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thesis entitled

THE CLIMATIC REGIONS OF THE SOCIALIST PEOPLE'S LIBYAN ARAB JAMAHIRIYA ACCORDING TO THORNTHWAITE'S WATER BALANCE METHOD

presented by

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has been accepted towards fulfillment
of the requirements for

Masters degree in Geography

Jay R. Harman
Major professor

Date 1/31/79

O-7639

THE CLIMATIC REGIONS OF THE SOCIALIST PEOPLE'S LIBYAN ARAB JAMAHIRIYA ACCORDING TO THORNTHWAITE'S WATER BALANCE METHOD

By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Geography

1978

ABSTRACT

THE CLIMATIC REGIONS OF THE SOCIALIST PEOPLE'S LIBYAN ARAB JAMAHIRIYA ACCORDING TO THORNTHWAITE'S WATER BALANCE METHOD

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Asseddigh M. El-Aghel

The interaction between climatic parameters among other factors, determines the soil moisture availability, which is a suitable indicator for the topoclimate of a region.

The present study was undertaken to define the climatic regions of Libya according to their moisture availability. Twenty-three station records of temperature and precipitation were examined for a 15-years period, in order to calculate the water balance of Libya according to Thornthwaite's method.

The calculations indicate that the country is under the influence of various degrees of aridity. Only one station is classified as dry subhumid. In the average year, water deficiency prevails. Three stations, however, indicate a seasonal water surplus.

Maps of thermal efficiency, the relative degree of aridity, and for climatic regions of Libya were drafted.

Asseddigh M. El-Aghel

Information about the seasonal and annual availability of water and the degree of water need is given for individual regions. The results should be useful in planning for future irrigation or grazing projects in Libya.

ACKNOWLEDGMENTS

I wish to express my sincere appreciation to the individuals who assisted in the completion of this study. Special appreciation is due to Professor D. Brunnschweiler, my committee chairman, not only for the advice and assistance he provided on the thesis, but also for igniting my interest in the research process. Special appreciation also goes to Professor J. Harman of the Department of Geography for his insights and corrections.

Grateful appreciation is expressed to the people of the Libyan Meteorological Department in Tripoli, whose assistance in data collection was invaluable.

I should also like to thank Mr. M. Lipsey, who completed the final draft of the maps and diagrams.

Finally, my sincerest gratitude to my family for their support, and to my friends who encouraged me to pursue the search for knowledge.

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I. INTRODUCTION AND STATEMENT OF PROBLEM

Availability of water is a prerequisite for most primary economic activities of people. An ample supply of water in some regions and its scarcity in others is almost entirely due to the climatic conditions on the surface of the earth. In general, the terms "humid" and "arid" characterize the water-rich and water-scarce areas of the world. Humid regions are characterized by a supply of water that is sufficient for, or exceeds, water needs, whereas arid zones have to contend with a water supply that does not meet their demand.

The arid zone has long engaged the attention of geographers, but the concept, definition, and effect of aridity continue to be a major problem in climatic research. Riley (1974, p. 82) defined aridity as the "lack of moisture", while Deacon (1958, p. 9) argued that the arid zones are "those areas where the water balance is adverse," and Steila (1972, p. 1) described the arid zone as "an area in which the potential water demand induced by solar radiation greatly exceeds precipitation." It should be emphasized at this stage that it is impossible to select a particular isohyet to serve as a boundary between humid and arid environments.

The decisive factors that are responsible for aridity are terrestrial, on one hand, atmospheric on the other. Of primary importance are the physical characteristics of air masses and their involvement in the general circulation of the air. Aridity prevails where precipitation fails to provide enough water to meet the demands of both evaporation and transpiration. In arid zones, the rainfall alone is not an adequate index of aridity, because the effectiveness of rain depends upon the rate of evaporation which, in turn, is governed by temperature. Secondary factors that affect the rate of evaporation are the humidity of the air, the prevailing winds, the nature of the surface, and the seasonal distribution of precipitation.

The meteorological approach has enabled scholars to conceive the function of the climatic variability on both a short- and long-term basis. Parameters like temperature, precipitation, pressure, wind, and humidity were the only elements on which climatic classifications were originally established.

A substantial improvement in our understanding of climatic types was made by Koeppen when he related the climatic regions to the distribution of vegetation (Koeppen, 1931). Thornthwaite greatly advanced the study of aridity. He first introduced the term evapotranspiration, defined as "the combined evaporation from the soil surface and transpiration from plants" (Thornthwaite, 1948, p. 55).

Furthermore, Thornthwaite introduced the concept of potential evapotranspiration which he defined as:

> The amount of water which will be lost from a surface completely covered with vegetation, if there is sufficient water in the soil at all times for the use of the vegetation (ibid., p. 15).

Potential evapotranspiration, equivalent to water need, is a most valuable component of a climatic classification.

Research has enabled climatologists to develop indices to classify regions according to their moisture availability. These indices are used in the classification of climate as well as in planning for irrigation. Dregne (1970) found that--

> For most of the countries in the arid zones of the world, the scattered and incomplete output could be doubled or tripled with the same water base if better farming methods are adopted (p. 15).

Shortage of water constitutes a great problem in Libya. Planning for the economic utilization of water is absolutely indispensable before any irrigation project can be undertaken. A sound knowledge of the degree of aridity can be a valuable help in making decisions concerning the utilization of the land.

The purpose of this study is to investigate the climate of Libya in terms of the water balance, in order to classify the climatic types of the country according to seasonal and annual moisture availability.

This study is intended to fill a major gap that exists in the meager climatic literature of Libya, with the hope of contributing toward a better understanding of the degree of aridity in Libya.

II. CHARACTERISTICS OF THE STUDY AREA

Location

Libya is a vast country (1750.000 Km^2) situated in the central part of North Africa. Physiographically, most of the country is a part of the great Northern African plateau, extending approximately from Longitude 9°E to 25°E and from Latitude 19°N to 33°N. Figure 1 indicates the main features of Libyan topography. The Tibesti and Tasili mountains are in the south and southwest. The Suda and Harruj Heights are in the central part, whereas the Jebel Al-Akhdar and Jebel Nefusa are in the north. Libya has no rivers, but some water courses called "waddies" exist that remain dry until the rainy season.

General Aspects of the Climate of Libya

The fundamental control of the climate of Libya is the general circulation. Libya lies under the effect of the east flank of the northern Atlantic anticyclone, and is, therefore, subjected to divergent and subsiding air, the major cause of aridity. During subsidence the air is adiabatically warmed, resulting in a thermal inversion and

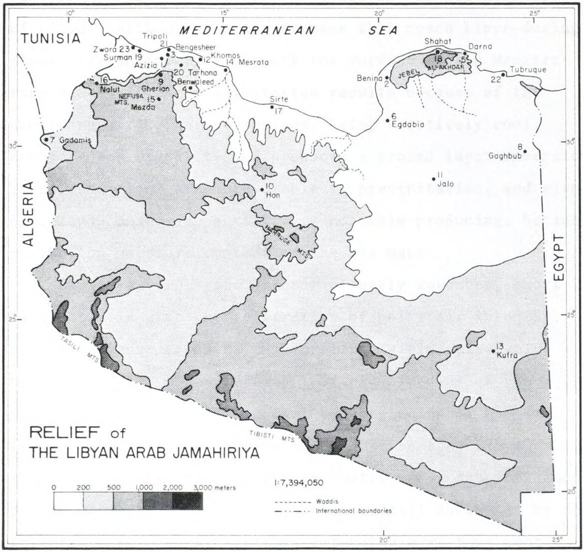
MEDITERRANEAN SEA
TUNISIA
ALGERIA
EGYPT
Tripoli 21
Bengesheer
Zwara 23
Surman 19
Azizia 1
3
Khomos 12
14 Mesrata
20 Tarhona
Benwaleed 4
16 Nalut
9 Gherian
NEFUSA MTS.
15 Mezda
Sirte 17
7 Gadamis
10 Hon
Shahat
18
Darna 5
JEBEL AL-AKHDAR
Benina 2
22 Tubruque
6 Egdabia
8 Gaghbub
11 Jalo
13 Kufra
TASILI MTS
TIBISTI MTS
RELIEF of THE LIBYAN ARAB JAMAHIRIYA
0 200 500 1,000 2,000 3,000 meters
1:7,394,050
Waddis
International boundaries
10°
15°
20°
25°
30°

Figure 1

a stable condition. Lower troposphere conditions are entirely unfavorable to precipitation during the strong summer dominance of the Azores High. Northerly and northeasterly (trade system) flow prevails in the northern part of Libya. Although the air streams that reach Libya during summer are in interaction with the surface of the Mediterranean Sea, little precipitation results because of the subsiding air. The sea surface, being relatively cool, enhances the stability and produces a ground layer inversion. These conditions are unfavorable to precipitation, and even over land convective activity is not rain-producing, because of the low moisture content of the air mass.

During autumn, late October or early November, short waves move in with the penetration of polar air into the Mediterranean. Frequent thunderstorms yield relatively heavy rainfall, often leading to rapid flooding of the waddies. These rainstorms mark the beginning of the dry farming cultivation. During the winter season, Libya, especially the northern part, is mostly under the influence of the westerlies. Winter weather is still dominated by the Atlantic high pressure systems extending over Northwest Africa, and occasionally, by anticyclones over Southeastern Asia; by far the most important synoptic feature, however, is an upper trough over the Mediterranean, inducing cyclogenesis throughout the winter season. Cyclonic storms and their associated fronts produce a distinct winter maximum of precipitation in Libya. However, only a strong cyclonic system, with a sufficiently southern trajectory, yields precipitation in the southern half of the country. The continental polar [cP] and the maritime polar [mP] air masses reach Libya thermally modified after a prolonged passage over the relatively warm Mediterranean; the accompanying increase in the lapse rate leads to instability. These processes produce showers over the northern part of the country. Figure 2 shows the distribution of mean annual rainfall in the country.

During the spring season, the westerlies still dominate the synoptic pattern of Libya. Strong meridional temperature gradients form or intensify depressions over Southern Tunisia and Northwestern Libya. These depressions move east-northeast, with cold fronts extending as far south as Latitude 20°N. Continental tropical air (cT) arrives with the southerly flow in warm sectors of depressions; it is associated with high temperatures and extremely low humidity, often less than 10% (Tryah-Sharaf, 1971, p. 94).

The arrival of the (cT) air mass on the coast of Libya indicates the approach of desert depression. The southerly flow, originating in the Sahara, is locally called ghibli. It carries desert dust northward to the Mediterranean, in rare occasions even beyond the Alps. The ghibli may cause

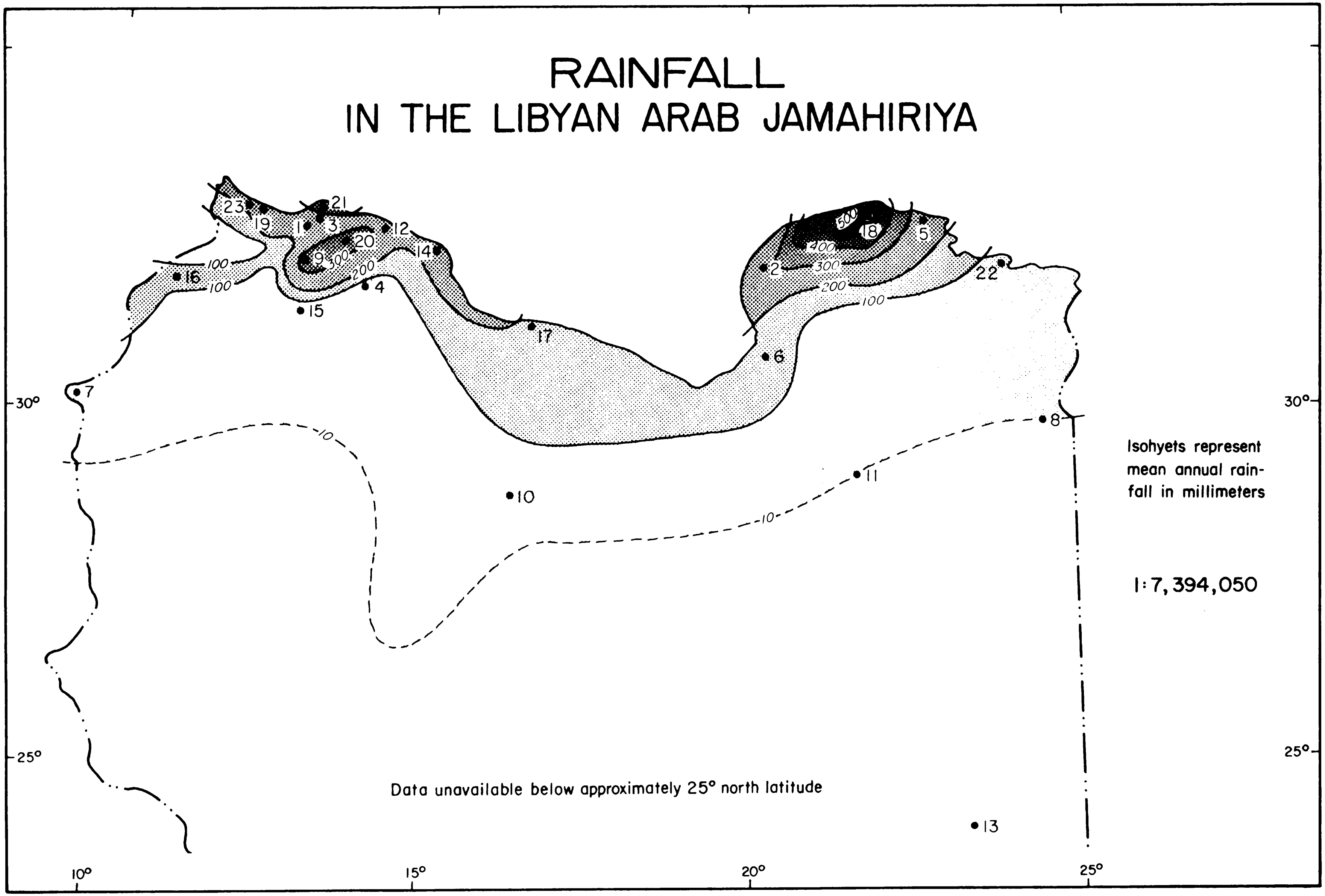
RAINFALL
IN THE LIBYAN ARAB JAMAHIRIYA
Isohyets represent mean annual rainfall in millimeters
1:7,394,050
Data unavailable below approximately 25° north latitude
10°
15°
20°
25°
30°
25°
100
200
300
400
500
10
1
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Figure 2

severe damage to crops if it occurs during the critical growth stage. Pedgley (1972, p. 229) pointed out that the "desert depressions are not frequent; an average of about six each year can be expected."* Since evaporation increases greatly during ghibli weather, they play a major role in reducing the meagerly available moisture even more.

Temperature

Libya receives high and practically uninterrupted amounts of solar radiation; consequently, high temperatures and evaporation rates as high as 127 cm per year have been recorded. The temperature curves reflect the constantly high intensity of insolation. Figure 3 shows the march of temperature at selected stations in Libya, which are representative of conditions in the northern plains and highlands, and in the desert. Insolation in Libya is most intense when the sun reaches the northern solstice. Maximum summer daytime temperature between 40°C and 45°C are common. Azizia (1) has long been known for the highest temperature measured at the earth surface; the terrestrial maximum of 58°C was recorded in 1922. The mean monthly temperature ranges, however, from 11.7°C to 27.6°C. This shows the strong

*This might be too large a number. More investigation is needed to determine precisely the frequency of desert depressions originating in that area.

The March of Temperature and Precipitation at Selected Stations

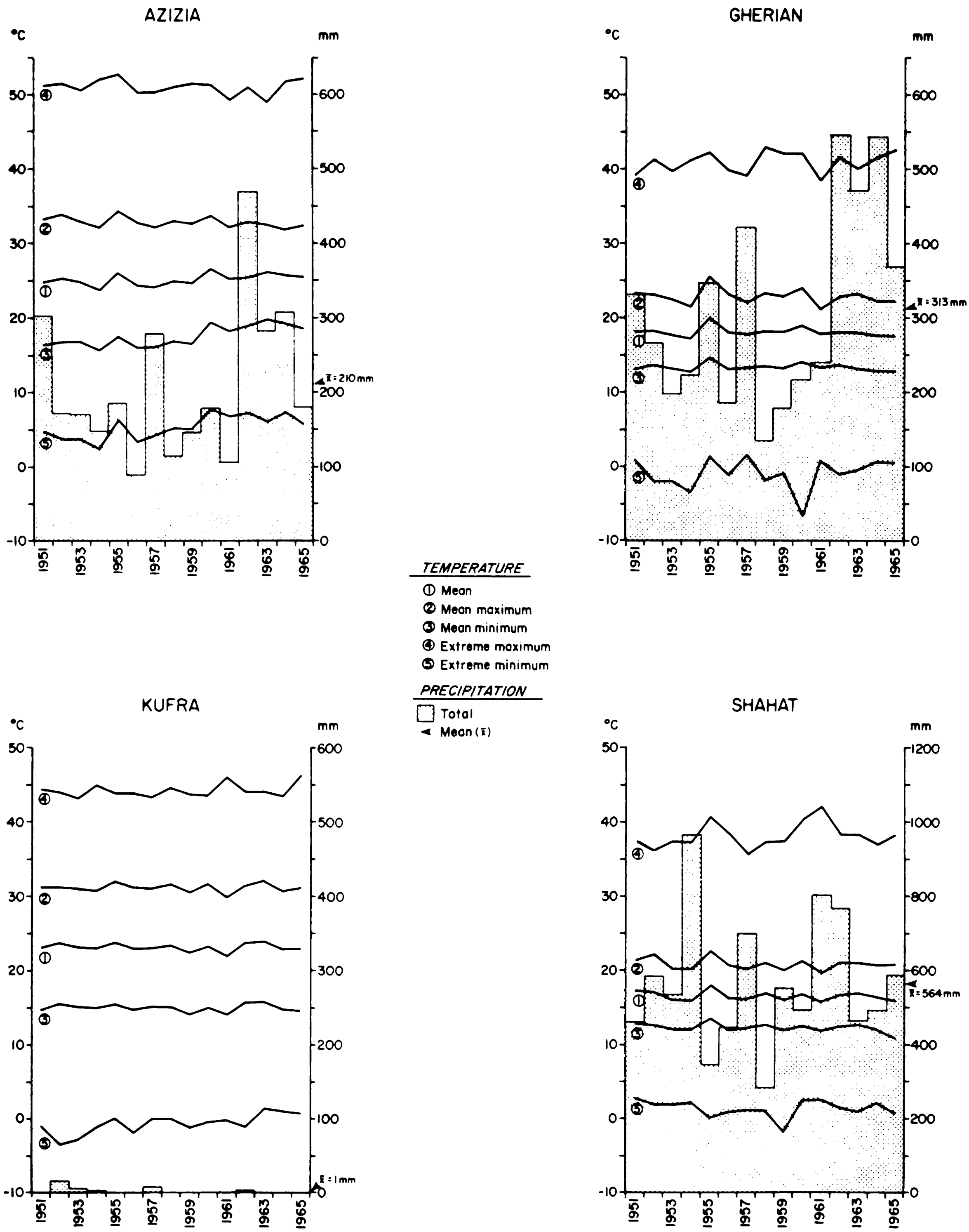

Figure 3.

influence of the northern air masses during winter seasons. The absolute minimum of -2.7°C was measured in February 1954. Cherian (9), located at a higher elevation (725 m), is known for the lowest mean January temperature (≈8.7°C) in the country, but the mean July temperature reaches almost the same value as at Azizia (≈27°C). The mean July temperature in Shahat (18) is ≈23°C. Since both Gherian and Shahat are situated at a high elevation, the lower mean July temperature of Shahat is due to both the latitudinal position half a degree to the north, and the flow pattern. The Northeasterlies (trade winds) reach Shahat without any modification in its characteristics, because the location of Shahat is much closer to the Mediterranean than that of Gherian.

There is a greater thermal uniformity during the high-sun season than in the winter when the temperatures show a greater variation. Daytime temperatures in the winter are lower than in the summer, and the night temperatures drop to low levels, sometimes below the freezing point. At Kufra (13), with a January mean temperature of 19.9°C, the maxima and minima recorded are, respectively, 30.6°C and -1.7°C. Both Gherian (9) and Shahat (18) have a summer maximum of ≈40°C, and to the south, at Kufra (13) and Jalo (11), maxima of ≈44°C are common because of the ground layer heating of the continental tropical air mass which prevails in those areas.

The relative humidity is affected by the type of air mass prevailing. In summer, the relative humidity rarely exceeds 50% in Libya, except in Shahat (18) and in a narrow strip along the coast. The relative humidity in the southern part of Libya is usually less than 30%. During winter and spring a rapid lowering in the relative humidity is caused by the movement of the desert depressions, which cause the flow of continental tropical air to the northern parts of the country.

The continuous insolation in Libya creates local low pressure zones which create diurnal onshore breezes. Such local circulations influence the climatic condition by only a slight increase in relative humidity, however. They affect only a narrow strip south of the coast, because the winds subside quickly after sunset when the surface of the ground cools rapidly by radiation loss.

Natural Vegetation

Natural vegetation, in spite of a relatively small number of plant genera, is quite variegated in Libya. Variation in soil moisture, which depends on the soil and climatic circumstances, leads to distinct variations in the distribution, density, and species associations of plants.

Arboreal vegetation is concentrated exclusively in the northern part of the country. The few remaining forests of

cypress, pines, and oaks are found in Jebel Al-Akhdar and in some niches of the coastal plain, while scattered stands of cypress, acacia, eucalyptus (introduced), locust, and lote trees are scattered over considerable areas of northwestern Libya.

The steppe region to the south, including the southern foothills of Jebel Al-Akhdar and Nefusa, is covered with several species of grass, shrubs and scattered trees. It is hard to draw a sharp boundary representing a border between the Mediterranean and desert species. However, Lauer and Frankeberg (1977), in their study concerning the plant-geographical margin of tropics in North Africa, have defined three different floristic divisions in the area, correlated to climatological parameters and migration routes, and explained in terms of plant physiology.

