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THE CLIMATE, BIOCLIMATE AND LAND USE

OF

NORTH-WEST AFRICA

Working document

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THE CLIMATE, BIOCLIMATE AND LAND USE OF NORTH-WEST AFRICA

THE CLIMATE

Introduction

The climate of Northern Africa is the result of two conflicting influences: on the one hand, the Mediterranean with its warm summers and mild wet winters, and on the other hand, the Saharean with its winds, extremes of heat and cold, dust storms and intense dryness. It is the highlands that form a more or less effective barrier to the desert and, conversely, to the rain clouds.

The climate is of the Mediterranean type with two main seasons: a cold and rainy one during the autumn and winter and a hot and dry one during most of the spring and all of the summer. Atlantic influences moderate the extremes of temperature throughout the region and in Morocco they also control the precipitation. In Algeria and Tunisia, however, the precipitation is largely influenced by the Mediterranean sea. In general, precipitation increases both with altitude and from south to north and is extremely irregular from year to year.

Appendix I shows the mean annual rainfall in North-West Africa. An important factor for agriculture is the annual and monthly variation but only an old small-scale map of Algeria and Tunisia was found on this subject 1/. These are shown in figures 1a and 1b. The average departures are of the order of 100% in the more humid zones and they attain 400% in the semi-arid regions. When the extremes are compared one obtains much wider departures.

The spread of cultivation, though determined largely by rainfall, is also influenced by temperature. Frosts are frequent, except in areas bordering on the sea. The yields of crops is very much dependent on the availability of moisture in the growing season.

Important climatic and bioclimatic studies of the three countries under study, namely Morocco, Algeria and Tunisia, are those listed below:

CCTA/CSA Climatological Atlas of Africa, Lagos/Nairobi, 1961.

Dubief, J. Le Climat du Sahara, 2 volumes, Université d'Alger, Institut des Recherches Sahariennes, Alger, 1959 and 1963.

Nuttonson, M.Y. The Physical Environment and Agriculture of Morocco, Algeria and Tunisia, American Institute of Crop Ecology, Washington, 1961.

Thomson, B.W. The Climate of Africa, Oxford University Press, Nairobi/ London/New York, 1965.

1/ Bernard, A., Atlas d'Algérie et de Tunisie, Alger, Paris, 1935?

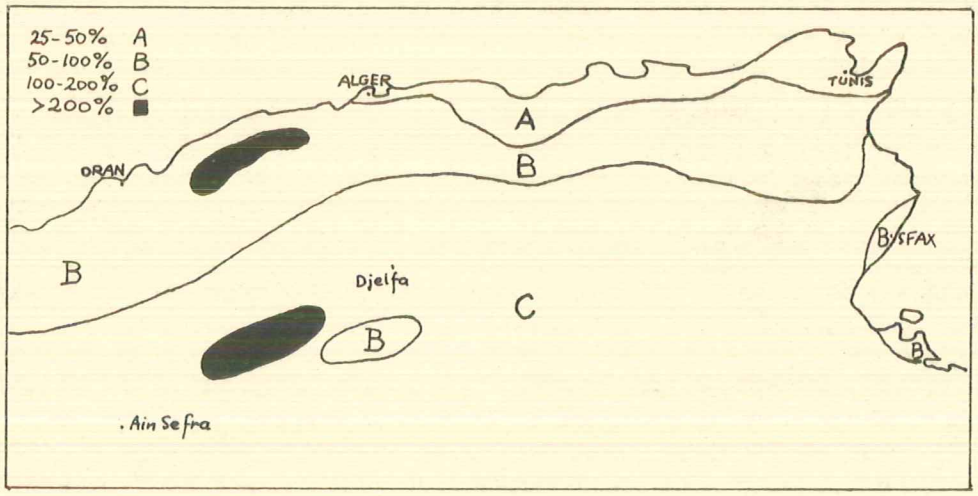


Figure 1a

Zones of Algeria and Tunisia where the observed mean maximum precipitation exceeds the mean annual value with the percentages mentioned.

