at each station. However, at Alexandria in 1967 the actual yields were low in contrast with other years. One of the main reasons for this was the 1967 War which displaced agriculture activity in Lower Egypt.

Table 14.c

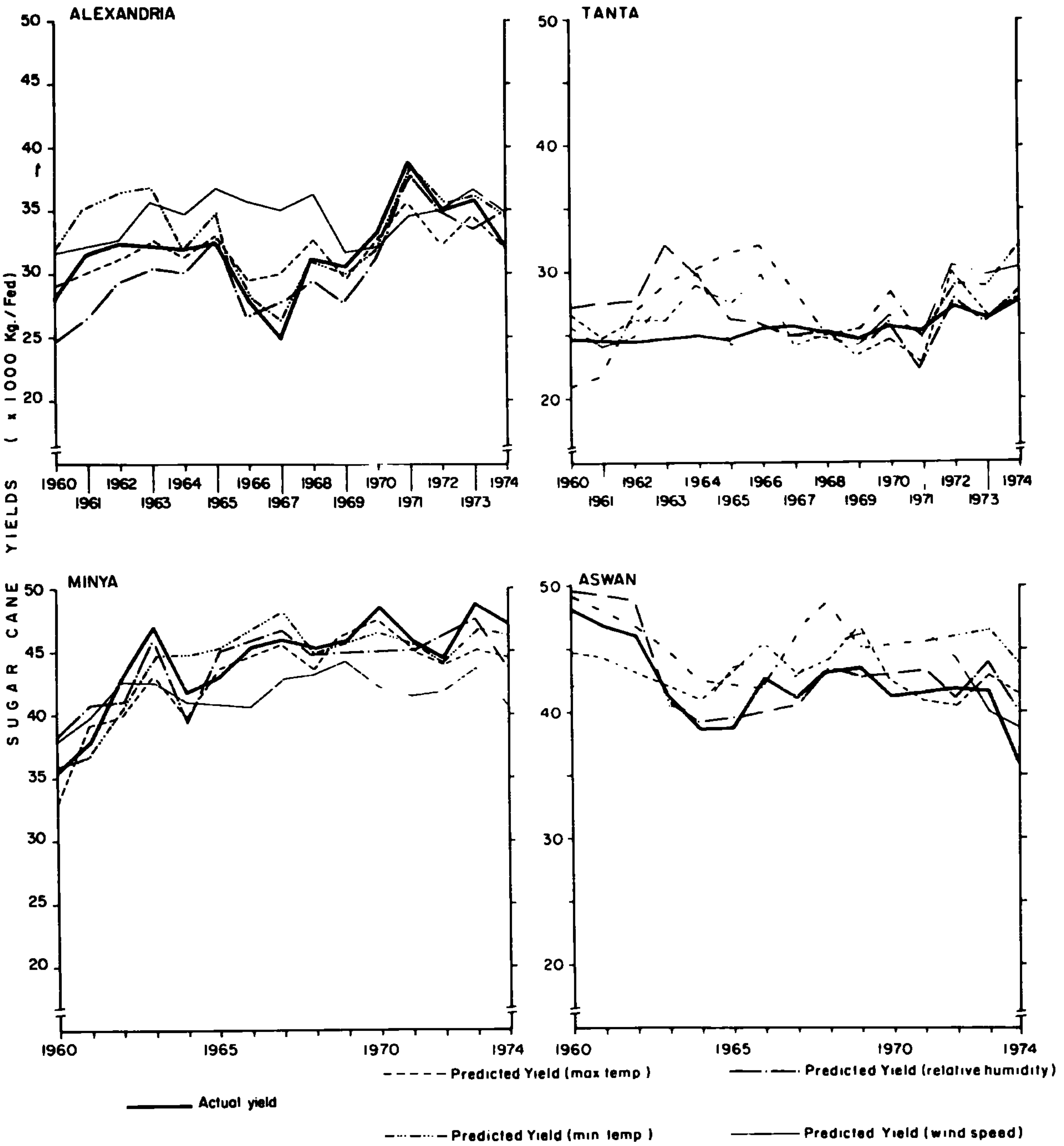
Correlation Coefficients between Actual and Predicted Sugar Cane Yields

Place Climatic variable	Alexandria	Tanta	Minya	Aswan
Maximum temperature	0.732	0.621	0.879	0.883
Minimum temperature	0.620	0.515	0.744	0.623
Relative humidity	0.616	0.476	0.686	0.683
Wind speed	0.501	0.584	0.429	0.609

N = 15 Significance level :-

5% = 0.514 2% = 0.592 1% = 0.641

Fig.14.3 ACTUAL AND PREDICTED SUGAR CANE YIELDS, USING MULTIPLE REGRESSION EQUATIONS FOR SELECTED CLIMATIC VARIABLES



CHAPTER 15

Summary and Conclusions

This thesis is divided into three sections. The main section begins with chapter three (Temperatures in Egypt), and deals in detail with surface, earth and water temperatures. The analysis of the 15 year daily maximum temperature record for Alexandria and Giza (1960 - 1974) revealed that during the spring months, especially April and May, the frequency and severity of hot spells is greatest. Furthermore, it is seen that the frequency of hot spells increases again in autumn. In October the number of hot spell occurrences constitutes a second peak, although, this is much smaller than the spring peak. The earth temperatures show that the highest monthly mean earth temperatures decrease with depth from 0.3 cm to 3 metres. In contrast, the minimum temperature values increase with depth. With regard to water temperatures, it can be seen that in Lower Egypt the mean air temperature is greater than the mean water temperature from March to August, while the opposite is the case for the rest of the year.

The results outlined in the precipitation chapter show that in Egypt the rainy season occurs between October and May with precipitation being heaviest on the Mediterranean Coast between Alexandria and El-Borolles, where the mean annual rainfall reaches 180 mm. It decreases southwards to about 25 mm in Cairo and 5 mm in Minya in Middle Egypt. The maximum rainfall over the coastal Mediterranean region occurs in January, but in Middle and Upper Egypt the maximum occurs in October and May. Selected statistical methods measuring monthly precipitation variability for selected stations in Egypt revealed that the months with the highest mean rainfall show the greatest variances and standard deviations. This is illustrated clearly by the months November to March at the coastal stations and by December, May and February at the inland stations. The lowest mean monthly rainfall data produced the lowest values for the variance, the median and the standard deviation. This is seen for instance during May at the coastal stations. Analysis of daily rainfall data for selected stations in Egypt showed that the rainy periods are of three to four days in duration in the coastal region and the middle part of the Delta. Longer periods, however, are rare, especially in the southern parts of the country. A study of the correlation coefficients between the rainfall and three main factors (latitude, longitude and elevation) showed that the highest positive correlation coefficients occurred between the mean monthly rainfall and the latitude (^{o}N) factor. Longitude (^{o}E) has the highest negative correlation with rainfall over Egypt.

The mean daily values of evaporation and evapotranspiration using Piche tube evaporometers for summer months exceed 20 mm/day at the Aswan, Kharga and Dakhla stations, while at Alexandria on the Mediterranean coast and Tanta in the middle of the Delta area, these values average only about 6 mm/day. Evaporation and evapotranspiration was also estimated using the Penman equation and the Thornthwaite formula for selected climatological stations in Egypt. These values obtained using the Penman equation and the Thornthwaite formula were very low in contrast with the values measured by the Piche tube in free air. The correlation coefficients relating measured evaporation by Pich tube in free air and Class 'A' Pan results at Giza and Aswan are very high and all significant at the 1% level.

The Khamsin has been defined as a very hot, dry and dusty south-easterly wind. The main weather features constituting Khamsin weather have been analysed. These are excessively high surface temperatures and extremely low humidities, associated with the invasion of south and south-east winds which produce rising dust and duststorms. Attempts have been made by the author to investigate the tracks of the Khamsin depressions for the four year period, 1970 - 1973. The results of this analysis showed that there are two types of depressions. The first is formed to the south of the Atlas mountains and the second originates over the Atlantic. Both effect the climate of Egypt, but it is the former depressions which usually produce the most intense Khamsin conditions.

Factor analysis techniques have been used to classify the climate of Egypt. The results obtained showed that the climate of Egypt can basically be divided into two climatic zones. The first comprises the Mediterranean coastal areas, including the Delta. The climate of this zone is of the Mediterranean type, which is characterized by mild rainy winters and hot dry summers. The second zone covers the rest of the country south of Cairo. The climate of this zone is of the desert type, which is characterized by warm winters with very little rain and hot dry summers. More detailed analysis permits a division with 5 climatic sub-zones. The new three regions added are the Delta area; the Red Sea and the Nile Valley region and the intermediate zone trending north west to south east and separating the desert area from the coastal region.

The second section deals with agricultural activity in Egypt. In this the different crop types are studied together with the pattern of agricultural expansion. Lorenz curves and Lorenz's Index of concentrations showed clearly that sugar cane is concentrated in Upper Egypt and rice in Lower Egypt, while the other crops are widely distributed throughout the country. The Delta and the Nile Valley have been classified into three main agricultural regions. The first region is called Lower Egypt. This region consists of the Delta proper from Cairo northward to the Mediterranean Sea. The second region is Middle Egypt. This region includes the narrow cultivated strip along the Nile from Cairo to Asyut. Upper Egypt is the third agricultural region. This region includes the narrow cultivated strip along the Nile from Asyut southwards to the Sudanese border.

The daily water discharge of the River Nile at Aswan, Cairo, Rosetta and Damietta are analysed for the three year period before the High Dam was built (1960 - 1962), and for the three year period after its completion (1973 - 1975). It is seen that the completion of the High Dam changed the discharge regime very markedly. Flood waters are now retained in Lake Nasser and released downstream only when required for irrigation purposes. As a result the Delta will never again be in danger of serious flooding.

The Blaney and Criddle method and the Penman equation have been used to estimate the irrigation requirements for the main crops in Egypt. The results obtained showed that the consumptive water use and the irrigation requirements calculated by the Blaney and Criddle method are greater for all crops than those obtained using the Penman (Et) potential evapotranspiration values. The main reason for this is that the Blaney and Criddle method depends on an empirical coefficient (K) which tends to over-estimate crop water requirements. Furthermore, the actual irrigation requirements are much higher for sugar cane and rice crops than the irrigation requirement estimates obtained from the Blaney and Criddle formula and the Penman equation. This is to be expected as the estimates stem only from climatological variables, while measured results also take into account the infiltration rates of individual soil type.

Multiple regression equations have been used in the third section to explain the relationships between selected climatic variables and the major crop yields at selected stations during the 15 year period 1960 - 1974. The techniques used in this section are similar to those used by Runge (1968) and Huda et al., (1975 and 1976).

The cotton growing season (March 1st to September 1st) was divided into four different stages. These were emergence, vegetative, growth and maturity stages. The results obtained for the first stage showed a beneficial effect on yield with an increase in maximum daily temperature during the emergence period (week 1) at all stations. It was also noted that the largest predicted increase in yield occurred at Alexandria, which had the lowest maximum temperatures. This was probably the result of the use of different varieties of seed. The results detailed in the main text for minimum temperature, relative humidity and wind speed suggested that the optimum temperature during the cotton emergence stage was in excess of 11°C, while the optimum relative humidity was about 30% and optimum wind speeds were between 3.5 and 4 knots.

During the second stage of cotton growth (weeks 2-8), the results indicated that an increase in maximum temperature above the average values had a beneficial effect on cotton yields at Alexandria, Tanta and Aswan, while at Minya a slight detrimental effect on yield was suggested. Beneficial effects on cotton yields due to an increase in minimum weekly temperatures were obtained at all stations during the vegetative period. The results outlined for relative humidity and wind speed during this period suggested that the optimum relative humidity values were 20% - 30% with optimum wind speeds of between 3.5 and 5.5 knots.

The results obtained during the third stage (weeks 8-22), suggested optimum values of less than 27°C for maximum temperatures, between 10°C and 15°C for minimum temperatures, less than 55% for relative humidities and between 3 to 5.5 knots for wind speeds.

The results outlined above for the maturity period (weeks 22-26), suggested that cotton yields decreased when the maximum temperature rose above 32°C and when minimum temperature rose above 19°C. It was also noted that the suggested optimum relative humidity values during this period were between 20% and 50%, and optimum wind speeds of between 2.5 and 5.5 knots.

The multiple regression techniques were also used to predict cotton yields at selected stations in Egypt, and correlation coefficients between actual and predicted yields were obtained. The results of these calculations showed that the predicted cotton yields using the maximum and minimum temperature equations had the highest correlation coefficients with the actual yields, in comparison with both the wind speed and relative humidity values.

The same techniques have also been used to explain the relationships between the three different periods (establishment, growth and maturity stages) of the wheat growing season (November 10th to May 10th). The results discussed in the main text showed that the optimum maximum temperatures during the establishment stage (weeks 1-5) were between 22°C and 25.5°C and optimum minimum temperatures were less than 12°C. Optimum relative humidities were about 65% and optimum wind speeds in excess of 8 knots.

During the second or growth stage (weeks 5-22), the results indicated that the optimum maximum temperatures were between 20°C and 25°C, minimum temperatures between

6.5°C and 11°C, relative humidities between 25% and 45%. Optimum wind speeds were between 2.5 and 10.5 knots in the first half of the growth stage (weeks 5-13) and between 6.0 and 9.0 knots in the second half (weeks 13-22),

During the maturity stage (weeks 22-26), the results showed that the suggested optimum maximum and minimum temperatures were 30°C - 33°C and 16°C - 17°C respectively, while optimum relative humidities were between 20% and 40% and wind speeds between 7 and 9 knots.

The correlation coefficients between the actual and predicted wheat yields indicated that the highest values occurred using maximum and minimum temperatures and the relative humidity equations.

Actual and predicted maize, rice and sugar cane yields have also been obtained using the same techniques as discussed above. The results showed that the highest correlation coefficients between actual and predicted maize yields were 0.909 and 0.871. These were found at Aswan with regard to the maximum and minimum temperatures respectively. Maximum temperature and relative humidity were the highest significant variables affecting rice yields. These two variables had the highest correlation coefficients between the actual and the predicted rice yields. The correlation coefficients calculated between the actual and predicted sugar cane yields indicated that the best estimators of sugar cane yields were maximum and minimum temperatures and relative humidities.

Overall, it was noted that the maximum and minimum temperatures were the most significant climatic variables affecting crop yields in Egypt, while relative humidities and wind speeds were less significant.

Finally, given the results for the cotton, wheat, maize, rice and sugar cane yields outlined above, it is evident that the multiple regression equations analysing climatic data have good predictive qualities in terms of annual yields. In general, these studies have not been as fruitful as might have been hoped. The first reason underlying the relatively disappointing record of this technique is the requirement of reliable meteorological and related crop yield data for an adequate number of years. In many cases such records are not available. Though reliable meteorological data are available over quite long periods for a number of stations in Egypt, accurate crop yield figures do not exist at the district or locality level. Perhaps even more important is the fact that the crop yield varies from year to year depending not only on climatic factors but also on the varieties/ type of plant used, soil conditions and especially management inputs. Physical and chemical soil conditions may also vary from place to place resulting in variations in crop yield.

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APPENDIX 1

Containing a Description of the Computer Cards Used for the Penman Evapotranspiration Values

(Eo1, Eo2 and Et)

Description of the Cards in Figure A

Card 1 (one for each month). Lead card.

(a) Columns 61 and 62 always 93.

(b) Column 74 is having the catchment number.

(c) Columns 77-80 bear the month and year number.

Card 2 (one for each month). Control card.

(a) Catchment area in hectares to one decimal place in columns 1-10.

(b) Latitude in degrees (+ = N, - = S) to one decimal place in columns 11-16.

(c) Altitude in metres, columns 17-21.

(d) Albedo normally 25 over grass land, columns 41-45.

(e) Temperature index, 2 = degrees C, columns 46-47

(f) Wind index, 3 = knots columns 48-50.

(g) Height of anemometer in meters, columns 51-54.

(h) Sun index, 1 = hours, columns 55-56.

(i) Total radiation index, 0 = no data, columns 57-58.

(j) Net radiation index, 0 = no data, columns 59-60.

(k) Data type, always 3, column 62.

(l) Source index, 1 = manual station,

PROGRAM

PROGRAMMER

Fig (A)

PAGE OF

DATE

73 80 Optional Sequence

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          10        20        30        40        50        60        70        80
1                                                              93           1  0170
2      100.0 +30.5 14.8                      25 2  3  10 1 0 0 3 1 1 1 8   1310170
3    25.0  9.0  17.0  12.0   0.0   6.4                         3 1 1       1010170
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		letter O	letter	number 1

APPENDIX 2

2A = Average weekly data for selected climatic variables during the cotton gorwing season.

2B = Constant values in the multiple regression equations for selected climatic variables for cotton yield.

2C = Average weekly data for selected climatic variables during the wheat growing season.

2D = Constant values in the multiple regression equations for selected climatic variables for wheat yield.

2E = Constant values in the multiple regression equations for selected climatic variables for maize, rice and sugar cane yields.

Appendix 2A

Distribution of the Average Weekly Maximum, Minimum Temperatures, Relative Humidity and Windspeed at Alexandria, Tanta, Minya and Aswan for the period (1960-1974)

Week No	Dates	Alexandria				Tanta			
		Max. temp. (°C)	Min. temp. (°C)	Rel. Humid. (%)	Wind speed (knot)	Max. temp. (°C)	Min. temp. (°C)	Rel. Humid. (%)	Wind speed (knot)
1	Mar 1-7	20.4	10.2	68.1	11.7	23.2	8.5	63.6	3.8
2	Mar 8-14	20.4	10.7	69.3	9.8	23.3	8.9	67.7	4.6
3	Mar 15-21	21.5	11.8	65.7	9.7	23.1	9.5	66.3	4.2
4	Mar 22-28	20.7	12.4	68.5	9.1	22.1	8.7	69.8	5.5
5	Mar 29-Apr 4	22.7	12.5	68.3	9.9	24.6	10.0	67.9	4.9
6	Apr 5-11	23.9	12.9	65.7	8.9	25.2	10.1	65.7	5.1
7	Apr 12-18	24.6	14.3	62.8	9.9	28.1	12.0	62.3	4.9
8	Apr 19-25	23.4	13.8	63.8	10.9	26.3	11.5	63.9	4.0
9	Apr 26-May 2	24.4	14.9	64.8	8.8	28.3	12.4	60.8	4.4
10	May 3-9	24.9	15.3	66.8	9.4	29.0	12.8	58.1	4.3
11	May 10-16	25.9	16.2	66.7	10.2	30.4	14.0	57.9	4.8
12	May 17-23	27.1	17.0	65.5	8.8	30.9	14.6	56.7	4.7
13	May 24-30	27.2	17.8	66.7	10.1	32.7	15.8	53.6	5.4
14	May 31-Jun 6	28.1	17.9	65.6	9.4	33.7	16.4	52.7	5.1
15	Jun 7-13	27.9	19.2	65.8	10.4	34.4	17.7	55.6	5.2
16	Jun 14-20	28.6	19.9	63.7	8.6	34.5	18.6	53.8	4.5
17	Jun 21-27	28.6	21.0	66.1	8.8	33.5	18.9	57.1	4.5
18	Jun 28-Jul 4	28.8	21.3	69.9	9.2	33.4	19.0	60.6	3.7
19	Jul 5-11	29.2	22.1	70.3	9.6	32.2	18.6	62.2	3.2
20	Jul 12-18	29.5	22.5	72.1	10.1	32.8	19.5	66.6	3.6
21	Jul 19-25	30.7	22.8	71.8	10.3	33.6	20.3	67.7	3.2
22	Jul 26-Aug 1	30.1	22.8	70.4	9.4	33.2	19.7	69.6	2.9
23	Aug 2-8	30.1	22.8	70.3	11.9	33.2	19.9	70.1	2.8
24	Aug 9-15	30.7	22.7	70.2	9.2	33.0	19.9	69.8	2.8
25	Aug 16-22	31.1	22.7	68.8	10.1	33.4	19.7	72.9	2.6
26	Aug 23-29	30.4	22.9	69.9	9.9	32.8	19.4	73.2	2.7