Although the authors do not present convincing climatic evidence for establishing floristic regions, their division of North Africa into an extra-tropical, desert, and tropical realm corresponds in a general way to the existing phytogeographic pattern. Of importance, here, is the use of the 100 mm isohyet which separates the desert flora from the Mediterranean species. Only north of this limit evergreens and maquis shrubs of the Mediterranean type are observed. The desert is characterized by a mixing of tropical and desert species in the southern part, and between Mediterranean and desert species in the northern part. In some areas,

desert species appear near the coast, an indication of the strong influence of the Saharrian aridity upon plant distribution.

III. REVIEW OF LITERATURE

Attention has long been given to the variability of climate which is the cause of either the scarcity or availability of water in various regions. Studies concerning the classification of regions according to their moisture conditions are numerous. Generally, scholars who have used the concept of water balance in their studies have recommended a more rational study of the water balance elements. As early as 1864, the American geographer Marsh (1864, p. 24) recognized the need for studying the components of the water balance, because accurate measurements of precipitation and runoff may be used to obtain an approximation of the combination of evaporation and transpiration.

Several scholars have studied the ratios between the precipitation and evaporation by simulating the actual conditions in laboratory situation and expressed these ratios as indices. Others have substituted the mean annual temperature for evaporation because of the importance of temperature in determining the soil moisture content.

De Martonne's (1927, p. 405) index of aridity reads:

$$I = \frac{P}{T + 10}$$

where P is annual precipitation in cm.
T is mean annual temperature in °C.

Values of $I > 2.00$ result for humid conditions, < 1.00 for aridity, with the realm of semi-aridity lying between 1.00 and 2.00.

The boundary between dry and humid climates defined by Koeppen (1936) is based on a similar ratio, $I = \frac{P}{T + 7}$, but takes seasonality into consideration. He distinguishes three types of periodicity.

$P = 2T + 14$	rainfall evenly distributed
$P = 2T$	rainfall concentrated in winter
$P = 2T + 28$	rainfall concentrated in summer

where P is annual rainfall in centimeters

T is average annual temperature in °C.

The boundary between humid and dry climates according to Koeppen classification (no dry season), for selected temperature and precipitation relationship, lies at the following values:

T (°C)	10	15	20	25	30	35
P (cm.)	34.3	44	54	63.5	73.6	83.3

The dry (B) climate is divided into two subdivisions: BW (desert, or arid climate) and BS (steppe or semiarid climate). Koeppen laid the boundary between BW and BS one-half the amount separating steppe from humid climates. The values of 2 and 1, for the humid/semiarid limit and the semiarid/arid limit, respectively, have held up well as simple indicators, or P/T ratios, prevailing in the transition zone between humid and arid climates throughout the world.

A refinement, representing a distinct improvement in assessing the water balance on a regional level, was presented by Thornthwaite (1948). He drafted a system of indices relating water surplus, water deficiency and water need. He stated that for places where there is water surplus in the net (total) water balance, the magnitude of the water surplus as compared to the water need (PE) constitutes an index of humidity. Similarly, for places with water deficiency in the annual calculation, the ratio between water deficiency and water need constitutes an index of aridity:

$$I_h \text{ (Humidity index)} = \frac{100S}{n}$$

$$I_a \text{ (Aridity index)} = \frac{100d}{n}$$

where S = water surplus

d = water deficit

n = water need (PE)

Based on somewhat deductive reasoning, rather than on the objective, empirical approach which is a characteristic of his theoretical work, Thornthwaite introduced a weighted* moisture index (ibid., p. 76).

$$I = \frac{100S - 60\ d}{n}$$

where I = moisture index
S = water surplus
d = water deficit
n = water need

*Assuming that the effect of one annual drought is not sufficient to counteract the moisture surplus of the same year.

Positive values of the index indicate humid conditions, negative values refer to aridity.

As a revision and improvement to his method of classification, Thornthwaite and Mather (1957) prepared a number of tables to test the validity of various calculations. Numerous regional studies applying Thornthwaite's system have since been published in English and other languages. Studies about Rhodesia, New Zealand, Turkey, China, and Canada, among others, have confirmed the validity of Thornthwaite's moisture index in differentiating regions according to their actual moisture conditions. The studies have also confirmed a good agreement between the distribution of vegetation and the categories of indices.

One of the most comprehensive applications of this system dealt with Africa and India (Carter, 1954). Carter found that each of the selected climatic factors was correlated with the topography. He asserted that the agreement with the topography was most noticeable in the case of potential evapotranspiration, less in the case of precipitation, and somewhere between the two extremes in the case of water surplus, deficiency, and moisture regions.

Chang (1955) used Thornthwaite's system to demonstrate the climatic conditions of China. He compared places in different latitudes in terms of potential evapotranspiration and found that in the winter season, the sea-transformed polar continental air mass is the main cause of the rapid

increase in the potential evapotranspiration south of Nanling Mountains. He declared that Thornthwaite's "moisture index fits well with the distribution of the soil and vegetation in China" (ibid., p. 403).

The significance of Thornthwaite's system has been stressed by most of the investigators who have applied his method of classification. Sanderson (1948) applied Thornthwaite's system to the Canada climatic classification. She concluded her study with the remark that

> Thornthwaite's method of using meteorological statistics to arrive at a knowledge of the real factors in climate, although not perfected, represents an invaluable addition to Canadian climatic research (p. 517).

Crowe (1954) wrote an analytical critique of Thornthwaite's climatic classification system. He referred to the need for much more careful work on the relationship between temperature and potential evapotranspiration. Nevertheless, he arrived at a conclusion similar to Sanderson's that "Thornthwaite's system has been extremely stimulating. His vehicle is certainly facing the right way" (p. 61).

Subrahanyan (1956) used Thornthwaite's concept of potential evapotranspiration to calculate the water balance of India. After he had determined the climatic regions in terms of their moisture conditions, he concluded that

> the water balance method offers a firm basis for appraising the problems in the planning stages,

> and it provides a sound means for determining proper practices on a day-to-day basis (p. 311).

Thornthwaite's system for determining moisture characteristics has been shown to be of significant interest to both geographers and environmental investigators. Their research efforts have shown that the Thornthwaite approach to monitoring moisture availability has been successful in both humid and arid regions.

IV. DATA SOURCES AND METHODS

Data Sources

Thornthwaite's method of climatic classification depends on the meteorological statistics for both temperature and precipitation. Though daily statistical compilations are preferable, the mean monthly statistics do lead to satisfactory results. The data used in this study have been derived from the publications of the Libyan Meteorological Department, where the climatic components were recorded at different stations for various periods. This study has availed itself of the data for the years 1951 to 1965 only, because the data before 1951 and after 1965 were either missing or incomplete. The period under study is characterized by the availability of complete data at all the stations that have been examined (Figure 1), except for Gadamis (7) where the record of the first eight months of 1961 was missing. However, the ratio of deviation of precipitation from the mean monthly temperature at the nearest station (Mizda, 15) was used in estimating the missing data.

There are no regular data available from the southern part of Libya. Data have to be collected from the area south of latitude 25°N in order to establish a reliable base

about the moisture availability within that region.

The stations are not evenly distributed in the study area. Sixty-five percent of the stations are in the western part of the area. In general, the distances separating the stations from each other vary. The results of the study would obviously be more precise if the station net work were more uniformly distributed. However, the available data are sufficient to yield a better definition of the degree of aridity in the agriculturally critical areas of the country.

The Application of Thornthwaite's System to Libya

The twelve steps developed by Thornthwaite and Mather (1957) represent an improvement over Thornthwaite's 1948 method of the water balance calculation. In particular, they are based on improved soil moisture retention values, and these have been used to compute the water balance of Libya. The mean monthly temperature was calculated for each station from the available data. For the same months, the means were summed up for fifteen years and the sum is divided by the number of years to obtain the individual mean monthly temperature for the period of study. All temperature data used were in degrees Centigrade.

By using the appropriate tables, the monthly heat index values (i's) were obtained for each station, corresponding

to the mean monthly temperatures. The sum of all the values of i for the twelve months was computed as the heat index (I) for that station. With the help of appropriate tables, the unadjusted evapotranspiration (unadj. PE) for each month was determined. These monthly values are a function of the mean monthly temperature and the monthly heat index, i. The unadjusted potential evapotranspiration values had to be adjusted for the length of the day and month. The correlation factors given in the tables vary with the month and with latitude. The adjusted potential evapotranspiration values were obtained by multiplying the unadjusted values by the correction factors. The sum of the twelve monthly values is thus the annual water need for that station. Then, the mean monthly precipitation was computed and tabulated for each station in millimeters. The variation in the distribution of the annual average precipitation was recognized.

The next step was to calculate the difference between precipitation and potential evapotranspiration (P-PE). The purpose of this step was to determine the months of moisture excess or deficiency. A negative value of P-PE (deficiency) indicates the amount by which the precipitation fails to supply the potential water need of an area covered by vegetation. A positive value of P-PE (excess or surplus) indicates the amount of the water available for the soil moisture recharge and runoff. At stations where the sum of

P-PE is negative, Thornthwaite's successive approximation method was used to obtain the initial value for the accumulation of the negative P-PE.

The value of 100 mm soil moisture retention was used in the calculation because it is most appropriate for deep-rooted crops and fine sandy soil which represent most of the Libyan land. The resulting depletion values are potential, and the purpose of this step is simply to facilitate the successive computational steps.

For the negative values in the computation of the accumulated potential water loss, the same soil water quantity was used to obtain the soil moisture storage after each amount of the accumulated potential water loss. The positive values of the difference between the precipitation and the potential evapotranspiration represent the additions of moisture to the soil, and in these cases the value was added.

As a help for later calculation, the difference in the amount of the soil moisture storage from one month to the next was obtained. When the value was above the water holding capacity of 100 mm it was assumed that there was no change in the soil storage.

The actual evapotranspiration was obtained on the assumption that the actual evapotranspiration is equal to the potential when the precipitation remains equal or exceeds the potential evapotranspiration; contrarily, when the

precipitation falls below the potential water need, the actual evapotranspiration equals the precipitation plus the amount of change in the soil moisture, regardless of its sign.

In any month, the difference between the actual and the potential evapotranspiration was treated as the moisture deficit (D) for that month. At stations where the soil had reached the water holding capacity, the excess of precipitation was counted as a moisture surplus (S). Annual values of water deficiency and water surplus were obtained from the sum of the twelve monthly values. The results of the calculations for 20 out of the 23 stations indicate that the soil does not reach its water holding capacity even during the rainy season in December, January and February. The monthly runoff is determined as 50% of the surplus. It is assumed that the other half will remain until the subsequent month, as long as the surplus continues to exist. If the accumulation of the water surplus is zero, it is assumed that the runoff will be 75% of the remaining surplus in the first month and 100% in the following month. The total runoff for a year should be equal to the annual water surplus.

V. THE CLIMATIC PATTERN OF LIBYA ACCORDING TO THORNTHWAITE'S WATER BALANCE METHOD

Before implementing any agricultural program, a knowledge of the amount of water stored in the soil to allow plant growth is necessary. Since the variability of precipitation alone is not adequate to determine the moisture efficiency of a region, the relation between precipitation, which replenishes the soil with water, and evapotranspiration, which depletes it, is an important and effective means of determining the availability or scarcity of water. Though the march of precipitation and evapotranspiration rarely coincides exactly throughout the year because of the influence of different factors, their relation determines the amount of water in the root zone available for plants, to recharge the soil,and for runoff. The concepts of potential evapotranspiration and water balance derived from it evaluate the interaction between the energy--heat input and potential evapotranspiration--and the moisture--precipitation and soil water--which represent the most active elements of the climate. The water balance indicates periods of moisture surplus or deficit which can be compared with one another and with the potential water need to produce

indices by which regions can be classified according to their moisture availability.

Potential Evapotranspiration

Figure 4 shows the pattern of overall water need in Libya. As it has been defined, the water need is the amount of moisture that would be transferred to the atmosphere directly from the surface of the earth, and indirectly through transpiration by the vegetation, if there were sufficient water available. It is expressed in millimeters depth of water over an area covered by vegetation.

The potential evapotranspiration serves as an index of thermal efficiency because it is a consequence of the mean temperature adjusted by a factor for the length of day. The effect of low temperatures upon the potential evapotranspiration is evident in Libya. The calculations show that the lower values of water-needs are experienced in the northern parts of the country and in areas of high elevations. The highest value of potential evapotranspiration (1266 mm) is experienced in Kufra (13). The central part of Calensho Desert, similarly, shows high values of potential evapotranspiration at Jalo (11), namely (1233 mm). Even though Zwara (23) is located on the shoreline, the computed value of the water-need shows an almost equally high figure, that is (1177 mm), a clear indication that distance from the

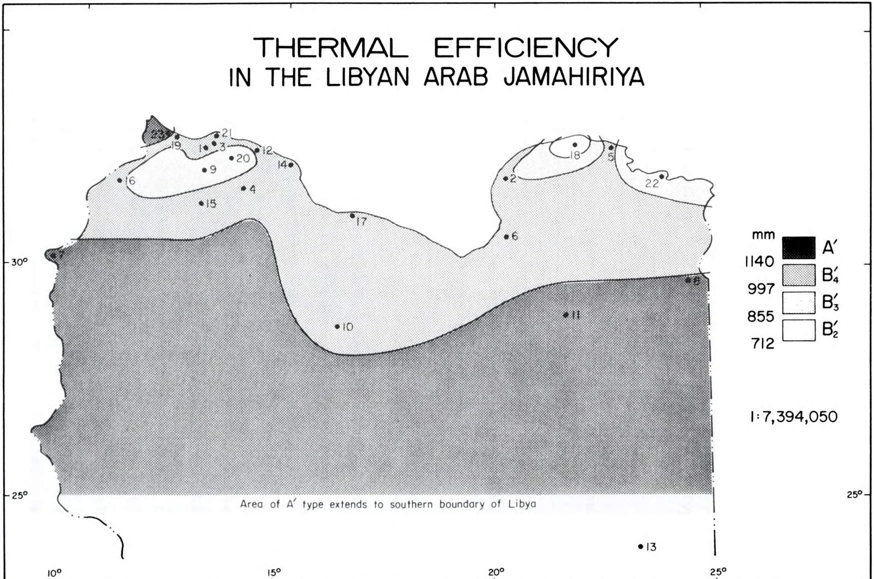
THERMAL EFFICIENCY
IN THE LIBYAN ARAB JAMAHIRIYA
mm
1140
997
855
712
A′
B'_4
B'_3
B'_2
1:7,394,050
Area of A′ type extends to southern boundary of Libya
30°
25°
10°
15°
20°
25°
1
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Figure 4

Mediterranean is not a major factor in the available-moisture distribution of Libya.

Thornthwaite divides the thermal climate into five subdivisions on the following basis:

PE in Millimeters	Thermal Efficiency Type	
142	E'	Frost
285	D'	Tundra
427	C'_1	Microthermal
570	C'_2	
712	B'_1	
855	B'_2	Mesothermal
997	B'_3	
1140	B'_4	
	A'	Megathermal

Megathermal and mesothermal are the only subdivisions that exist in the climate of Libya. The mesothermal is represented in the northern part of Libya by its three subdivisions, B'_4, B'_3, and B'_2. The B'_4-type spreads over a large area, extending to approximately 200 Km south of the coast. The extension of the B'_2-type is restricted to the high parts of the Jebel Al-Akhdar. The B'_3-type occurs on the Jebel Nefusa, the edge of the Jebel Al-Akhdar, and in a tiny strip of the northeastern coast. According to the thermal efficiency scheme of Thornthwaite's system, the A'-type is the most extensive in Libya. Zwara (23) is classified as megathermal, and so are Kufra (13) and Jalo (11). This increase

in the value of the potential water need around Zwara might be due to the adiabatic warming, the result of the subsidence effect east of the Tunisian Tell.

The two lowest computed values of potential evapotranspiration were found in Shahat (830 mm) and in Gherian (955 mm), both stations being located on a high altitude, 621 m and 725 m, respectively. They were, respectively, classified as B_2' and B_3'. Both Tarhona (20) and Tubruque (22) represent the B_3'-type of thermalefficiency.

The calculations indicate that approximately 60% of the stations used in this study fall under the B_4'-type of thermal efficiency, which means that 60% of the country would need between 997 mm and 1140 mm of water each year for successful rain-based agriculture.

Moisture Index

As is shown on page 18, Thornthwaite's moisture index is based on the relationship between the water surplus, water deficiency, and water need. The index is established under the assumption that 60% of the water in the wet season will counteract a deficiency of 100% in the dry season. The zero index value is considered the borderline between the moist and dry climates: positive values denote a moist climate, and negative values represent a dry climate.

The Climatic Types		The Moisture Indices
A	Perhumid	100 and above
B_4	Humid	80 to 100
B_3	Humid	60 to 80
B_2	Humid	40 to 60
B_1	Humid	20 to 40
C_2	Moist Sub-humid	0 to 20
C_1	Dry Sub-humid	-20 to 0
D	Semi-arid	-20 to -40
E	Arid	-60 to -40

The zero moisture index is important because it indicates that the water supply and the water need are equal. A zero moisture index is regarded as lying within the sub-humid province, only a value of < -20 is indicative of an arid climate. The range of the indices between +20 and -20 represent the critical zone of sub-humidity; within this range changes may recur quickly from the negative moisture index "dry sub-humid" to the positive value "moist sub-humid", and vice versa. On an annual base, the climatic type will change according to the increase or decrease in precipitation. Areas with a value of 100 or above moisture index are classified as perhumid. In these areas water surplus continually exists. On the other hand, areas with a value of the -60 moisture index are correlated with megathermal conditions (A'). In these areas the water deficiency

is equal to the water need because of a total lack of precipitation.

Based on the above analysis, Libya can be classified into the following climatic zones (Figure 5) in accordance with Thornthwaite's moisture index.

Dry Sub-humid, Type C_1

This type of climate is not extensive in Libya. The only area where C_1 occurs is in the northern part of the eastern plateau. Shahat (18) has a moisture index of -9-1. It seems that elevation and the specific meteorological conditions together in the Shahat are very important elements in enhancing precipitation and reducing potential evapotranspiration. The C_1 type coincides with an elevation of approximately 500 meters and above, where a considerable water surplus occurs during the winter season. Surficial runoff occurs around Shahat and is directed through the waddies, either northward to the sea or toward the desert depressions south of the plateau. A large portion of this water evaporates directly; the rest of it infiltrates to replenish the underground water supply which is later pumped for the human and agricultural uses.

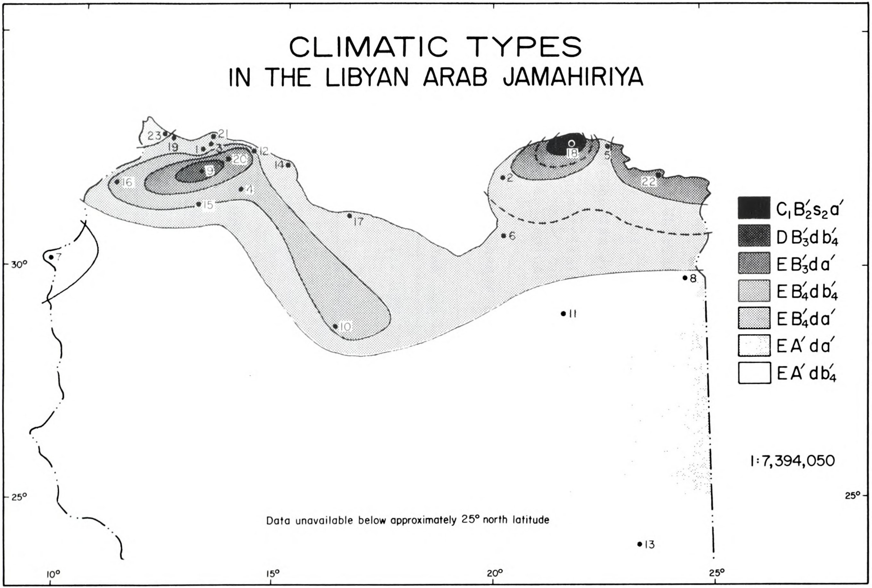
CLIMATIC TYPES
IN THE LIBYAN ARAB JAMAHIRIYA
C1 B'2 s2 a'
D B'3 d b'4
E B'3 d a'
E B'4 d b'4
E B'4 d a'
E A' d a'
E A' d b'4
1:7,394,050
Data unavailable below approximately 25° north latitude
30°
25°
10°
15°
20°
25°
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Figure 5

Semi-arid, Type D

According to the results of the computation of the water balance, the D type of climate, too, has a limited distribution. The area around Gherian (9) has largely a semi-arid climate. Gherian (9) has a moisture index of -39.3 which is very close to the next drier type. Although the elevation of Gherian is higher than that of Shahat, Gherian has less precipitation and higher potential evapotranspiration, as is indicated below:

Shahat (621 m)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
PE	21	23	24	52	86	117	131	128	93	71	45	29	830
P	126	93	62	14	8	2	1	3	7	67	61	120	564

Gherian (725 m)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
PE	13	21	37	58	100	149	167	159	114	74	42	21	955
P	71	51	31	33	3	4	0	1	5	23	24	57	313

During the winter season (December, January and February) Gherian (9) records much less potential evapotranspiration than Shahat (18). This reduction is caused by both the

elevation and the presence of modified continental polar air (NcP) under northerly and northwesterly flow. However, NcP air, which arrives in Shahat from a westerly and northwesterly direction, is further modified over the Mediterranean. This modification in the temperature and moisture content increases both the potential evapotranspiration and the precipitation around Shahat.

There is no doubt of the presence of an area under the influence of the D-type of climate next to the C_1-type around Shahat. This area, however, is not represented by any station used in this study.

Arid, Type E

The arid E-type of climate is very extensive in Libya. There are five regions differentiated in the arid zone, according to the differences in both the thermal efficiency and its seasonal concentration. Generally, the regions conform with the relief: the higher the elevation, the lower is the potential evapotranspiration. Good examples of that differentiation are to be found in Azizia (1) and Tarhona (20). Both of them rank under the E-type of climate, but they differ in thermal efficiency. Since Tarhona has a higher elevation--with both stations lying at the same latitude--the difference in thermal efficiency must be caused by relief effects. Some stations, such as Tarhona (20),

Tripoli (21), and Darna (5), whose moisture indices are approximately -42, tend to be nearer to the next moist type. Their climates must be more moist than that of those stations with lower values of moisture indices, such as Gaghbub (8), Jalo (11), and Kufra (13), whose indices are nearly -60. This latter value indicates that there is very little or no precipitation. However, the -42 moisture index value does indicate an appreciable amount of precipitation interacting with the potential water need.