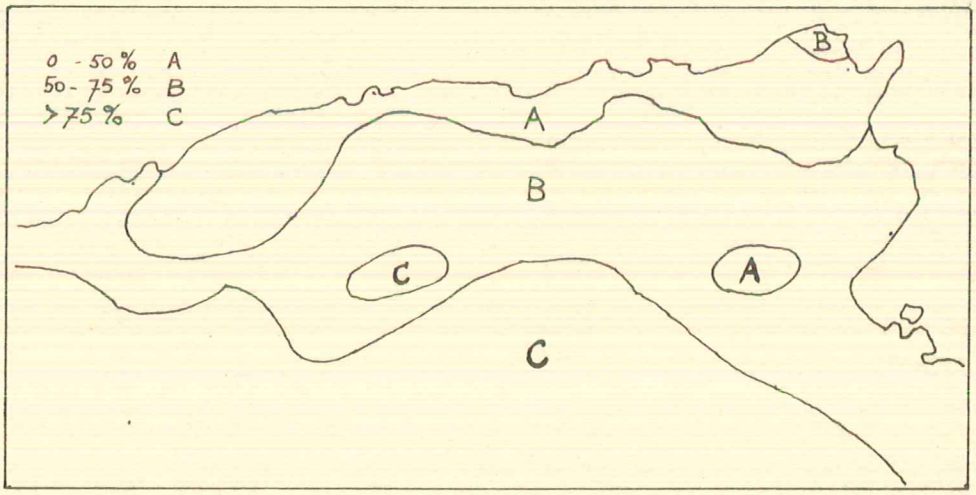


Figure 1b

Zones of Algeria and Tunisia where the observed mean minimum precipitation is lower than the mean annual value with the percentages mentioned.

UNESCO/FAO Bioclimatic map of the Mediterranean Zone, Paris, 1963.

Walter, H. and Lieth, H. Klimadiagramm Weltatlas, Fischer Verlag, Jena, 1967.

An interesting study on the delineation of the arid zones of Morocco was published by Ionesco 1/. Since the UNESCO/FAO publication is based on those climatic factors which have a definite action on crop growth, it was decided to take this map as the basic information for our studies on the crop-climatic conditions.

According to Nuttonson (page 26) the climate and land use (rainfed and irrigated) can be generally correlated. Table 1 is copied from his publication (see next page).

According to FAO Production Yearbook (volume 20, 1966) the land use data are as follows:

TABLE 2

Land Use Data of Morocco, Algeria and Tunisia
in 000 ha

	Arable land and land under permanent crops	Permanent meadows and pastures	Forested land	Other area	Total area
Morocco	7860	7650	5337	23658	44505
Algeria	7066	38405	3045	189658	238174
Tunisia	4334	5652	841	1691	12518
Total	19260	51707	9223	215007	295197

Also copied from Nuttonsons' report (page 40) is figure 2: a map of land utilization and crop distribution of North-West Africa.