Appendix 2A Continued

Week No	Dates	Minya				Aswan			
		Max. temp. (°C)	Min. temp. (°C)	Rel. Humid (%)	Wind speed (knot)	Max. temp. (°C)	Min. temp. (°C)	Rel. Humid (%)	Wind speed (knot)
1	Mar 1-7	25.4	7.8	49.9	5.0	29.1	10.9	29.5	8.8
2	Mar 8-14	25.3	8.3	49.0	5.4	30.4	12.0	25.6	8.4
3	Mar 15-21	25.9	9.5	46.9	6.2	29.1	12.9	25.9	9.1
4	Mar 22-28	24.8	8.9	49.3	6.2	29.0	11.8	24.5	9.2
5	Mar 29-Apr 4	27.7	9.5	47.7	6.2	32.1	14.0	22.5	8.7
6	Apr 5-11	28.1	10.9	44.9	6.6	33.9	15.7	21.1	10.2
7	Apr 12-18	30.9	12.9	38.0	7.2	35.2	16.8	21.9	8.6
8	Apr 19-25	30.0	13.9	39.6	7.5	35.3	17.8	21.6	8.5
9	Apr 26-May 2	30.9	14.0	39.0	6.6	36.9	18.0	20.2	9.5
10	May 3-9	31.9	15.1	38.2	6.5	36.0	18.9	20.6	7.8
11	May 10-16	33.1	15.9	35.9	6.7	37.7	20.6	20.7	8.9
12	May 17-23	33.7	15.8	34.3	6.1	38.4	19.9	21.9	8.7
13	May 24-30	35.9	17.4	32.4	7.0	40.1	22.2	17.8	8.5
14	May 31-Jun 6	36.4	18.3	32.3	7.2	40.4	22.2	17.8	8.7
15	Jun 7-13	37.0	19.1	34.1	7.4	42.2	24.1	18.1	8.6
16	Jun 14-20	37.5	20.0	32.5	7.7	42.4	23.6	17.1	8.6
17	Jun 21-27	36.4	20.4	38.1	6.1	41.1	23.5	18.6	7.5
18	Jun 28-Jul 4	36.4	19.6	38.5	6.1	41.3	23.5	18.4	6.9
19	Jul 5-11	35.7	19.9	39.1	5.9	40.6	23.3	21.4	6.3
20	Jul 12-18	36.1	20.3	40.1	6.0	40.7	23.5	24.4	7.9
21	Jul 19-25	36.4	20.7	43.3	4.8	40.8	23.5	23.7	6.5
22	Jul 26-Aug 1	35.9	20.3	44.3	3.2	41.9	23.8	22.7	8.1
23	Aug 2-8	36.2	20.0	44.1	4.4	40.6	23.7	24.9	5.6
24	Aug 9-15	36.0	20.8	44.0	5.1	40.6	23.3	24.7	6.9
25	Aug 16-22	35.8	20.3	46.1	3.5	40.5	23.3	25.9	6.8
26	Aug 23-29	35.6	19.9	47.9	4.8	40.0	22.8	26.9	6.2

Appendix 2B

Constant Values in the Multiple Regression Equations for Maximum Temperature (Cotton Yield)

Variable / Place	Constant (Ao)	Max. temp. (a_1)	Max. temp. x week (a_2)	Max. temp. x week^2 (a_3)	Year (m)	F "test" value
Alexandria	8.7392	5.1325	-0.8592	0.0271	-0.1104	4.730
Tanta	26.3137	2.0968	-0.4752	0.0156	0.0123	4.986
Minya	12.6622	1.0589	-0.1722	0.0046	0.0320	3.071
Aswan	-12.8971	-4.1315	0.7671	-0.0250	0.3217	5.162

Constant Values in the Multiple Regression Equations for Minimum Temperature (Cotton Yield)

Variable / Place	Constant (Ao)	Min. temp. (a_1)	Min. temp. x week (a_2)	Min. temp. x week^2 (a_3)	Year (m)	F "test" value
Alexandria	24.4839	0.6993	0.2013	-0.0173	-0.0326	3.981
Tanta	12.9472	-0.0314	-0.0959	0.0035	0.0559	3.762
Minya	2.9758	2.3930	-0.7006	0.0301	-0.0102	3.542
Aswan	-7.8942	-1.6071	-0.0260	0.0021	0.3076	4.630

DF. (4, 10)

Appendix 2B Continued

Constant Values in the Multiple Regression Equations for Relative Humidity (Cotton Yield)

Variable / Place	Constant (Ao)	Rel. Humid. (a_1)	Rel. Humid. x week (a_2)	Rel. Humid.$_2$ x week^2 (a_3)	Year (M)	F "test" value
Alexandria	4.4423	-0.2705	0.0489	0.0017	-0.0968	3.978
Tanta	6.7747	0.0293	-0.0139	-0.0005	0.0782	1.086
Minya	6.9545	-0.2034	0.0205	0.0004	0.0219	3.470
Aswan	-0.7296	0.4579	-0.0814	0.0031	0.2766	4.959

Constant Values in the Multiple Regression Equations for Wind Speed (Cotton Yield)

Variable / Place	Constant (Ao)	Wind speed (a_1)	Wind speed x week (a_2)	Wind speed$_2$ x week^2 (a_3)	Year (M)	F "test" value
Alexandria	1.8969	-0.0033	0.0549	-0.0022	-0.0509	1.249
Tanta	5.6776	0.3838	-0.4571	0.0257	0.0345	3.963
Minya	6.3417	1.7209	-0.1772	0.0020	0.0219	4.143
Aswan	7.6396	0.7173	-0.2133	0.0060	0.3212	2.955

Appendix 2B Continued

The Significant Constant Values in the Multiple Regression Equations for Maximum Temperature (Cotton Yield)

Variable Place	Constant (Ao)	Max. temp. (a_1)	Max. temp. x week (a_2)	Max. temp. x $week^2$ (a_3)	Year (M)
Alexandria	8.7392	5.1325	-0.8592	0.0271	-0.1104
Sig DF (4,10)		2.5%	2.5%	5%	5%
Tanta	26.4974	0.4658	-0.1169		
Sig DF (2,12)		5%	1%		
Minya	10.2262	0.2399	-0.0015		
Sig DF (2,12)		5%	5%		
Aswan	-42.7597	-1.4405		0.0102	0.3756
Sig DF (3,11)		5%		2.5%	1%

Appendix 2B Continued

The Significant Constant Values in the Multiple Regression Equations for Minimum Temperature (Cotton Yield)

Variable / Place	Constant (Ao)	Min. temp. (a_1)	Min. temp. x week (a_2)	Min. temp. x week^2 (a_3)	Year (M)
Alexandria	26.9645		0.3362	-0.0232	
Sig DF (2,12)			1%	2.5%	
Tanta	14.9261	0.4342	-0.0397		0.0547
Sig DF (3,11)		5%	2.5%		5%
Minya	14.0766	0.2083	-0.0328		
Sig DF (2,12)		5%	5%		
Aswan	-8.4867	-1.7531		0.0181	0.3097
Sig DF (3,11)		5%		2.5%	1%

Appendix 2B Continued

The Significant Constant Values in the Multiple Regression Equations for Relative Humidity (Cotton Yield)

Variable Place	Constant (Ao)	Rel. humid. (a_1)	Rel. humid. x week (a_2)	Rel. humid. x week^2 (a_3)	Year (M)
Alexandria	6.7669	-0.2374	0.0759		0.0638
Sig DF (3,11)		5%	5%		1%
Minya	7.0663	-0.1829	0.0116		
Sig DF (2,12)		2.5%	5%		
Aswan	-0.8992		0.0501		0.3105
Sig DF (2,12)			1%		0.1%

Appendix 2B Continued

The Significant Constant Values in the Multiple Regression Equations for Wind Speed (Cotton Yield)

Variable / Place	Constant (Ao)	Wind speed (a_1)	Wind speed x week (a_2)	Wind speed x week^2 (a_3)	Year (M)
Tanta	5.4845	1.9356	-0.1053		
Sig DF (2,12)		2.5%	2.5%		
Minya	5.5946		-0.4345	0.0227	0.0369
Sig DF (3,11)			2.5%	2.5%	5%

Appendix 2C

Distribution of Average Weekly Maximum and Minimum Daily Temperature, Average Daily Relative Humidity and Average Daily Wind Speed at Alexandria, Tanta, Minya for the period (1960-1974)

Wheat Yield

Week No.	Dates	Alexandria				Tanta			
		Max. temp. (°C)	Min. temp. (°C)	Rel. hum. (%)	Wind speed (knot)	Max. temp. (°C)	Min. temp. (°C)	Rel. hum. (%)	Wind speed (knot)
1	Nov 10-16	24.3	14.2	66.4	5.6	25.4	12.2	74.4	2.4
2	Nov 17-23	24.5	13.9	66.0	5.5	25.1	12.2	76.9	5.2
3	Nov 24-30	23.2	13.2	67.2	6.8	23.8	11.5	76.4	4.6
4	Dec 1-7	22.5	11.7	67.7	7.5	23.1	9.9	72.3	3.7
5	Dec 8-14	21.3	10.7	68.5	9.4	21.3	10.0	73.6	3.7
6	Dec 15-21	20.3	9.9	65.0	10.7	21.0	9.5	72.0	5.3
7	Dec 22-28	19.3	10.0	70.0	8.6	19.6	7.6	74.0	5.0
8	Dec 29-Jan 4	19.2	9.7	71.1	11.3	19.8	7.4	75.0	5.7
9	Jan 5-11	19.8	9.6	75.2	7.8	20.6	7.1	71.2	2.5
10	Jan 12-18	18.4	9.5	75.1	11.1	19.0	7.2	71.8	2.7
11	Jan 19-25	17.3	8.9	71.4	9.0	18.1	7.2	68.6	3.6
12	Jan 26-Feb 1	17.3	9.2	68.8	10.8	17.9	6.3	70.7	2.8
13	Feb 2-8	18.0	9.5	69.5	10.2	18.9	5.8	70.0	3.3
14	Feb 9-15	18.5	10.3	73.0	8.5	20.5	6.5	71.4	2.2
15	Feb 16-22	19.6	9.9	68.0	9.7	21.6	7.5	71.2	2.9
16	Feb 23-Mar 1	19.4	10.4	68.9	9.1	21.2	7.4	71.3	3.3
17	Mar 2-8	20.4	10.8	68.1	11.2	23.2	8.5	64.7	3.9
18	Mar 9-15	20.4	11.7	69.3	9.7	23.3	9.0	68.3	4.9
19	Mar 16-22	21.5	11.9	65.7	9.7	23.1	9.5	65.7	4.4
20	Mar 23-29	20.7	12.1	68.5	9.1	22.1	8.7	69.6	5.9
21	Mar 30-Apr 5	22.6	13.6	68.3	9.9	24.6	10.0	67.7	5.1
22	Apr 6-12	23.9	13.2	65.7	9.0	25.2	10.1	66.5	5.1
23	Apr 13-19	24.6	14.3	62.8	9.9	28.1	12.0	63.0	4.9
24	Apr 20-26	23.3	14.6	63.8	10.9	26.3	11.5	64.7	4.1
25	Apr 27-May 3	24.5	15.3	65.1	8.8	28.3	12.4	61.0	4.5
26	May 4-10	24.7	15.6	67.3	9.4	29.0	12.8	58.4	4.3

Appendix 2C Continued

Week No.	Dates	Minya				Aswan			
		Max. temp. (°C)	Min. temp. (°C)	Rel. hum. (%)	Wind speed (knot)	Max. temp. (°C)	Min. temp. (°C)	Rel. hum. (%)	Wind speed (knot)
1	Nov 10-16	26.7	13.4	55.4	4.6	30.8	13.6	31.6	6.4
2	Nov 17-23	26.3	12.4	60.9	4.8	29.4	12.9	36.7	7.4
3	Nov 24-30	25.6	12.0	61.7	4.6	28.5	13.5	40.6	7.8
4	Dec 1-7	24.8	9.0	62.9	3.3	26.1	10.7	38.6	7.6
5	Dec 8-14	23.0	8.6	61.4	3.8	25.6	10.3	41.0	7.5
6	Dec 15-21	22.3	8.3	60.3	3.5	24.9	9.2	43.2	7.5
7	Dec 22-28	20.4	6.4	64.5	4.8	24.1	7.6	44.6	8.4
8	Dec 29-Jan 4	20.3	6.5	63.8	3.7	23.1	7.0	43.7	7.1
9	Jan 5-11	21.0	6.1	63.3	4.1	24.4	8.1	38.9	6.6
10	Jan 12-18	20.6	5.3	61.7	3.5	23.1	7.5	39.6	6.6
11	Jan 19-25	19.8	5.2	56.5	4.3	22.9	6.9	41.2	8.0
12	Jan 26-Feb 1	18.9	5.0	59.8	4.0	22.1	6.5	41.0	8.2
13	Feb 2-8	20.2	4.5	55.2	5.1	23.0	6.2	40.4	8.5
14	Feb 9-15	22.5	5.4	53.9	4.1	25.0	8.3	38.1	8.5
15	Feb 16-22	23.4	5.5	52.2	5.6	26.9	9.2	35.8	9.5
16	Feb 23-Mar 1	23.1	6.8	52.7	4.7	27.4	9.7	32.2	8.6
17	Mar 2-8	25.4	7.8	50.0	5.0	29.1	10.9	29.9	8.5
18	Mar 9-15	25.3	8.3	49.0	5.4	30.4	12.0	26.1	8.8
19	Mar 16-22	25.9	9.5	46.9	6.2	29.3	12.9	25.6	9.2
20	Mar 23-29	24.8	8.9	49.3	6.2	28.9	11.8	24.9	9.4
21	Mar 30-Apr 5	27.7	9.5	47.7	6.2	32.0	14.0	22.8	9.2
22	Apr 6-12	28.1	10.9	44.9	6.6	34.1	15.7	21.5	9.7
23	Apr 13-19	31.0	12.9	38.0	7.2	35.8	16.8	21.8	11.4
24	Apr 20-26	30.0	13.9	39.6	7.5	35.4	17.8	22.3	8.3
25	Apr 27-May 3	30.9	14.0	39.1	6.6	36.7	18.0	19.9	8.8
26	May 4-10	32.0	15.1	38.1	6.5	36.2	18.9	19.5	9.1

Appendix 2D

The Constant Values in the Multiple Regression Equations for Maximum Temperature (Wheat Yield)

Variable / Place	Constant (Ao)	Max. temp. (a_1)	Max. temp. x week (a_2)	Max. temp. x week^2 (a_3)	Year (M)	F "test" value
Alexandria	10.4977	3.0569	-0.5074	0.0144	0.0739	3.949
Tanta	29.8451	-1.4511	0.0717	-0.0021	0.1360	7.427
Minya	12.3788	0.1952	-0.1114	0.0047	0.1073	7.795
Aswan	12.0758	-0.2032	-0.1068	0.0056	0.0362	7.242

The Constant Values in the Multiple Regression Equations for Minimum Temperature (Wheat Yield)

Variable / Place	Constant (Ao)	Min. temp. (a_1)	Min. temp. x week (a_2)	Min. temp. x week^2 (a_3)	Year (M)	F "test" value
Alexandria	14.5405	-0.8565	0.4614	-0.0251	0.1264	3.990
Tanta	10.9805	-0.6431	-0.0334	0.0027	0.1497	5.311
Minya	6.5171	0.1204	-0.0413	0.0024	0.1189	6.016
Aswan	5.7921	0.0029	-0.0872	0.0043	0.0553	3.953

Appendix 2D Continued

The Constant Values in the Multiple Regression Equations for Relative Humidity (Wheat Yield)

Variable / Place	Constant (Ao)	Rel. humid. (a_1)	Rel. humid. x week (a_2)	Rel. humid. x $week^2$ (a_3)	Year (M)	F "test" value
Alexandria	8.8136	-0.2589	0.0510	-0.0021	-0.0084	3.806
Tanta	6.7586	-0.2025	0.0469	-0.0018	0.1752	4.386
Minya	7.4398	0.0230	0.0043	-0.0003	0.1043	6.302
Aswan	1.6169	0.4098	-0.0627	0.0023	0.0743	14.565

The Constant Values in the Multiple Regression Equations for Wind Speed (Wheat Yield)

Variable / Place	Constant (Ao)	Wind speed (a_1)	Wind speed x week (a_2)	Wind speed x $week^2$ (a_3)	Year (M)	F "test" value
Alexandria	3.9405	0.2678	-0.1166	0.0023	0.3831	4.713
Tanta	7.4746	0.0396	-0.0144	0.0007	0.2088	5.428
Minya	8.3037	0.3179	-0.1029	0.0044	0.1048	6.473
Aswan	5.8759	0.3695	-0.0731	0.0022	0.0691	3.987

Appendix 2D Continued

The Significant Constant Values in the Multiple Regression Equations for Maximum Temperature (Wheat Yield)

Variable / Place	Constant (Ao)	Max. temp. (a_1)	Max. temp. x week (a_2)	Max. temp. x week^2 (a_3)	Year (M)
Alexandria	25.9927		0.0737		
Sig DF (1,13)			2.5%		
Tanta	7.0419		0.5604		0.1399
Sig DF (2,12)			1%		2.5%
Minya	15.2239		-0.1159	0.0052	0.0946
Sig DF (3,11)			5%	5%	0.1%
Aswan	14.2833	-0.8062		0.0018	0.0434
Sig DF (3,11)		0.01%		2.5%	5%

Appendix 2D Continued

The Significant Constant Values in the Multiple Regression Equations for Minimum Temperature (Wheat Yield)

Variable / Place	Constant (Ao)	Min. temp. (a_1)	Min. temp. x week (a_2)	Min. temp. x week^2 (a_3)	Year (M)
Alexandria	13.5191		-0.3299	0.0189	0.1505
Sig DF (3,11)			5%	2.5%	5%
Tanta	11.2980	-0.3231	0.0316		0.1458
Sig DF (3,11)		2.5%	5%		1%
Minya	6.6537	-0.2718	0.0188		0.1223
Sig DF (3,11)		5%	5%		0.01%
Aswan	6.9770	-0.3372		0.0006	0.0560
Sig DF (3,11)		5%		5%	2.5%

Appendix 2D Continued

The Significant Constant Values in the Multiple Regression Equations for Relative Humidity (Wheat Yield)

Variable / Place	Constant (Ao)	Rel. humid. (a_1)	Rel. humid. x week (a_2)	Rel. humid. x week^2 (a_3)	Year (M)
Alexandria	8.4565		-0.0424		
Sig DF (1,13)			5%		
Tanta	5.7629		-0.0514		0.1806
Sig DF (2,12)			5%		0.01%
Minya	7.5133	-0.0295	0.2816		0.1113
Sig DF (3,11)		1%	5%		0.01%
Aswan	1.6169	0.4098	-0.0627	0.0023	0.0743
Sig DF (4,10)		1%	2.5%	5%	5%

Appendix 2D Continued

The Significant Constant Values in the Multiple Regression Equations for Wind Speed (Wheat Yield)

Variable / Place	Constant (Ao)	Wind speed (a_1)	Wind speed x week (a_2)	Wind speed x week^2 (a_3)	Year (M)
Alexandria	3.9405	0.2678	-0.1166	0.0023	0.3831
Sig DF (4,10)		2.5%	5%	5%	5%
Tanta	7.5059		0.0321		0.2084
Sig DF (2,12)			5%		0.01%
Minya	8.32286		0.1196		0.1212
Sig DF (2,12)			2.5%		0.01%
Aswan	6.1149	0.3289	-0.0089		
Sig DF (2,12)		2.5%	5%		

Appendix 2E

The Constant Values in Multiple Regression Equations for Maximum Temperature (Maize Yield)

Variable / Place	Constant (Ao)	Max. temp. (a_1)	Max. temp. x week (a_2)	Max. temp. x week^2 (a_3)	Year (M)	F "test" value
Alexandria	27.437	-3.488	0.537	-0.020	-0.059	3.928
Tanta	16.931	-1.366	-0.205	0.028	0.201	3.658
Minya	31.468	-0.671	-0.373	0.032	0.216	3.646
Aswan	0.633	-0.318	0.047	-0.004	0.308	4.836

The Constant Values in Multiple Regression Equations for Minimum Temperature (Maize Yield)

Variable / Place	Constant (Ao)	Min. temp. (a_1)	Min. temp. x week (a_2)	Min. temp. x week^2 (a_3)	Year (M)	F "test" value
Alexandria	29.938	1.948	-0.435	0.011	-0.112	3.836
Tanta	6.382	0.746	-0.693	0.053	0.174	3.801
Minya	2.408	-3.378	0.068	0.028	0.180	3.689
Aswan	4.784	0.869	-0.115	0.014	0.289	4.488

Appendix 2E Continued

The Constant Values in Multiple Regression Equations for Relative Humidity (Maize Yield)