Seasonal Variation of Effective Moisture

While the moisture index represents the general state of a region in terms of its humidity or aridity, it is important for a climatic classification to determine the seasonal variation in the climatic components. Thornthwaite defined the indices of the climatic subdivisions in terms of regional humidity and aridity, as it is shown in the following tables:

	Moist Climates A, B, C_2	Aridity Indices
r	Little or no water deficiency	0 to 16.7
s	Moderate summer water deficiency	16.7 to 33.3
w	Moderate winter water deficiency	16.7 to 33.3
s_2	Large summer water deficiency	33.3 and above
w_2	Large winter water deficiency	33.3 and above

	Dry Climates C_1, D, E	Humidity Indices
d	Little or no water surplus	0 to 10
s	Moderate winter water surplus	10 to 20
w	Moderate summer water surplus	10 to 20
s_2	Large winter water surplus	20 and above
w_2	Large summer water surplus	20 and above

Calculations show that there is no region in Libya with a positive moisture index. The country is completely under the influence of the dry climate. According to the computed indices of humidity, the two subdivisions found in Libya are: s_2 in Shahat (18), indicating that this area has a large winter surplus. It usually receives the greatest annual rainfall in the country. The rest of the stations are ranked under the d-type of climate which denotes little or no water surplus. The surplus is very little in Gherian (9) and Tarhona (20) and non-existing at the other stations.

Summer Concentration of Thermal Efficiency

Though the thermal efficiency index does denote the annual water need, it does not provide us with enough information about the times when the water need is most acute. In this connection, the concept of summer concentration, defined as the sum of the monthly water need for June, July, and August, expressed as a percentage of the annual water need, is valuable. In the northern latitudes, the

ratio of the summer concentration of the thermal efficiency is 100% in the tundra climates. The ratio progressively decreases until the equator is reached, where it theoretically approaches 25% for each season.

According to Thornthwaite's system there is a characteristic summer concentration for each thermal efficiency type as shown below.

Summer Concentration of Thermal Efficiency	Summer Concentration Type
%	
48.0	a'
51.9	b'_4
56.3	b'_3
61.6	b'_2
68.0	b'_1
76.3	c'_2
88.0	c'_1
	d'

The ratio of the summer concentration to the thermal efficiency in Libya ranges between 42 and 50 percent. Accordingly, only two types, a' and b'_4, are to be found in Libya.

It seems that the elevation is a minor element in reducing the evapotranspiration during the summer season. In Libya, marine effects are more easily discernible if we compare Gherian (9), which has a higher elevation and

greater percentage of summer concentration, with Shahat (18), which has a lower elevation and lower percentage of summer concentration. The lower ratio in the latter case is due to the influence of the prevailing northeasterly flow in summer.

VI. SURFACE WATER AVAILABILITY

The results of the calculations assessing the relationship between various climatic and terrestrial controls in Thornthwaite's system are discussed in the following paragraphs. They are also presented in graphic and tabular form in the Appendix.

General Observations

As was to be expected in a climate of high thermal efficiency and low precipitation, water need greatly exceeds availability at all locations in Libya in the average annual situation. Of critical importance, however, is the uneven seasonal distribution of elements making up the regional water budget.

At all the stations in Libya, water shortage is the lowest in the winter season and reaches a maximum during July and August. The curves indicating precipitation vary from one station to another and do not coincide with water need curves anywhere. During the rainy period, precipitation exceeds potential evapotranspiration at 13 out of the 23 stations. In general, vegetation starts utilizing the soil moisture by March. From that point on artificial

methods for irrigation, using underground water, are necessary to meet the water needs of plants and crops.

Water Deficit

In July the drought reaches its highest peak: the water deficit ranges from 123 mm in Shahat (18) to 205 mm in Gadamis (7). For 87% of the stations in Libya, July is the driest month, August for the rest of the stations. It was found that 20 out of the 23 stations, for which the water balance has been computed, July is the month with the highest water deficit. Only Sirt (17), Shahat (18) and Surman (19), have a higher water deficit in August, due to the high average temperature in that month.

Eight stations (4, 7, 8, 10, 11, 13, 15, and 22) are characterised by the existence of a water deficit each month of the average year. These stations are located far to the south from the coast, except for Tubruque (22). The existence of a water deficit all year round in Turbuque is probably due to the adiabatic warming east of the Jebel Al-Akhdar. The water deficit appears during April in both Shahat (18) and Gherian (9). However, it ends during October in the former and during the following month in the latter. The annual water deficiency for Gherian (666 mm) is much higher than that for Shahat (476 mm). The lower water deficiency in Shahat might be due to both the latitudinal position

(Shahat is 70 km to the north more than Gherian) and the influence of the prevailing summer northeasterlies, which arrive somewhat land-modified at Gherian only.

Even though Nalut (16) is situated at the high elevation of 639 m, water deficiency begins during February. Only during the months of December and January of the average year does precipitation satisfy the relatively low water need of Nalut. Similar conditions exist in both Sirte (17) and Surnam (19), where a water deficiency occurs between February and November. All other stations have enough precipitation during December through February to meet the water need.

The results of the water balance calculations show that most of the agricultural land in Libya experiences a water deficiency during the period of growth. It is obvious that ground water supply is necessary to prevent plant water stress between the months of March and November. The growing of vegetables and crops is impossible with natural rainfall alone.

Water Surplus

The dry period generally comes to a close by the end of the fall season. In late September or early October symoptic conditions start to favor precipitation over Libya. The high value of water deficit recorded for July drops to

approximately 50% or less at most of the stations.

The calculations indicate that only three stations experience a moisture surplus. Any water surplus is absent in the other 20 stations, because, in an average year, the excess of precipitation is not sufficient to complete the replenishment of the soil moisture to bring the soil to its water-holding capacity. However, short-term moisture surpluses may occur in any month between October and March. Annual water surpluses may also occur occasionally in the northern parts of the country. December and January are the wettest months in Libya. In the average, most of the stations located in the northern part of Libya receive more than 40 mm of rainfall during January. Only one station (Shahat, 18) receives more than 100 mm in January alone. The ample rainfall in northern Libya in both December and January is related to the high frequency of the strong westerly and northwesterly flows as a result of the movement of the Mediterranean depressions.

Anomalous Years

During the rainy years it is evident that the upper level conditions are most conducive for precipitation. When upper troughs move in from the northwest, strong convergence takes place at the surface, resulting in heavy precipitation. Such a condition developed during 1957. The rainfall

statistics of that year indicate a positive deviation from the mean annual precipitation in most of the northern stations (Table 1).

Hon (10) recorded a positive deviation of 229% from its average rainfall. This increase in the quantity of precipitation was enough to raise the normal average percentage of P/PE from 3% to 10% in 1957. Such an unusual amount of precipitation may cause severe damage, but it is very important for the replenishment of underground water to supply the water need of the vegetation.

The precipitation in Tarhona (20) in 1957 was 60% above average. The P/PE value rose by 20%, increasing from 29 to 49%. A large portion of the increased precipitation was concentrated in the waddies and caused flood problems around Tripoli. January 1957 was the rainiest month ever in Tarhona (229 mm), where the January average is only 67 mm. Most of that precipitation had run off surficially because the value of PE was very low, and the soil quickly reached its maximum water-holding capacity. Similarly, the unusually high rainfall in 1957 found Tripoli (21), Azizia (1), Gharian (9), and Shahat (18) in the state of maximum saturation, with their precipitation increased over the annual average percentages by 59, 32, 34 and 24%, respectively. The total annual increases experienced by Tarhara (20), Tripoli (21), and Shahat (18), were respectively, 187 mm, 181 mm, and 136 mm.

TABLE 1.

Stations	Average P / PE	Precipitation in mm		P/PE		Deviation of P/Average P		January P / Average P	
	%	1957	1964	1957	1964	1957	1964	1957	1964
1. Azizia	20	278	307	26	29	32	46	50	75
2. Benina	23	351	167	34	16	44	-31	45	20
3. Bengesheer	26	383	356	36	33	36	26	49	48
4. Benwaleed	7	112	61	10	5	51	-18	28	35
5. Darna	28	478	266	48	27	68	-6	29	30
6. Egdabia	13	229	92	22	9	66	-33	38	19
7. Gadamis	3	34	37	3	3	-3	6	20	29
8. Gaghbub	1	8	5	1	0.4	-20	-50	40	0.0
9. Gherian	33	421	543	44	57	34	73	51	80
10. Hon	3	112	3	10	0.3	229	-91	41	0.0
11. Jalo	1	7	1	0.6	0.1	-30	-90	60	0.0
12. Khomos	21	320	298	30	28	47	37	56	57
13. Kufra	0	5	0.0	0.4	0.0	400	0.0	50	0.0
14. Mesrata	25	432	317	41	30	62	19	41	53
15. Mezda	6	120	62	11	6	79	-7	24	49
16. Nalut	13	191	77	19	8	47	-41	38	22
17. Sirte	17	430	239	42	23	143	35	75	49
18. Shahat	68	700	494	84	60	24	-12	39	19
19. Surman	23	350	262	35	26	53	14	49	69
20. Tarhona	29	461	306	49	33	68	12	84	51
21. Tripoli	30	489	263	47	25	59	-14	44	46
22. Tubruque	9	136	118	14	12	53	33	83	40
23. Zwara	18	309	278	26	24	46	32	35	66

It is not difficult to see that these additional quantities of precipitation could result in an increase of agricultural production if the additional water could be stored for the deficit periods. In 1964, Azizia (1), Gherian (9), and Tarhona (20) in the state of optimum saturation, recorded positive deviations from their mean precipitation. Gherian (9) recorded an increase of 73% of its annual mean rainfall; Azizia (1) and Tarhona (20) recorded an increase of 46 and 12 percent, respectively. It seems that the mean upper level trough was located to the west, leaving these areas under the influence of the positive vorticity advection.

At the same time, Shahat (18) had recorded a negative deviation of 12% from its mean precipitation. This indicates that the area around Shahat was under the influence of the subsiding air of a negative vorticity advection at the upper level, which did not favor precipitation.

Rainfall in the southern parts of Libya may occur as convectional showers. It has no seasonal regularity. Although the showers scarcely moisten the soil before evaporating, their contribution to the growth of vegetation in that region is very important. Concentration of rainfall into a small number of rainy days is highly characteristic of the region south of the 100mm isohyet. Elevation within this region certainly has some effect on the amount of rainfall. However, the isohyetal trends could not be drawn in

the higher mountain districts of the south because the non-availability of data in this area.

Relative Degree of Aridity

Thornthwaite (1948), indicates that

> the aridity of a place in a given period of time depends not on the numerical amount of the water deficiency but rather on the relation of this deficiency to the water need (p. 68).

A relative humidity or aridity of a place can be obtained from:

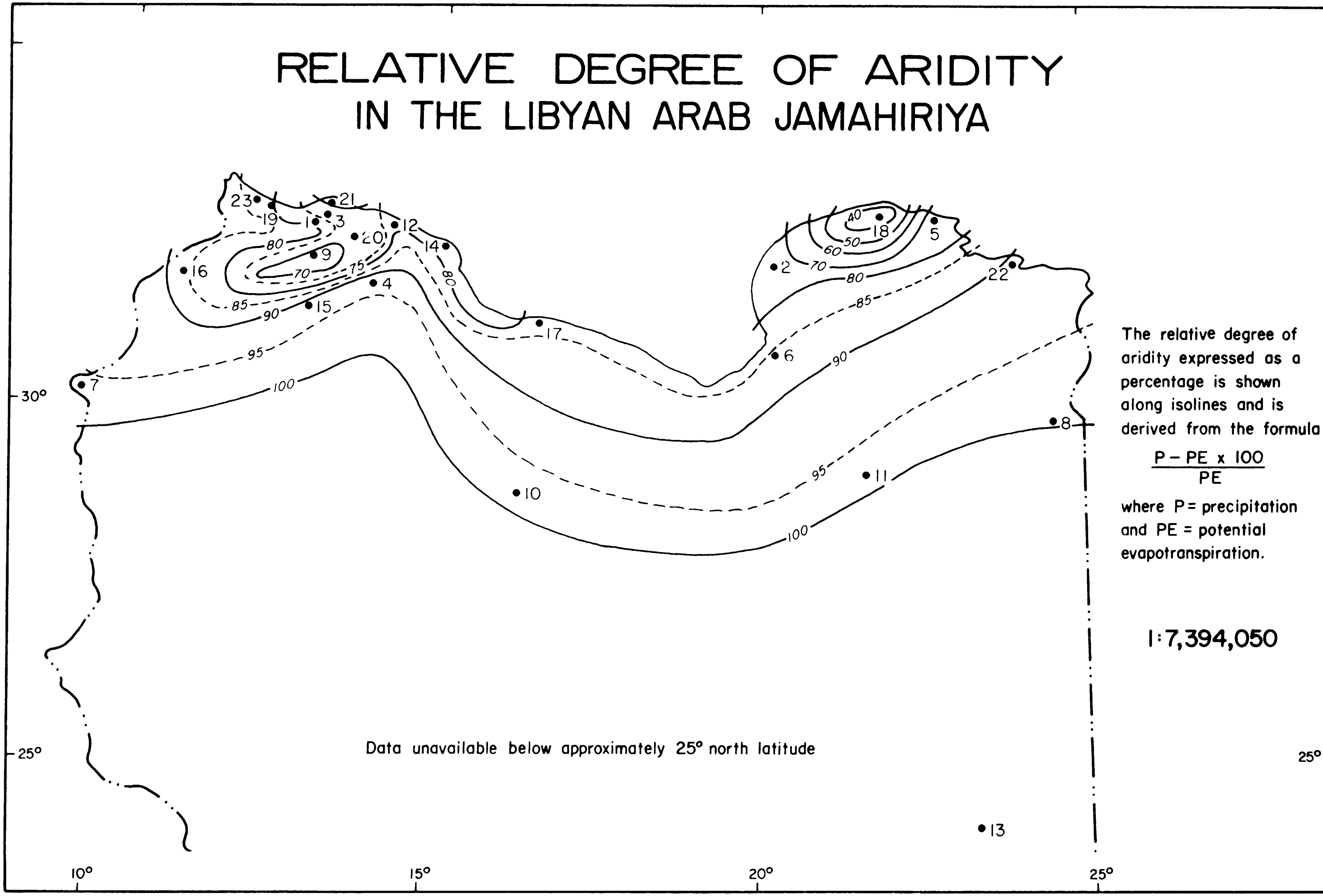
$$\frac{P - PE \times 100}{PE}$$

where P is precipitation

PE is potential evapotranspiration

A ratio of zero indicates that water supply is equal to water need.

The overall relative degree of aridity in Libya is shown in Figure 6. The 100% relative aridity zone is located south of the 100mm isohyet. Precipitation in that region occurs only in traces, or evaporates completely before moistening the soil. Life within this region depends entirely on the underground water supply, which is available locally. To the north of this region, several regions of varied relative degrees of aridity exist. The lowest value of relative aridity (32%) was computed for Shahat (18). The area would reach zero percent aridity if precipitation


RELATIVE DEGREE OF ARIDITY
IN THE LIBYAN ARAB JAMAHIRIYA
The relative degree of aridity expressed as a percentage is shown along isolines and is derived from the formula
P − PE x 100 / PE
where P = precipitation and PE = potential evapotranspiration.
1:7,394,050
Data unavailable below approximately 25° north latitude
30°
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10°
15°
20°
25°
40
50
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Figure 6

increased by 266 mm. Zero percent aridity is represented within the best regions for non-irrigated cultivation, and it may exist in Shahat (18) during some individual years when the precipitation is enhanced by a high frequency of cyclones. Dry-farming exists around Shahat (18) because of the availability of water needed during the period between November and March. This is mostly true within the area of 70% relative aridity or less.

The cultivated crops and vegetation in the non-irrigated farms, especially the cereals, terminate their life cycles by April, the season of harvest; and it is the month in which an acute water deficiency begins to manifest itself within this region. In the northwestern part of the country, the lowest value of relative aridity is 67% and exists around Gherian (9). Both Tripoli (21) and Tarhona (20) recorded a 70% relative aridity. The farms relying on rainfall are found between Gherian (9) and Tarhona (20). The major crops of these farms are barley and hard wheat. Even though dry-farming may exist around Tripoli (21), farmers prefer to use artificial irrigation since it increases their production by a considerable proportion. The differentiation of regions in terms of the relative degree of aridity may help in the planning for agricultural and grazing projects in the country, because the knowledge of the amount and seasonal variability of the water needed is the key to establishing a successful project. Libya would

need a more denser station network and, especially, a careful consideration of local soil conditions.

It is worth noting that the distribution of natural vegetation species varies considerably with the variation of moisture index. In the northern part of the country, forests appear mainly within regions dominated by C_1 and D climates. The variability of soil moisture content within these regions, among other factors, leads to variation in tree species. Forests dominated by pines, cypress and oak are common in the northeastern plateau where the humidity index indicates a considerable water surplus. Trees better adjusted to long drought, like lote, locust, and olive, are spread over the northwestern part of Libya where the humidity index indicates little or no water surplus. Acacia forests, along with various other scattered trees, shrubs and grass are occurring within regions dominated by the E-type climate. It is noteworthy that the boundaries of natural vegetation in North Africa drawn by Lauer (1977) imply a close agreement with the distribution of climatic regions in Libya as established in the present study.

Regarding the agricultural conditions, Falkner's (1938) rare study on crop-rainfall relationships in North Africa, shows the boundaries of non-irrigated agriculture. Using an empiric formula, he stated that "agriculture is possible from where the difference from the corrected annual precipitation in centimeters and the average annual temperature in

centigrades does not drop below the value of 12" (ibid., p. 213). According to the Falkner formula, the calculations indicate only two areas in Libya, Gherian (9) and Shahat (18), in which the results of the formula do not drop below 12. There are, therefore, corresponding results of Falkner's formula and Thornthwaite's water balance method, both indicating a water surplus in Gherian and Shahat. However, there is disagreement between the two methods in Tarhona (20), where dry-farming actually exists; the value of Falkner's formula is 10.7; whereas, the water balance indicates a small water surplus. It seems that there are other factors beside annual temperature and precipitation values which should be taken into consideration in order to arrive at a meaningful interpretation of the effectiveness of climatic factors for agriculture.

VII. CONCLUSION

Thornthwaite's water balance method is useful for determining rational climatic zones and evaluating the effect of climate in a regional setting. The distribution and the types of natural vegetation, as well as crops, correspond to specific moisture indices, and they are valid indicators of the relationship between climate, vegetation, and land use.

In this study, it has been assumed that means of climatic parameters for 15 years duration are suitable to establish a regional pattern of climatic classification. Variability in individual years must, of course, be considered,but the results derived from this study remain clearly applicable for the long-term climatic conditions.

Thornthwaite's method has great usefulness and results in an accurate evaluation of climate in spite of its reliance on only the two most common recorded parameters, temperature and precipitation. However, its utility in analyzing land use may be limited if viewed in a deterministic manner. Obviously, a specific type of land use is often established by individuals who make decisions independently of environmental considerations.

The present study was undertaken to define the climatic regions of Libya according to their moisture availability. Indices of moisture were calculated for 23 stations with a sufficient long period of observation. Only three of them indicate a water surplus. Maps for climatic regions of Libya and the relative degree of aridity were drafted. Information about the availability of water and the degree of water need concerning each region was provided and should be helpful in planning for future irrigation or grazing projects.

Maps provided by this study also could be used as for the timing of certain agricultural activities. Correlation could be made between the yield of crops and the actual evapotranspiration and water deficiency for each climatic region.

The results of this research do not represent a final and conclusive analysis of the climatic regions of Libya. A serious attempt has been made to define the climatic regions of Libya according to the variability of their moisture element. In order to reach a comprehensive understanding of the Libyan climate and the problems that such a classification entails, detailed research of much greater magnitude in the area of the relationship between energy and moisture availability within specific localities is necessary.