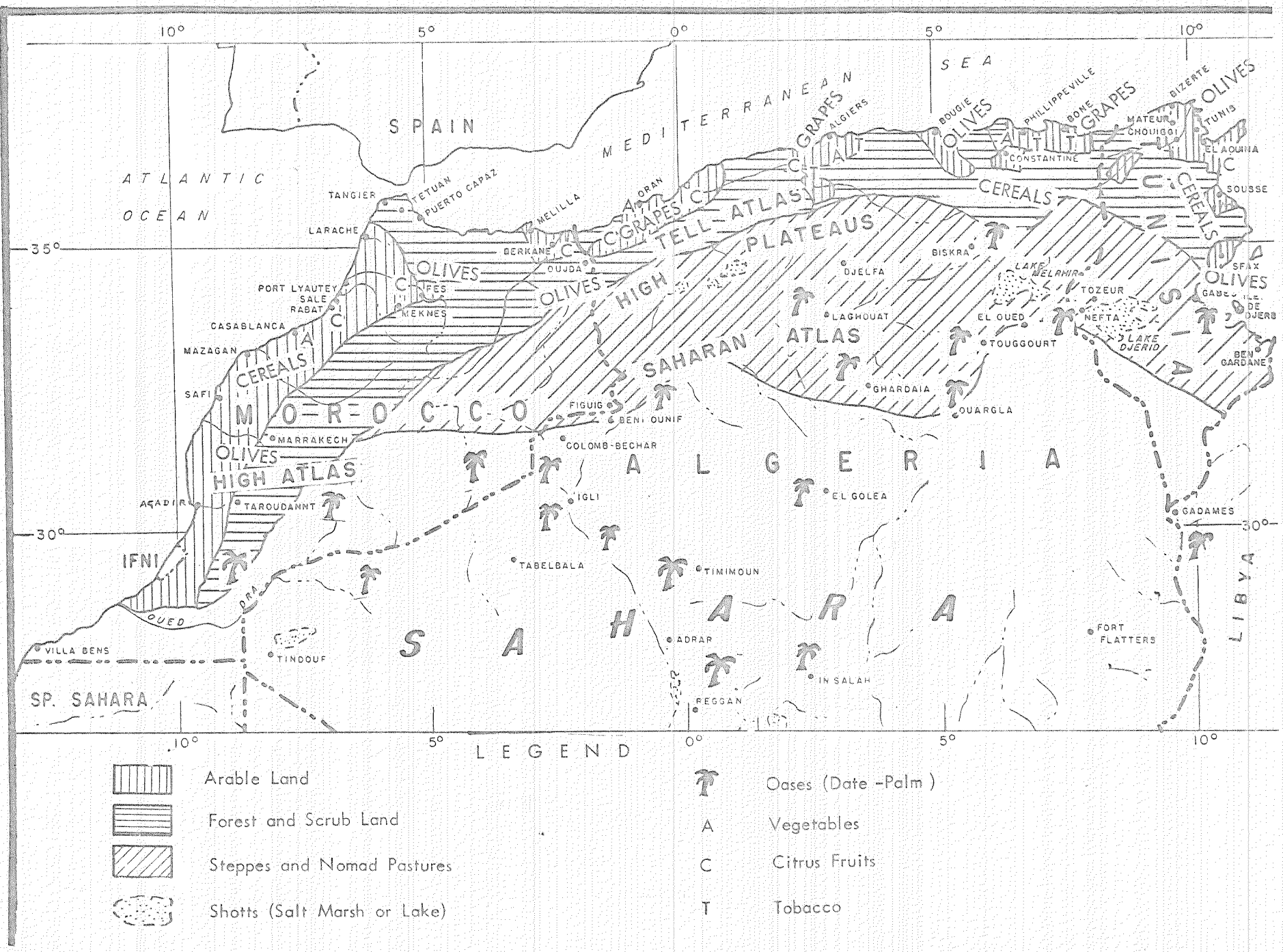
1/ Ionesco, T. Considérations sur les zones arides du Maroc, Les Cahiers de la Recherche Agronomique, Rabat, 1965.

TABLE 1

Climate and Land Use Data of North West Africa

Zone	Main Land Uses	Important crops		Rainfall (mm)	Winter Climate	Typical Regions
		Rain-fed Farming	Irrigated Farming			
Arid	Mainly nomadic grazing. Irrigated farming	Barley and wheat sometimes grown in shifting cultivation in places where moisture accumulates		0-250	mild	Central Morocco
				0-325	cold	Parts of North Algerian high plateau
Semi-Arid	Nomadic or semi-nomadic grazing Cereals and fallow. Drought tolerant tree crops. Forests generally degraded. Irrigated farming	Cereals with wheat on better soils. Olives, almonds etc. in milder areas. Eucalyptus and Acacia		250-400	mild	Tunisian Salue; part of Moroccan litoral and of central plains
				325-450	cold	Algerian high plateau
Sub-humid	Semi-nomadic grazing rotational farming on rain-fed land. Forests often degraded. Plantation forest. Irrigated farming.	Cereals, mainly wheat and barley; maize, cotton, sorghum; pulses melons; olives and carobs in lowlands; vines, Eucalyptus and Pinus halepenses; chestnut, walnut.		400-650	mild	Parts of North African coastal belt from Rabat to Tunis
				450-700	cold	Part of North African mountains. Lower mountain areas generally.
				650 +	mild	Part of Algerian and north Tunisian coastal mountains.
Humid	Transhumant grazing, rotational farming. Tree crops. Climax forests in some mountain areas, secondary forest predominate.	Cereals, pulses, summer crops, olives, vines, chestnut, walnuts, Pinus nigra, cedars.		700 +	cold	Northern and western slopes in high mountains in North Africa