Variable Place	Constant (Ao)	Rel. humid. (a_1)	Rel. humid. x week (a_2)	Rel. humid. x week^2 (a_3)	Year (M)	F "test" value
Alexandria	10.650	0.182	-0.078	0.005	-0.125	3.142
Tanta	11.545	-1.247	0.320	-0.016	0.357	3.806
Minya	10.371	0.399	-0.123	0.007	0.217	3.264
Aswan	2.570	1.030	-0.299	0.016	0.372	3.836

The Constant Values in Multiple Regression Equations for Wind Speed (Maize Yield)

Variable Place	Constant (Ao)	Wind speed (a_1)	Wind speed x week (a_2)	Wind speed x week^2 (a_3)	Year (M)	F "test" value
Alexandria	8.027	1.114	-0.262	0.011	-0.034	3.538
Tanta	11.023	0.771	-0.531	0.041	0.204	3.853
Minya	13.391	0.565	-0.102	-0.003	0.204	3.603
Aswan	4.490	-1.081	0.288	-0.016	0.325	4.657

Appendix 2E Continued

The Constant Values in Multiple Regression Equations for Maximum Temperature (Rice Yield)

Variable Place	Constant (Ao)	Max. temp. (a_1)	Max. temp. x week (a_2)	Max. temp. x week^2 (a_3)	Year (M)	F "test" value
Alexandria	-2.4585	-0.8802	0.2162	-0.0085	0.0071	3.673
Tanta	2.9915	-0.3507	0.1669	-0.0094	0.0161	3.504
Minya	1.3612	0.7961	-0.1299	0.0045	0.0390	3.807

The Constant Values in Multiple Regression Equations for Minimum Temperature (Rice Yield)

Variable Place	Constant (Ao)	Min. temp. (a_1)	Min. temp. x week (a_2)	Min. temp. x week^2 (a_3)	Year (M)	F "test" value
Alexandria	6.7974	-0.3665	0.1414	-0.0087	0.0239	3.975
Tanta	1.2319	-0.2071	0.0918	-0.0048	0.0305	3.763
Minya	3.6621	0.8527	-0.1248	0.0032	0.0171	3.816

Appendix 2E Continued

The Constant Values in Multiple Regression Equations for Relative Humidity (Rice Yield)

Variable / Place	Constant (Ao)	Rel. humid. (a_1)	Rel. humid. x week (a_2)	Rel. humid$_2$ x week^2 (a_3)	Year (M)	F "test" value
Alexandria	1.7758	0.2497	-0.0589	0.0025	0.0053	4.995
Tanta	2.0533	-0.0831	0.0123	-0.0004	0.0236	4.790
Minya	2.7822	-0.2657	0.0261	-0.0003	0.0234	3.913

The Constant Values in Multiple Regression Equations for Wind Speed (Rice Yield)

Variable / Place	Constant (Ao)	Wind speed (a_1)	Wind speed x week (a_2)	Wind speed$_2$ x week^2 (a_3)	Year (M)	F "test" value
Alexandria	1.7788	-0.1065	0.0026	0.0003	0.0221	3.433
Tanta	1.9909	0.6015	-0.1159	0.0041	0.0266	3.906
Minya	2.0459	-0.7534	0.1495	-0.0049	0.0288	3.525

Appendix 2E Continued

The Constant Values in Multiple Regression Equations for Maximum Temperature (Sugar cane Yield)

Variable / Place	Constant (Ao)	Max. temp. (a_1)	Max. temp. x week (a_2)	Max. temp. x week^2 (a_3)	Year (M)	F "test" value
Alexandria	1473.350	170.6006	-13.5645	0.1763	4.2365	6.731
Tanta	678.2463	-19.7890	1.3369	-0.2551	2.8138	4.223
Minya	178.2693	323.0782	-34.0076	0.6708	11.4891	8.037
Aswan	1110.780	23.3082	1.6809	-0.8089	-10.7679	8.934

The Constant Values in Multiple Regression Equations for Minimum Temperature (Sugar cane Yield)

Variable / Place	Constant (Ao)	Min. temp. (a_1)	Min. temp. x week (a_2)	Min. temp. x week^2 (a_3)	Year (M)	F "test" value
Alexandria	893.1973	-35.6544	4.4934	-0.9469	7.4265	4.880
Tanta	551.0818	-9.6271	1.3465	-0.3432	2.2581	3.778
Minya	425.0910	195.3061	-15.0621	0.2694	10.9192	6.478
Aswan	1013.227	41.4638	-7.0561	0.1605	-8.9045	5.352

Appendix 2E Continued

The Constant Values in Multiple Regression Equations for Relative Humidity (Sugar cane Yield)

Variable / Place	Constant (Ao)	Rel. humid. (a_1)	Rel. humid. x week (a_2)	Rel. humid x week^2 (a_3)	Year (M)	F "test" value
Alexandria	294.6019	-21.8071	1.7543	-0.1126	9.8794	3.882
Tanta	517.6520	5.4517	-0.5208	0.8405	2.8297	3.326
Minya	632.5716	-25.0519	1.6198	-0.1534	6.0612	4.637
Aswan	919.0894	16.7893	-1.0608	0.1226	-10.2702	4.164

The Constant Values in Multiple Regression Equations for Wind Speed (Sugar cane Yield)

Variable / Place	Constant (Ao)	Wind speed (a_1)	Wind speed x week (a_2)	Wind speed x week^2 (a_3)	Year (M)	F "test" value
Alexandria	611.2466	127.1059	-8.8773	0.1098	7.0512	3.386
Tanta	473.6182	8.7611	-0.3999	0.4700	2.7846	5.481
Minya	869.1081	109.8504	-10.0399	0.1535	8.9442	3.119
Aswan	776.8877	-16.5687	2.0912	-0.1867	-12.0490	5.808

APPENDIX 3

Containing a Complete Example for the Multiple Regression Equations for Maximum Temperature at Alexandria

1 - Daily Maximum Temperatures at Alexandria (1960-1974)

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******************** MAXIMUM TEMPERATURE AT ALEXANDRIA (1960-1974)*********
********* ALEXANDRIA MAXIMUM TEMPERATURE 1960 *****************
21.0 19.0 21.0 19.0 17.0 16.0 18.0 18.0 17.0 15.0 15.0 16.0 16.0 19.0ALEXMX60JA
22.0 17.0 14.0 17.0 16.0 18.0 19.0 19.0 18.0 20.0 17.0 19.0 19.0 22.0ALEXMX60JA
20.0 19.0 19.0                                                       ALEXMX60JA
22.0 22.0 22.0 22.0 18.0 19.0 17.0 20.0 23.0 23.0 18.0 17.0 17.0 19.0ALEXMX60FB
20.0 19.0 21.0 22.0 19.0 19.0 19.0 20.0 18.0 18.0 20.0 18.0 18.0 20.0ALEXMX60FB
20.0 20.0 19.0 21.0 20.0 22.0 20.0 22.0 20.0 19.0 15.0 14.0 16.0 17.0ALEXMX60MA
17.0 18.0 17.0 23.0 20.0 18.0 21.0 20.0 19.0 19.0 20.0 18.0 19.0 18.0ALEXMX60MA
19.0 20.0 25.0                                                       ALEXMX60MA
28.0 19.0 28.0 35.0 38.0 38.0 23.0 25.0 22.0 22.0 24.0 21.0 22.0 20.0ALEXMX60AP
19.0 21.0 24.0 27.0 22.0 21.0 21.0 20.0 24.0 24.0 25.0 23.0 23.0 23.0ALEXMX60AP
33.0 34.0                                                            ALEXMX60AP
35.0 37.0 30.0 23.0 31.0 24.0 30.0 22.0 23.0 23.0 30.0 29.0 28.0 29.0ALEXMX60MY
25.0 23.0 24.0 32.0 33.0 31.0 32.0 25.0 23.0 30.0 30.5 24.0 25.0 24.0ALEXMX60MY
25.0 29.0 38.0                                                       ALEXMX60MY
28.0 24.0 25.0 26.0 27.0 27.0 37.0 30.0 27.0 26.0 27.0 26.0 25.0 29.0ALEXMX60JU
26.0 25.0 29.0 27.0 28.0 27.0 26.0 26.0 26.0 26.0 26.0 26.0 25.0 28.0ALEXMX60JU
29.0 28.0                                                            ALEXMX60JU
30.0 29.0 29.0 30.0 30.0 31.0 30.0 26.0 26.0 28.0 27.0 28.0 30.0 30.0ALEXMX60JL
30.0 28.0 29.0 28.0 28.0 31.0 33.0 33.0 30.0 30.0 29.0 30.0 31.0 30.0ALEXMX60JL
32.0 29.0 30.0                                                       ALEXMX60JL
30.0 31.0 30.0 31.0 31.0 31.0 31.0 31.0 30.0 29.0 32.0 32.0 30.0 31.0ALEXMX60AG
30.0 30.0 30.0 29.0 30.0 29.0 30.0 32.0 31.0 31.0 30.0 31.0 30.0 29.0ALEXMX60AG
28.0 28.0 30.0                                                       ALEXMX60AG
30.0 30.0 28.0 29.0 28.0 29.0 30.0 30.0 30.0 31.0 32.0 35.0 38.0 38.0ALEXMX60SP
29.0 30.0 30.0 29.0 30.0 28.0 29.0 29.0 27.0 30.0 29.0 29.0 27.0 28.0ALEXMX60SP
28.0 30.0                                                            ALEXMX60SP
29.0 27.0 28.0 28.0 27.0 27.0 30.0 27.0 26.0 28.0 29.0 26.0 29.0 27.0ALEXMX60OC
29.0 27.0 30.0 28.0 24.0 28.0 30.0 30.0 32.0 26.0 27.0 30.0 29.0 26.0ALEXMX60OC
25.0 24.0 23.0                                                       ALEXMX60OC
25.0 27.0 30.0 29.0 26.0 24.0 24.0 20.0 22.0 21.0 23.0 26.0 20.0 22.0ALEXMX60NO
25.0 26.0 30.0 29.0 23.0 23.0 25.0 26.0 23.0 21.0 20.0 19.0 18.0 19.0ALEXMX60NO
22.0 20.0                                                            ALEXMX60NO
20.0 24.0 21.0 21.0 20.0 20.0 20.0 23.0 22.0 22.0 22.0 22.0 21.0 19.0ALEXMX60DC
21.0 22.0 22.0 18.0 19.0 22.0 22.0 18.0 18.0 16.0 18.0 21.0 20.0 20.0ALEXMX60DC
23.0 26.0 21.0                                                       ALEXMX60DC
```

Alex = Alexandria
Mx = Maximum temperature
60 = 1960
JA = January
FB = February
MA = March
AP = April
MY = May
JU = June
JL = July
AG = August
SP = September
OC = October
NO = November
DC = December

```
********** ALEXANDRIA MAXIMUM TEMPERATURE 1961 ******************
21.0 20.0 20.0 20.0 21.0 21.0 21.0 21.0 18.0 20.0 19.0 17.0 19.0 19.0ALEXMX61JA
19.0 17.0 16.0 14.0 13.0 10.0 16.0 17.0 17.0 17.0 14.0 12.0 16.0 18.0ALEXMX61JA
18.0 18.0 19.0                                                        ALEXMX61JA
17.0 15.0 13.0 16.0 18.0 18.0 21.0 16.0 16.0 12.0 11.0 15.0 18.0 18.0ALEXMX61FB
18.0 19.0 15.0 15.0 17.0 21.0 22.0 22.0 15.0 17.0 19.0 17.0 18.0 18.0ALEXMX61FB
17.0 17.0 18.0 23.0 18.0 17.0 18.0 20.0 19.0 17.0 19.0 21.0 20.0 20.0ALEXMX61MA
21.0 23.0 27.0 21.0 21.0 21.0 18.0 19.0 23.0 25.0 20.0 21.0 20.0 20.0ALEXMX61MA
19.0 21.0 22.0                                                        ALEXMX61MA
19.0 20.0 21.0 31.0 26.0 35.0 29.0 24.0 27.0 28.0 28.0 30.0 21.0 21.0ALEXMX61AP
24.0 24.0 18.0 21.0 21.0 22.0 20.0 22.0 22.0 24.0 25.0 22.0 22.0 22.0ALEXMX61AP
28.0 22.0                                                             ALEXMX61AP
23.0 22.0 23.0 23.0 23.0 25.0 28.0 32.0 23.0 24.0 31.0 24.0 23.0 30.0ALEXMX61MA
30.0 27.0 25.0 26.0 29.0 29.0 30.0 37.0 38.0 26.0 24.0 25.0 23.0 24.0ALEXMX61MA
25.0 25.0 27.0                                                        ALEXMX61MA
31.0 39.0 31.0 23.0 24.0 26.0 26.0 26.0 26.0 25.0 26.0 25.0 29.0 26.0ALEXMX61JU
26.0 29.0 27.0 24.0 26.0 26.0 27.0 28.0 28.0 27.0 27.0 28.0 28.0 30.0ALEXMX61JU
31.0 28.0                                                             ALEXMX61JU
27.0 27.0 27.0 28.0 29.0 28.0 28.0 27.0 27.0 27.0 28.0 28.0 27.0 28.0ALEXMX61JL
30.0 29.0 29.0 29.0 28.0 29.0 29.0 29.0 28.0 30.0 29.0 27.0 30.0 29.0ALEXMX61JL
30.0 29.0 29.0                                                        ALEXMX61JL
28.0 30.0 29.0 31.0 30.0 30.0 30.0 30.0 29.0 30.0 31.0 30.0 29.0 30.0ALEXMX61AG
30.0 30.0 30.0 30.0 29.0 30.0 29.0 30.0 31.0 30.0 33.0 31.0 32.0 32.0ALEXMX61AG
31.0 29.0 28.0                                                        ALEXMX61AG
31.0 31.0 30.0 29.0 30.0 31.0 31.0 30.0 29.0 28.0 30.0 31.0 27.0 28.0ALEXMX61SP
30.0 28.0 27.0 28.0 29.0 28.0 28.0 28.0 28.0 29.0 31.0 29.0 30.0 31.0ALEXMX61SP
30.0 30.0                                                             ALEXMX61SP
27.0 27.0 27.0 28.0 27.0 27.0 28.0 28.0 27.0 27.0 29.0 29.0 32.0 29.0ALEXMX61OC
29.0 29.0 27.0 27.0 27.0 26.0 25.0 24.0 27.0 24.0 25.0 25.0 27.0 27.0ALEXMX61OC
25.0 24.0 27.0                                                        ALEXMX61OC
24.0 25.0 25.0 29.0 25.0 24.0 24.0 24.0 25.0 20.0 23.0 25.0 25.0 26.0ALEXMX61NO
24.0 27.0 26.0 24.0 24.0 25.0 26.0 24.0 25.0 23.0 24.0 25.0 25.0 23.0ALEXMX61NO
22.0 23.0                                                             ALEXMX61NO
24.0 26.0 23.0 24.0 23.0 24.0 23.0 22.0 21.0 23.0 23.0 24.0 20.0 21.0ALEXMX61DC
21.0 21.0 23.0 22.0 22.0 18.0 19.0 18.0 19.0 18.0 16.0 19.0 18.0 18.0ALEXMX61DC
17.0 16.0 16.0                                                        ALEXMX61DC
```

```
********* ALEXANDRIA MAXIMUM TEMPERATURE 1962 *****************
22.0 21.0 21.0 21.0 21.0 22.0 18.0 20.0 19.0 18.0 18.0 19.0 19.0 19.0ALEXMX62JA
17.0 14.0 14.0 10.0 17.0 15.0 17.0 17.0 14.0 14.0 16.0 18.0 18.0 19.0ALEXMX62JA
20.0 18.0 19.0                                                       ALEXMX62JA
18.0 15.0 14.0 16.0 19.0 18.0 22.0 16.0 17.0 12.0 12.0 15.0 18.0 19.0ALEXMX62FB
19.0 19.0 16.0 17.0 25.0 22.0 23.0 15.0 17.0 19.0 17.0 18.0 18.0 20.0ALEXMX62FB
19.0 18.0 18.0 23.0 18.0 17.0 18.0 20.0 19.0 19.0 15.0 19.0 21.0 22.0ALEXMX62MA
31.0 22.0 27.0 21.0 22.0 21.0 18.0 18.0 23.0 25.0 20.0 21.0 22.0 20.0ALEXMX62MA
20.0 21.0 22.0                                                       ALEXMX62MA
21.0 20.0 22.0 31.0 26.0 30.0 29.0 25.0 27.0 28.0 28.0 29.0 21.0 23.0ALEXMX62AP
20.0 22.0 18.0 23.0 21.0 22.0 23.0 22.0 22.0 26.0 25.0 21.0 22.0 25.0ALEXMX62AP
23.0 22.0                                                            ALEXMX62AP
20.0 22.0 25.0 23.0 20.0 25.0 26.0 28.0 35.0 29.0 24.0 31.0 25.0 30.0ALEXMX62MY
33.0 27.0 25.0 29.0 29.0 30.0 35.0 33.0 29.0 24.0 25.0 25.0 24.0 26.0ALEXMX62MY
27.0 25.0 27.0                                                       ALEXMX62MY
29.0 30.0 31.0 25.0 24.0 26.0 26.0 29.0 25.0 26.0 26.0 25.0 29.0 25.0ALEXMX62JU
27.0 29.0 28.0 24.0 26.0 29.0 28.0 29.0 27.0 27.0 28.0 25.0 27.0 29.0ALEXMX62JU
30.0 29.0                                                            ALEXMX62JU
29.0 27.0 28.0 28.0 29.0 29.0 28.0 27.0 27.0 29.0 28.0 29.0 26.0 29.0ALEXMX62JL
29.0 29.0 28.0 28.0 29.0 27.0 29.0 28.0 32.0 30.0 29.0 28.0 27.0 26.0ALEXMX62JL
31.0 30.0 29.0                                                       ALEXMX62JL
29.0 28.0 29.0 32.0 31.0 32.0 32.0 29.0 30.0 30.0 29.0 31.0 30.0 27.0ALEXMX62AG
29.0 30.0 32.0 29.0 28.0 30.0 31.0 30.0 31.0 33.0 32.0 32.0 30.0 30.0ALEXMX62AG
29.0 29.0 28.0                                                       ALEXMX62AG
29.0 30.0 29.0 30.0 30.0 31.0 29.0 28.0 30.0 31.0 27.0 26.0 26.0 25.0ALEXMX62SP
31.0 28.0 28.0 28.0 29.0 29.0 28.0 30.0 28.0 28.0 29.0 29.0 31.0 30.0ALEXMX62SP
30.0 27.0                                                            ALEXMX62SP
29.0 27.0 28.0 31.0 29.0 27.0 28.0 29.0 27.0 27.0 30.0 29.0 32.0 30.0ALEXMX62OC
29.0 30.0 29.0 28.0 27.0 26.0 26.0 24.0 29.0 24.0 29.0 26.0 27.0 28.0ALEXMX62OC
26.0 25.0 27.0                                                       ALEXMX62OC
26.0 25.0 27.0 28.0 25.0 25.0 24.0 27.0 26.0 20.0 23.0 25.0 25.0 27.0ALEXMX62NO
25.0 28.0 25.0 24.0 24.0 24.0 28.0 26.0 24.0 25.0 25.0 24.0 25.0 26.0ALEXMX62NO
24.0 25.0                                                            ALEXMX62NO
25.0 26.0 24.0 25.0 23.0 24.0 25.0 22.0 22.0 21.0 23.0 22.0 20.0 21.0ALEXMX62DC
22.0 23.0 24.0 22.0 22.0 18.0 19.0 20.0 18.0 16.0 16.0 20.0 19.0 20.0ALEXMX62DC
19.0 18.0 16.0                                                       ALEXMX62DC
```