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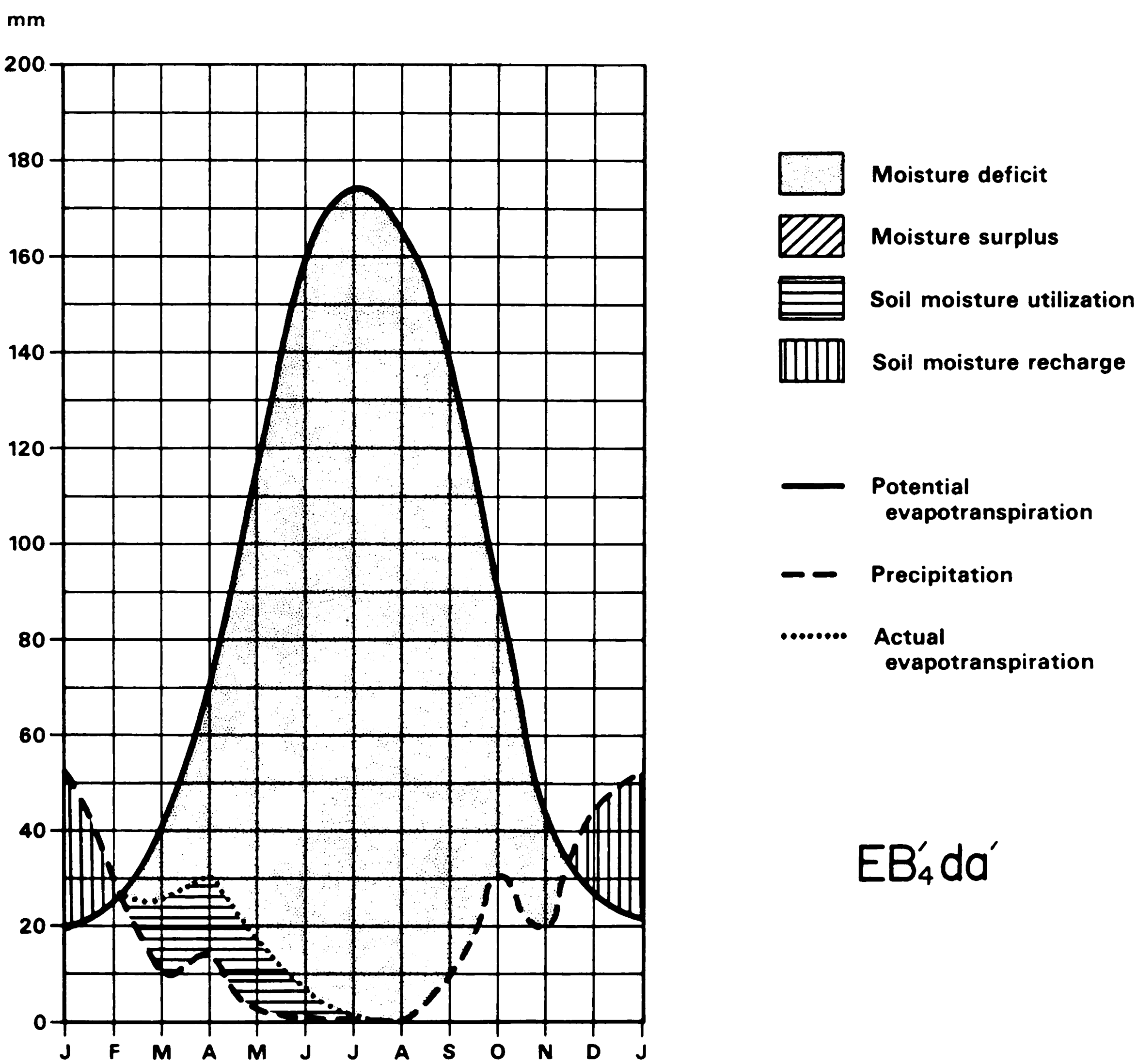
APPENDIX

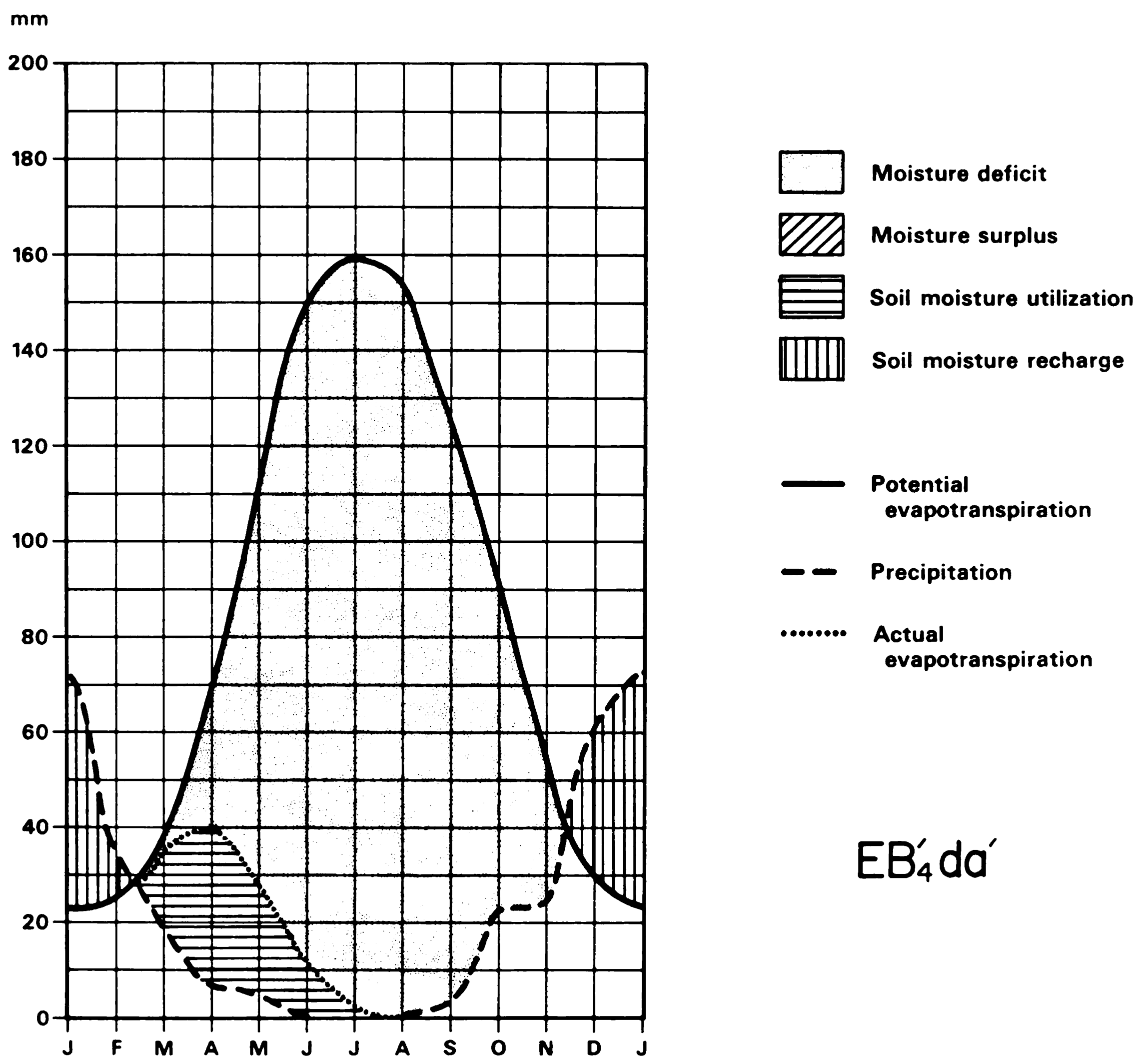
AZIZIA

AZIZIA	Location: 32° 32' N Lat., 13° 01' E long.			Elevation: 116 meters								No. 1
	J	F	M	A	M	J	J	A	S	O	N	D	Year
X̄ °C	11.7	12.9	15.3	18.4	22.1	26.5	27.6	27.6	25.9	21.7	17.5	13.4	
I	3.62	4.20	5.44	7.19	9.49	12.49	13.28	12.28	12.06	9.23	6.66	4.45	101.39
Unadj. PE	0.8	1.0	1.4	2.2	3.1	4.5	4.8	4.8	4.4	3.0	1.8	1.0	
Adj. PE	21.0	26	43	71	111	159	174	166	136	88	48	26	1069
P	51	29	11	14	3	1	0	0	8	30	19	44	210
P- E	30	3	-32	-57	-108	-158	-174	-166	-128	-58	-29	18	-859
Acc. Pot. W.L.		(-65)	-97	-154	-262	-420	-594	-760	-888	-946	-975		
St.	48	51	37	21	7	1	0	0	0	0	0	18	
ΔSt.	+30	+3	-14	-16	-14	-6	-1	0	0	0	0	+18	
AE	21	26	25	30	17	7	1	0	8	30	19	26	210
D	0	0	18	41	94	152	173	166	128	58	29	0	859
S	0	0	0	0	0	0	0	0	0	0	0	0	



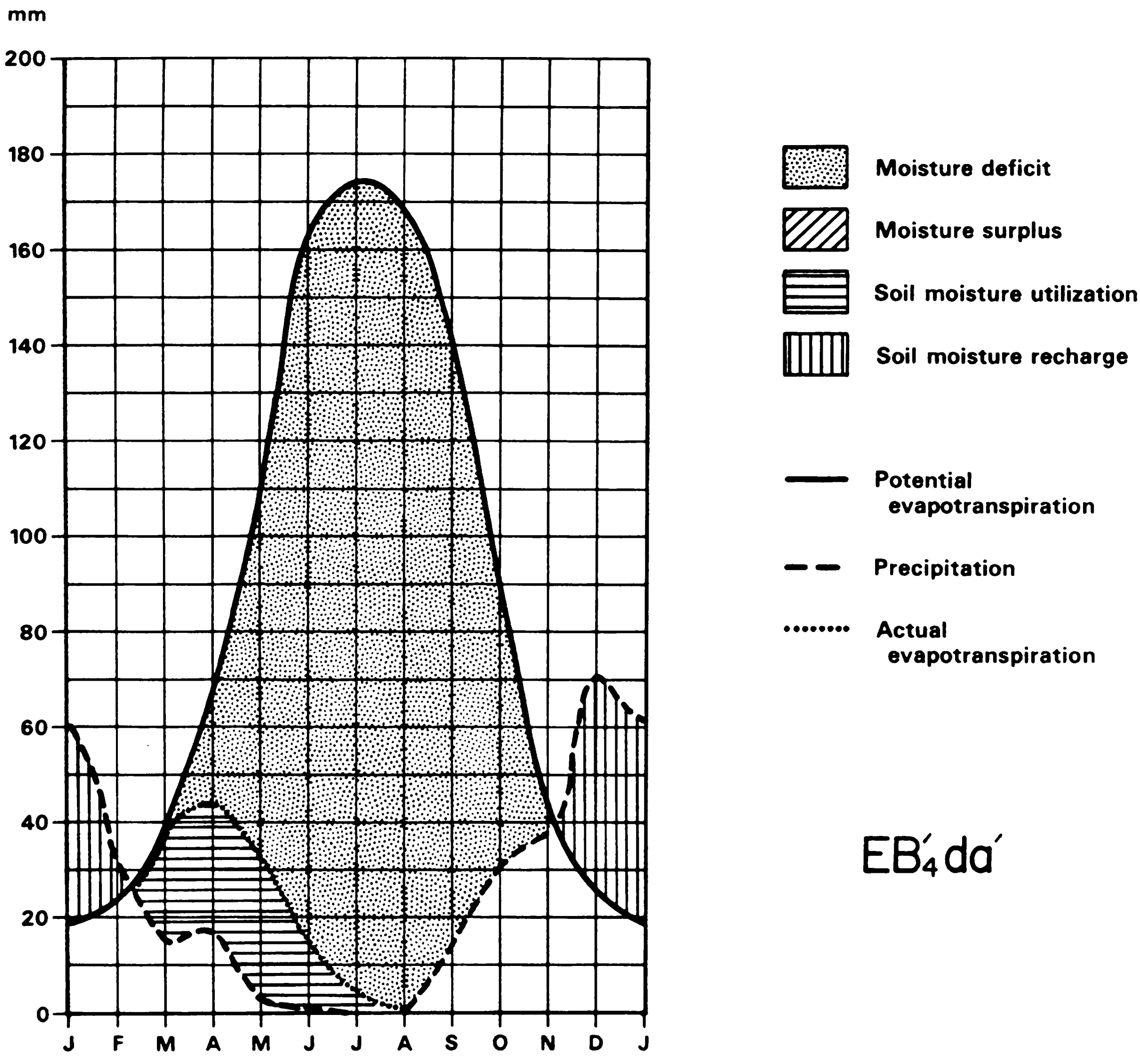
BENINA

BENINA	Location: 22° 05' N Lat., 20° 16' E long. Elevation: 121 meters											No. 2
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\bar{X}$ °C	12.5	12.9	15.0	18.5	21.9	25.5	26.0	26.3	24.9	22.5	18.5	14.2	
I	4.0	4.20	5.28	7.25	9.36	11.78	12.13	12.35	11.37	9.75	7.25	4.86	99.58
Unadj. PE	0.9	1.0	1.3	2.2	3.1	4.2	4.4	4.5	4.0	3.2	2.2	1.2	
Adj. PE	24	26	40	71	111	149	160	155	124	94	58	31	1043
P	72	34	18	6	4	0	0	0	2	23	24	61	244
P- E	48	8	-22	-65	-107	-149	-160	-155	-122	-71	-34	30	
Acc. Pot. W.L.		(-15)	-37	-102	-209	-358	-518	-673	-795	-866	-900		
St.	78	86	68	35	12	3	0	0	0	0	0	30	
ΔSt.	+48	+8	-18	-33	-23	-9	-3	0	0	0	0	+30	
AE	24	26	36	39	27	9	3	0	2	23	24	31	244
D	0	0	4	32	84	140	157	155	122	71	34	0	799
S	0	0	0	0	0	0	0	0	0	0	0	0	



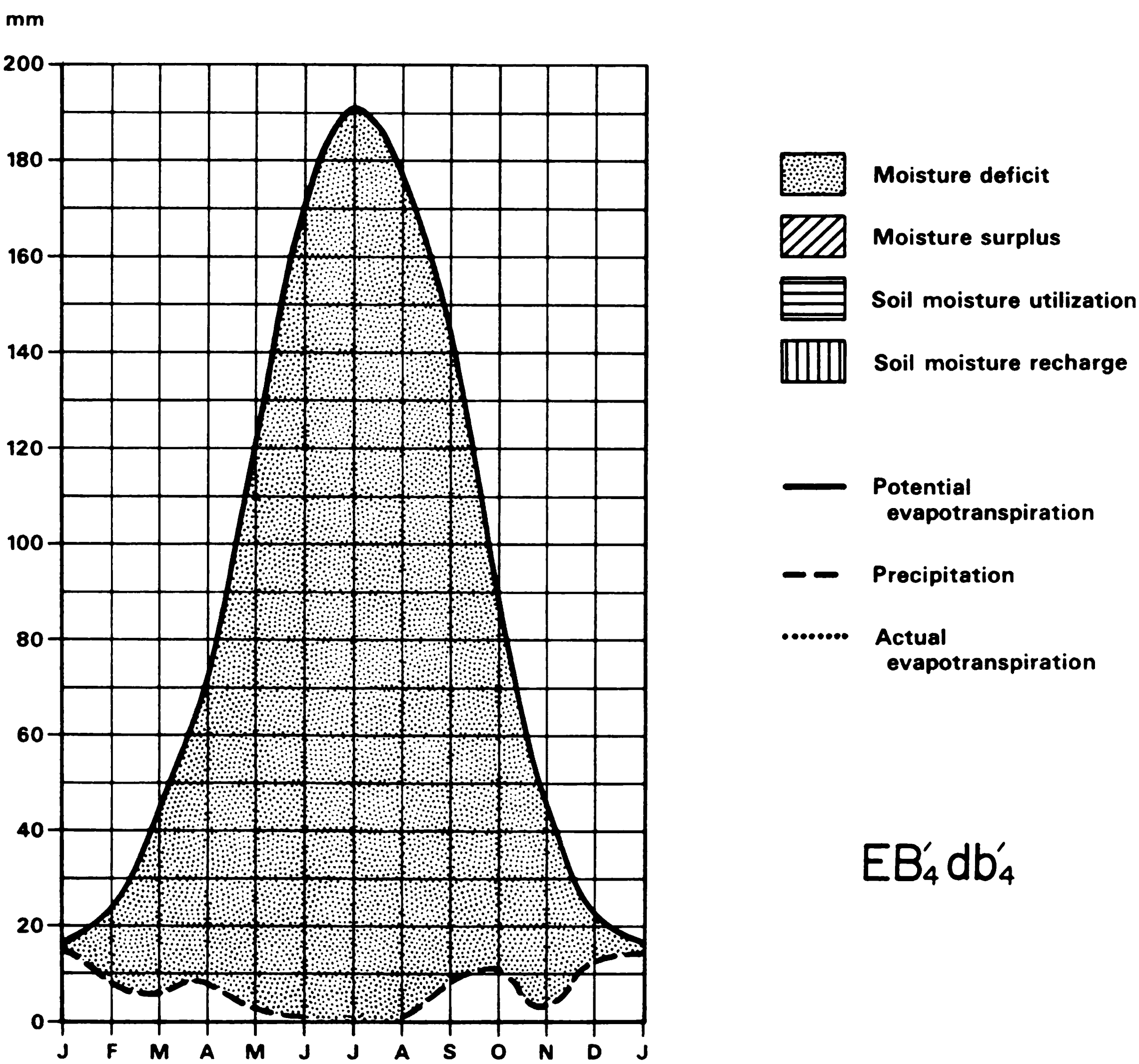
BENGESHEER

BENGESHEER	Location: 32° 41' N lat., 13° 11' E long.				Elevation: 74 meters								No. 3
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\bar{X}$ °C	11.8	12.8	15.4	18.6	22.1	26.9	27.7	27.9	26.4	22.3	17.7	13.4	
I	3.67	4.15	5.49	7.31	9.49	12.78	13.36	13.50	12.42	9.62	6.78	4.45	103.02
Unadj. PE	0.7	0.9	1.4	2.0	3.0	4.6	4.8	4.9	4.5	3.1	1.8	1.0	
Adj. PE	19	23	43	65	107	163	174	169	139	91	47	26	1066
P	61	31	15	17	2	1	0	1	15	31	37	71	282
P–E	42	8	-28	-48	-105	-162	-174	-168	-124	-60	-10	45	
Acc. Pot. W.L.		(-5)	-33	-81	-186	-348	-522	-690	-814	-874	-884		
St.	87	95	71	44	15	3	0	0	0	0	0	45	
ΔSt.	+42	+8	-24	-27	-29	-12	-3	0	0	0	0	+45	
AE	19	23	39	44	31	13	3	1	15	31	37	26	282
D	0	0	4	21	76	150	171	168	124	60	10	0	784
S	0	0	0	0	0	0	0	0	0	0	0	0	0



BENWALEED

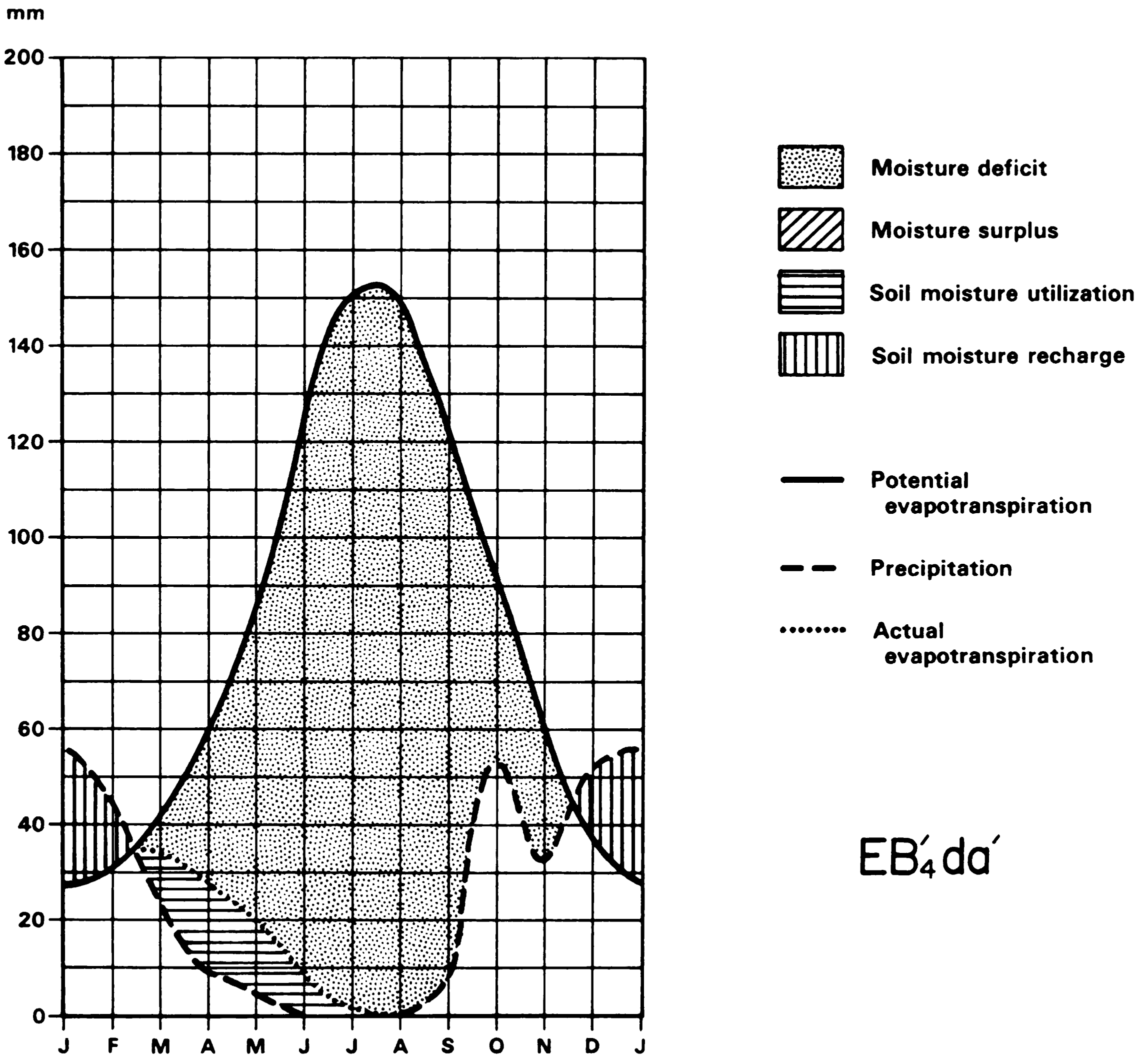
BENWALEED	Location: 31° 45' N lat., 14° 00' E long.				Elevation: 230 meters							No. 4
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\bar{X}$ °C	11.6	13.6	16.8	19.6	23.5	27.8	29.5	29.1	26.7	22.5	18.0	13.0	
I	3.58	4.55	6.26	7.91	10.41	13.43	14.69	14.39	12.63	9.75	6.95	4.25	108.8
Unadj. PE	0.6	0.9	1.5	2.2	3.4	4.9	5.3	5.2	4.6	3.1	1.8	0.9	
Adj. PE	16	23	46	71	120	172	191	178	142	91	47	24	1121
P	14	8	6	8	3	0	0	0	8	11	3	13	74
P–E	-2	-15	-40	-63	-117	-172	-191	-178	-134	-80	-44	-11	
Acc. Pot. W.L.	-512	-527	-567	-630	-747	-919	-1110	-1288	-1422	-1502	-1546	-1557	
St.	0	0	0	0	0	0	0	0	0	0	0	0	
ΔSt.	0	0	0	0	0	0	0	0	0	0	0	0	
AE	14	8	6	8	3	0	0	0	8	11	3	13	74
D	2	15	40	63	117	172	191	178	134	80	44	11	1047
S	0	0	0	0	0	0	0	0	0	0	0	0	