Mild winters: cereals, pulses, temperate vegetables and fodder in winter; sub tropic and tropical annuals in summer including maize, sorghum, tomatoes, cotton. Double cropping is feasible where irrigation water is abundant. Numerous sub-tropic and tropic perennial crops; citrus, banana, sugar cane, rice, where abundant irrigation is available in summer. Alfalfa (lucerne) is widely grown. Cold winters: mainly cereals. Tropical and sub-tropical crops can be grown where season is long enough. Alfalfa fairly common. Temperate tree crops and vegetables in uplands.



LAND UTILIZATION AND CROP DISTRIBUTION MAP OF NORTH-WEST AFRICA

M o r o c c o

Relief is among the principal determinants of climate. As a whole, except for the higher mountain areas, the climate is Mediterranean with dry, hot summers and wet cool winters. In winter the westerly winds bring rain to the coastal belt and still more to the mountain ranges facing the coast. Southeast of the mountain ranges, the rainfall decreases rapidly. In summer a northeasterly wind brings no rain, but blows steadily across the land.

The mean annual precipitation, as given in climatological tables is subject to a large probably error if applied to any one year. This uncertainty grows if one proceeds east and south. In the drier areas rainfall becomes more and more of an accident and tends to fall not only less frequently but more in torrential downfalls and less in steady rains at predictable periods.

Hail is frequent at elevations above 1000 meters and can be most destructive. Snow is very rarely seen on the coast of Morocco, but as one leaves the coast, snowfall is common. Between 600 and 900 meters occasional snow may fall, but will disappear rapidly. Between 1000 and 2000 meters the snow may stay for a few days to a maximum of a month. Above 2000 meters it may lie from six to nine months on north and west facing ground.

The country can be divided into the following climatic regions:

a) The Northern Region - temperatures along the Atlantic coast are equable but on the summits of the highland zone frost and snow are common features. There is much difference in the amount of precipitation, from over 1000 mm on the exposed slopes in the highlands in the western areas of the Atlantic coast to 700 mm at Tetuan, less than 400 mm at Melilla to about 250 mm in many areas of the eastern plains of the northern zone. This zone is very mountainous and is suitable only for pastures, tree and vine crops.

b) The Atlantic Coastal Plain - This climate, which is modified by the cool Canaries stream and by the mountain barriers, is equable and moist, though at times the summer sun may be very hot and winter temperatures may drop to the freezing point.

Going from Tangiers south-westwards the amount of annual precipitation decreases gradually from 900 mm to 625 mm at Larache, 520 mm at Rabat, less than 300 mm at Mogador and 225 mm at Agadir.

The plains and plateaux facing the Atlantic and flanked by the Atlas ranges form the most important agricultural area of Morocco.

c) The Interior Region - The temperatures extremes are similar to those for the mountain zone, but the precipitation is very much lower. The summers in the Sebou valley can be very hot and the precipitation (380-670 mm) is determined by the topography. The Eastern Meseta has a very continental climate with high summer temperatures and cold winters (rainfall about 750 mm). The plains of Tadla and the Haouz are increasingly continental and the valleys become increasingly hot and dry as one goes south. The annual precipitation goes from 400 to 175 mm.

d) The Atlas Mountains - Winter temperatures may remain below freezing for weeks while the summers are hot. Precipitation is high and middle Atlas is about 500-750 mm on the north-western slopes, while it is only 150 mm in the rain-shadow and in the Anti-Atlas. A large part of the mountain areas consist of fairly well-watered forest lands and grazing lands.

e) The Northeastern Plain - North of the Middle Atlas and east of the Taza corridor the climate is rather dry but temperatures are equable. The precipitation varies considerably with the topographical features of the different hills and the mountain slopes. It ranges from 200 (near the Atlas)-400 (near the Algerian border).

f) The Eastern Plateaux - This region, rising to 2000 m is alternately hot and cold, desert-like, windswept and bare. Precipitation is from nearly rainless to 250 mm.

g) The Southwestern Desert - Extreme summer temperatures, hot and dusty winds and winter frosts are rather common. Precipitation, usually occurring during storms, ranges from 50 - 75 mm per year and near the coast from 150-200 mm. As a whole, arid conditions prevail beyond the Anti-Atlas.