```
********* ALEXANDRIA MAXIMUM TEMPERATURE 1963 *****************
25.0 21.0 22.0 23.0 25.0 22.0 21.0 20.0 21.0 22.0 22.0 23.0 24.0 22.0ALEXMX63JA
21.0 20.0 19.0 17.0 20.0 23.0 22.0 24.0 20.0 20.0 16.0 12.0 12.0 17.0ALEXMX63JA
19.0 21.0 19.0                                                        ALEXMX63JA
19.0 20.0 20.0 23.0 25.0 25.0 27.0 20.0 20.0 19.0 18.0 19.0 23.0 25.0ALEXMX63FB
20.0 21.0 24.0 23.0 21.0 20.0 23.0 20.0 21.0 22.0 18.0 18.0 19.0 22.0ALEXMX63FB
23.0 22.0 20.0 17.0 17.0 18.0 18.0 18.0 18.0 18.0 22.0 22.0 22.0 22.0ALEXMX63MA
17.0 19.0 24.0 18.0 19.0 25.0 23.0 28.0 31.0 28.0 19.0 21.0 24.0 21.0ALEXMX63MA
21.0 21.0 25.0                                                        ALEXMX63MA
27.0 25.0 25.0 21.0 21.0 22.0 22.0 25.0 22.0 21.0 22.0 27.0 34.0 24.0ALEXMX63AP
26.0 26.0 22.0 25.0 29.0 24.0 32.0 24.0 21.0 22.0 24.0 26.0 23.0 23.0ALEXMX63AP
22.0 23.0                                                             ALEXMX63AP
23.0 24.0 28.0 24.0 22.0 25.0 24.0 24.0 24.0 24.0 29.0 26.0 25.0 23.0ALEXMX63MY
25.0 24.0 26.0 32.0 23.0 23.0 30.0 28.0 23.0 30.0 33.0 25.0 24.0 22.0ALEXMX63MY
24.0 30.0 29.0                                                        ALEXMX63MY
24.0 24.0 26.0 29.0 25.0 25.0 23.0 26.0 22.0 25.0 25.0 29.0 26.0 27.0ALEXMX63JU
27.0 22.0 36.0 23.0 26.0 29.0 28.0 28.0 27.0 27.0 27.0 30.0 28.0 28.0ALEXMX63JU
22.0 23.0                                                             ALEXMX63JU
26.0 27.0 28.0 30.0 31.0 31.0 31.0 30.0 31.0 30.0 32.0 32.0 30.0 31.0ALEXMX63JL
32.0 33.0 31.0 32.0 32.0 33.0 32.0 31.0 30.0 32.0 32.0 30.0 32.0 31.0ALEXMX63JL
31.0 29.0 29.0                                                        ALEXMX63JL
29.0 28.0 30.0 31.0 32.0 31.0 30.0 31.0 30.0 31.0 32.0 31.0 30.0 31.0ALEXMX63AG
36.0 40.0 36.0 38.0 40.0 36.0 34.0 36.0 32.0 33.0 34.0 34.0 30.0 30.0ALEXMX63AG
30.0 30.0 31.0                                                        ALEXMX63AG
31.0 32.0 30.0 30.0 31.0 32.0 31.0 30.0 31.0 32.0 31.0 32.0 30.0 32.0ALEXMX63SP
30.0 28.0 30.0 32.0 31.0 31.0 29.0 28.0 28.0 29.0 30.0 31.0 28.0 28.0ALEXMX63SP
28.0 29.0                                                             ALEXMX63SP
27.0 30.0 28.0 27.0 28.0 30.0 27.0 28.0 28.0 28.0 29.0 26.0 27.0 26.0ALEXMX63OC
28.0 30.0 27.0 27.0 27.0 28.0 28.0 28.0 30.0 26.0 24.0 26.0 24.0 26.0ALEXMX63OC
28.0 26.0 25.0                                                        ALEXMX63OC
25.0 26.0 26.0 27.0 29.0 27.0 26.0 26.0 26.0 26.0 24.0 25.0 24.0 25.0ALEXMX63NO
26.0 26.0 25.0 26.0 27.0 25.0 26.0 27.0 23.0 24.0 23.0 22.0 20.0 26.0ALEXMX63NO
24.0 22.0                                                             ALEXMX63NO
22.0 23.0 22.0 19.0 20.0 19.0 20.0 20.0 22.0 21.0 24.0 20.0 21.0 23.0ALEXMX63DC
20.0 20.0 21.0 21.0 23.0 22.0 19.0 18.0 18.0 16.0 16.0 17.0 18.0 19.0ALEXMX63DC
21.0 22.0 20.0                                                        ALEXMX63DC
```

```
********* ALEXANDRIA MAXIMUM TEMPERATURE 1964 *****************
20.0 21.0 21.0 18.0 19.0 19.0 17.0 17.0 18.0 19.0 19.0 16.0 16.0 15.0ALEXMX64JA
13.0 17.0 19.0 18.0 17.0 19.0 18.0 18.0 18.0 18.0 19.0 19.0 16.0 17.0ALEXMX64JA
16.0 18.0 17.0                                                       ALEXMX64JA
17.0 17.0 18.0 19.0 18.0 17.0 18.0 17.0 18.0 17.0 17.0 17.0 19.0 19.0ALEXMX64FB
21.0 20.0 20.0 18.0 18.0 16.0 15.0 16.0 16.0 17.0 18.0 18.0 19.0 19.0ALEXMX64FB
20.0 22.0 26.0 28.0 26.0 24.0 22.0 21.0 20.0 18.0 17.0 20.0 22.0 24.0ALEXMX64MA
28.0 27.0 23.0 23.0 21.0 20.0 17.0 22.0 21.0 20.0 20.0 21.0 22.0 20.0ALEXMX64MA
19.0 20.0 20.0                                                       ALEXMX64MA
25.0 21.0 21.0 35.0 22.0 28.0 23.0 20.0 22.0 20.0 22.0 20.0 22.0 21.0ALEXMX64AP
22.0 22.0 21.0 20.0 22.0 20.0 22.0 22.0 24.0 28.0 27.0 29.0 21.0 21.0ALEXMX64AP
19.0 22.0                                                            ALEXMX64AP
21.0 21.0 21.0 22.0 23.0 23.0 24.0 21.0 21.0 21.0 22.0 23.0 23.0 23.0ALEXMX64MY
24.0 24.0 26.0 29.0 29.0 25.0 24.0 25.0 27.0 25.0 25.0 29.0 37.0 38.0ALEXMX64MY
42.0 38.0 30.0                                                       ALEXMX64MY
25.0 28.0 36.0 27.0 31.0 31.0 38.0 27.0 28.0 30.0 41.0 27.0 27.0 28.0ALEXMX64JU
29.0 28.0 26.0 30.0 35.0 37.0 38.0 26.0 26.0 29.0 29.0 29.0 29.0 28.0ALEXMX64JU
29.0 28.0                                                            ALEXMX64JU
30.0 31.0 32.0 31.0 30.0 32.0 30.0 31.0 32.0 30.0 32.0 35.0 33.0 35.0ALEXMX64JL
33.0 31.0 33.0 32.0 32.0 32.0 31.0 30.0 32.0 32.0 30.0 32.0 30.0 31.0ALEXMX64JL
31.0 29.0 30.0                                                       ALEXMX64JL
28.0 30.0 30.0 29.0 30.0 30.0 30.0 29.0 30.0 29.0 31.0 32.0 31.0 30.0ALEXMX64AG
32.0 35.0 36.0 33.0 31.0 32.0 30.0 28.0 29.0 30.0 31.0 30.0 31.0 30.0ALEXMX64AG
30.0 31.0 30.0                                                       ALEXMX64AG
32.0 30.0 29.0 28.0 29.0 30.0 31.0 30.0 29.0 30.0 32.0 31.0 32.0 31.0ALEXMX64SP
29.0 28.0 32.0 34.0 33.0 32.0 31.0 30.0 29.0 30.0 30.0 31.0 30.0 31.0ALEXMX64SP
28.0 27.0                                                            ALEXMX64SP
26.0 28.0 30.0 27.0 28.0 30.0 27.0 28.0 27.0 28.0 28.0 26.0 27.0 26.0ALEXMX64OC
27.0 28.0 27.0 28.0 28.0 30.0 28.0 26.0 24.0 28.0 26.0 25.0 25.0 26.0ALEXMX64OC
24.0 25.0 26.0                                                       ALEXMX64OC
25.0 26.0 27.0 27.0 29.0 27.0 27.0 26.0 27.0 27.0 28.0 26.0 24.0 25.0ALEXMX64NO
26.0 25.0 25.0 26.0 25.0 26.0 24.0 23.0 22.0 20.0 22.0 23.0 24.0 20.0ALEXMX64NO
21.0 22.0                                                            ALEXMX64NO
24.0 23.0 22.0 19.0 19.0 20.0 20.0 20.0 22.0 21.0 24.0 20.0 20.0 19.0ALEXMX64DC
20.0 20.0 21.0 23.0 22.0 23.0 21.0 19.0 20.0 18.0 18.0 16.0 19.0 19.0ALEXMX64DC
21.0 22.0 20.0                                                       ALEXMX64DC
```

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********* ALEXANDRIA MAXIMUM TEMPERATURF 1965 *****************
17.0 17.0 18.0 19.0 17.0 17.0 16.0 18.0 20.0 20.0 19.0 19.0 17.0 19.0ALEXMX65JA
18.0 18.0 19.0 17.0 18.0 18.0 18.0 20.0 19.0 20.0 18.0 18.0 18.0 16.0ALEXMX65JA
18.0 18.0 17.0                                                       ALEXMX65JA
19.0 20.0 16.0 13.0 15.0 18.0 18.0 15.0 16.0 24.0 19.0 18.0 16.0 17.0ALEXMX65FB
17.0 21.0 20.0 18.0 18.0 22.0 23.0 17.0 18.0 18.0 23.0 19.0 26.0 19.0ALEXMX65FB
18.0 18.0 23.0 23.0 29.0 24.0 21.0 23.0 20.0 18.0 19.0 18.0 18.0 18.0ALEXMX65MA
19.0 23.0 26.0 20.0 23.0 26.0 21.0 18.0 20.0 20.0 24.0 18.0 20.0 24.0ALEXMX65MA
24.0 19.0 20.0                                                       ALEXMX65MA
20.0 20.0 16.0 16.0 20.0 25.0 26.0 34.0 34.0 32.0 19.0 19.0 25.0 30.0ALEXMX65AP
21.0 20.0 23.0 19.0 22.0 28.0 33.0 39.0 20.0 23.0 24.0 20.0 21.0 20.0ALEXMX65AP
21.0 21.0                                                            ALFXMX65AP
21.0 22.0 23.0 21.0 22.0 20.0 22.0 20.0 20.0 22.0 33.0 22.0 20.0 20.0ALFXMX65MY
20.0 22.0 21.0 22.0 23.0 26.0 26.0 24.0 28.0 29.0 23.0 24.0 25.0 31.0ALEXMX65MY
35.0 30.0 30.0                                                       ALEXMX65MY
28.0 28.0 33.0 22.0 23.0 30.0 29.0 28.0 28.0 28.0 28.0 26.0 26.0 27.0ALEXMX65JU
27.0 28.0 28.0 28.0 26.0 28.0 28.0 28.0 27.0 28.0 28.0 28.0 22.0 29.0ALEXMX65JU
28.0 29.0                                                            ALEXMX65JU
30.0 30.0 29.0 28.0 28.0 27.0 29.0 30.0 29.0 29.0 28.0 26.0 26.0 25.0ALEXMX65JL
28.0 29.0 30.0 32.0 33.0 35.0 33.0 33.0 32.0 30.0 30.0 31.0 31.0 30.0ALEXMX65JL
31.0 31.0 32.0                                                       ALFXMX65JL
32.0 31.0 30.0 30.0 30.0 31.0 30.0 30.0 31.0 31.0 30.0 30.0 31.0 31.0ALEXMX65AG
30.0 29.0 28.0 29.0 28.0 27.0 29.0 31.0 30.0 29.0 29.0 28.0 29.0 31.0ALEXMX65AG
30.0 32.0 30.0                                                       ALEXMX65AG
30.0 30.0 31.0 32.0 30.0 30.0 29.0 29.0 28.0 29.0 30.0 31.0 30.0 29.0ALFXMX65SP
27.0 28.0 29.0 30.0 31.0 31.0 29.0 28.0 30.0 30.0 30.0 32.0 31.0 30.0ALEXMX65SP
29.0 28.0                                                            ALEXMX65SP
28.0 30.0 29.0 28.0 29.0 29.0 28.0 28.0 25.0 25.0 28.0 30.0 31.0 29.0ALEXMX65OC
28.0 27.0 26.0 27.0 27.0 28.0 28.0 26.0 27.0 28.0 27.0 28.0 27.0 29.0ALEXMX65OC
30.0 31.0 30.0                                                       ALEXMX65OC
29.0 27.0 25.0 24.0 22.0 25.0 23.0 21.0 20.0 20.0 22.0 21.0 23.0 24.0ALEXMX65NO
26.0 24.0 24.0 25.0 22.0 26.0 23.0 23.0 22.0 23.0 21.0 22.0 21.0 20.0ALEXMX65NO
20.0 22.0                                                            ALEXMX65NO
20.0 23.0 22.0 21.0 23.0 22.0 23.0 24.0 22.0 23.0 22.0 21.0 22.0 23.0ALEXMX65DC
21.0 18.0 19.0 19.0 20.0 20.0 19.0 20.0 19.0 20.0 21.0 20.0 19.0 20.0ALEXMX65DC
21.0 21.0 20.0                                                       ALEXMX65DC
```

```
********** ALEXANDRIA MAXIMUM TEMPERATURE 1966 *****************
19.0 18.0 19.0 22.0 21.0 19.0 18.0 18.0 17.0 15.0 16.0 18.0 19.0 19.0ALEXMX66JA
18.0 14.0 18.0 14.0 15.0 14.0 17.0 17.0 14.0 17.0 15.0 13.0 17.0 16.0ALEXMX66JA
18.0 19.0 16.0                                                        ALEXMX66JA
17.0 15.0 16.0 17.0 16.0 18.8 19.8 23.0 21.0 14.0 19.0 18.0 19.0 19.0ALEXMX66FB
20.0 22.0 20.0 19.0 19.0 20.0 21.0 19.0 24.0 20.0 20.0 19.0 20.0 20.0ALEXMX66FB
20.0 20.0 19.0 18.0 17.0 18.0 19.0 20.0 23.0 21.0 22.0 22.0 25.0 20.0ALEXMX66MA
25.0 22.0 21.0 20.0 19.0 18.0 20.0 19.0 20.0 21.0 20.0 20.0 21.0 28.0ALEXMX66MA
32.0 21.0 25.0                                                        ALEXMX66MA
35.0 21.0 20.0 20.0 21.0 23.0 22.0 30.0 31.0 20.0 19.0 20.0 23.0 35.0ALEXMX66AP
25.0 29.0 26.0 24.0 28.0 25.0 24.0 25.0 22.0 22.0 20.0 30.0 24.0 22.0ALEXMX66AP
23.0 24.0                                                             ALEXMX66AP
37.0 23.0 23.0 24.0 24.0 28.0 24.0 25.0 30.0 31.0 22.0 23.0 23.0 24.0ALEXMX66MY
25.0 35.0 38.0 32.0 38.0 24.0 24.0 26.0 29.0 28.0 25.0 24.0 24.0 23.0ALEXMX66MY
25.0 28.0 24.0                                                        ALEXMX66MY
27.0 29.0 29.0 27.0 27.0 27.0 26.0 28.0 27.0 26.0 28.0 28.0 34.0 28.0ALEXMX66JU
28.0 27.0 28.0 32.0 37.0 28.0 29.0 27.0 26.0 28.0 30.0 30.0 28.0 28.0ALEXMX66JU
29.0 34.0                                                             ALEXMX66JU
29.0 28.0 30.0 28.0 28.0 28.0 30.0 30.0 30.0 32.0 28.0 30.0 28.0 28.0ALEXMX66JL
30.0 30.0 30.0 31.0 32.0 31.0 32.0 32.0 24.0 27.0 31.0 30.0 30.0 30.0ALEXMX66JL
31.0 30.6 31.0                                                        ALEXMX66JL
30.0 30.0 31.0 30.0 30.0 31.0 33.0 30.0 32.0 32.0 30.0 29.0 30.0 30.0ALEXMX66AG
30.0 29.0 30.0 32.0 32.0 33.0 32.0 27.0 29.0 27.0 22.0 29.0 30.0 31.0ALEXMX66AG
29.0 28.0 29.0                                                        ALEXMX66AG
28.0 28.0 29.0 28.0 29.0 28.0 29.0 28.0 28.0 28.0 30.0 32.0 32.0 28.0ALEXMX66SP
29.0 29.0 28.0 28.0 26.0 27.0 28.0 26.0 28.0 28.0 29.0 26.0 28.0 26.0ALEXMX66SP
27.0 28.0                                                             ALEXMX66SP
28.0 31.0 33.0 28.0 32.0 28.0 30.0 30.0 30.0 31.0 29.0 29.0 29.0 30.0ALEXMX66OC
29.0 29.0 29.0 30.0 28.0 28.0 28.0 29.0 28.0 28.0 28.0 27.0 28.0 29.0ALEXMX66OC
28.0 28.0 27.0                                                        ALEXMX66OC
29.0 30.0 30.0 28.0 31.0 28.0 28.0 27.0 29.0 23.0 24.0 25.0 24.0 26.0ALEXMX66NO
24.0 25.0 25.0 25.0 25.0 25.0 26.0 25.0 25.0 26.0 26.0 24.0 25.0 25.0ALEXMX66NO
25.0 23.0                                                             ALEXMX66NO
22.0 22.0 23.0 22.0 23.0 26.0 24.0 27.0 26.0 22.0 20.0 21.0 21.0 20.0ALEXMX66DC
20.0 18.0 17.0 18.0 15.0 18.0 19.0 19.0 23.0 19.0 18.0 19.0 16.0 19.0ALEXMX66DC
20.0 18.0 19.0                                                        ALEXMX66DC
```