EB′₄db′₄

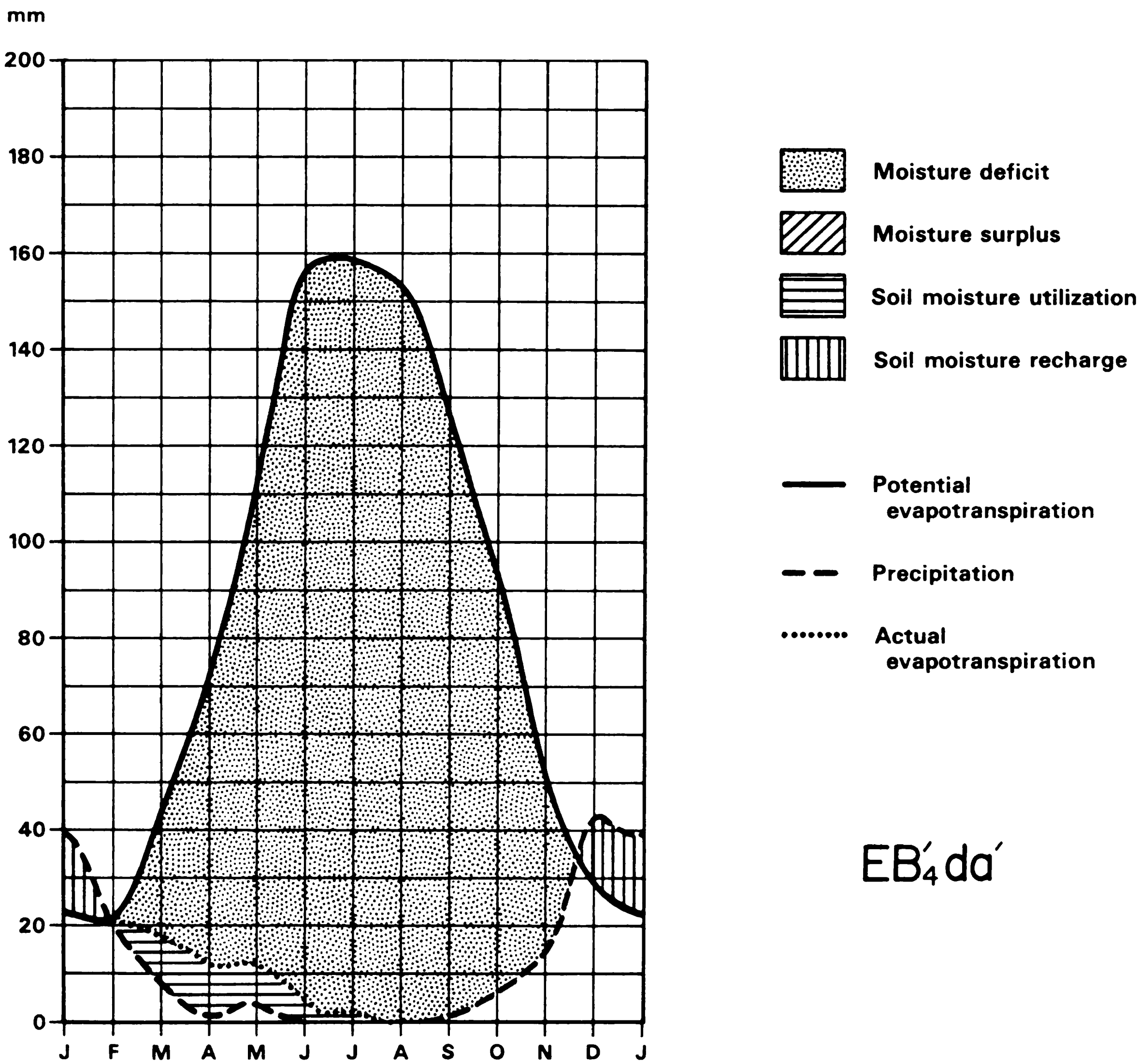
DARNA

DARNA	Location: 32° 47' N lat., 22° 39' E long. Elevation: 10 meters											No. 5
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\bar{X}$ °C	14.0	14.4	15.6	17.7	20.1	23.7	25.5	26.1	24.7	22.4	19.2	15.8	
I	4.75	4.96	5.60	6.78	8.22	10.55	11.78	12.21	11.23	9.68	7.67	5.71	99.14
Unadj. PE	1.1	1.2	1.4	1.9	2.5	3.6	4.2	4.4	3.9	3.2	2.3	1.5	
Adj. PE	29	31	43	62	89	127	152	152	121	94	61	39	1000
P	56	45	24	9	5	0	0	1	6	53	32	53	284
P-E	27	14	-19	-53	-84	-127	-152	-151	-115	-41	-29	14	
Acc. Pot. W.L.		(-58)	-77	-130	-214	-341	-493	-644	-759	-800	-829		
St.	41	55	45	26	11	3	1	0	0	0	0	14	
ΔSt.	+27	+14	-10	-19	-15	-8	-2	-1	0	0	0	+14	
AE	29	31	34	28	20	8	2	2	6	53	32	39	284
D	0	0	9	34	69	119	150	150	115	41	29	0	716
S	0	0	0	0	0	0	0	0	0	0	0	0	



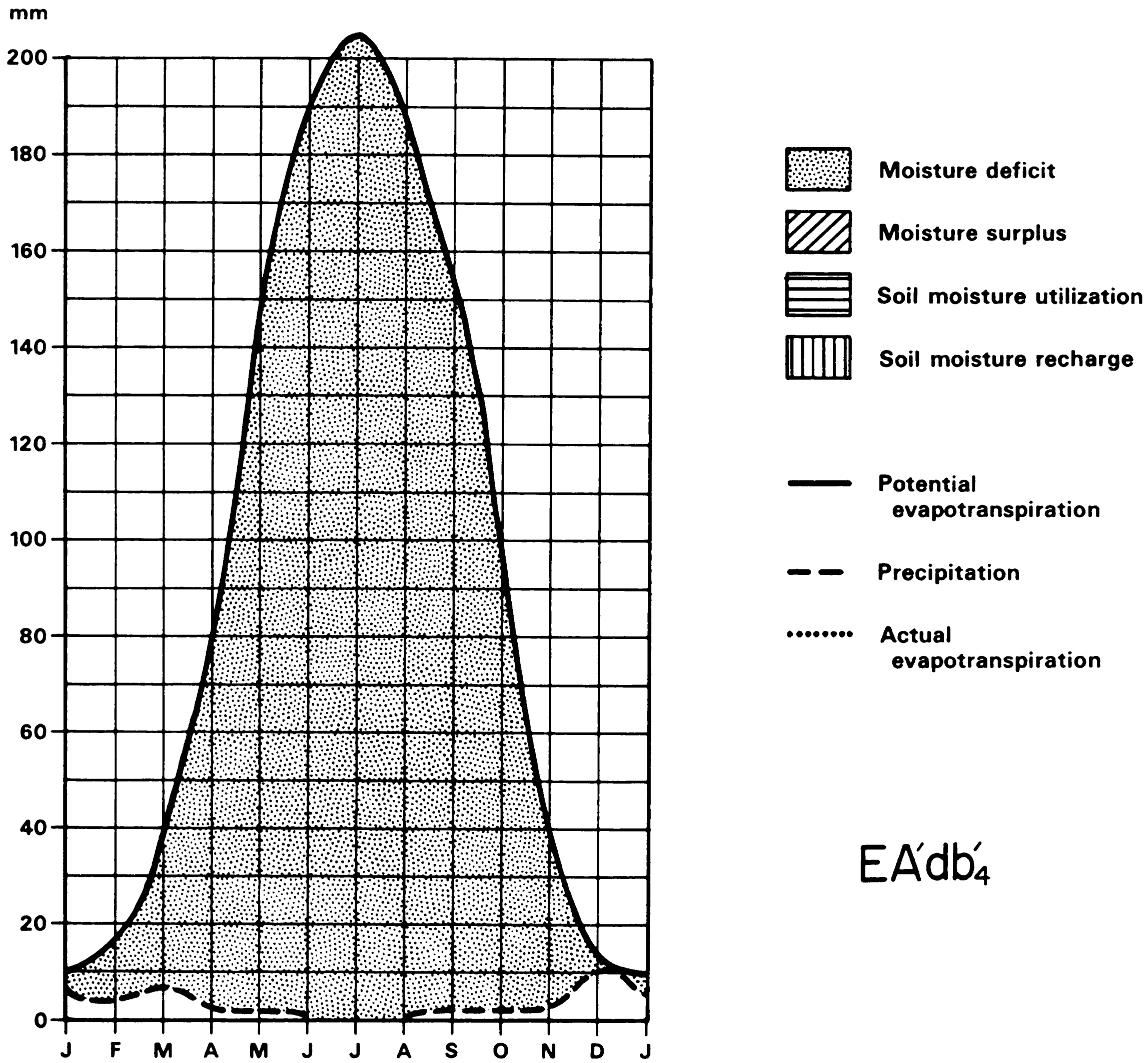
EGDABIA

EGDABIA	Location: 30° 46' N lat., 20° 13' E long.				Elevation: 60 meters								No. 6
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\overline{X}$ °C	12.6	12.6	16.2	19.6	23.0	26.2	25.9	26.2	25.2	22.8	18.4	14.3	
I	4.05	4.05	5.93	7.91	10.08	12.28	12.06	12.28	11.57	9.95	7.19	4.91	102.26
Unadj. PE	0.8	0.8	1.5	2.2	3.3	4.5	4.4	4.5	4.1	3.2	2.0	1.1	
Adj. PE	22	21	46	71	117	158	158	154	127	94	53	29	1050
P	39	19	8	1	5	0	0	0	1	7	15	43	138
P- E	17	-2	-38	-70	-112	-158	-158	-154	-126	-87	-38	14	
Acc. Pot. W.L.	(-113)	-115	-153	-223	-335	-493	-651	-805	-931	-1018	-1056		
St.	31	31	21	10	3	1	0	0	0	0	0	14	
ΔSt.	+17	0	-10	-11	-7	-2	-1	0	0	0	0	14	
AE	22	19	18	12	12	2	1	0	1	7	15	29	138
D	0	2	28	59	105	156	157	154	126	87	38	0	912
S	0	0	0	0	0	0	0	0	0	0	0	0	



GADAMIS

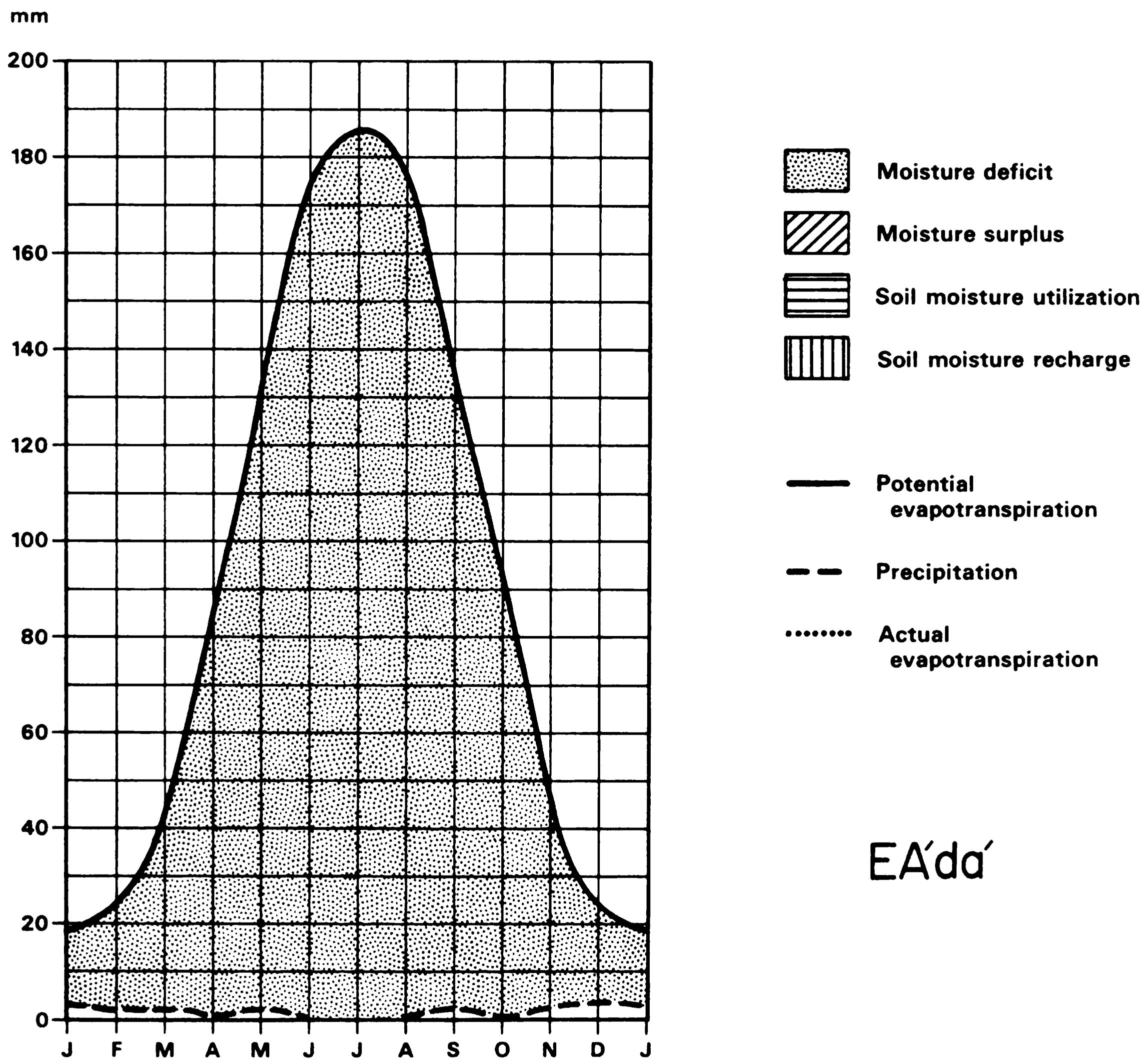
GADAMIS	Location: 30° 08' N lat., 9° 40' E long.					Elevation: 361 meters							No. 7
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\overline{X}$ °C	10.2	12.9	16.7	21.1	25.7	30.2	31.4	30.6	28.0	22.4	16.6	11.6	
I	2.94	4.20	6.21	8.85	11.92	15.22	16.15	15.53	13.58	9.68	6.15	3.58	114.01
Unadj. PE	0.4	0.7	1.4	2.6	4.2	5.4	5.7	5.5	4.9	3.1	1.4	0.5	
Adj. PE	11	18	43	84	149	190	205	188	151	91	37	13	1180
P	5	4	6	2	1	1	0	0	2	2	2	10	35
P- E	-6	-14	-37	-82	-148	-189	-205	-188	-149	-89	-35	-3	
Acc. Pot. W.L.	-516	-530	-569	-649	-797	-986	-1191	-1379	-1528	-1617	-1652	-1655	
St.	0	0	0	0	0	0	0	0	0	0	0	0	
ΔSt.	0	0	0	0	0	0	0	0	0	0	0	0	
AE	5	4	6	2	1	1	0	0	2	2	2	10	35
D	6	14	37	82	148	189	205	188	149	89	35	3	1145
S	0	0	0	0	0	0	0	0	0	0	0	0	



EA′db′₄

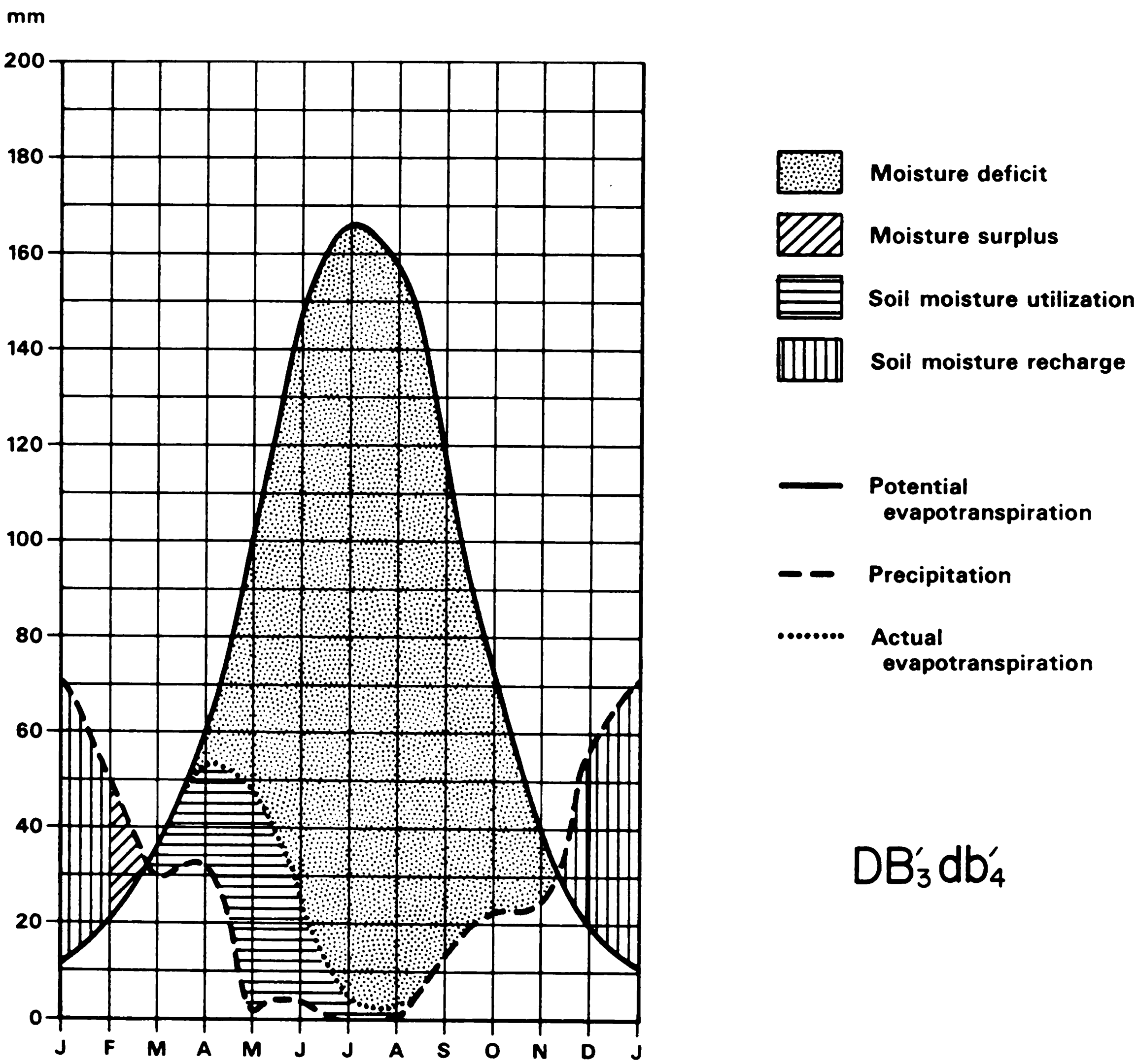
GAGHBUB

GAGHBUB	Location: 29° 45' N lat., 24° 31' E long.				Elevation: 12 meters								No. 8
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\bar{X}$ °C	12.0	13.6	16.8	21.0	24.8	28.4	29.0	29.0	26.3	23.3	18.2	13.6	
I	3.67	4.55	6.26	8.78	11.30	13.87	14.32	14.32	12.35	10.28	7.07	4.55	111.32
Unadj. PE	0.7	0.9	1.5	2.7	3.8	5.0	5.2	5.2	4.4	3.3	1.9	0.9	
Adj. PE	19	23	46	87	133	174	186	176	136	97	51	24	1152
P	2	1	1	0	1	0	0	0	1	0	1	3	10
P-E	-17	-22	-45	-87	-132	-174	-186	-176	-135	-97	-50	-21	
Acc. Pot. W.L.	-527	-549	-594	-681	-813	-987	-1173	-1349	-1484	-1581	-1631	-1652	
St.	0	0	0	0	0	0	0	0	0	0	0	0	
ΔSt.	0	0	0	0	0	0	0	0	0	0	0	0	
AE	2	1	1	0	1	0	0	0	1	0	1	3	10
D	17	22	45	87	132	174	186	176	135	97	50	21	1142
S	0	0	0	0	0	0	0	0	0	0	0	0	