A l g e r i a

The outstanding feature of the climate is the wide range of precipitation and temperatures. In general, the precipitation decreases towards the interior, the rainfall tends to increase where the land is higher, and lower lying areas are exceptionally dry; also there is a sharp contrast between the exposed wet north and west slopes of mountains and hills and the much drier south and east slopes. The bulk of the precipitation falls in the autumn, winter and spring.

As a result of the effects of the sea and the desert, and the altitudes and exposure temperatures often vary greatly within short distances. Frost is very rare in the coastal regions, but away from the sea temperatures are much lower. The country can be divided into four climatic regions.

a) The Coastal Region - The winter is cool, mild and rainy, the summer is rainless, hot and the atmosphere has a high humidity. The diurnal range of temperature is small.

b) The Inner Tell Region - The summer is generally mild with cool nights, though the summer heat about mid-day may be excessive during July and August. Winters are relatively cold and are subject to considerable snowfall. The precipitation is fairly heavy in the western part of the region and especially the areas exposed to the sea winds are well-watered. The high plains in the interior are relatively dry, hot and the climate is fairly continental with a considerable range of temperature. The lower plain of the Cheliff is even drier and hotter. The eastern part of Algeria is subject to heavy rain and snow in the mountains of Djurdjura, the Kabylie des Babors, the Kabylie de Collo and the Edough mountains. The mountain chains lying behind have a more or less maritime climate.

c) High Plateaux - This area and the Saharan Atlas is excluded from the maritime influences and is subject to a continental climate. The High Plateaux of Oran and Algiers have very cold winters with heavy snows. Summers are hot with high diurnal ranges of temperatures.

In the higher land surrounding the High Plateaux the precipitation is higher, while the summer temperature is somewhat lower.

d) Algerian Sahara - This region is characterised mainly by the great variation and range of its temperatures, the exceptionally great aridity of the atmosphere and the almost complete absence of rain, The rain that does fall usually comes in heavy storms, sometimes accompanied by hail. The runoff may cause much damage.

T u n i s i a

The climate ranges from typically Mediterranean in the north to steppe-like in the centre and to Saharan in the south. It is modified by the proximity of the sea and the desert and by variations in altitude. Tunisia receives only a very limited share of the Atlantic rains and they often reach only the northern part of the country.

Precipitation constitutes the climatic factor that effects most directly crop production of the country. Precipitation consists mainly of rain, although snow falls in some mountain districts (Kromirie, Dorsale). Falls of soft hail are more frequent than snow. Precipitation is largely concentrated in the winter months, from October to April.

The annual precipitation fluctuates considerably in amount as well as in its distribution from year to year. The further south one goes the more pronounced are the local rainfall variations and the more unstable is the local agriculture, and livestock production.

The Tunisian climate is rather continental and characterised by considerable seasonal and diurnal fluctuations of temperature.

The cool winter season is generally sunny with cool northwest winds. In coastal districts the influence of the sea is most marked at this time of the year. Much of the interior is exposed to prolonged cold spells. Frosts are common.

In the hot summer season average temperatures are about 25°C though there is considerable variation from year to year.

Inland high temperatures are common everywhere, usually associated with a low relative humidity.

Climatically Tunisia can be divided into three zones:

a) The Northern Region -Including the north coast and the Mediterranean slopes of the adjacent mountains. It has a relatively temperate climate with a moderate rainfall.

b) The Central Region - Has a much large diurnal and annual range of temperature that the north coast; rainfall decreases rapidly to the south. Especially in the northern mountains the winter may be very cold with much rain and wind and frost and snow. In the steppes it is cold and windy and the local showers may bring heavy rain, but there is also considerable sunshine.

c) The Southern Region - Which includes a part of the Sahara, is desert, with a great range of temperature and scanty irregular rainfall. The summer is hot and excessively so in the south.