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********** ALEXANDRIA MAXIMUM TFMPFRATURE 1967 ******************
19.0 19.0 20.0 19.0 20.0 19.0 19.0 20.0 20.0 20.0 21.0 22.0 20.0 18.0ALEXMX67JA
20.0 18.0 16.0 15.0 14.0 13.0 15.0 17.0 18.0 19.0 18.0 18.0 18.0 12.0ALEXMX67JA
17.0 16.0 18.0                                                       ALEXMX67JA
16.0 16.0 18.0 18.0 17.0 18.0 21.0 20.0 16.0 18.0 18.0 17.0 18.0 16.0ALEXMX67FB
18.0 17.0 20.0 20.0 19.0 20.0 20.0 18.0 18.0 21.0 20.0 18.0 18.0 19.0ALEXMX67FB
20.0 22.0 18.0 19.0 18.0 18.0 17.0 19.0 20.0 18.0 19.0 20.0 20.0 21.0ALEXMX67MA
19.0 18.0 20.0 20.0 24.0 20.0 21.0 19.0 19.0 20.0 17.0 17.0 19.0 20.0ALEXMX67MA
21.0 20.0 19.0                                                       ALEXMX67MA
26.0 30.0 20.0 20.0 21.0 25.0 21.0 19.0 18.0 19.0 21.0 22.0 22.0 20.0ALEXMX67AP
31.0 27.0 22.0 23.0 20.0 30.0 22.0 22.0 31.0 30.0 20.0 23.0 20.0 22.0ALEXMX67AP
24.0 22.0                                                            ALEXMX67AP
22.0 32.0 27.0 22.0 23.0 23.0 26.0 24.0 23.0 24.0 25.0 29.0 32.0 33.0ALEXMX67MY
28.0 27.0 25.0 24.0 27.0 25.0 26.0 25.0 34.0 38.0 38.0 24.0 25.0 26.0ALEXMX67MY
28.0 25.0 25.0                                                       ALEXMX67MY
27.0 29.0 29.0 26.0 27.0 27.0 28.0 27.0 26.0 28.0 35.0 28.0 28.0 26.0ALEXMX67JU
28.0 31.0 38.0 28.0 29.0 27.0 27.0 28.0 29.0 30.0 28.0 29.0 34.0 29.0ALEXMX67JU
27.0 28.0                                                            ALEXMX67JU
30.0 31.0 29.0 28.0 29.0 29.0 28.0 29.0 29.0 29.0 30.0 31.0 29.0 29.0ALEXMX67JL
29.0 28.0 30.0 32.0 33.0 33.0 35.0 32.0 30.0 33.0 32.0 31.0 31.0 34.0ALFXMX67JL
31.0 31.0 32.0                                                       ALEXMX67JL
32.0 31.0 30.0 30.0 30.0 30.0 30.0 30.0 31.0 30.0 31.0 32.0 32.0 31.0ALEXMX67AG
30.0 29.0 28.0 30.0 31.0 31.0 30.0 29.0 28.0 27.0 30.0 31.0 29.0 28.0ALEXMX67AG
30.0 32.0 31.0                                                       ALEXMX67AG
30.0 30.0 31.0 32.0 29.0 30.0 29.0 30.0 29.0 28.0 29.0 29.0 28.0 27.0ALEXMX67SP
28.0 28.0 28.0 29.0 29.0 31.0 30.0 28.0 30.0 30.0 31.0 32.0 31.0 29.0ALEXMX67SP
29.0 30.0                                                            ALFXMX67SP
28.0 29.0 28.0 29.0 28.0 29.0 25.0 21.0 27.0 30.0 28.0 32.0 28.0 27.0ALEXMX67OC
28.0 30.0 29.0 31.0 30.0 29.0 28.0 27.0 31.0 28.0 28.0 28.0 28.0 27.0ALEXMX67OC
28.0 27.0 25.0                                                       ALEXMX67OC
23.0 20.0 22.0 23.0 21.0 20.0 22.0 22.0 24.0 23.0 23.0 24.0 24.0 25.0ALEXMX67NO
26.0 24.0 24.0 24.0 23.0 20.0 19.0 20.0 22.0 21.0 22.0 23.0 23.0 23.0ALEXMX67NO
23.0 22.0                                                            ALEXMX67NO
20.0 23.0 22.0 23.0 23.0 24.0 20.0 21.0 22.0 22.0 21.0 23.0 23.0 24.0ALEXMX67DC
21.0 18.0 18.0 18.0 20.0 20.0 21.0 21.0 20.0 20.0 21.0 21.0 20.0 22.0ALEXMX67DC
21.0 20.0 20.0                                                       ALEXMX67DC
```

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********** ALEXANDRIA MAXIMUM TEMPERATURE 1968 ******************
19.0 21.0 20.0 19.0 17.0 18.0 18.0 19.0 18.0 19.0 18.0 15.0 16.0 12.0ALEXMX68JA
13.0 19.0 19.0 18.0 17.0 19.0 18.0 18.0 18.0 17.0 18.0 19.0 16.0 16.0ALEXMX68JA
16.0 17.0 15.0                                                      ALEXMX68JA
16.0 18.0 18.0 19.0 18.0 17.0 18.0 17.0 17.0 17.0 19.0 18.0 21.0 19.0ALEXMX68FB
18.0 21.0 26.0 21.0 19.0 16.0 16.0 17.0 19.0 18.0 18.0 19.0 19.0 22.0ALEXMX68FB
28.0 22.0 26.0 18.0 26.0 19.0 18.0 20.0 24.0 20.0 22.0 21.0 28.0 27.0ALEXMX68MA
23.0 13.0 16.0 17.0 18.0 19.0 20.0 20.0 21.0 21.0 21.0 21.0 20.0 20.0ALEXMX68MA
19.0 20.0 29.0                                                      ALEXMX68MA
21.0 21.0 32.0 34.0 27.0 22.0 23.0 23.0 25.0 30.0 28.0 35.0 38.0 37.0ALEXMX68AP
37.0 33.0 35.0 22.0 22.0 21.0 20.0 20.0 22.0 24.0 23.0 25.0 27.0 28.0ALEXMX68AP
26.0 25.0                                                           ALEXMX68AP
25.0 26.0 26.0 27.0 26.0 26.0 28.0 28.0 28.0 28.0 24.0 28.0 28.0 28.0ALEXMX68MY
30.0 28.0 27.0 35.0 26.0 26.0 25.0 25.0 27.0 28.0 28.0 30.0 28.0 33.0ALEXMX68MY
32.0 29.0 28.0                                                      ALEXMX68MY
30.0 38.0 38.0 38.0 37.0 27.0 29.0 28.0 30.0 34.0 31.0 29.0 28.0 30.0ALEXMX68JU
32.0 32.0 33.0 29.0 29.0 29.0 25.0 32.0 31.0 32.0 35.0 30.0 31.0 30.0ALEXMX68JU
31.0 30.0                                                           ALEXMX68JU
31.0 31.0 32.0 31.0 30.0 31.0 30.0 31.0 32.0 30.0 32.0 36.0 33.0 30.0ALEXMX68JL
33.0 31.0 33.0 32.0 32.0 32.0 31.0 30.0 32.0 32.0 29.0 30.0 32.0 29.0ALEXMX68JL
31.0 29.0 29.0                                                      ALEXMX68JL
28.0 30.0 29.0 30.0 30.0 28.0 31.0 29.0 34.0 38.0 34.0 35.0 39.0 40.0ALEXMX68AG
38.0 36.0 32.0 31.0 33.0 31.0 30.0 28.0 29.0 30.0 31.0 30.0 30.0 32.0ALEXMX68AG
30.0 30.0 31.0                                                      ALEXMX68AG
32.0 30.0 30.0 30.0 30.0 30.0 30.0 31.0 29.0 32.0 32.0 30.0 29.0 30.0ALEXMX68SP
28.0 30.0 32.0 34.0 31.0 31.0 29.0 30.0 28.0 29.0 30.0 31.0 38.0 28.0ALEXMX68SP
27.0 26.0                                                           ALEXMX68SP
27.0 30.0 28.0 27.0 30.0 27.0 27.0 28.0 28.0 28.0 26.0 27.0 26.0 30.0ALEXMX68OC
27.0 27.0 27.0 28.0 28.0 30.0 38.0 24.0 28.0 26.0 25.0 26.0 28.0 26.0ALEXMX68OC
24.0 25.0 25.0                                                      ALEXMX68OC
25.0 26.0 26.0 27.0 29.0 27.0 27.0 26.0 26.0 26.0 26.0 26.0 24.0 25.0ALEXMX68NO
24.0 25.0 25.0 26.0 25.0 26.0 23.0 24.0 23.0 22.0 20.0 18.0 20.0 17.0ALEXMX68NO
21.0 22.0                                                           ALEXMX68NO
22.0 23.0 22.0 19.0 20.0 19.0 20.0 20.0 22.0 21.0 25.0 20.0 20.0 19.0ALEXMX68DC
20.0 20.0 21.0 21.0 23.0 21.0 18.0 18.0 16.0 16.0 16.0 19.0 21.0 22.0ALEXMX68DC
21.0 20.0 20.0                                                      ALEXMX68DC
```

```
********** ALEXANDRIA MAXIMUM TEMPERATURE 1969 ******************
21.0 21.0 23.0 15.0 16.0 16.0 16.0 15.0 18.0 18.0 21.0 15.0 18.0 18.0ALEXMX69JA
18.0 19.0 21.0 17.0 19.0 19.0 17.0 14.0 13.0 17.0 16.0 16.0 14.0 12.0ALEXMX69JA
13.0 15.0 15.0                                                       ALEXMX69JA
18.0 19.0 20.0 18.0 19.0 24.0 17.0 18.0 18.0 18.0 18.0 16.0 18.0 19.0ALEXMX69FB
20.0 19.0 24.0 19.0 19.0 19.0 20.0 23.0 20.0 22.0 27.0 21.0 20.0 23.0ALEXMX69FB
26.0 26.0 22.0 24.0 24.0 34.0 21.0 19.0 18.0 18.0 18.0 20.0 19.0 19.0ALEXMX69MA
27.0 24.0 28.0 24.0 19.0 18.0 18.0 18.0 18.0 21.0 25.0 37.0 21.0 31.0ALEXMX69MA
21.0 24.0 30.0                                                       ALEXMY69MA
18.0 20.0 20.0 20.0 21.0 23.0 28.0 29.0 20.0 19.0 19.0 19.0 23.0 28.0ALEXMX69AP
20.0 20.0 25.0 28.0 26.0 21.0 24.0 23.0 33.0 23.0 21.0 22.0 21.0 20.0ALEXMX69AP
27.0 32.0                                                            ALEXMX69AP
22.0 23.0 23.0 23.0 22.0 26.0 33.0 34.0 25.0 26.0 23.0 23.0 23.0 25.0ALEXMX69MY
29.0 24.0 25.0 25.0 27.0 30.0 28.0 25.0 26.0 26.0 26.0 28.0 27.0 28.0ALEXMX69MY
32.0 32.0 30.0                                                       ALFXMX69MY
31.0 29.0 28.0 27.0 31.0 34.0 37.0 21.0 31.0 39.0 35.0 31.0 39.0 32.0ALEXMX69JU
28.0 28.0 29.0 30.0 25.0 29.0 29.0 30.0 29.0 31.0 32.0 39.0 27.0 28.0ALFXMX69JU
26.0 28.0                                                            ALEXMX69JU
29.0 28.0 29.0 29.0 28.0 29.0 30.0 29.0 30.0 30.0 30.0 30.0 29.0 28.0ALEXMX69JL
28.0 28.0 28.0 28.0 29.0 30.0 29.0 30.0 31.0 29.0 29.0 29.0 29.0 29.0ALEXMX69JL
29.0 30.0 29.0                                                       ALEXMX69JL
29.0 30.0 30.0 30.0 29.0 28.0 30.0 28.0 29.0 29.0 29.0 29.0 29.0 30.0ALEXMX69AG
30.0 31.0 32.0 31.0 31.0 29.0 30.0 29.0 30.0 30.0 30.0 31.0 30.0 30.0ALEXMX69AG
30.0 32.0 30.0                                                       ALEXMX69AG
30.0 30.0 30.0 31.0 30.0 30.0 31.0 30.0 31.0 31.0 29.0 30.0 30.0 28.0ALEXMX69SP
31.0 33.0 30.0 30.0 32.0 30.0 30.0 34.0 33.0 30.0 30.0 29.0 29.0 28.0ALEXMX69SP
28.0 29.0                                                            ALEXMX69SP
27.0 28.0 27.0 28.0 27.0 28.0 30.0 28.0 28.0 28.0 29.0 28.0 27.0 28.0ALEXMX69OC
27.0 28.0 27.0 28.0 27.0 29.0 29.0 26.0 23.0 24.0 25.0 25.0 26.0 26.0ALEXMX69OC
29.0 26.0 24.0                                                       ALEXMX69OC
26.0 26.0 27.0 24.0 24.0 23.0 23.0 24.0 24.0 23.0 24.0 24.0 24.0 24.0ALEXMX69NO
23.0 24.0 24.0 24.0 23.0 23.0 23.0 23.0 24.0 24.0 23.0 24.0 23.0 25.0ALFXMX69NO
25.0 24.0                                                            ALEXMX69NO
20.0 23.0 24.0 23.0 20.0 21.0 20.0 24.0 23.0 23.0 23.0 23.0 24.0 21.0ALEXMX69DC
21.0 19.0 20.0 20.0 20.0 20.0 22.0 22.0 19.0 20.0 20.0 18.0 19.0 21.0ALEXMX69DC
21.0 20.0 20.0                                                       ALEXMX69DC
```

```
********** ALEXANDRIA MAXIMUM TEMPERATURE 1970 ******************
20.0 20.0 22.0 22.0 24.0 21.0 23.0 22.0 22.0 21.0 18.0 21.0 21.0 20.0MXALEX70JA
20.0 21.0 21.0 20.0 19.0 17.0 18.0 16.0 19.0 20.0 16.0 18.0 18.0 17.0MXALEX70JA
19.0 20.0 19.0                                                       MXALEX70JA
21.0 20.0 21.0 20.0 20.0 20.0 20.0 20.0 22.0 22.0 25.0 28.0 21.0 20.0MXALEX70FE
20.0 22.0 20.0 17.0 17.0 20.0 18.0 19.0 18.0 21.0 20.0 22.0 21.0 22.0MXALEX70FE
30.0 18.0 19.0 29.0 30.0 29.0 27.0 25.0 21.0 20.0 20.0 20.0 22.0 26.0MXALEX70MA
31.0 34.0 22.0 20.0 20.0 23.0 19.0 20.0 20.0 20.0 20.0 21.0 22.0 24.0MXALEX70MA
31.0 33.0 20.0                                                       MXALEX70MA
20.0 22.0 28.0 23.0 23.0 20.0 20.0 22.0 27.0 30.0 35.0 43.0 22.0 22.0MXALEX70AP
21.0 21.0 21.0 18.0 21.0 22.0 23.0 25.0 23.0 24.0 29.0 26.0 24.0 25.0MXALEX70AP
25.0 28.0                                                            MXALEX70AP
25.0 22.0 21.0 20.0 22.0 25.0 27.0 28.0 26.0 29.0 35.0 37.0 34.0 25.0MXALEX70MA
24.0 24.0 33.0 36.0 25.0 33.0 38.0 25.0 24.0 27.0 25.0 23.0 24.0 25.0MXALEX70MA
27.0 25.0 27.0                                                       MXALEX70MA
24.0 27.0 25.0 25.0 25.0 26.0 27.0 28.0 30.0 29.0 30.0 30.0 28.0 28.0MXALEX70JU
28.0 28.0 29.0 29.0 30.0 30.0 28.0 28.0 27.0 29.0 30.0 30.0 29.0 28.0MXALEX70JU
28.0 29.0                                                            MXALEX70JU
30.0 31.0 29.0 29.0 30.0 29.0 29.0 28.0 29.0 29.0 29.0 31.0 30.0 30.0MXALEX70JL
30.0 30.0 34.0 30.0 29.0 29.0 29.0 29.0 30.0 31.0 30.0 31.0 30.0 30.0MXALEX70JL
30.0 30.0 29.0                                                       MXALEX70JL
29.0 30.0 30.0 31.0 32.0 30.0 30.0 31.0 31.0 32.0 32.0 29.0 31.0 30.0MXALEX70AU
30.0 31.0 31.0 31.0 31.0 30.0 31.0 32.0 31.0 32.0 30.0 33.0 30.0 29.0MXALEX70AU
30.0 29.0 30.0                                                       MXALEX70AU
30.0 30.0 29.0 28.0 29.0 29.0 29.0 29.0 29.0 28.0 29.0 29.0 29.0 29.0MXALEX70SP
29.0 29.0 29.0 28.0 29.0 29.0 31.0 35.0 34.0 31.0 29.0 24.0 28.0 29.0MXALEX70SP
26.0 24.0                                                            MXALEX70SP
26.0 25.0 30.0 27.0 27.0 25.0 25.0 25.0 25.0 26.0 24.0 25.0 25.0 25.0MXALEX70OC
25.0 25.0 23.0 27.0 31.0 31.0 35.0 28.0 26.0 30.0 26.0 24.0 22.0 22.0MXALEX70OC
24.0 23.0 23.0                                                       MXALEX70OC
25.0 25.0 26.0 25.0 25.0 26.0 26.0 25.0 24.0 24.0 24.0 24.0 20.0 22.0MXALEX70NO
23.0 24.0 24.0 24.0 23.0 22.0 22.0 22.0 24.0 21.0 23.0 21.0 13.0 20.0MXALEX70NO
22.0 21.0                                                            MXALEX70NO
22.0 21.0 22.0 22.0 21.0 19.0 20.0 18.0 20.0 17.0 16.0 14.0 16.0 17.0MXALEX70DE
16.0 17.0 19.0 18.0 15.0 18.0 18.0 19.0 18.0 19.0 20.0 19.0 20.0 20.0MXALEX70DE
20.0 20.0 22.0                                                       MXALEX70DE
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********** ALEXANDRIA MAXIMUM TEMPERATURE 1971 ******************
24.0 25.0 25.0 24.0 20.0 19.0 20.0 19.0 15.0 16.0 19.0 18.0 18.0 20.0MXALEX71JA
20.0 19.0 19.0 20.0 20.0 20.0 19.0 21.0 20.0 17.0 19.0 18.0 17.0 19.0MXALEX71JA
20.0 18.0 19.0                                                       MXALEX71JA
19.0 21.0 18.0 15.0 19.0 21.0 18.0 18.0 18.0 19.0 17.0 19.0 15.0 18.0MXALEX71FR
19.0 22.0 22.0 22.0 22.0 24.0 18.0 19.0 18.0 22.0 21.0 19.0 17.0 21.0MXALEX71FR
29.0 24.0 21.0 20.0 20.0 19.0 21.0 25.0 26.0 19.0 22.0 20.0 20.0 16.0MXALEX71MR
21.0 32.0 21.0 20.0 21.0 20.0 24.0 24.0 27.0 23.0 20.0 20.0 20.0 26.0MXALEX71MR
27.0 22.0 22.0                                                       MXALEX71MR
21.0 23.0 21.0 21.0 23.0 20.0 21.0 23.0 23.0 22.0 25.0 19.0 20.0 22.0MXALEX71AP
20.0 18.0 19.0 20.0 20.0 20.0 24.0 20.0 21.0 22.0 28.0 29.0 31.0 29.0MXALEX71AP
37.0 27.0                                                            MXALEX71AP
26.0 28.0 31.0 31.0 30.0 33.0 32.0 25.0 25.0 25.0 24.0 24.0 29.0 26.0MXALEX71MY
25.0 25.0 26.0 25.0 29.0 25.0 26.0 29.0 38.0 26.0 31.0 26.0 26.0 28.0MXALFX71MY
30.0 26.0 24.0                                                       MXALEX71MY
26.0 27.0 26.0 26.0 33.0 26.0 26.0 32.0 26.0 26.0 28.0 29.0 28.0 28.0MXALEX71JU
29.0 30.0 32.0 33.0 32.0 32.0 28.0 28.0 28.0 28.0 28.0 20.0 29.0 29.0MXALEX71JU
29.0 29.0                                                            MXALEX71JU
32.0 33.0 28.0 28.0 29.0 29.0 30.0 30.0 29.0 29.0 28.0 28.0 29.0 29.0MXALEX71JL
30.0 29.0 29.0 30.0 34.0 30.0 30.0 30.0 29.0 29.0 29.0 30.0 29.0 30.0MXALFX71JL
30.0 30.0 30.0                                                       MXALEX71JL
30.0 31.0 30.0 30.0 26.0 32.0 30.0 31.0 32.0 32.0 31.0 30.0 31.0 31.0MXALEX71AG
32.0 31.0 30.0 31.0 30.0 31.0 30.0 30.0 30.0 30.0 30.0 30.0 30.0 31.0MXALEX71AG
32.0 30.0 30.0                                                       MXALEX71AG
30.0 30.0 31.0 31.0 32.0 31.0 30.0 30.0 28.0 28.0 29.0 32.0 30.0 29.0MXALEX71SP
30.0 30.0 30.0 29.0 29.0 28.0 28.0 28.0 28.0 28.0 28.0 27.0 27.0 27.0MXALEX71SP
29.0 28.0                                                            MXALEX71SP
29.0 28.0 29.0 28.0 32.0 37.0 25.0 24.0 25.0 27.0 26.0 27.0 26.0 26.0MXALFX71OC
26.0 26.0 26.0 28.0 26.0 25.0 26.0 26.0 26.0 25.0 26.0 26.0 24.0 27.0MXALFX71OC
24.0 28.0 26.0                                                       MXALEX71OC
25.0 25.0 26.0 26.0 25.0 21.0 22.0 22.0 19.0 20.0 23.0 22.0 20.0 22.0MXALEX71NO
24.0 23.0 25.0 26.0 23.0 23.0 24.0 24.0 24.0 24.0 23.0 22.0 24.0 24.0MXALFX71NO
24.0 25.0                                                            MXALEX71NO
23.0 22.0 20.0 20.0 21.0 20.0 19.0 20.0 21.0 18.0 17.0 19.0 17.0 16.0MXALEX71DC
16.0 19.0 18.0 19.0 17.0 19.0 20.0 18.0 20.0 19.0 19.0 20.0 20.0 21.0MXALEX71DC
21.0 20.0 22.0                                                       MXALEX71DC
```

```
********* ALEXANDRIA MAXIMUM TEMPERATURE 1972 *****************
19.8 18.8 18.4 18.2 18.0 17.8 17.6 18.4 18.6 18.8 18.0 19.4 18.6 16.0ALEXMX72JA
18.9 18.6 19.0 20.2 20.0 20.3 18.6 21.2 20.0 18.0 18.6 18.3 17.3 19.2ALEXMX72JA
20.1 18.5 19.2                                                       ALEXMX72JA
17.4 18.2 23.6 25.0 18.7 17.7 16.2 16.9 17.3 18.7 18.5 19.1 21.6 19.2ALEXMX72FB
23.4 18.6 18.6 17.6 17.8 18.5 19.4 22.9 21.0 18.8 19.8 22.8 21.2 20.9ALEXMX72FB
20.2 22.0 21.8 19.2 19.2 19.6 21.8 26.5 20.5 19.6 21.5 26.0 20.6 18.6ALEXMX72MA
14.4 16.8 19.2 19.8 22.3 21.0 20.0 18.4 19.3 19.4 19.5 26.8 23.7 30.3ALEXMX72MA
30.3 20.7 20.8                                                       ALEXMX72MA
20.6 22.0 21.8 20.6 24.0 26.4 30.4 22.8 20.6 21.8 25.8 32.4 28.2 28.5ALEXMX72AP
23.2 23.0 25.4 25.7 28.9 26.2 23.0 22.0 20.6 28.6 35.5 35.6 30.1 29.2ALEXMX72AP
22.6 18.8                                                            ALEXMX72AP
22.0 31.5 27.0 29.4 23.6 21.7 28.5 24.8 23.4 23.3 25.6 22.6 22.8 23.0ALEXMX72MY
23.0 24.0 26.1 28.6 30.9 28.1 24.9 23.8 25.7 25.6 25.0 25.5 25.9 25.0ALEXMX72MY
24.0 27.9 25.2                                                       ALEXMX72MY
25.5 26.0 26.0 27.6 27.6 28.4 30.3 36.5 26.4 26.8 27.5 27.6 27.6 30.8ALEXMX72JU
30.4 31.7 32.8 36.1 33.8 28.8 28.0 27.9 29.0 29.5 29.1 28.6 28.4 28.5ALEXMX72JU
29.1 29.0                                                            ALEXMX72JU
32.4 32.6 28.0 28.2 29.0 29.0 29.4 30.4 29.7 29.2 28.6 28.5 28.0 29.4ALEXMX72JL
29.4 29.5 29.4 29.0 29.8 33.6 29.7 29.6 29.7 29.4 28.6 29.1 30.4 29.4ALEXMX72JL
29.9 29.7 23.9                                                       ALEXMX72JL
30.6 35.9 34.0 31.4 32.9 31.0 30.4 31.4 30.7 29.8 30.1 30.6 30.4 31.0ALEXMX72AG
30.8 31.2 31.0 30.8 32.4 30.6 30.2 30.7 31.8 31.0 30.6 35.8 31.0 30.2ALEXMX72AG
29.2 30.2 35.2                                                       ALEXMX72AG
30.0 30.1 30.8 31.4 31.8 30.6 30.5 30.5 27.9 27.5 28.9 30.7 30.0 29.4ALEXMX72SP
29.5 29.6 30.4 30.9 29.2 27.8 28.0 28.2 27.6 28.4 27.5 27.2 27.0 26.8ALEXMX72SP
26.8 28.8                                                            ALEXMX72SP
29.1 28.8 28.6 28.4 30.2 36.8 25.1 24.6 24.4 26.6 25.7 27.0 26.0 26.4ALEXMX72OC
26.0 25.7 26.2 27.2 26.0 25.3 25.8 25.9 25.4 25.8 25.5 24.5 23.9 24.5ALEXMX72OC
27.6 24.5 25.8                                                       ALEXMX72OC
24.7 23.6 24.0 24.2 22.4 22.8 23.5 23.5 24.4 24.0 23.4 24.6 26.6 24.8ALEXMX72NO
23.2 24.4 21.9 20.3 21.9 22.7 20.3 18.6 21.8 22.0 21.2 24.6 26.0 26.0ALEXMX72NO
24.8 25.3                                                            ALEXMX72NO
24.4 23.5 22.2 21.2 21.0 19.6 19.8 19.1 18.1 24.1 20.8 18.5 17.8 19.8ALEXMX72DC
17.4 16.1 16.5 15.7 17.6 19.3 16.9 13.8 18.0 19.4 17.8 18.4 15.9 17.6ALEXMX72DC
19.0 17.9 19.6                                                       ALEXMX72DC
```