GHERIAN

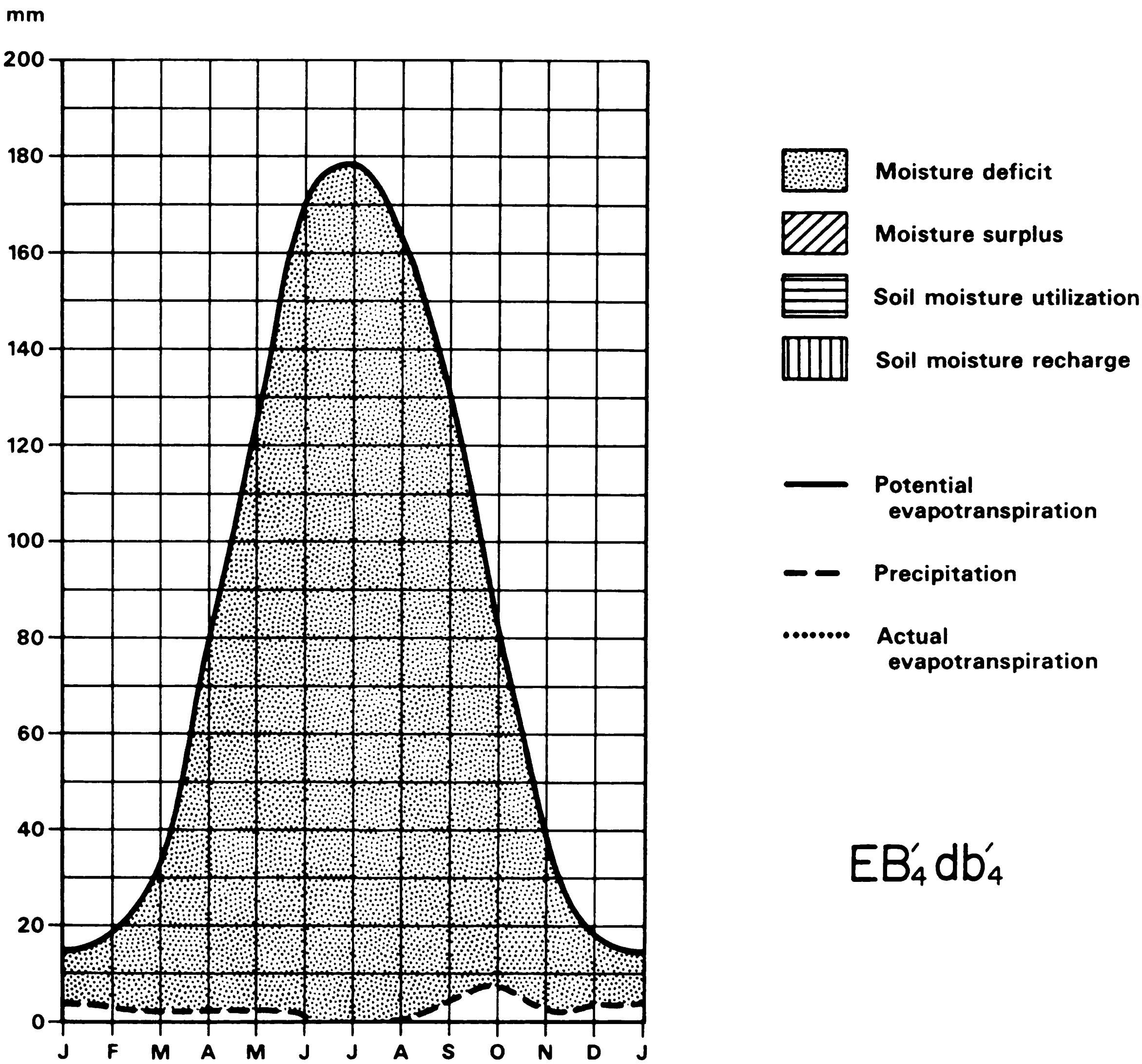
GHERIAN	Location: 32° 10' N lat., 13° 00' E long. Elevation: 725 meters											No. 9
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\bar{X}$ °C	8.7	10.5	13.2	16.2	20.5	25.5	26.9	26.8	24.0	19.8	15.3	10.7	
I	2.31	3.08	4.35	5.93	8.47	11.78	12.78	12.70	10.75	8.03	5.44	3.16	88.78
Unadj. PE	0.5	0.8	1.2	1.8	2.8	4.2	4.6	4.6	3.7	2.5	1.6	0.8	
Adj. PE	13	21	37	58	100	149	167	159	114	74	42	21	955
P	71	51	31	33	3	4	0	1	15	23	24	57	313
P-E	58	30	-6	-25	-97	-145	-167	-158	-99	-51	-18	36	
Acc. Pot. W.L.			-6	-31	-128	-273	-440	-598	-697	-748	-766		
St.	94	100	94	73	27	6	1	0	0	0	0	36	
ΔSt.	+58	+6	-6	-21	-46	-21	-5	-1	0	0	0	+36	
AE	13	21	37	54	49	25	5	2	15	23	24	21	289
D	0	0	0	4	51	124	162	157	99	51	18	0	666
S	0	24	0	0	0	0	0	0	0	0	0	0	24



DB′₃ db′₄

HON

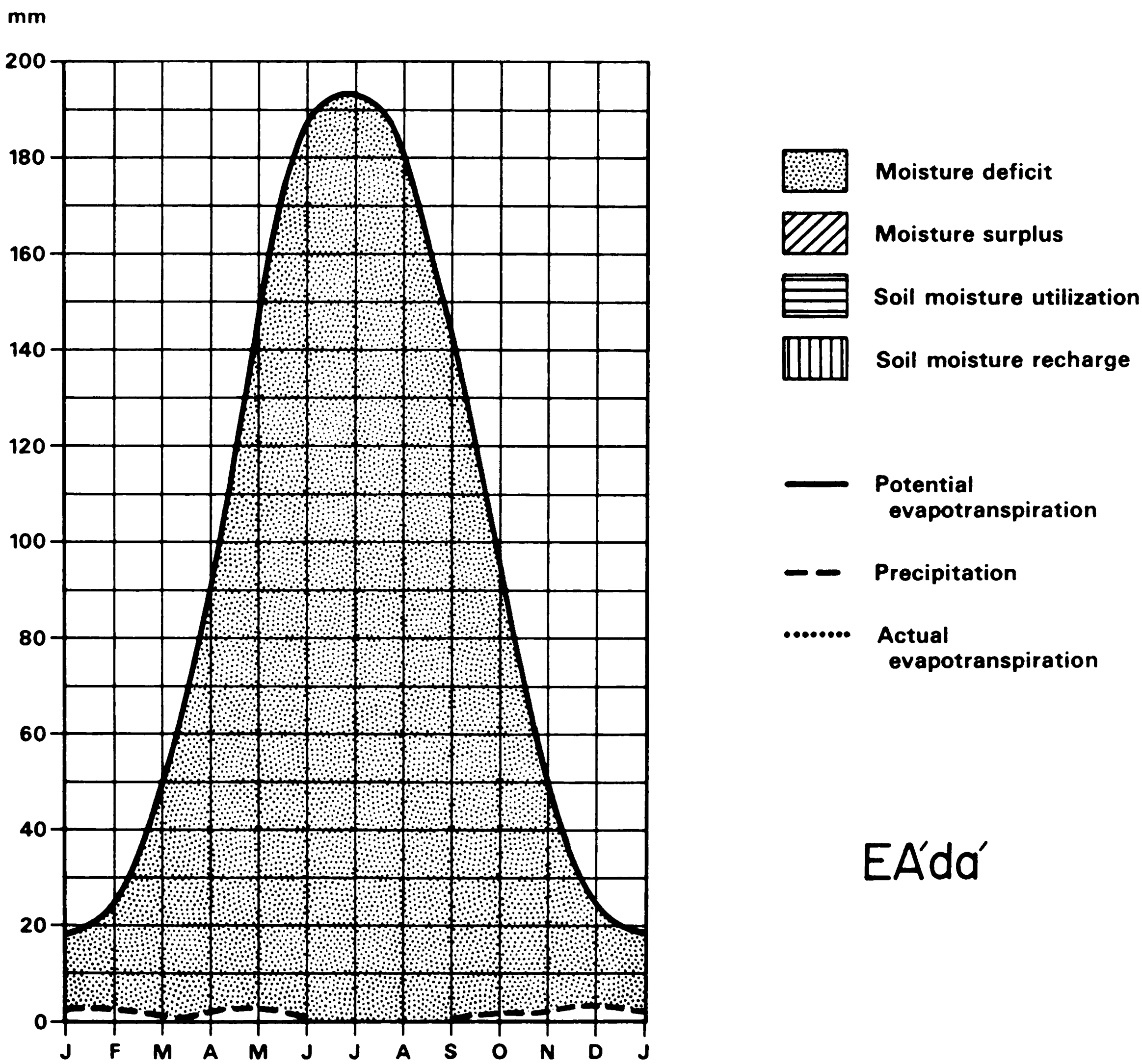
HON	Location: 29° 08' N lat., 15° 56' E long.				Elevation: 207 meters								No. 10
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\overline{X}$ °C	10.7	12.6	14.7	20.5	24.0	28.2	28.1	27.6	26.0	21.9	16.8	12.0	
I	3.16	4.05	5.12	8.47	10.75	13.72	13.65	13.28	12.13	9.36	6.26	3.76	103.71
Unadj. PE	0.6	0.7	1.1	2.5	3.5	5.0	5.0	4.8	4.3	3.0	1.6	0.7	
Adj. PE	16	18	34	80	123	174	178	163	133	88	43	19	1069
P	4	3	2	2	2	1	0	0	5	8	3	4	34
P- E	-12	-15	-32	-78	-121	-173	-178	-163	-128	-80	-40	-15	
Acc. Pot. W.L.	-522	-537	-569	-647	-768	-941	-1119	-1282	-1410	-1490	-1530	-1545	
St.	0	0	0	0	0	0	0	0	0	0	0	0	
ΔSt.	0	0	0	0	0	0	0	0	0	0	0	0	
AE	4	3	2	2	2	1	0	0	5	8	3	4	34
D	12	15	32	78	121	173	178	163	128	80	40	15	1035
S	0	0	0	0	0	0	0	0	0	0	0	0	



$EB'_4 db'_4$

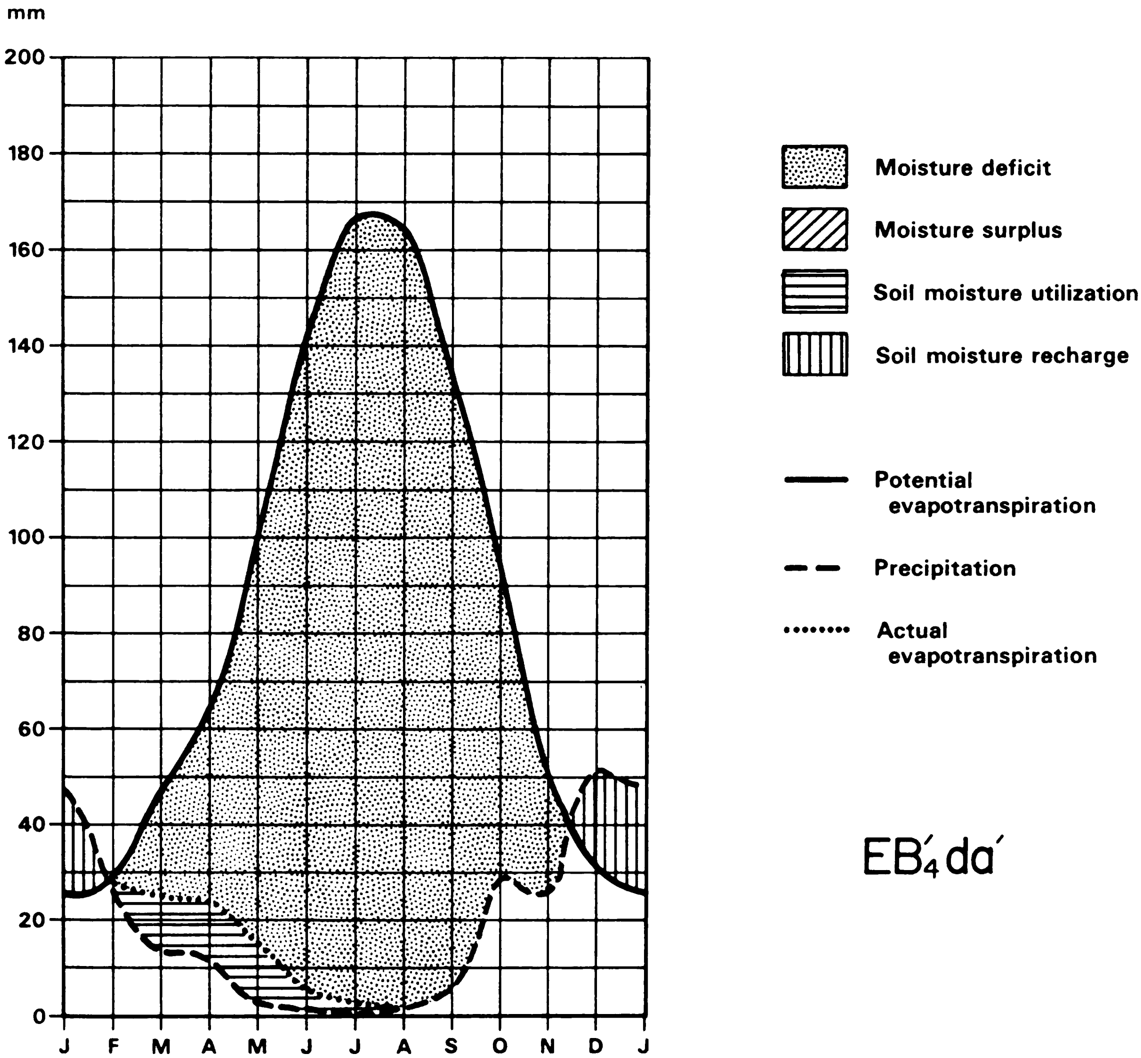
JALO

JALO	Location: 29° 09' N lat., 21° 14' E long. Elevation: 35 meters											No. 11
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\overline{X}$ °C	13.1	14.7	18.2	22.2	26.0	29.8	29.8	29.7	27.4	24.0	18.8	14.8	
I	4.30	5.12	7.07	9.55	12.13	14.92	14.92	14.84	13.14	10.75	7.43	5.17	119.34
Unadj. PE	0.7	0.9	1.6	2.8	4.3	5.4	5.4	5.3	4.8	3.4	1.8	0.9	
Adj. PE	19	23	49	90	151	188	193	180	148	100	48	24	1213
P	1	1	0	1	2	0	0	0	0	1	1	3	10
P- E	-18	-22	-49	-89	-149	-188	-193	-180	-148	-99	-47	-21	
Acc. Pot. W.L.	-528	-550	-599	-688	-837	-1025	-1218	-1398	-1546	-1645	-1692	-1713	
St.	0	0	0	0	0	0	0	0	0	0	0	0	
ΔSt.	0	0	0	0	0	0	0	0	0	0	0	0	
AE	1	1	0	1	2	0	0	0	0	1	1	3	10
D	18	22	49	89	149	188	193	180	148	99	47	21	1203
S	0	0	0	0	0	0	0	0	0	0	0	0	



KHOMOS

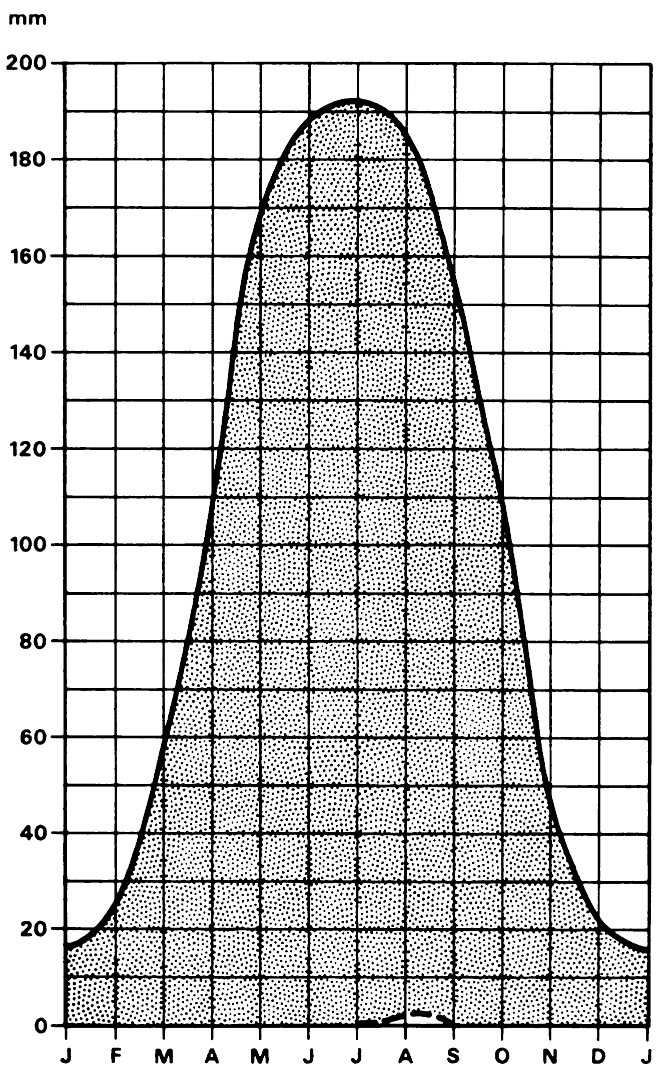
KHOMOS	Location: 32° 39' N lat., 14° 17' E long.				Elevation: 18 meters								No. 12
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\overline{X}$ °C	14.3	14.4	16.4	18.6	21.6	25.3	27.0	27.6	26.2	23.0	19.3	15.0	
I	4.45	4.96	6.04	7.31	9.17	11.64	12.85	13.28	12.28	10.08	7.73	5.28	105.07
Unadj. PE	1.0	1.1	1.5	1.9	2.8	4.0	4.6	4.8	4.4	3.3	2.1	1.2	
Adj. PE	27.0	28.0	46	62	100	142	167	166	136	97	55	31	1057
P	48	26	14	13	3	1	0	1	6	29	26	51	218
P- E	21	-2	-32	-49	-97	-141	-167	-165	-130	-68	-29	20	
Acc. Pot. W.L.	(-86)	-88	-120	-169	-266	-407	-574	-739	-869	-937	-966		
St.	41	40	29	18	6	2	0	0	0	0	0	20	
ΔSt.	+21	-1	-11	-11	-12	-4	-2	0	0	0	0	+20	
AE	27	27	25	24	15	5	2	1	6	29	26	31	218
D	0	1	21	38	85	137	165	165	130	68	29	0	839
S	0	0	0	0	0	0	0	0	0	0	0	0	

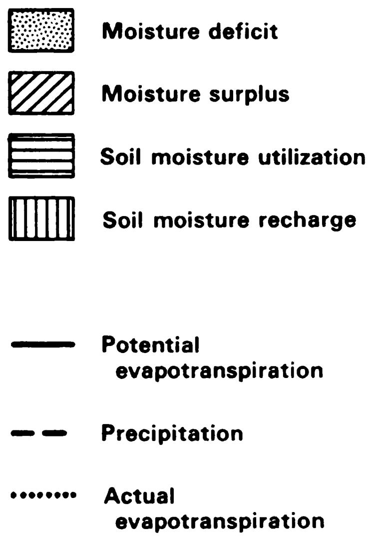


EB'₄da'

KUFRA

KUFRA	Location: 24° 12' N lat., 23° 20' E long.					Elevation: 389 meters							No. 13
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\overline{X}$ °C	12.9	15.3	19.4	24.0	28.0	30.6	30.6	30.7	28.2	24.7	18.9	14.3	
I	4.2	5.44	7.79	10.75	13.58	15.53	15.53	15.61	13.72	11.23	7.49	4.91	125.78
Unadj. PE	0.6	0.9	1.9	3.3	4.9	5.5	5.5	5.5	5.0	3.6	1.7	0.8	
Adj. PE	17	24	59	105	169	188	191	185	153	107	46	22	1266
P	0	0	0	0	0	0	0	1	0	0	0	0	1
P- E	-17	-24	-59	-105	-169	-188	-191	-184	-153	-107	-46	-22	
Acc. Pot. W.L.	-527	-551	-610	-715	-884	-1072	-1263	-1447	-1600	-1707	-1753	-1775	
St.	0	0	0	0	0	0	0	0	0	0	0	0	
ΔSt.	0	0	0	0	0	0	0	0	0	0	0	0	
AE	0	0	0	0	0	0	0	1	0	0	0	0	1
D	17	24	59	105	169	188	191	184	153	107	46	22	1265
S	0	0	0	0	0	0	0	0	0	0	0	0	0

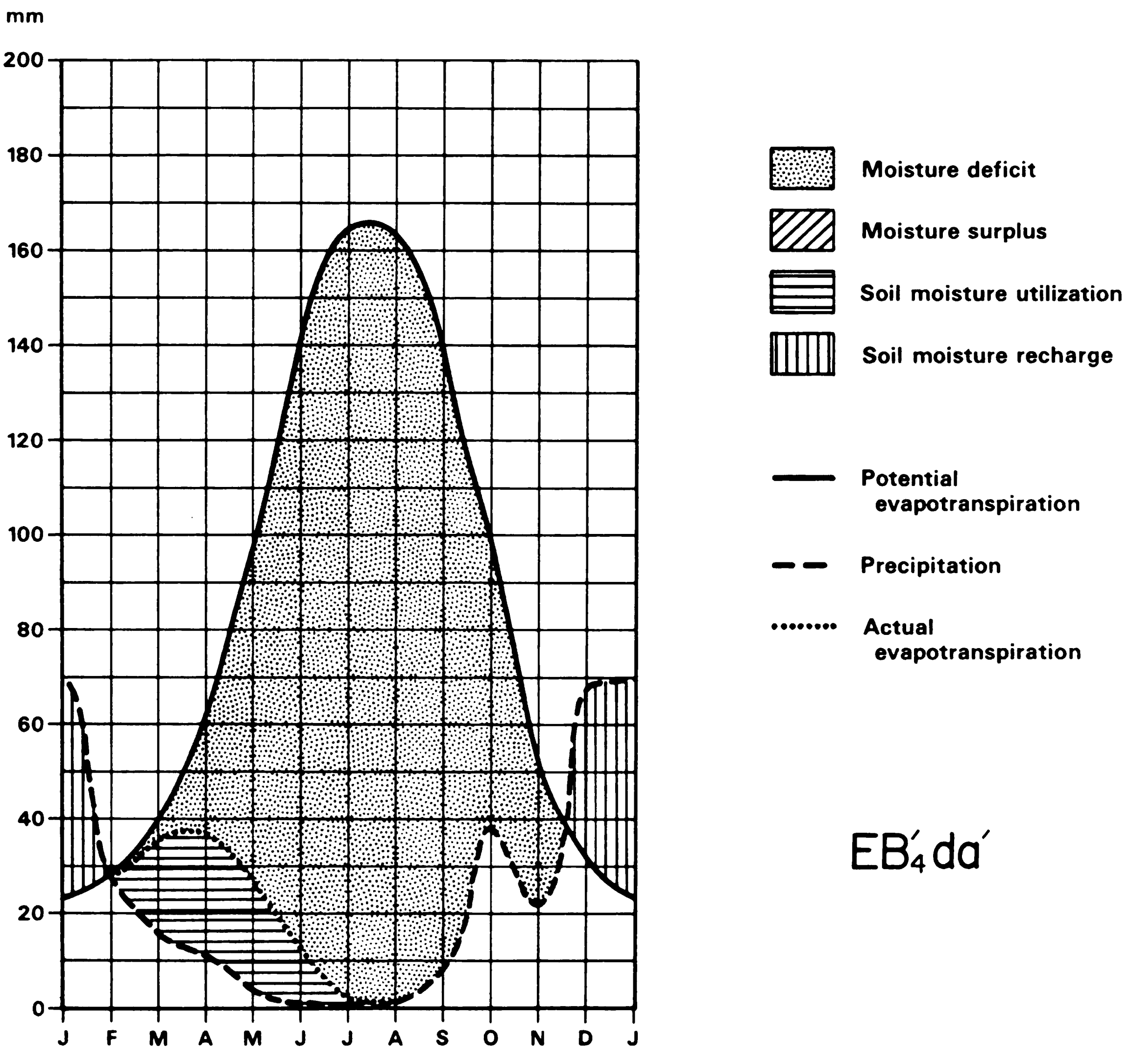




EA'da'