THE BIOCLIMATE AND LAND USE

Introduction

In the climatic classification used in the UNESCO-FAO study the factors taken into account are:

a) temperature
b) precipitation and number of days of rain
c) atmospheric humidity, mist and dew

A hot month is a month in which the average temperature is above 20°C and hence with no risk of frost.

A cold month is a month in which the average temperature is 0°C or below. When the mean temperature of the coldest month, t, is over 15°C, frost is an infrequent phenomenon and the 15°C limit is taken as the boundary between frostfree and frost-prone regions.

Climates with coldest month temperatures between -5°C and +15°C are rated as follows:

$15°C > t$ 1/ $\geq 10°C$ = warm temperate
$10°C > t \geq 0°C$ = temperate
$0°C > t \geq -5°C$ = cold temperate

A dry month is a month in which the total of precipitations P (in mm) is equal to or less than twice the mean temperature T of the month (in °C), or $P \leq 2T$

This relation, according to the UNESCO-FAO study, works very well for the Mediterranean region.

Data on precipitation, P, and temperature, T, are put together in the ombrothermic diagrams, in such order that the T scale is double that of P.

A humid month is defined as $P \geq 2T$
A semi-dry month is defined as $2T < P < 3T$

These ombrothermic diagrams are also used by Walter and Lieth in the Klima-diagramm-Weltatlas.

Furthermore, the UNESCO-FAO study makes use of a "xerothermic index" or "index of hot weather drought". The monthly index X_m is the degree of drought of a given dry month and is defined as the number of days in the month which can be deemed dry from the biological point of view. The index is based on the number of days without rain, days with mist and dew and the degree of atmospheric humidity.

1/ t designates mean temperature of the coldest month

The xerothermic index, X, for the dry season is the sum of the calculated monthly indices for the dry months.

The Classification of Bioclimate - UNESCO-FAO Study

In this classification climates are derived initially on the basis of temperature, with three groups of climates distinguishable according to the average temperature of the coldest month (t).

1. Warm, warm temperate and temperate climates when $t \geq 0^{\circ}C$. (constant positive temperature curve).

2. Cold and cold temperate climates when $t < 0^{\circ}C$. (negative temperature curve at certain points in the year).

3. Glacial climate when the mean temperature, T, is less than $0^{\circ}C$ for all the months of the year (constant negative temperature curve).

A second division is then made on the basis of the distribution, nature and intensity of the drier periods.

Group I: Where a climate in the first group (warm, warm temperate and temperate) has a dry season lasting the greater part of the year, the climate is desert when the value of the xerothermic index is over 300, or hot sub-desert when $200 < x < 300$ (dry period lasting from 9 to 11 months). When rainfall may not occur every year (broadly when $x > 355$) the climate is true desert.

Sub-desert climates can be subdivided into accentuated ($250 < x < 300$) and attenuated ($200 < x < 250$).

Climates in Group I, with dry seasons of from 1 to 8 months, are classed as Mediterranean if the dry season coincides with the period of longest daylight or tropical if it coincides with the period of shortest daylight. Thus in this classification "Mediterranean" is in some sort the converse of "tropical".

Climates with two separate dry seasons are called bixeric, and those with no dry seasons are axeric.

The Mediterranean climate as a whole presents subdivisions according to the values of x. We thus get:

a) Xerothermomediterranean, i.e., warm and dry when $150 < x < 200$;

b) Thermomediterranean, subdivided in turn into accentuated with a long dry season when $125 < x < 150$ and attenuated with a shorter dry season, when $100 < x < 125$;

c) Mesomediterranean again subdivided into accentuated with a long dry season when $75 < x < 100$, and attenuated with a shorter dry season when $40 < x < 75$;

d) Finally sub-Mediterranean, a transitional climate when $0 < x < 40$.

This last type of climate is not regarded as Mediterranean proper or 'eumediterranean'.

The climates of tropical and bixeric patters are subdivided initially into 'warm' and 'temperate' according as the mean temperature of the coldest month is above or below 15°C.

Each of these subdivisions is then broken down, according to the values of x, into:

Accentuated (long dry season), when $150 < x < 200$;
Intermediate, when $100 < x < 150$;
Attenuated (short dry season), when $40 < x < 100$;
Transitional (ultra short dry season), when $1 < x < 40$.