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********** ALEXANDRIA MAXIMUM TEMPERATURE 1973 *******************
17.8 16.3 18.1 20.4 20.7 20.4 22.0 19.6 19.6 19.1 20.0 17.8 14.9 12.8ALEXMX73JA
13.9 14.4 15.2 18.9 18.1 20.2 19.9 19.1 18.3 21.0 21.6 19.6 18.9 18.6ALEXMX73JA
20.4 17.7 17.7                                                       ALEXMX73JA
18.5 17.5 19.7 20.0 18.9 20.1 20.8 18.5 18.3 19.2 19.0 20.0 23.4 19.0ALEXMX73FP
21.1 29.9 32.7 19.2 19.2 19.2 17.6 19.0 17.0 19.7 19.5 24.8 25.2 19.7ALEXMX73FP
18.5 14.2 14.6 15.8 17.4 15.8 16.0 17.0 17.8 17.9 23.0 26.8 20.2 20.2ALEXMX73MR
18.8 23.2 22.4 28.2 20.4 19.6 19.2 18.5 19.0 20.1 20.8 21.8 22.5 23.3ALEXMX73MR
20.6 21.0 23.4                                                       ALEXMX73MR
30.2 25.9 21.0 20.0 23.0 23.0 19.4 21.2 19.6 21.6 23.7 25.6 24.3 20.9ALEXMX73AP
20.5 26.2 20.4 20.6 24.8 22.6 21.3 22.0 25.5 29.2 21.3 21.4 22.1 21.2ALEXMX73AP
21.6 25.1                                                            ALFXMX73AP
28.4 24.4 23.1 23.0 24.8 25.6 24.3 25.2 25.8 27.4 23.0 23.0 28.8 25.1ALEXMX73MY
21.9 22.5 23.0 25.4 24.4 25.2 29.0 30.5 30.0 26.0 27.3 25.8 26.0 25.3ALEXMX73MY
24.5 25.2 24.9                                                       ALEXMX73MY
28.0 26.1 26.0 26.6 26.5 25.9 27.4 27.4 30.4 38.3 26.8 26.6 26.5 26.5ALFXMX73JU
27.5 26.7 26.5 27.1 26.1 26.6 27.4 27.8 28.4 30.0 31.3 27.4 28.0 29.0ALEXMX73JU
29.9 27.2                                                            ALEXMX73JU
29.2 29.5 28.6 28.6 28.6 28.4 28.2 29.0 29.0 28.8 29.6 30.6 29.0 29.1ALEXMX73JI
28.7 28.7 30.1 31.8 32.4 34.0 34.6 31.6 30.3 32.3 32.1 31.0 31.2 34.2ALFXMX73JL
30.5 30.7 31.3                                                       ALEXMX73JL
31.6 30.5 30.0 30.1 29.4 30.0 30.2 30.0 30.6 31.6 31.5 30.7 30.0 29.2ALEXMX73AG
29.5 30.0 29.5 29.6 29.5 29.6 29.5 29.6 29.3 30.0 30.0 29.4 30.2 30.5ALFXMX73AG
29.8 29.5 30.3                                                       ALEXMX73AG
29.5 29.6 30.0 29.3 29.0 30.0 29.2 29.6 29.4 29.8 29.5 29.0 29.1 28.6ALEXMX73SP
28.6 28.0 28.0 28.6 28.9 31.2 29.4 28.4 28.9 30.2 30.0 33.3 31.4 29.1ALFXMX73SP
29.1 29.4                                                            ALEXMX73SP
28.2 28.8 28.4 28.7 28.8 28.5 21.2 27.9 29.6 28.5 31.6 27.6 26.7 27.7ALEXMX73OC
28.9 28.6 31.0 30.2 28.5 28.0 27.2 30.4 27.5 27.4 28.3 27.9 26.4 26.6ALFXMX73OC
27.4 25.8 23.8                                                       ALFXMX73OC
22.8 18.0 21.0 21.9 21.0 21.1 22.3 22.0 23.1 23.6 23.4 22.7 27.7 23.3ALEXMX73WO
24.6 25.4 24.2 24.2 24.0 23.4 23.0 20.4 18.9 19.9 21.7 21.0 22.4 23.4ALEXMX73NO
22.4 22.7                                                            ALEXMX73NO
20.4 22.4 22.2 22.4 23.0 23.5 18.8 21.0 21.3 22.0 21.6 22.4 22.6 23.3ALEXMX73DC
20.8 17.4 17.4 17.8 19.9 19.9 20.7 20.4 20.6 20.8 21.0 20.4 19.9 21.3ALEXMX73DC
20.5 21.6 19.9                                                       ALFXMX73DC
```

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********** ALEXANDRIA MAXIMUM TEMPERATURE 1974 ******************
18.9 18.7 20.4 20.9 17.7 19.0 18.6 15.0 16.2 17.7 18.2 18.5 18.0 13.9ALEXMX74JA
17.7 14.3 13.9 16.7 16.6 13.7 16.8 14.8 13.2 16.8 15.9 17.3 18.5 18.3ALEXMX74JA
16.3 17.9 17.0                                                        ALEXMX74JA
15.6 16.2 17.0 17.6 16.6 18.8 19.7 22.8 20.5 15.7 18.4 19.1 18.7 22.0ALEXMX74FB
20.8 19.3 19.4 20.5 19.0 23.6 19.6 19.1 18.6 19.9 20.4 20.2 19.1 17.4ALEXMX74FB
17.6 17.1 17.7 18.8 19.0 19.8 21.3 22.2 22.4 22.1 25.2 20.3 25.4 24.5ALEXMX74MA
21.3 21.4 18.4 18.1 19.5 19.9 21.6 21.2 20.6 20.5 20.8 20.4 27.1 31.6ALEXMX74MA
21.0 20.8 24.4                                                        ALEXMX74MA
34.4 21.4 20.2 19.6 20.9 23.1 30.5 20.7 19.8 20.2 23.4 34.2 25.8 28.7ALEXMX74AP
25.8 23.6 28.2 24.0 23.4 24.4 25.2 21.8 21.8 20.8 30.2 24.2 22.0 22.8ALEXMX74AP
27.8 32.2                                                             ALEXMX74AP
36.6 22.6 22.4 22.0 23.7 27.5 24.2 24.8 29.6 30.6 22.0 22.4 22.8 24.0ALEXMX74MY
24.4 25.4 34.3 38.4 32.4 38.5 24.0 24.6 24.0 25.8 28.3 25.5 28.2 25.8ALEXMX74MY
25.8 28.3 24.7                                                        ALEXMX74MY
26.0 28.1 28.7 26.0 26.4 26.0 26.5 27.6 26.6 26.0 28.1 34.8 27.5 26.7ALEXMX74JU
26.4 27.6 31.5 37.4 27.9 27.6 27.0 27.0 28.4 29.0 29.1 30.4 28.0 29.3ALEXMX74JU
34.2 29.6                                                             ALEXMX74JU
29.3 29.0 28.6 29.0 29.1 28.6 29.0 29.2 29.9 28.3 27.7 28.4 29.2 29.8ALEXMX74JL
31.1 31.2 30.1 31.0 31.1 32.6 30.6 30.0 29.2 29.0 28.5 22.4 30.0 30.0ALEXMX74JL
30.0 29.6 29.7                                                        ALEXMX74JL
30.4 31.0 31.5 30.2 31.2 32.1 31.1 32.8 30.7 31.4 30.8 31.2 30.5 29.4ALEXMX74AG
29.5 30.2 30.8 30.0 30.6 31.0 30.3 30.0 30.5 31.0 30.0 30.8 30.1 29.5ALEXMX74AG
29.5 29.8 30.6                                                        ALEXMX74AG
29.8 29.5 29.5 29.7 29.5 30.6 30.1 31.9 35.6 34.4 31.1 29.9 30.1 30.5ALEXMX74SP
29.5 29.7 29.3 29.2 28.0 28.0 28.0 28.6 28.3 29.8 35.7 33.7 29.5 28.5ALEXMX74SP
27.4 27.5                                                             ALEXMX74SP
27.0 27.2 29.0 28.6 27.9 29.6 29.8 32.1 29.4 28.3 28.0 27.7 27.5 28.0ALEXMX74OC
30.0 30.1 30.6 30.9 28.0 30.9 35.8 30.0 30.1 27.8 28.6 28.6 33.8 29.8ALEXMX74OC
27.4 27.9 28.6                                                        ALEXMX74OC
31.6 26.0 25.2 24.4 25.3 25.3 26.0 26.8 27.6 26.6 27.0 24.6 23.8 24.2ALEXMX74NO
23.4 24.0 22.0 23.3 22.6 22.9 22.2 23.3 23.2 21.0 23.2 23.0 22.4 22.2ALEXMX74NO
23.1 23.2                                                             ALEXMX74NO
23.3 20.6 16.9 15.9 20.2 17.2 19.4 18.8 18.4 17.6 15.9 19.8 18.4 20.5ALEXMX74DC
19.1 18.3 18.2 19.3 19.9 18.6 16.4 17.9 15.9 15.4 18.3 18.1 19.2 18.6ALEXMX74DC
18.6 19.3 18.9                                                        ALEXMX74DC
```

2 - Weekly Average Maximum Temperatures at Alexandria (1960-1974)

```
MAXIMUM TEMPERATURE
WEEKLY AVERAGES
YEAR = 1960
  1   18.7   2   16.6   3   17.6   4   19.1   5   20.9   6   19.7   7   19.3   8   19.0
  9   19.4  10   19.7  11   17.4  12   19.6  13   21.0  14   29.4  15   21.4  16   22.3
 17   25.0  18   30.6  19   26.4  20   28.1  21   27.1  22   27.6  23   28.6  24   26.7
 25   26.6  26   27.4  27   29.3  28   28.4  29   30.0  30   30.3  31   30.3  32   30.9
 33   30.0  34   30.6  35   29.3  36   29.1  37   33.3  38   28.9  39   28.7  40   28.0
 41   27.4  42   28.0  43   28.6  44   26.1  45   22.9  46   25.4  47   23.0  48   20.3
 49   21.0  50   21.3  51   19.9  52   20.6
YEAR = 1961
  1   20.6   2   19.0   3   15.0   4   15.9   5   16.6   6   16.0   7   16.9   8   19.2
  9   18.3  10   18.3  11   21.9  12   21.0  13   20.3  14   26.6  15   25.6  16   21.1
 17   23.6  18   23.0  19   26.4  20   28.0  21   29.0  22   28.9  23   25.1  24   26.9
 25   26.6  26   28.4  27   27.7  28   27.9  29   28.9  30   29.0  31   29.4  32   30.0
 33   29.7  34   30.6  35   30.6  36   30.0  37   28.9  38   28.0  39   30.0  40   27.3
 41   28.7  42   27.1  43   25.6  44   25.6  45   23.6  46   25.3  47   24.4  48   24.0
 49   22.9  50   21.9  51   20.1  52   17.4
YEAR = 1962
  1   20.9   2   18.9   3   14.9   4   16.6   5   17.1   6   16.6   7   17.6   8   19.7
  9   19.1  10   18.0  11   23.3  12   21.0  13   21.0  14   26.1  15   25.1  16   21.6
 17   23.4  18   22.4  19   28.3  20   29.0  21   27.9  22   27.9  23   25.9  24   27.0
 25   27.1  26   28.1  27   28.0  28   28.1  29   28.3  30   29.0  31   29.7  32   30.4
 33   29.3  34   31.3  35   29.3  36   29.6  37   27.7  38   28.6  39   29.1  40   28.4
 41   29.1  42   27.9  43   26.7  44   26.3  45   24.3  46   25.6  47   25.1  48   25.0
 49   23.6  50   21.7  51   20.4  52   18.3
YEAR = 1963
  1   22.7   2   22.0   3   20.3   4   17.3   5   20.1   6   22.0   7   22.1   8   20.7
  9   20.1  10   18.4  11   20.6  12   24.7  13   22.9  14   23.0  15   25.1  16   26.0
 17   23.0  18   24.1  19   25.1  20   25.1  21   27.6  22   25.6  23   25.0  24   27.4
 25   26.9  26   26.3  27   29.7  28   31.1  29   32.0  30   31.1  31   29.7  32   30.9
 33   35.9  34   34.1  35   30.6  36   30.7  37   30.7  38   29.9  39   29.0  40   28.1
 41   27.4  42   27.9  43   26.3  44   26.1  45   26.3  46   25.3  47   25.0  48   22.7
 49   20.3  50   21.3  51   20.3  52   18.4
YEAR = 1964
  1   19.3   2   17.1   3   17.3   4   17.9   5   17.4   6   17.4   7   19.1   8   16.6
  9   21.7  10   21.1  11   23.9  12   20.1  13   21.0  14   24.3  15   21.3  16   21.3
 17   24.1  18   21.9  19   22.1  20   25.7  21   27.4  22   33.9  23   30.3  24   29.4
 25   31.6  26   28.9  27   31.0  28   32.9  29   31.6  30   31.1  31   29.4  32   30.1
 33   32.6  34   30.0  35   30.6  36   29.4  37   30.4  38   31.6  39   29.6  40   28.0
 41   27.1  42   28.0  43   25.7  44   25.7  45   27.3  46   25.3  47   23.1  48   22.4
 49   20.3  50   20.6  51   21.3  52   19.0
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ALEXANDRIA
MAXIMUM TEMPERATURE
WEEKLY AVERAGES
YEAR = 1965
  1   17.3   2   18.9   3   18.0   4   18.4   5   17.3   6   17.9   7   18.1   8   19.9
  9   20.9  10   22.0  11   20.3  12   21.7  13   20.7  14   22.4  15   25.7  16   26.3
 17   21.3  18   21.4  19   22.7  20   22.0  21   25.6  22   30.7  23   26.9  24   27.1
 25   27.6  26   27.7  27   28.7  28   27.3  29   32.1  30   30.7  31   30.9  32   30.4
 33   29.4  34   29.0  35   30.3  36   29.9  37   29.1  38   29.7  39   30.0  40   28.7
 41   28.0  42   27.3  43   27.4  44   28.0  45   21.9  46   23.9  47   22.9  48   21.1
 49   22.4  50   21.4  51   19.4  52   20.3
YEAR = 1966
  1   19.4   2   17.4   3   15.7   4   15.6   5   16.9   6   18.8   7   19.6   8   20.4
  9   19.4  10   20.0  11   22.1  12   19.6  13   26.0  14   22.4  15   24.7  16   25.9
 17   23.3  18   26.1  19   25.4  20   30.9  21   25.7  22   26.4  23   26.9  24   28.7
 25   29.6  26   29.7  27   28.9  28   29.4  29   31.1  30   29.0  31   30.4  32   31.0
 33   30.4  34   28.4  35   29.0  36   28.4  37   29.7  38   27.3  39   27.4  40   30.0
 41   29.7  42   28.7  43   28.1  44   28.6  45   27.1  46   24.9  47   25.4  48   23.7
 49   24.4  50   20.3  51   18.4  52   18.4
YEAR = 1967
  1   19.3   2   20.1   3   15.9   4   17.1   5   17.0   6   18.3   7   18.0   8   19.4
  9   19.1  10   18.4  11   19.7  12   20.0  13   20.3  14   22.3  15   21.9  16   23.7
 17   24.3  18   24.4  19   26.1  20   27.0  21   30.0  22   27.0  23   27.0  24   30.6
 25   28.3  26   29.3  27   29.0  28   29.4  29   31.9  30   31.7  31   30.9  32   30.6
 33   30.1  34   29.4  35   30.0  36   30.0  37   28.1  38   29.3  39   30.3  40   28.0
 41   27.6  42   29.3  43   28.1  44   24.0  45   22.1  46   24.4  47   21.0  48   22.4
 49   22.1  50   21.7  51   19.7  52   20.7
YEAR = 1968
  1   18.9   2   16.7   3   17.6   4   17.4   5   17.0   6   17.6   7   20.6   8   17.6
  9   22.0  10   21.3  11   20.7  12   20.0  13   20.1  14   26.0  15   32.9  16   24.7
 17   25.0  18   25.9  19   27.4  20   28.6  21   27.3  22   32.6  23   31.9  24   30.7
 25   29.6  26   31.1  27   30.9  28   32.3  29   31.6  30   30.7  31   29.3  32   32.7
 33   35.6  34   29.9  35   30.7  36   30.0  37   30.1  38   30.7  39   29.9  40   28.0
 41   27.6  42   29.3  43   26.1  44   25.4  45   26.7  46   25.0  47   23.3  48   20.4
 49   20.3  50   20.7  51   19.7  52   19.3
YEAR = 1969
  1   18.3   2   17.6   3   18.6   4   14.6   5   16.9   6   18.9   7   19.3   8   21.4
  9   23.1  10   21.7  11   23.0  12   19.6  13   26.0  14   23.0  15   21.1  16   23.9
 17   23.9  18   24.4  19   26.7  20   26.4  21   26.6  22   30.0  23   31.4  24   31.7
 25   29.0  26   29.9  27   28.9  28   29.3  29   28.9  30   29.3  31   29.6  32   28.9
 33   30.6  34   29.9  35   30.3  36   30.4  37   30.3  38   31.3  39   29.0  40   27.9
 41   28.0  42   27.9  43   25.0  44   26.0  45   23.6  46   23.9  47   23.3  48   23.4
 49   22.1  50   22.0  51   20.4  52   19.9
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ALEXANDRIA
MAXIMUM TEMPERATURE
WEEKLY AVERAGES
YEAR = 1970
   1   21.7    2   20.7    3   19.4    4   17.7    5   20.0    6   21.3    7   21.1    8   19.0
   9   23.0   10   24.6   11   25.0   12   20.3   13   24.4   14   22.6   15   28.6   16   21.6
  17   25.1   18   23.3   19   30.9   20   28.6   21   26.6   22   25.7   23   27.1   24   28.7
  25   28.7   26   29.1   27   29.3   28   29.7   29   30.0   30   30.3   31   30.1   32   30.7
  33   30.7   34   31.3   35   29.7   36   28.9   37   28.9   38   30.7   39   27.3   40   26.4
  41   25.0   42   28.1   43   25.4   44   24.4   45   24.9   46   23.0   47   22.4   48   20.0
  49   20.3   50   16.1   51   17.9   52   19.7
YEAR = 1971
   1   22.4    2   17.9    3   19.6    4   18.7    5   18.6    6   18.6    7   19.6    8   20.6
   9   21.6   10   21.7   11   21.4   12   22.7   13   22.6   14   21.7   15   21.6   16   20.1
  17   28.1   18   29.4   19   26.3   20   25.9   21   28.9   22   26.7   23   27.9   24   29.1
  25   29.9   26   28.0   27   29.6   28   28.9   29   30.3   30   29.4   31   29.6   32   31.1
  33   30.9   34   30.1   35   30.4   36   30.4   37   29.7   38   28.6   39   27.7   40   29.4
  41   25.9   42   26.1   43   25.7   44   25.7   45   21.7   46   23.1   47   23.6   48   23.4
  49   20.1   50   17.4   51   18.7   52   20.0
YEAR = 1972
   1   18.4    2   18.3    3   19.4    4   18.9    5   20.3    6   17.7    7   19.7    8   19.7
   9   21.2   10   21.2   11   19.3   12   20.0   13   24.7   14   24.0   15   25.8   16   24.9
  17   28.9   18   24.9   19   24.4   20   26.2   21   25.2   22   25.7   23   29.1   24   29.8
  25   30.4   26   29.3   27   29.5   28   29.0   29   30.1   30   29.5   31   31.2   32   30.6
  33   31.1   34   31.5   35   30.8   36   30.5   37   29.4   38   28.9   39   27.5   40   29.6
  41   25.8   42   26.0   43   25.1   44   24.9   45   23.4   46   23.7   47   21.2   48   24.9
  49   20.1   50   19.2   51   16.8   52   18.0
YEAR = 1973
   1   19.4    2   17.7    3   17.2    4   19.6    5   18.8    6   19.3    7   23.6    8   18.7
   9   19.0   10   17.8   11   22.8   12   19.7   13   23.3   14   21.9   15   22.3   16   22.6
  17   23.2   18   24.9   19   25.4   20   23.9   21   27.8   22   25.7   23   28.9   24   26.7
  25   27.6   26   28.9   27   28.7   28   29.3   29   31.9   30   31.7   31   30.5   32   30.7
  33   29.6   34   29.6   35   29.9   36   29.5   37   28.9   38   29.1   39   30.4   40   27.5
  41   28.5   42   28.9   43   27.8   44   23.0   45   22.4   46   24.6   47   21.6   48   22.1
  49   21.7   50   21.4   51   19.5   52   20.8
YEAR = 1974
   1   19.2    2   16.8    3   15.7    4   16.4    5   16.8    6   18.9    7   20.0    8   20.0
   9   18.3   10   21.7   11   21.3   12   20.6   13   25.7   14   22.3   15   25.4   16   24.4
  17   24.2   18   26.7   19   25.2   20   31.1   21   25.8   22   26.8   23   26.4   24   28.9
  25   29.2   26   30.0   27   28.9   28   29.2   29   30.9   30   28.4   31   30.5   32   31.4
  33   30.1   34   30.5   35   29.8   36   31.0   37   30.7   38   28.5   39   30.3   40   28.4
  41   28.7   42   30.9   43   29.8   44   27.3   45   26.4   46   23.6   47   22.6   48   22.5
  49   18.1   50   18.5   51   18.0   52   18.2
```