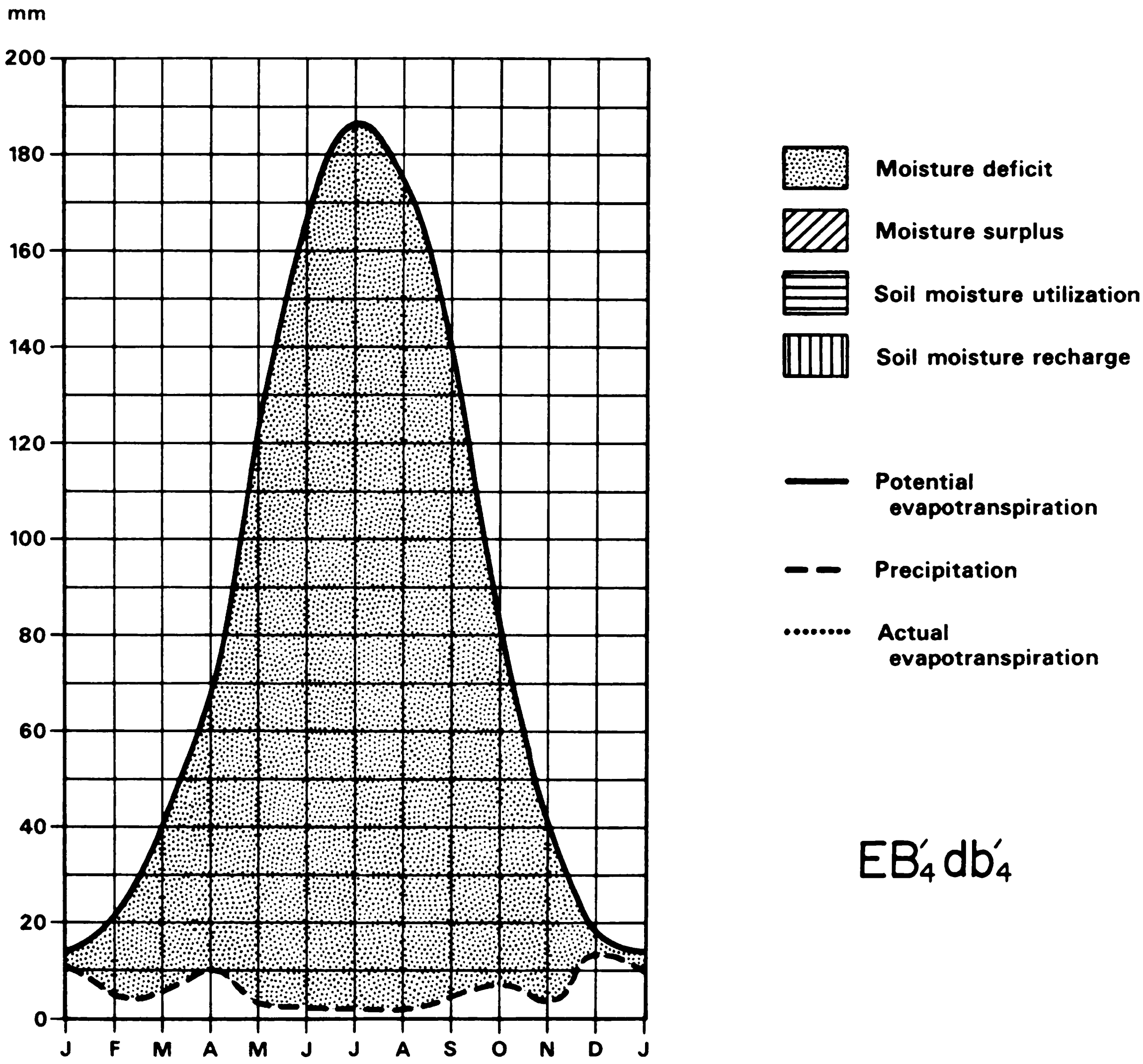
MESRATA

MESRATA	Location: 32° 23' N lat., 15° 05' E long. Elevation: 10 meters											No. 14
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\overline{X}$ °C	13.3	14.2	16.2	18.4	21.5	25.4	27.0	27.5	26.4	23.4	19.2	15.0	
I	4.4	4.86	5.93	7.19	9.10	11.71	12.85	13.21	12.42	10.35	7.67	5.28	104.97
Unadj. PE	0.9	1.1	1.4	2.0	2.8	4.1	4.6	4.8	4.5	3.4	2.1	1.2	
Adj. PE	24	29	43	65	99	144	166	164	139	100	55	32	1060
P	69	27	16	12	4	1	0	1	8	38	22	68	266
P- E	45	-2	-27	-53	-95	-143	-166	-163	-131	-62	-33	36	
Acc. Pot. W.L.	(-20)	-22	-49	-102	-197	-340	-506	-669	-800	-862	-895		
St.	81	80	60	35	13	3	1	0	0	0	0	36	
ΔSt.	+45	-1	-20	-25	-22	-10	-2	-1	0	0	0	+36	
AE	24	28	36	37	26	11	2	2	8	38	22	32	266
D	0	1	7	28	73	133	164	162	131	62	33	0	794
S	0	0	0	0	0	0	0	0	0	0	0	0	



MEZDA

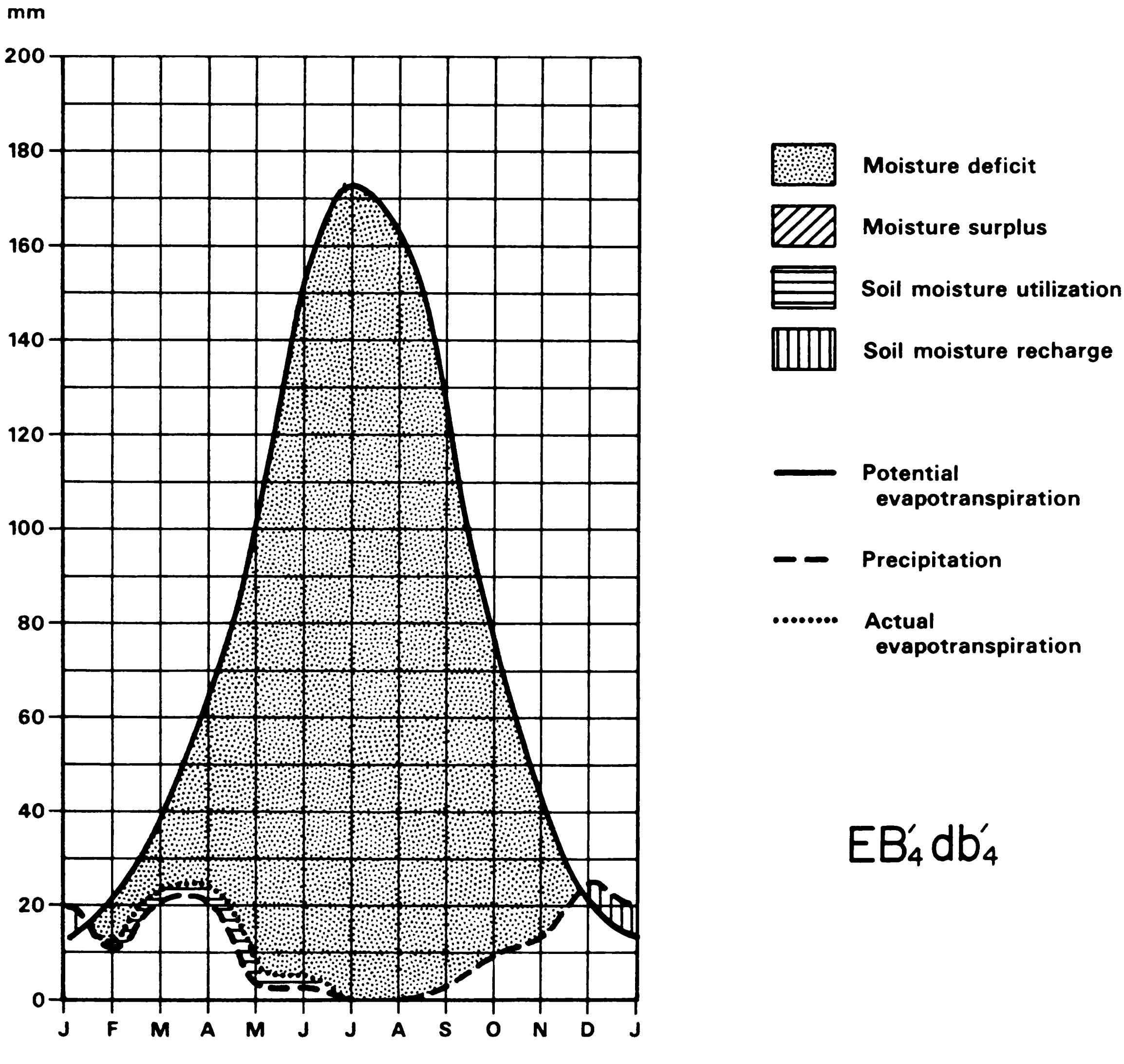
MEZDA	Location: 31° 26' N lat., 12° 45' E long.				Elevation: 522 meters								No. 15
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\bar{X}$ °C	10.0	12.4	15.5	19.0	23.4	27.6	29.1	28.7	26.0	21.6	16.4	11.6	
I	2.86	3.96	5.55	7.55	10.35	13.28	14.39	14.09	12.13	9.17	6.04	3.58	102.95
Unadj. PE	0.5	0.8	1.4	2.1	3.5	4.8	5.2	5.1	4.4	2.8	1.6	0.7	
Adj. PE	14	21	43	68	124	168	187	174	136	82	42	18	1077
P	10	5	6	10	3	2	1	1	5	7	3	14	67
P- E	-4	-16	-37	-58	-121	-166	-186	-173	-131	-75	-39	-4	
Acc. Pot. W.L.	-514	-530	-567	-625	-746	-912	-1098	-1271	-1402	-1477	-1516	-1520	
St.	0	0	0	0	0	0	0	0	0	0	0	0	
ΔSt.	0	0	0	0	0	0	0	0	0	0	0	0	
AE	10	5	6	10	3	2	1	1	5	7	3	14	67
D	4	16	37	58	121	166	186	173	131	75	39	4	1010
S	0	0	0	0	0	0	0	0	0	0	0	0	



$EB'_4 db'_4$

NALUT

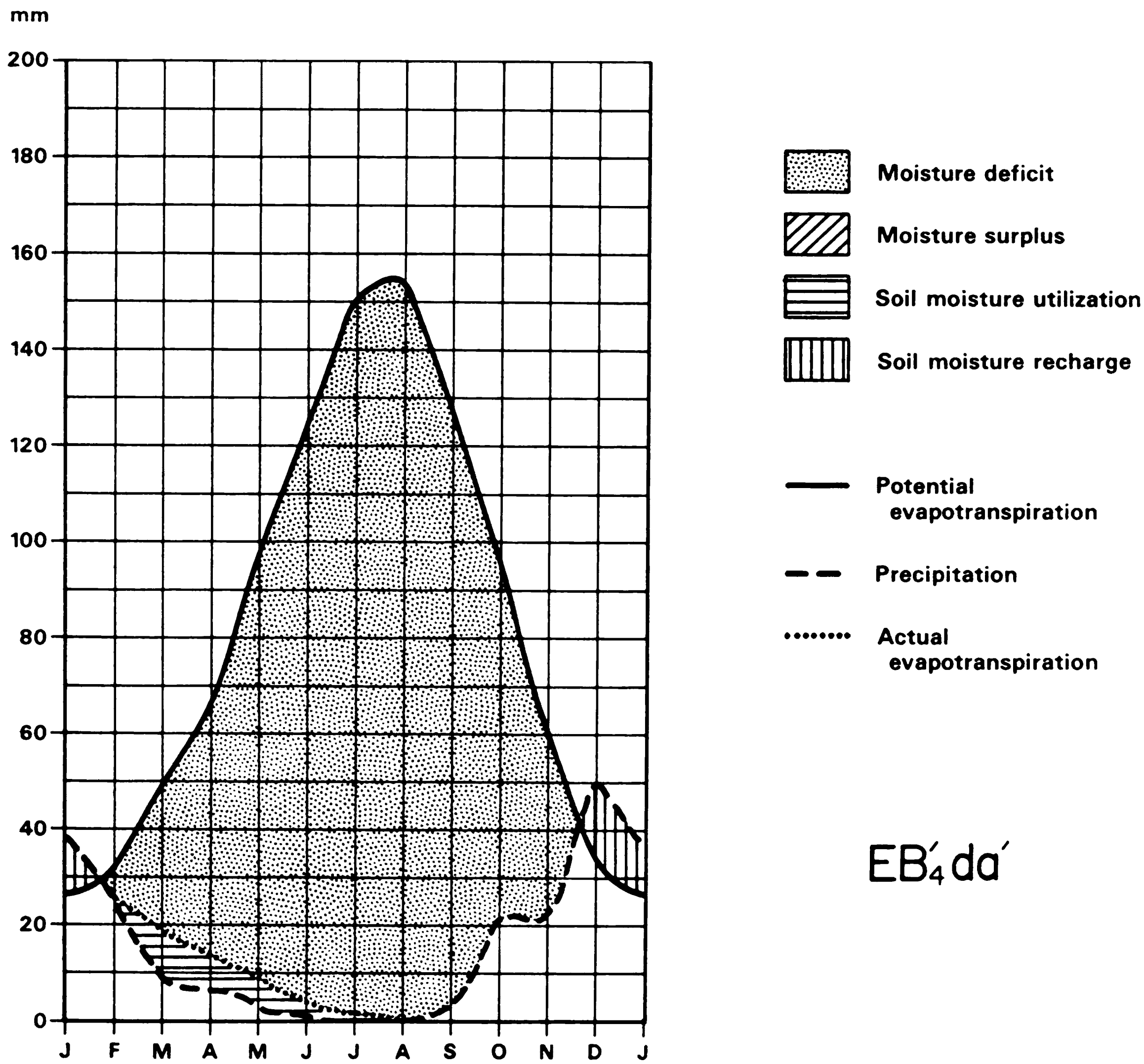
NALUT	Location: 31° 51' N lat., 10° 59' E long. Elevation: 639 meters											No. 16
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\bar{X}$ °C	9.0	11.2	14.2	17.4	21.5	26.1	27.5	27.5	25.2	20.2	15.4	10.7	
I	2.44	3.39	4.86	6.61	9.10	12.21	13.21	13.21	11.57	8.28	5.49	3.16	93.53
Unadj. PE	0.5	0.8	1.3	2.0	2.9	4.4	4.8	4.8	4.1	2.6	1.6	0.8	
Adj. PE	14	21	40	65	103	154	173	164	127	76	42	21	1000
P	19	10	22	22	3	3	0	0	3	10	13	25	130
P- E	5	-11	-18	-43	-100	-151	-173	-164	-124	-66	-29	4	
Acc. Pot. W.L.	(-230)	-241	-259	-302	-402	-553	-726	-890	-1014	-1080	-1109		
St.	9	8	7	4	2	0	0	0	0	0	0	4	
ΔSt.	+5	-1	-1	-3	-2	-2	0	0	0	0	0	+4	
AE	14	11	23	25	5	5	0	0	3	10	13	21	130
D	0	10	17	40	98	149	173	164	124	66	29	0	870
S	0	0	0	0	0	0	0	0	0	0	0	0	



$EB'_4 db'_4$

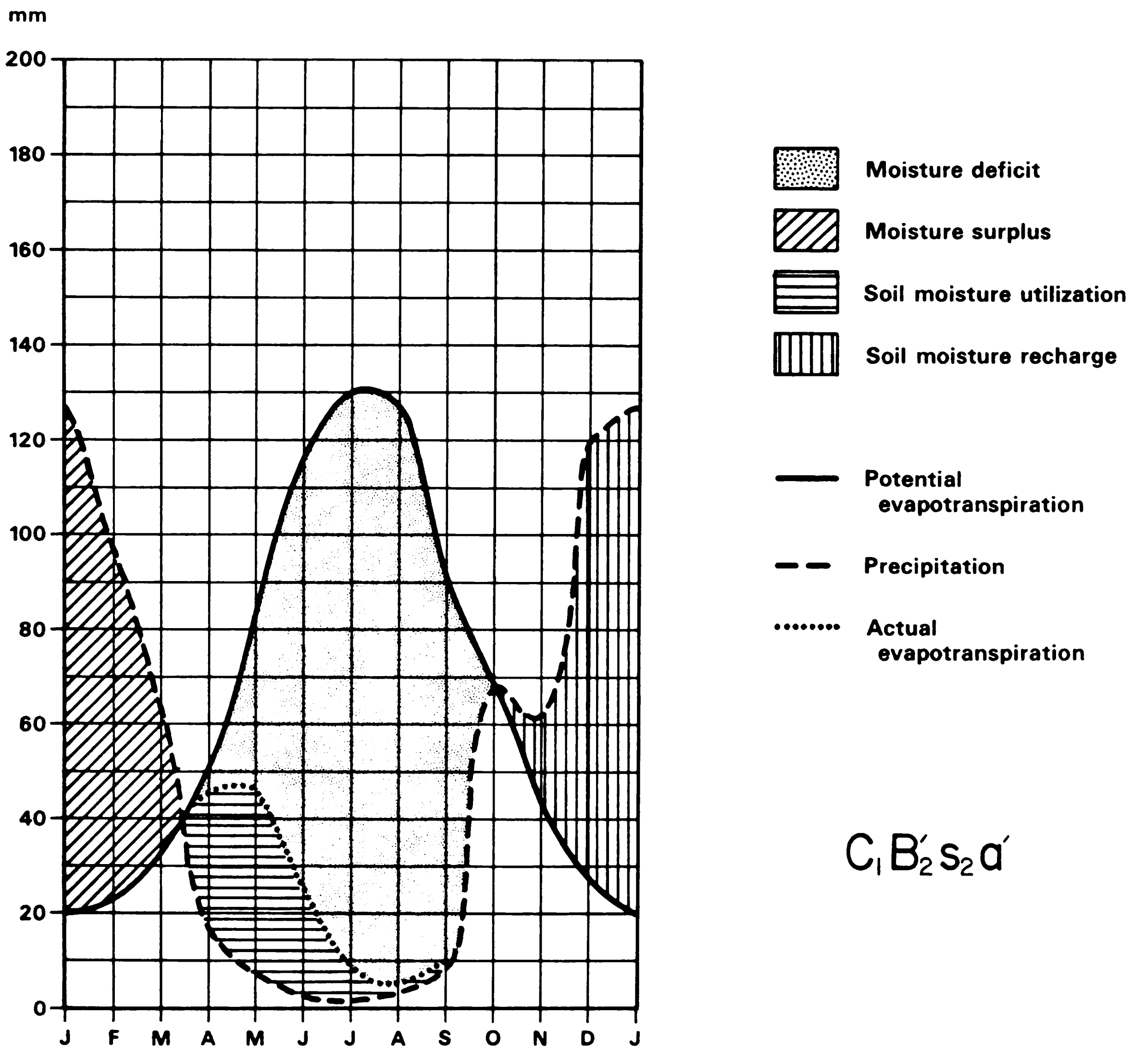
SIRTE

SIRTE	Location: 31° 13' N lat., 16° 35' E long. Elevation: 18 meters												No. 17
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\overline{X}$ °C	13.4	14.4	16.5	18.1	21.3	23.9	25.5	26.5	25.2	23.1	19.3	15.1	
I	4.45	4.96	6.10	7.01	8.97	10.68	11.78	12.49	11.57	10.15	7.73	5.33	101.22
Unadj. PE	1.0	1.2	1.6	2.0	2.8	3.6	4.2	4.5	4.1	3.4	2.3	1.3	
Adj. PE	27	31	49	65	99	126	151	154	127	100	61	34	1024
P	38	25	9	7	3	1	0	0	3	21	21	49	177
P- E	11	-6	-40	-58	-96	-125	-151	-154	-124	-79	-40	15	
Acc. Pot. W.L.	(-130)	-136	-176	-234	-330	-455	-606	-760	-884	-963	-1003		
St.	26	25	16	9	3	1	0	0	0	0	0	15	
ΔSt.	+11	-1	-9	-7	-6	-2	-1	0	0	0	0	+15	
AE	27	26	18	14	9	3	1	0	3	21	21	34	177
D	0	5	31	51	90	123	150	154	124	79	40	0	847
S	0	0	0	0	0	0	0	0	0	0	0	0	