For bixeric climates, the xerothermic index x is calculated by adding together the indices for the two dry periods.

The final category in Group I is that of the axeric climates, i.e., climates with a xerothermic index of 0. Here, as rainfall is adequate for the vegetation, the consideration for the delimitation of the bioclimates is temperature. Here we get, on the one hand the category of warm axeric qualified as equatorial if $t \geq 20^{\circ}$ and a sub-equatorial if $15^{\circ} < t < 20^{\circ}$ and on the other that of temperate axeric which may be subdivisible into temperate axeric with semi-dry season (as defined above), warm temperate if $10^{\circ} < t < 15^{\circ}$ or temperate if $0^{\circ} < t < 10^{\circ}$.

The transition from Mediterranean to temperate axeric climate is often via a zone of climate with semi-dry season. On the other hand the transition from tropical to Mediterranean climate is generally via a zone either of desert or sub-desert climate or of bixeric climate. The first way the pure tropical climate becomes increasingly arid until we get a desert (or sub-desert) climate in which the bias is first tropical then inderterminate and finally Mediterranean.

The second way, a summer rainfall minimum becomes increasingly marked until we get a summer in addition to the winter dry season making the climate bixeric. Then the winter dry season vanishes and we get a Mediterranean climate.

Obviously, in either of the latter types of transitional climate, the bias will be tropical in some years and Mediterranean in other so that precise boundaries are extremely difficult to trace and valid only as mean positions.

Group II: In the second group of climates (cold and cold temperate) the season of frosts comes into the differentiation. These climates are divisible into cold desert when the season of frosts and the dry season together total between 11 and 12, cold sub-desert (9 to 10 months), cold steppic (5 to 8 months), cold sub-axeric (2 to 4 months) and cold axeric, which is sub-divided solely according to the lenght of the frosty season.

Group III: The third group consist of one climate only, the glacial with permanent frost.

The Classification of Bioclimate - Papadakis' system

As in the case of the other studies carried out by the W.S.R.O. for the I.W.P. also the crop-ecological classification system of J. Papadakis has been used for North Africa.

There is no direct correlation between the systems used for the UNESCO-FAO study and the one of Papadakis. It was, however, attempted to make a broad correlation for those climatic stations for which the classification was available in the two systems.

Since the criteria of the classification of UNESCO-FAO and Papadakis are different, it happens that the same climatic class according to Papadakis does occur in different bioclimatic zones, as delineated on the map accompanying the UNESCO-FAO study.

The classification system of Papadakis is based on the following climatic characteristics:

- monthly average daily maximum temperature (DT_{Max})
- monthly average daily minimum temperature (DT_{Min})
- monthly average lowest temperature (MT_{low}), and
- rainfall (R)

The data on DT_{Max}, DT_{Min}, and MT_{low} are combined in 6 types of winter severity and 9 types of summer heat. These types coincide with the temperature requirements of specific crops; e.g. Triticum (wheat), winter type, and Oryza (rice), summer type.

The winter and summer types are combined in 40 temperature regimes.

The 6 fundamental humidity regimes and their 14 subdivisions are mainly based on the combined information on the monthly amounts of rainfall (R) and potential evapo-transpiration (Ep) plus their yearly distribution.
This information is given in months which are humid ($R \geq Ep$), dry R + water stored in the soil $< Ep/2$ or intermediate.

Further use is made of the annual humidity index (R/Ep) or the annual summation of monthly humidity indices.

A combination of the temperature and humidity regimes results in 10 fundamental climatic groups, subdivided in 61 climatic units, which at their turn can be subdivided further. The names of these groups and units are classical while also a numerican system is used.

A relation has been established between the climatic classes and the possibility to grow a certain crop or, mostly, a group of crops with more or less the same climatic requirements.

Therefore each climatic class has definite crop-ecologic characteristics and agricultural potentialities.

The short explanation of the climatic classes in terms of climatic characteristics and crops is given in Appendix II.

It must be added that a full study of the climate-crop relationships in North Africa will take many more months and the classes of Papadakis are, therefore, only to be used as indications.