YEAR=1960

WEEK	Y	WEEK*Y	WEEK**2*Y
1	19.40	19.40	19.40
2	19.70	39.40	78.80
3	17.40	52.20	156.60
4	19.60	78.40	313.60
5	21.00	105.00	525.00
6	29.40	176.40	1058.40
7	21.40	149.80	1048.60
8	22.30	178.40	1427.20
9	25.00	225.00	2025.00
10	30.60	306.00	3060.00
11	26.40	290.40	3194.40
12	28.10	337.20	4046.40
13	27.10	352.30	4579.90
14	27.60	386.40	5409.60
15	28.60	429.00	6435.00
16	26.70	427.20	6835.20
17	26.60	452.20	7687.40
18	27.40	493.20	8877.59
19	29.30	556.70	10577.30
20	28.40	568.00	11359.99
21	30.00	630.00	13230.00
22	30.30	666.60	14665.20
23	30.30	696.90	16028.70
24	30.90	741.60	17798.39
25	30.00	750.00	18750.00
26	30.60	795.60	20685.60
MEAN	26.31	380.90	6918.20

YEAR=1961

WEEK	Y	WEEK*Y	WEEK**2*Y
1	18.30	18.30	18.30
2	18.30	36.60	73.20
3	21.90	65.70	197.10
4	21.00	84.00	336.00
5	20.30	101.50	507.50
6	26.60	159.60	957.60
7	25.40	177.80	1244.60
8	21.20	169.60	1356.80
9	23.50	211.50	1903.50
10	22.70	227.00	2270.00
11	26.50	291.50	3206.50
12	28.10	337.20	4046.40
13	29.00	377.00	4901.00
14	28.70	401.80	5625.20
15	25.40	381.00	5715.00
16	26.70	427.20	6835.20
17	26.60	452.20	7687.40
18	28.40	511.20	9201.59
19	27.50	522.50	9927.50
20	27.80	556.00	11120.00
21	29.10	611.10	12833.10
22	29.00	638.00	14036.00
23	29.50	678.50	15605.50
24	30.00	720.00	17280.00
25	29.70	742.50	18562.49
26	30.60	795.60	20685.60
MEAN	25.84	372.88	6774.34

3 - Weekly Average Maximum Temperatures Multiplied by Week Number during the Cotton Growing Season at Alexandria (1960-1974)

```
YEAR=1962                                          YEAR=1963
WEEK     Y       WEEK*Y    WEEK**2*Y              WEEK     Y       WEEK*Y    WEEK**2*Y
  1    19.10      19.10       19.10                 1    20.10      20.10       20.10
  2    18.00      36.00       72.00                 2    18.40      36.80       73.60
  3    23.30      69.90      209.70                 3    20.60      61.80      185.40
  4    21.00      84.00      336.00                 4    24.70      98.80      395.20
  5    21.00     105.00      525.00                 5    22.90     114.50      572.50
  6    26.10     156.60      939.60                 6    23.00     138.00      828.00
  7    25.10     175.70     1229.90                 7    25.10     175.70     1229.90
  8    21.60     172.80     1382.40                 8    26.00     208.00     1664.00
  9    23.40     210.60     1895.40                 9    23.00     207.00     1863.00
 10    22.40     224.00     2240.00                10    24.10     241.00     2410.00
 11    28.30     311.30     3424.30                11    25.10     276.10     3037.10
 12    29.00     348.00     4176.00                12    25.10     301.20     3614.40
 13    27.90     362.70     4715.09                13    27.60     358.80     4664.40
 14    27.90     390.60     5468.39                14    25.60     358.40     5017.60
 15    25.90     388.50     5827.50                15    25.00     375.00     5625.00
 16    27.00     432.00     6912.00                16    27.40     438.40     7014.40
 17    27.10     460.70     7831.90                17    26.90     457.30     7774.09
 18    28.10     505.80     9104.40                18    26.30     473.40     8521.20
 19    28.00     532.00    10108.00                19    29.70     564.30    10721.70
 20    28.10     562.00    11240.00                20    31.10     622.00    12440.00
 21    28.30     594.30    12480.30                21    32.00     672.00    14112.00
 22    29.00     638.00    14036.00                22    31.10     684.20    15052.40
 23    29.70     683.10    15711.29                23    29.70     683.10    15711.29
 24    30.40     729.60    17510.39                24    30.90     741.60    17798.39
 25    29.30     732.50    18312.50                25    35.90     897.50    22437.49
 26    31.30     813.80    21158.80                26    34.10     886.60    23051.60
MEAN   26.01     374.56     6802.53               MEAN   26.59     388.14     7147.48
```

YEAR=1964

WEEK	Y	WEEK*Y	WEEK**2*Y
1	21.70	21.70	21.70
2	21.10	42.20	84.40
3	23.90	71.70	215.10
4	20.10	80.40	321.60
5	21.00	105.00	525.00
6	24.30	145.80	874.80
7	21.30	149.10	1043.70
8	21.30	170.40	1363.20
9	24.10	216.90	1952.10
10	21.90	219.00	2190.00
11	22.10	243.10	2674.10
12	25.70	308.40	3700.80
13	27.40	356.20	4630.59
14	33.90	474.60	6644.39
15	30.30	454.50	6817.50
16	29.40	470.40	7526.40
17	31.60	537.20	9132.40
18	28.90	520.20	9363.59
19	31.00	589.00	11191.00
20	32.90	658.00	13159.99
21	31.60	663.60	13935.60
22	31.10	684.20	15052.40
23	29.40	676.20	15552.59
24	30.10	722.40	17337.60
25	32.60	815.00	20375.00
26	30.00	780.00	20280.00
MEAN	26.87	391.35	7152.51

YEAR=1965

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.90	20.90	20.90
2	22.00	44.00	88.00
3	20.30	60.90	182.70
4	21.70	86.80	347.20
5	20.70	103.50	517.50
6	22.40	134.40	806.40
7	25.70	179.90	1259.30
8	26.30	210.40	1683.20
9	21.30	191.70	1725.30
10	21.40	214.00	2140.00
11	22.70	249.70	2746.70
12	22.00	264.00	3168.00
13	25.60	332.80	4326.40
14	30.70	429.80	6017.20
15	26.90	403.50	6052.50
16	27.10	433.60	6937.60
17	27.60	469.20	7976.40
18	27.70	498.60	8974.80
19	28.70	545.30	10360.70
20	27.30	546.00	10920.00
21	32.10	674.10	14156.10
22	30.70	675.40	14858.80
23	30.90	710.70	16346.09
24	30.40	729.60	17510.39
25	29.40	735.00	18374.99
26	29.00	754.00	19604.00
MEAN	25.83	372.99	6811.57

YEAR=1966

WEEK	Y	WEEK*Y	WEEK**2*Y
1	19.40	19.40	19.40
2	20.00	40.00	80.00
3	22.10	66.30	198.90
4	19.60	78.40	313.60
5	26.00	130.00	650.00
6	22.40	134.40	806.40
7	24.70	172.90	1210.30
8	25.90	207.20	1657.60
9	23.30	209.70	1887.30
10	26.10	261.00	2610.00
11	25.40	279.40	3073.40
12	30.90	370.80	4449.60
13	25.70	334.10	4343.30
14	26.40	369.60	5174.39
15	26.90	403.50	6052.50
16	28.70	459.20	7347.20
17	29.60	503.20	8554.40
18	29.70	534.60	9622.80
19	28.90	549.10	10432.89
20	29.40	588.00	11759.99
21	31.10	653.10	13715.10
22	29.00	638.00	14036.00
23	30.40	699.20	16081.59
24	31.00	744.00	17856.00
25	30.40	760.00	18999.99
26	28.40	738.40	19198.39
MEAN	26.59	382.44	6928.11

YEAR=1967

WEEK	Y	WEEK*Y	WEEK**2*Y
1	19.10	19.10	19.10
2	18.40	36.80	73.60
3	19.70	59.10	177.30
4	20.00	80.00	320.00
5	20.30	101.50	507.50
6	22.30	133.80	802.80
7	21.90	153.30	1073.10
8	23.70	189.60	1516.80
9	24.30	218.70	1968.30
10	24.40	244.00	2440.00
11	26.10	287.10	3158.10
12	27.00	324.00	3888.00
13	30.00	390.00	5070.00
14	27.00	378.00	5292.00
15	27.00	405.00	6075.00
16	30.60	489.60	7833.60
17	28.30	481.10	8178.70
18	29.30	527.40	9493.20
19	29.00	551.00	10469.00
20	29.40	588.00	11759.99
21	31.90	669.90	14067.89
22	31.70	697.40	15342.80
23	30.90	710.70	16346.09
24	30.60	734.40	17625.60
25	30.10	752.50	18812.50
26	29.40	764.40	19874.39
MEAN	26.25	384.09	7007.12

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YEAR=1968                                        YEAR=1969
 WEEK        Y      WEEK*Y   WEEK**2*Y           WEEK        Y      WEEK*Y   WFEK**2*Y
    1    22.00       22.00       22.00              1    23.10       23.10       23.10
    2    21.30       42.60       85.20              2    21.70       43.40       86.80
    3    20.70       62.10      186.30              3    23.00       69.00      207.00
    4    20.00       80.00      320.00              4    19.60       78.40      313.60
    5    20.10      100.50      502.50              5    26.00      130.00      650.00
    6    26.00      156.00      936.00              6    23.00      138.00      828.00
    7    32.90      230.30     1612.10              7    21.10      147.70     1033.90
    8    24.70      197.60     1580.80              8    23.90      191.20     1529.60
    9    25.00      225.00     2025.00              9    23.90      215.10     1935.90
   10    25.90      259.00     2590.00             10    24.40      244.00     2440.00
   11    27.40      301.40     3315.40             11    26.70      293.70     3230.70
   12    28.60      343.20     4118.40             12    26.40      316.80     3801.60
   13    27.30      354.90     4613.70             13    26.60      345.80     4495.40
   14    32.60      456.40     6389.60             14    30.00      420.00     5880.00
   15    31.90      478.50     7177.50             15    31.40      471.00     7065.00
   16    30.70      491.20     7859.20             16    31.70      507.20     8115.20
   17    29.60      503.20     8554.40             17    29.00      493.00     8381.00
   18    31.10      559.80    10076.40             18    29.90      538.20     9687.59
   19    30.90      587.10    11154.89             19    28.90      549.10    10432.89
   20    32.30      646.00    12920.00             20    29.30      586.00    11720.00
   21    31.60      663.60    13935.60             21    28.90      606.90    12744.89
   22    30.70      675.40    14858.80             22    29.30      644.60    14181.20
   23    29.30      673.90    15499.70             23    29.60      680.80    15658.40
   24    32.70      784.80    18835.20             24    28.90      693.60    16646.39
   25    35.60      890.00    22250.00             25    30.60      765.00    19125.00
   26    29.90      777.40    20212.39             26    29.90      777.40    20212.39
 MEAN    28.11      406.23     7370.42           MEAN    26.80      383.42     6939.44
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YEAR=1970                                                  YEAR=1971
  WEEK        Y         WEEK*Y      WEEK**2*Y                WEEK        Y         WEEK*Y      WEEK**2*Y
    1       23.00        23.00        23.00                    1       21.60        21.60        21.60
    2       24.60        49.20        98.40                    2       21.70        43.40        86.80
    3       25.00        75.00       225.00                    3       21.40        64.20       192.60
    4       20.30        81.20       324.80                    4       22.70        90.80       363.20
    5       24.40       122.00       610.00                    5       22.60       113.00       565.00
    6       22.60       135.60       813.60                    6       21.70       130.20       781.20
    7       28.60       200.20      1401.40                    7       21.60       151.20      1058.40
    8       21.60       172.80      1382.40                    8       20.10       160.80      1286.40
    9       25.10       225.90      2033.10                    9       28.10       252.90      2276.10
   10       23.30       233.00      2330.00                   10       29.40       294.00      2940.00
   11       30.90       339.90      3738.90                   11       26.30       289.30      3182.30
   12       28.60       343.20      4118.40                   12       25.90       310.80      3729.60
   13       26.60       345.80      4495.40                   13       28.90       375.70      4884.09
   14       25.70       359.80      5037.20                   14       26.70       373.80      5233.20
   15       27.10       406.50      6097.50                   15       27.90       418.50      6277.50
   16       28.70       459.20      7347.20                   16       29.10       465.60      7449.60
   17       28.70       487.90      8294.30                   17       29.90       508.30      8641.09
   18       29.10       523.80      9428.40                   18       28.00       504.00      9072.00
   19       29.30       556.70     10577.30                   19       29.60       562.40     10685.60
   20       29.70       594.00     11879.99                   20       28.90       578.00     11559.99
   21       30.00       630.00     13230.00                   21       30.30       636.30     13362.30
   22       30.30       666.60     14665.20                   22       29.40       646.80     14229.59
   23       30.10       692.30     15922.90                   23       29.60       680.80     15658.40
   24       30.70       736.80     17683.20                   24       31.10       746.40     17913.60
   25       30.70       767.50     19187.49                   25       30.90       772.50     19312.49
   26       31.30       813.80     21158.80                   26       30.10       782.60     20347.60
  MEAN      27.15       386.22      7003.98                  MEAN      26.67       383.61      6965.77
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YEAR=1972                                                      YEAR=1973
 WEEK          Y         WEEK*Y     WEEK**2*Y                   WEEK          Y         WEEK*Y     WEEK**2*Y
   1        21.20        21.20        21.20                       1        19.00        19.00        19.00
   2        21.20        42.40        84.80                       2        17.80        35.60        71.20
   3        19.30        57.90       173.70                       3        22.80        68.40       205.20
   4        20.00        80.00       320.00                       4        19.70        78.80       315.20
   5        24.70       123.50       617.50                       5        23.30       116.50       582.50
   6        24.00       144.00       864.00                       6        21.90       131.40       788.40
   7        25.80       180.60      1264.20                       7        22.30       156.10      1092.70
   8        24.90       199.20      1593.60                       8        22.60       180.80      1446.40
   9        28.90       260.10      2340.90                       9        23.20       208.80      1879.20
  10        24.90       249.00      2490.00                      10        24.90       249.00      2490.00
  11        24.40       268.40      2952.40                      11        25.40       279.40      3073.40
  12        26.20       314.40      3772.80                      12        23.90       286.80      3441.60
  13        25.20       327.60      4258.80                      13        27.80       361.40      4698.20
  14        25.70       359.80      5037.20                      14        25.70       359.80      5037.20
  15        29.10       436.50      6547.50                      15        28.90       433.50      6502.50
  16        29.80       476.80      7628.80                      16        26.70       427.20      6835.20
  17        30.40       516.80      8785.59                      17        27.60       469.20      7976.40
  18        29.30       527.40      9493.20                      18        28.90       520.20      9363.59
  19        29.50       560.50     10649.50                      19        28.70       545.30     10360.70
  20        29.00       580.00     11600.00                      20        29.30       586.00     11720.00
  21        30.10       632.10     13274.10                      21        31.90       669.90     14067.89
  22        29.50       649.00     14278.00                      22        31.70       697.40     15342.80
  23        31.20       717.60     16504.79                      23        30.50       701.50     16134.50
  24        30.60       734.40     17625.60                      24        30.70       736.80     17683.20
  25        31.10       777.50     19437.50                      25        29.60       740.00     18500.00
  26        31.50       819.00     21294.00                      26        29.60       769.60     20009.60
 MEAN       26.83       386.76      7034.98                     MEAN       25.94       378.01      6909.09
```

YEAR=1974

WEEK	Y	WEEK*Y	WEEK**2*Y
1	18.30	18.30	18.30
2	21.70	43.40	86.80
3	21.30	63.90	191.70
4	20.60	82.40	329.60
5	25.70	128.50	642.50
6	22.30	133.80	802.80
7	25.40	177.80	1244.60
8	24.40	195.20	1561.60
9	24.20	217.80	1960.20
10	26.70	267.00	2670.00
11	25.20	277.20	3049.20
12	31.10	373.20	4478.40
13	25.80	335.40	4360.20
14	26.80	375.20	5252.80
15	26.40	396.00	5940.00
16	28.90	462.40	7398.40
17	29.20	496.40	8438.80
18	30.00	540.00	9720.00
19	28.90	549.10	10432.89
20	29.20	584.00	11679.99
21	30.90	648.90	13626.89
22	28.40	624.80	13745.59
23	30.50	701.50	16134.50
24	31.40	753.60	18086.39
25	30.10	752.50	18812.50
26	30.50	793.00	20618.00
MEAN	26.69	384.28	6972.40

PROGRAM (4)
PROGRAMMER

PAGE OF
DATE

Crop yield	Y	week×Y	week²×Y	Year	
3.51	26.31	380.90	6918.20	1.0	ALEXMXCT60
2.66	25.84	372.88	6774.34	2.0	ALEXMXCT61
4.32	26.01	374.56	6802.53	3.0	ALEXMXCT62
4.38	26.59	388.14	7147.48	4.0	ALEXMXCT63
4.96	26.87	391.35	7152.51	5.0	ALEXMXCT64
4.74	25.83	372.99	6811.57	6.0	ALEXMXCT65
5.30	26.59	382.44	6928.11	7.0	ALEXMXCT66
0.66	26.25	384.09	7007.12	8.0	ALEXMXCT67
1.71	28.11	406.23	7370.42	9.0	ALEXMXCT68
2.70	26.80	383.42	6939.44	10.0	ALEXMXCT69
3.80	27.15	386.22	7003.98	11.0	ALEXMXCT70
3.25	26.67	383.61	6965.77	12.0	ALEXMXCT71
3.23	26.83	386.76	7034.98	13.0	ALEXMXCT72
2.43	25.94	378.01	6909.09	14.0	ALEXMXCT73
4.65	26.69	384.28	6972.40	15.0	ALEXMXCT74

4 - Mean weekly average obtained from Step (3) for each year, have been used to calculate the constant values in the maximum temperature equation

WRITTEN	Ø	O	I	1
PUNCH	zero	letter O	letter	number 1

5 - The multiple regression equation for maximum temperatures at Alexandria, obtained from step 4 :-

$$Y = 8.739 + 5.133 \sum_{i=1}^{n} (t^{o}_{i}\ x_{i}) - 0.859 \sum_{i=1}^{n} (t^{1}_{i}\ x_{i}) + 0.027 \sum_{i=1}^{n} (t^{2}_{i}\ x_{i}) - 0.110\ T$$

Where Y = cotton yield (Quintar/Fed.) (Quintar = 157.5 kg)

x = weekly average maximum temperature at Alexandria during the cotton growing season period (March 1st-September 1st).

t = the number of each of the 7-day periods (it is one for the period from March 1st-7th and 26 for the period August 23rd-29th).

n = 26 7-day periods in a given season of the year

T = year number (beginning with one in 1960 and ending with fifteen in 1974).