SHAHAT

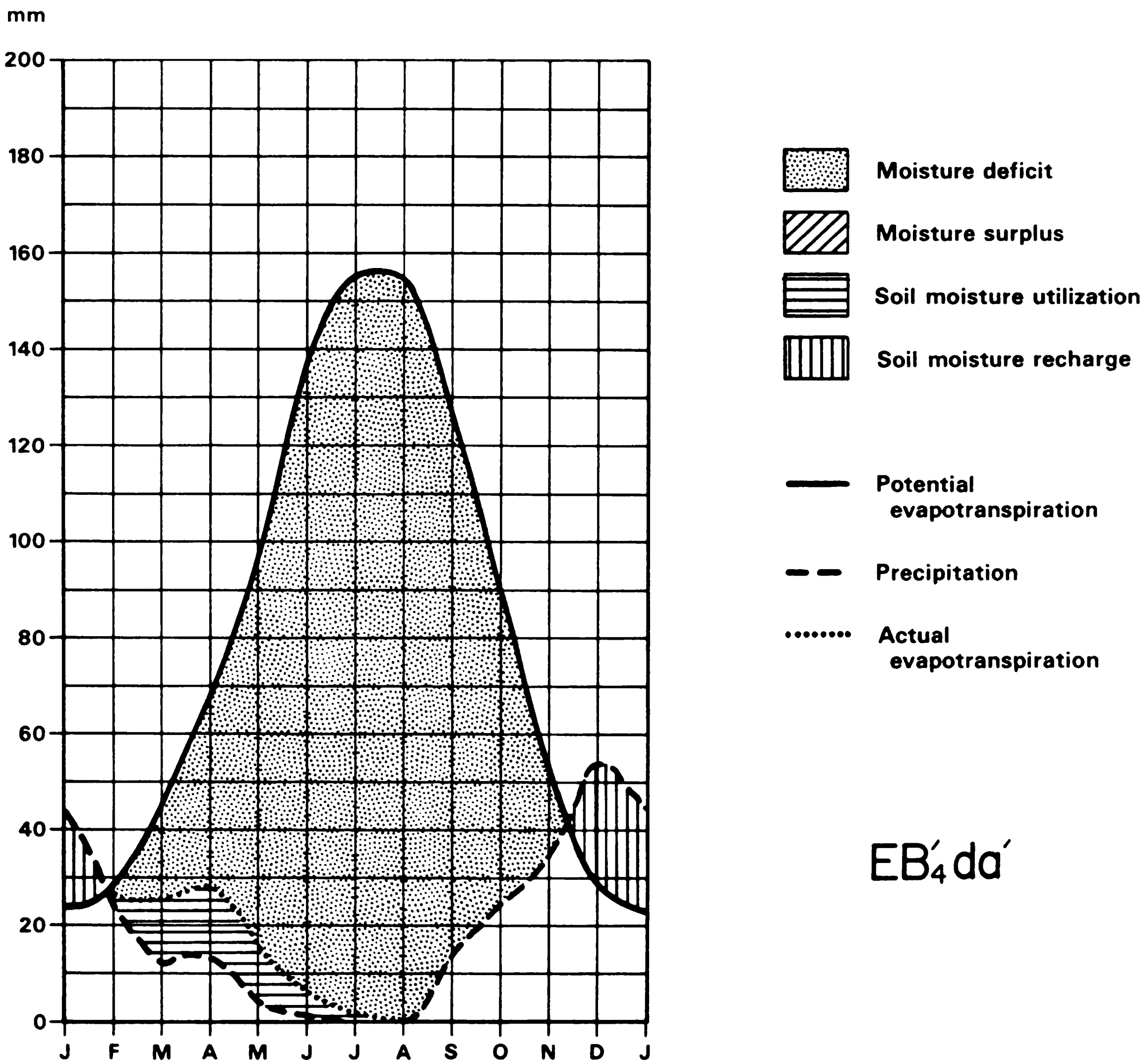
SHAHAT	Location: 32° 49' N lat., 21° 52' E long. Elevation: 621 meters											No. 18
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\bar{X}$ °C	9.4	9.9	11.7	14.5	18.4	22.2	22.9	23.2	21.0	18.4	15.1	11.2	
I	2.60	2.81	3.62	5.01	7.19	9.55	10.01	10.21	8.78	7.19	5.33	3.39	75.69
Unadj. PE	0.8	0.9	1.1	1.6	2.4	3.3	3.6	3.7	3.0	2.4	1.7	1.1	
Adj. PE	21	23	34	52	86	117	131	128	93	71	45	29	830
P	126	93	62	14	8	2	1	3	7	67	61	120	564
P- E	105	70	28	-38	-78	-115	-130	-125	-86	-4	16	91	
Acc. Pot. W.L.				-38	-116	-231	-361	-486	-572	-576			
St.	100	100	100	68	30	9	2	1	0	0	16	100	
ΔSt.	0	0	0	-32	-38	-21	-7	-1	-1	0	+16	+84	
AE	21	23	34	46	46	23	8	4	8	67	45	29	354
D	0	0	0	6	40	94	123	124	85	4	0	0	476
S	105	70	28	0	0	0	0	0	0	0	0	7	210



$C_1 B_2' s_2 a'$

SURMAN

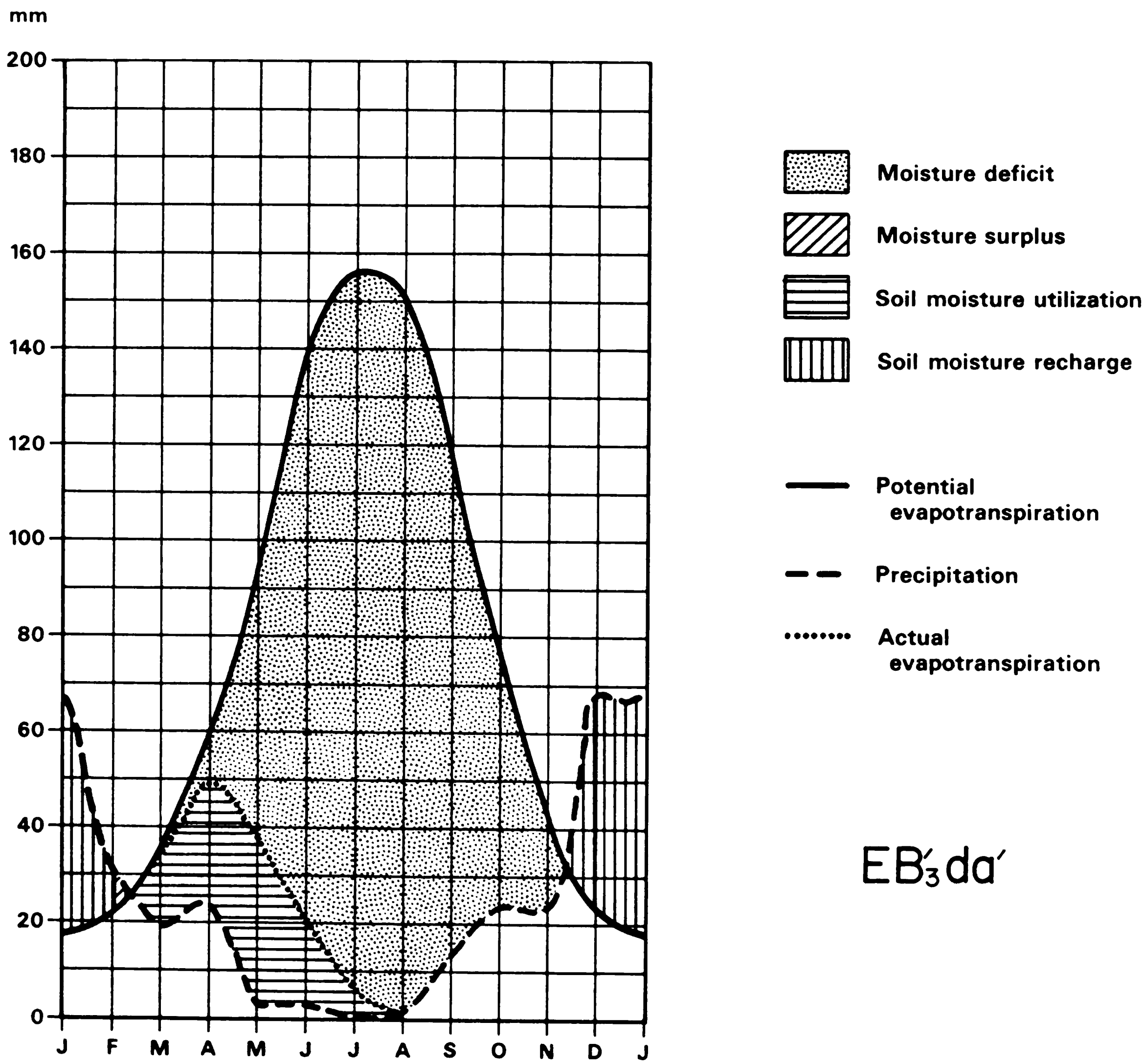
SURMAN	Location: 32° 45' N lat., 12° 35' E long.					Elevation: 20 meters (estimated)							No. 19
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\overline{X}$ °C	12.2	13.4	15.7	18.2	20.8	24.7	25.7	26.5	25.3	22.0	17.9	14.0	
I	3.86	4.45	5.65	7.07	8.66	11.23	11.92	12.49	11.64	9.42	6.90	4.75	98.04
Unadj. PE	0.9	1.1	1.5	2.1	2.7	3.9	4.3	4.5	4.1	3.1	2.0	1.1	
Adj. PE	24	28	46	68	96	138	156	155	127	91	53	29	1011
P	44	24	13	14	4	1	0	0	14	25	35	55	229
P– E	20	-4	-33	-54	-92	-137	-156	-155	-113	-66	-18	26	
Acc. Pot. W.L.	(-75)	-79	-112	-166	-258	-395	-551	-706	-819	-885	-903		
St.	46	44	32	18	7	2	0	0	0	0	0	26	
ΔSt.	+20	-2	-12	-14	-11	-5	-2	0	0	0	0	+26	
AE	24	26	25	28	15	6	2	0	14	25	35	29	229
D	0	2	21	40	81	132	154	155	113	66	18	0	782
S	0	0	0	0	0	0	0	0	0	0	0	0	



EB′₄da′

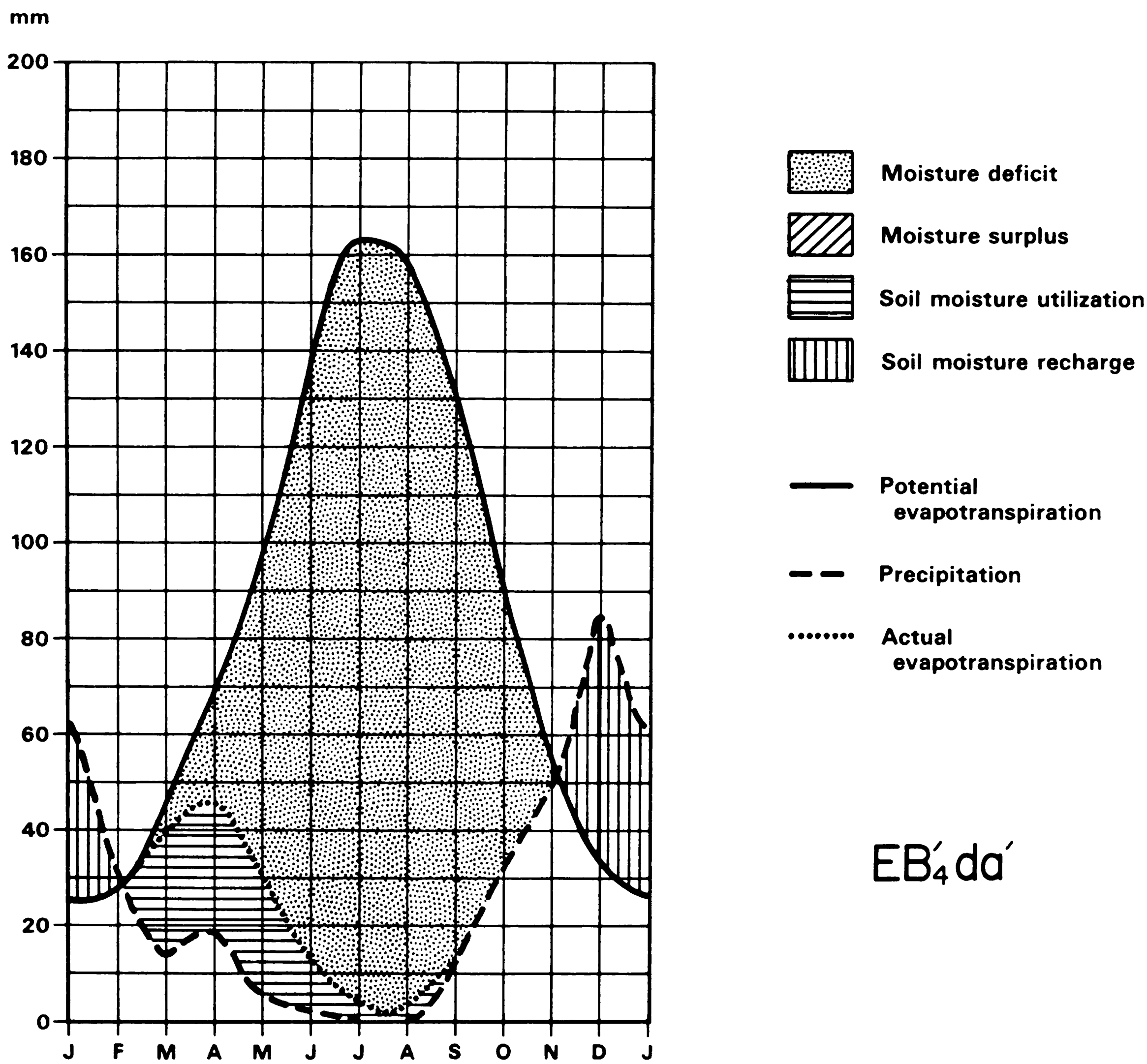
TARHONA

TARHONA	Location: 32° 26' N lat., 13° 38' E long. Elevation: 430 meters											No. 20
	J	F	M	A	M	J	J	A	S	O	N	D	Year
X̄ °C	10.0	11.0	13.3	16.4	20.1	24.8	25.8	26.0	24.4	20.2	15.8	11.6	
I	2.86	3.30	4.40	6.04	8.22	11.30	11.99	12.13	11.02	8.28	5.71	3.58	88.83
Unadj. PE	0.7	0.8	1.2	1.8	2.6	3.9	4.3	4.4	3.8	2.7	1.7	0.9	
Adj. PE	19	21	37	58	93	138	156	152	117	79	45	23	938
P	67	32	20	24	3	2	0	0	13	23	22	68	274
P- E	48	11	-17	-34	-90	-136	-156	-152	-104	-56	-23	45	
Acc. Pot. W.L.			-17	-51	-141	-277	-433	-585	-689	-745	-768		
St.	93	100	84	59	24	6	1	0	0	0	0	45	
ΔSt.	+48	+7	-16	-25	-35	-18	-5	-1	0	0	0	+45	
AE	19	21	36	49	38	20	5	1	13	23	22	23	270
D	0	0	1	9	55	118	151	151	104	56	23	0	668
S	0	4	0	0	0	0	0	0	0	0	0	0	4



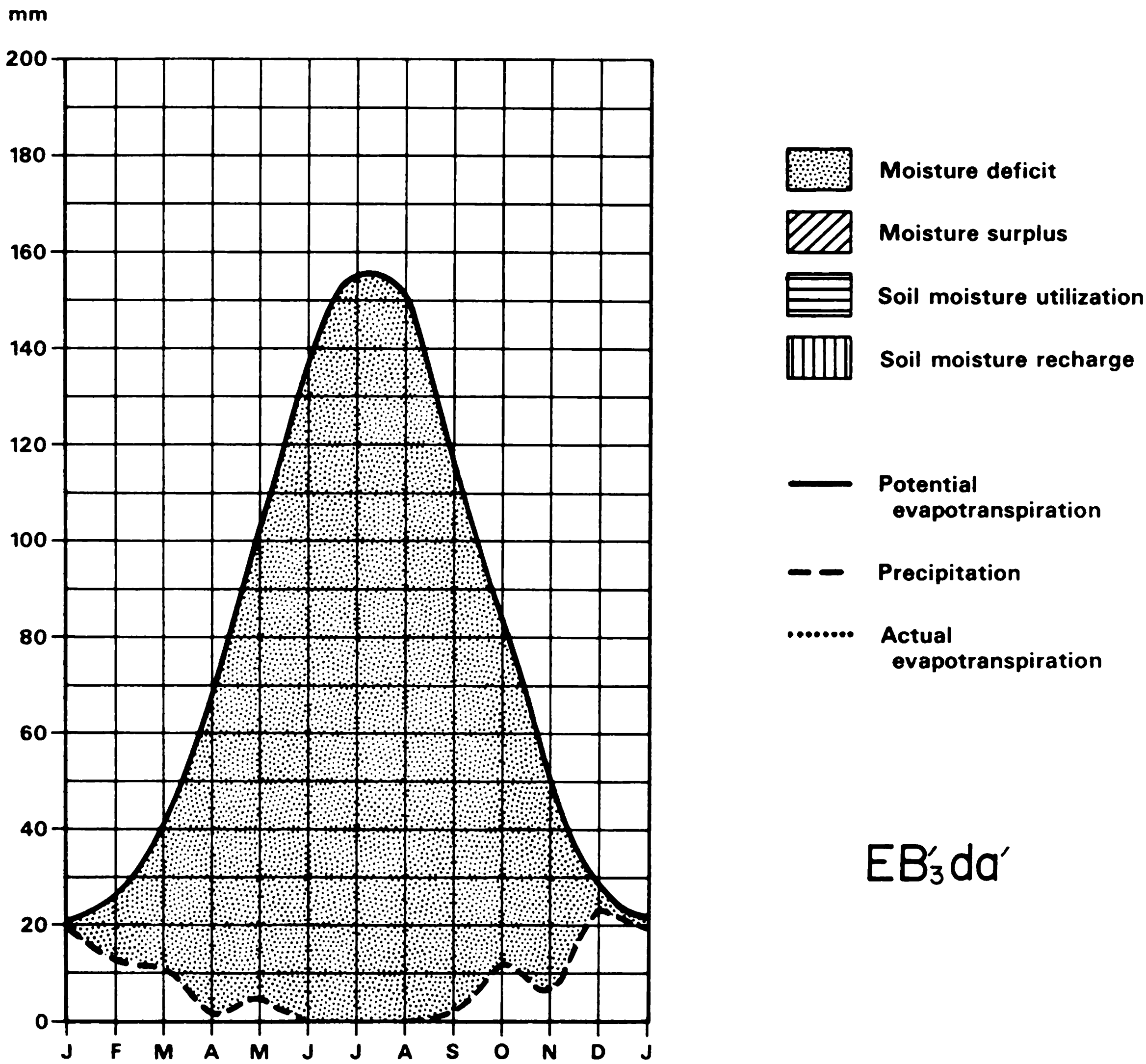
TRIPOLI

TRIPOLI	Location: 32° 54' N lat., 13° 11' E long. Elevation: 30 meters												No. 21
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\overline{X}$ °C	12.9	13.6	15.8	18.2	20.8	24.8	26.3	26.7	25.8	22.5	18.5	14.7	
I	4.20	4.55	5.71	7.07	8.66	11.30	12.35	12.63	11.99	9.75	7.25	5.12	100.58
Unadj. PE	1.0	1.0	1.5	2.1	2.7	3.9	4.5	4.6	4.3	3.2	2.2	1.3	
Adj. PE	26	26	46	69	96	139	163	159	133	93	57	34	1041
P	61	31	14	18	5	1	0	0	13	33	48	84	308
P- E	35	5	-32	-51	-91	-138	-163	-159	-120	-60	-9	50	
Acc. Pot. W.L.		(-10)	-42	-93	-184	-322	-485	-644	-764	-824	-833		
St.	85	90	65	38	15	4	1	0	0	0	0	50	
ΔSt.	+35	+5	-25	-27	-23	-11	-3	-1	0	0	0	+50	
AE	26	26	39	45	28	12	3	1	13	33	48	34	308
D	0	0	7	24	68	127	160	158	120	60	9	0	733
S	0	0	0	0	0	0	0	0	0	0	0	0	



TUBRUQUE

TUBRUQUE	Location: 32° 05' N lat., 23° 59' E long. Elevation: 46 meters												No. 22
	J	F	M	A	M	J	J	A	S	O	N	D	Year
X̄ °C	11.8	12.8	15.0	18.0	21.5	24.7	25.7	25.9	23.9	21.4	17.4	13.3	
I	3.67	4.15	5.28	6.95	9.10	11.23	11.92	12.06	10.68	9.04	6.61	4.40	95.09
Unadj. PE	0.8	1.0	1.4	2.1	2.9	3.9	4.3	4.4	3.7	2.9	1.9	1.1	
Adj. PE	21	26	43	68	104	138	156	152	114	85	50	29	986
P	19	13	11	1	4	0	0	0	1	11	6	23	89
P-E	-2	-13	-32	-67	-100	-138	-156	-152	-113	-74	-44	-6	
Acc. Pot. W.L.	-512	-525	-557	-624	-724	-862	-1018	-1170	-1283	-1357	-1401	-1407	
St.	0	0	0	0	0	0	0	0	0	0	0	0	
ΔSt.	0	0	0	0	0	0	0	0	0	0	0	0	
AE	19	13	11	1	4	0	0	0	1	11	6	23	89
D	2	13	32	67	100	138	156	152	113	74	44	6	897
S	0	0	0	0	0	0	0	0	0	0	0	0	



EB'₃da'

ZWARA

ZWARA	Location: 32° 56' N lat., 12° 05' E long.				Elevation: 8 meters							No. 23
	J	F	M	A	M	J	J	A	S	O	N	D	Year
$\overline{X}$ °C	12.7	15.1	18.5	20.6	24.7	27.8	29.0	29.2	26.9	23.1	18.4	14.1	
I	4.10	5.33	7.25	8.53	11.23	13.43	14.32	14.47	12.78	10.15	7.19	4.81	113.59
Unadj. PE	0.7	1.1	1.9	2.5	3.8	4.9	5.2	5.2	4.6	3.3	1.9	0.9	
Adj. PE	18	28	59	82	136	175	189	179	142	96	50	23	1177
P	33	15	13	18	6	1	0	0	8	34	31	52	211
P- E	15	-13	-46	-64	-130	-174	-189	-179	-134	-62	-19	29	
Acc. Pot. W.L.	(-80)	-93	-139	-203	-333	-507	-696	-875	-1009	-1071	-1090		
St.	44	38	24	12	3	1	0	0	0	0	0	29	
ΔSt.	+15	-6	-14	-12	-9	-2	-1	0	0	0	0	+29	
AE	18	21	27	30	15	3	1	0	8	34	31	23	211
D	0	7	32	52	121	172	188	179	134	62	19	0	966
S	0	0	0	0	0	0	0	0	0	0	0	0