```
ALEXANDRIA    VARIABLE=MAX.TEMPERATURE    CROP=COTTON

        1960  1961  1962  1963  1964  1965  1966  1967  1968  1969  1970  1971  1972  1973  1974AVERAGE

  1    19.40 18.30 19.10 20.10 21.70 20.90 19.40 19.10 22.00 23.10 23.00 21.60 21.20 19.00 18.30   20.41
  2    19.70 18.30 18.00 18.40 21.10 22.00 20.00 18.40 21.30 21.70 24.60 21.70 21.20 17.80 21.70   20.39
  3    17.40 21.90 23.30 20.60 23.90 20.30 22.10 19.70 20.70 23.00 25.00 21.40 19.30 22.80 21.30   21.51
  4    19.60 21.00 21.00 24.70 20.10 21.70 19.60 20.00 20.00 19.60 20.30 22.70 20.00 19.70 20.60   20.71
  5    21.00 20.30 21.00 22.90 21.00 20.70 26.00 20.30 20.10 26.00 24.40 22.60 24.70 23.30 25.70   22.67
  6    29.40 26.60 26.10 23.00 24.30 22.40 22.40 22.30 26.00 23.00 22.60 21.70 24.00 21.90 22.30   23.87
  7    21.40 25.40 25.10 25.10 21.30 25.70 24.70 21.90 32.90 21.10 28.60 21.60 25.80 22.30 25.40   24.55
  8    22.30 21.20 21.60 26.00 21.30 26.30 25.90 23.70 24.70 23.90 21.60 20.10 24.90 22.60 24.40   23.37
  9    25.00 23.50 23.40 23.00 24.10 21.30 23.30 24.30 25.00 23.90 25.10 28.10 28.90 23.20 24.20   24.42
 10    30.60 22.70 22.40 24.10 21.90 21.40 26.10 24.40 25.90 24.40 23.30 29.40 24.90 24.90 26.70   24.87
 11    26.40 26.50 28.30 25.10 22.10 22.70 25.40 26.10 27.40 26.70 30.90 26.30 24.40 25.40 25.20   25.93
 12    28.10 28.10 29.00 25.10 25.70 22.00 30.90 27.00 28.60 26.40 28.60 25.90 26.20 23.90 31.10   27.11
 13    27.10 29.00 27.90 27.60 27.40 25.60 25.70 30.00 27.30 26.60 26.60 28.90 25.20 27.80 25.80   27.23
 14    27.60 28.70 27.90 25.60 33.90 30.70 26.40 27.00 32.60 30.00 25.70 26.70 25.70 25.70 26.80   28.07
 15    28.60 25.40 25.90 25.00 30.30 26.90 26.90 27.00 31.90 31.40 27.10 27.90 29.10 28.90 26.40   27.91
 16    26.70 26.70 27.00 27.40 29.40 27.10 28.70 30.60 30.70 31.70 28.70 29.10 29.80 26.70 28.90   28.61
 17    26.60 26.60 27.10 26.90 31.60 27.60 29.60 28.30 29.60 29.00 28.70 29.90 30.40 27.60 29.20   28.58
 18    27.40 28.40 28.10 26.30 28.90 27.70 29.70 29.30 31.10 29.90 29.10 28.00 29.30 28.90 30.00   28.81
 19    29.30 27.50 28.00 29.70 31.00 28.70 28.90 29.00 30.90 28.90 29.30 29.60 29.50 28.70 28.90   29.19
 20    28.40 27.80 28.10 31.10 32.90 27.30 29.40 29.40 32.30 29.30 29.70 28.90 29.00 29.30 29.20   29.47
 21    30.00 29.10 28.30 32.00 31.60 32.10 31.10 31.90 31.60 28.90 30.00 30.30 30.10 31.90 30.90   30.65
 22    30.30 29.00 29.00 31.10 31.10 30.70 29.00 31.70 30.70 29.30 30.30 29.40 29.50 31.70 28.40   30.08
 23    30.30 29.50 29.70 29.70 29.40 30.90 30.40 30.90 29.30 29.60 30.10 29.60 31.20 30.50 30.50   30.11
 24    30.90 30.00 30.40 30.90 30.10 30.40 31.00 30.60 32.70 28.90 30.70 31.10 30.60 30.70 31.40   30.69
 25    30.00 29.70 29.30 35.90 32.60 29.40 30.40 30.10 35.60 30.60 30.70 30.90 31.10 29.60 30.10   31.07
 26    30.60 30.60 31.30 34.10 30.00 29.00 28.40 29.40 29.90 29.90 31.30 30.10 31.50 29.60 30.50   30.41
EXECUTION TERMINATED


£SIG
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6 - Weekly Average Maximum Temperatures During Cotton Growing Season
at Alexandria for the Period 1960-1974

7 - The Net Change in Mean Weekly Average Maximum Temperatures Multiplied by Week Number during the Cotton Growing Season, if the Weekly Average Maximum Temperatures Increase by 1 °C

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.57	383.84	6984.71

WEEK	Y	WEEK*Y	WEEK**2*Y
1	21.40	21.40	21.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	383.88	6984.75

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	21.40	42.80	85.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	383.92	6984.87

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	22.50	67.50	202.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	383.96	6985.06

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	21.70	86.80	347.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.00	6985.33

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	23.70	118.50	592.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.03	6985.67

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	24.90	149.40	896.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.07	6986.10

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	25.60	179.20	1254.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.11	6986.60

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	24.40	195.20	1561.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.15	6987.17

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	25.40	228.60	2057.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.19	6587.83

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	25.90	259.00	2590.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.23	6988.56

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	26.90	295.90	3254.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.26	6989.37

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	28.10	337.20	4046.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.30	6990.25

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	28.20	366.60	4765.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.34	6991.21

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	29.10	407.40	5703.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.38	6992.25

```
WEEK        Y       WEEK*Y    WEEK**2*Y
   1     20.40       20.40        20.40
   2     20.40       40.80        81.60
   3     21.50       64.50       193.50
   4     20.70       82.80       331.20
   5     22.70      113.50       567.50
   6     23.90      143.40       860.40
   7     24.60      172.20      1205.40
   8     23.40      187.20      1497.60
   9     24.40      219.60      1976.40
  10     24.90      249.00      2490.00
  11     25.90      284.90      3133.90
  12     27.10      325.20      3902.40
  13     27.20      353.60      4596.80
  14     28.10      393.40      5507.60
  15     28.90      433.50      6502.50
  16     28.60      457.60      7321.60
  17     28.60      486.20      8265.40
  18     28.80      518.40      9331.20
  19     29.20      554.80     10541.20
  20     29.50      590.00     11800.00
  21     30.70      644.70     13538.69
  22     30.10      662.20     14568.40
  23     30.10      692.30     15922.90
  24     30.70      736.80     17683.20
  25     31.10      777.50     19437.50
  26     30.40      790.40     20550.39
MEAN     26.61      384.42      6993.37
```

```
WEEK        Y       WEEK*Y    WEEK**2*Y
   1     20.40       20.40        20.40
   2     20.40       40.80        81.60
   3     21.50       64.50       193.50
   4     20.70       82.80       331.20
   5     22.70      113.50       567.50
   6     23.90      143.40       860.40
   7     24.60      172.20      1205.40
   8     23.40      187.20      1497.60
   9     24.40      219.60      1976.40
  10     24.90      249.00      2490.00
  11     25.90      284.90      3133.90
  12     27.10      325.20      3902.40
  13     27.20      353.60      4596.80
  14     28.10      393.40      5507.60
  15     27.90      418.50      6277.50
  16     29.60      473.60      7577.60
  17     28.60      486.20      8265.40
  18     28.80      518.40      9331.20
  19     29.20      554.80     10541.20
  20     29.50      590.00     11800.00
  21     30.70      644.70     13538.69
  22     30.10      662.20     14568.40
  23     30.10      692.30     15922.90
  24     30.70      736.80     17683.20
  25     31.10      777.50     19437.50
  26     30.40      790.40     20550.39
MEAN     26.61      384.46      6994.56
```

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	29.60	503.20	8554.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.50	6995.83

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	29.80	536.40	9655.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.53	6997.17

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	30.20	573.80	10902.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.57	6958.60

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	30.50	610.00	12200.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.61	7000.10

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	31.70	665.70	13979.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.65	7001.67

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	31.10	684.20	15052.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.69	7003.33

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	31.10	715.30	16451.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.73	7005.06

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	31.70	760.80	18259.20
25	31.10	777.50	19437.50
26	30.40	790.40	20550.39
MEAN	26.61	384.76	7006.87

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	32.10	802.50	20062.50
26	30.40	790.40	20550.39
MEAN	26.61	384.80	7008.75

WEEK	Y	WEEK*Y	WEEK**2*Y
1	20.40	20.40	20.40
2	20.40	40.80	81.60
3	21.50	64.50	193.50
4	20.70	82.80	331.20
5	22.70	113.50	567.50
6	23.90	143.40	860.40
7	24.60	172.20	1205.40
8	23.40	187.20	1497.60
9	24.40	219.60	1976.40
10	24.90	249.00	2490.00
11	25.90	284.90	3133.90
12	27.10	325.20	3902.40
13	27.20	353.60	4596.80
14	28.10	393.40	5507.60
15	27.90	418.50	6277.50
16	28.60	457.60	7321.60
17	28.60	486.20	8265.40
18	28.80	518.40	9331.20
19	29.20	554.80	10541.20
20	29.50	590.00	11800.00
21	30.70	644.70	13538.69
22	30.10	662.20	14568.40
23	30.10	692.30	15922.90
24	30.70	736.80	17683.20
25	31.10	777.50	19437.50
26	31.40	816.40	21226.39
MEAN	26.61	384.84	7010.71

8 - Predicted Cotton Yields for each year during the period 1960-1974 (Quintar/Feddan)

```
(5.133 * 26.31)-( 0.859 * 380.90)+(0.027 *  6918.20)-(0.110 *  1.0)+  8.739 =    3.277  ALEXMXCT60

(5.133 * 25.84)-( 0.859 * 372.88)+(0.027 *  6774.34)-(0.110 *  2.0)+  8.739 =    3.759  ALEXMXCT61

(5.133 * 26.01)-( 0.859 * 374.56)+(0.027 *  6802.53)-(0.110 *  3.0)+  8.739 =    3.840  ALEXMXCT62

(5.133 * 26.59)-( 0.859 * 388.14)+(0.027 *  7147.48)-(0.110 *  4.0)+  8.739 =    4.355  ALEXMXCT63

(5.133 * 26.87)-( 0.859 * 391.35)+(0.027 *  7152.51)-(0.110 *  5.0)+  8.739 =    3.061  ALEXMXCT64

(5.133 * 25.83)-( 0.859 * 372.99)+(0.027 *  6811.57)-(0.110 *  6.0)+  8.739 =    4.179  ALEXMXCT65

(5.133 * 26.59)-( 0.859 * 382.44)+(0.027 *  6928.11)-(0.110 *  7.0)+  8.739 =    2.999  ALEXMXCT66

(5.133 * 26.25)-( 0.859 * 384.09)+(0.027 *  7007.12)-(0.110 *  8.0)+  8.739 =    1.859  ALEXMXCT67

(5.133 * 28.11)-( 0.859 * 406.23)+(0.027 *  7370.41)-(0.110 *  9.0)+  8.739 =    2.087  ALEXMXCT68

(5.133 * 26.80)-( 0.859 * 383.42)+(0.027 *  6939.43)-(0.110 * 10.0)+  8.739 =    3.210  ALEXMXCT69

(5.133 * 27.15)-( 0.859 * 386.22)+(0.027 *  7003.98)-(0.110 * 11.0)+  8.739 =    4.234  ALEXMXCT70

(5.133 * 26.67)-( 0.859 * 383.61)+(0.027 *  6965.77)-(0.110 * 12.0)+  8.739 =    2.871  ALEXMXCT71

(5.133 * 26.83)-( 0.859 * 386.76)+(0.027 *  7034.98)-(0.110 * 13.0)+  8.739 =    2.745  ALEXMXCT72

(5.133 * 25.94)-( 0.859 * 378.01)+(0.027 *  6909.09)-(0.110 * 14.0)+  8.739 =    2.184  ALEXMXCT73

(5.133 * 26.69)-( 0.859 * 384.28)+(0.027 *  6972.40)-(0.110 * 15.0)+  8.739 =    2.247  ALEXMXCT74
EXECUTION TERMINATED
```

9 - Predicted Cotton Yields for each week during Cotton Growing Season

```
(5.133 * 26.57)-(C.859 * 383.84)+(0.027 *  6984.71)+  8.739 =   3.992  ALEXCTMXBA

(5.133 * 26.61)-(0.859 * 383.88)+(0.027 *  6984.75)+  8.739 =   4.164  ALEXCTMX 1

(5.133 * 26.61)-(C.859 * 383.92)+(0.027 *  6984.87)+  8.739 =   4.133  ALEXCTMX 2

(5.133 * 26.61)-(C.859 * 383.96)+(0.027 *  6985.06)+  8.739 =   4.103  ALEXCTMX 3

(5.133 * 26.61)-(C.859 * 384.00)+(0.027 *  6985.33)+  8.739 =   4.076  ALEXCTMX 4

(5.133 * 26.61)-(C.859 * 384.03)+(0.027 *  6985.67)+  8.739 =   4.060  ALEXCTMX 5

(5.133 * 26.61)-(C.859 * 384.07)+(0.027 *  6986.10)+  8.739 =   4.037  ALEXCTMX 6

(5.133 * 26.61)-(C.859 * 384.11)+(0.027 *  6986.60)+  8.739 =   4.016  ALEXCTMX 7

(5.133 * 26.61)-(0.859 * 384.15)+(0.027 *  6987.17)+  8.739 =   3.997  ALEXCTMX 8

(5.133 * 26.61)-(C.859 * 384.19)+(0.027 *  6987.83)+  8.739 =   3.980  ALEXCTMX 9

(5.133 * 26.61)-(0.859 * 384.23)+(0.027 *  6988.56)+  8.739 =   3.966  ALEXCTMX10

(5.133 * 26.61)-(0.859 * 384.26)+(0.027 *  6989.37)+  8.739 =   3.962  ALEXCTMX11

(5.133 * 26.61)-(0.859 * 384.30)+(0.027 *  6990.25)+  8.739 =   3.951  ALEXCTMX12

(5.133 * 26.61)-(0.859 * 384.34)+(0.027 *  6991.21)+  8.739 =   3.943  ALEXCTMX13
EXECUTION TERMINATED
```

BA = Basic week
(no change in weekly
average maximum
temperature)

```
(5.133 * 26.61)-(0.859 * 384.38)+(0.027 *   6992.25)+  8.739 =    3.937  ALEXCTMX14

(5.133 * 26.61)-(0.859 * 384.42)+(0.027 *   6993.37)+  8.739 =    3.933  ALEXCTMX15

(5.133 * 26.61)-(0.859 * 384.46)+(0.027 *   6994.56)+  8.739 =    3.930  ALEXCTMX16

(5.133 * 26.61)-(0.859 * 384.50)+(0.027 *   6995.83)+  8.739 =    3.930  ALEXCTMX17

(5.133 * 26.61)-(0.859 * 384.53)+(0.027 *   6997.17)+  8.739 =    3.940  ALEXCTMX18

(5.133 * 26.61)-(0.859 * 384.57)+(0.027 *   6998.60)+  8.739 =    3.945  ALEXCTMX19

(5.133 * 26.61)-(0.859 * 384.61)+(0.027 *   7000.10)+  8.739 =    3.951  ALEXCTMX20

(5.133 * 26.61)-(0.859 * 384.65)+(0.027 *   7001.67)+  8.739 =    3.959  ALEXCTMX21

(5.133 * 26.61)-(0.859 * 384.69)+(0.027 *   7003.33)+  8.739 =    3.969  ALEXCTMX22

(5.133 * 26.61)-(0.859 * 384.73)+(0.027 *   7005.06)+  8.739 =    3.982  ALEXCTMX23

(5.133 * 26.61)-(0.859 * 384.76)+(0.027 *   7006.87)+  8.739 =    4.005  ALEXCTMX24

(5.133 * 26.61)-(0.859 * 384.80)+(0.027 *   7008.75)+  8.739 =    4.021  ALEXCTMX25

(5.133 * 26.61)-(0.859 * 384.84)+(0.027 *   7010.71)+  8.739 =    4.040  ALEXCTMX26

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Step 10

The Net Change in Cotton Yield Using the Multiple Regression Equation for Maximum Temperature at Alexandria (see Figure 12.5 in the text)

Week No.	The result of the equations obtained for each week	The result of the basic equation	Net change in cotton yield (Quintar/Fed.) *	Net change in cotton yield (kg/Fed.)
1	4.164	3.992	0.172	27.090
2	4.133		0.141	22.200
3	4.103		0.111	17.480
4	4.076		0.084	13.230
5	4.060		0.068	10.710
6	4.037		0.045	7.088
7	4.016		0.024	3.780
8	3.997		0.005	0.788
9	3.980		-0.012	-1.890
10	3.9666		-0.026	-4.095
11	3.962		-0.030	-4.725
12	3.951		-0.041	-6.458
13	3.943		-0.049	-7.718
14	3.937		-0.055	-8.663
15	3.933		-0.059	-0.292
16	3.930		-0.062	-9.765
17	3.930		-0.062	-9.765
18	3.940		-0.052	-8.190
19	3.945		-0.047	-7.403
20	3.951		-0.041	-6.458
21	3.959		-0.033	-5.198
22	3.969		-0.023	-3.623
23	3.982		-0.010	-1.575
24	4.005		0.013	2.048
25	4.021		0.029	4.568
26	4.040		0.048	7.560

* Quintar = 157.5 Kg