The Bioclimate and Present Land Use of North-West Africa

The xerothermic index selected as the lower limit of desert conditions is 300. The desert does not reach the coast, where the high humidity gives rise to a lower index number. The higher areas in the desert are subdesert. A fairly large extent is an absolute desert, i.e., areas where there may be years without rain.

The subdesert zones have partly summer rains (tropical), partly winter rains (Mediterranean). In the deserts of North Africa the trend is towards a tropical pattern as far as the 20th parallel, then there is an intermediate zone northwards to the 28th parallel, after which the climate has a Mediterranean pattern.

The zone of Mediterranean-biased sub-desert climates begins in Morocco, in the lower valley of the Sous, and one arm is thrust along the Atlantic coast, The other skirts the anti-Atlas, extends along the eastern slope of the range, up the Moulouya Valley and over much of the central part of the Moroccan and Algerian high plateau, and thence marches with the southern slopes of the Algerian section of the Saharan Atlas to beyond Chott-el-Hodna when it swings away from the Aruès and Tébéssa mountains to reach the coast in Tunisia at approximately the level of Sfax. Everywhere else the climate is Mediterranean (save on the crests of the Moroccan Atlas).

M o r o c c o

The region with a desert climate and a xerothermic index (x.i.) between 300 and 355 can be found in the east (Jebel Bani) and South of the country and in an enclave along the middle reaches of the Moulouya. Representative stations are Figuig (MI) 1/ with a x.i. of 345 and a climatic class of 3.23 2/ and Foum el Hassane with a x.i. of 330 and a climatic class of 3.23.

The regions with a subdesertic climate with a long dry season (x.i. between 250 and 300) are found in a small zone along the eastside of the Atlas, extending southwards and northwards into broader zones. Representative stations are Guercif (M2) with a x.i. of 290 and climatic class 3.24 and Boûarfa (M3) with a x.i. of 260 and a climatic class of 3.272. The winter in Boûarfa (altitude nearly 1300 m) is colder than in Guercif (altitude 360 m) and this explains the difference in the climatic classes.

A part of the region with a sub-desertic climate has a shorter dry season, the x.i. is between 200 and 250, and is found in parts of the Tensift and Sous valleys and an extension of the last region along the coast southward. A re-

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1/ code in brackets refers to Appendix III.
2/ numbers according to the climatic classification system of Papadakis, see Appendix II for details.

latively small zone all along the eastside of the Atlas finishes in a somewhat broader zone on the Haut Plateau. This region extends into Algeria. Representative stations are Chichaoua (M4) with a x.i. of 240 and a climatic class of 6.1924 and Taroudant (M5) with a x.i. of 210 and a climatic class of 6.812. The summer in the last station is a bit warmer, which explains the difference in the climatic classes.

A xerothermomediterranean (hot-dry) climate with a x.i. between 150 and 200 prevails throughout the Marrakech region and borders the southern and eastern foot of the Anti-Atlas, as the preceding climates.

Representative stations are Agadir (M6) with a x.i. of 180 and a climatic class of 6.1924 and El Borouj (M7) with a x.i. of 160 and a climatic class of 6.811. Marrakech was classified as 3.24 because of the higher summer temperatures.

A thermomediterranean (hot but less dry than the preceding) climate with a x.i. of between 125 and 150 is found in the somewhat higher lowlands of Central Morocco, on the southern and eastern slopes of the Atlas and bordering the lower reaches of the Moulouya in the northeast of the country. As representative stations were chosen Settat (M8) which has a x.i. of 125 and a climatic class of 6.1313, and Berkane (M9) with a x.i. of 140 and a climatic class of 6.171. The summer in Settat is a bit warmer than in Berkane, explaining the difference in the climatic class. Ait Ourir was classified as 6.811.

The thermomediterranean climate with a shorter dry season (x.i. between 100 and 125) is found in the lowlands of central Morocco, also on the southern and eastern slopes of the Atlas, and on Mediterranean coast. Representative stations are Rommani (Marchand) (M10) with a x.i. of 105 and a climatic class of 6.1312 and Melilla (M11) with a x.i. of 120 and a climatic class of 6.161. The difference in climatic class is due to the higher summer temperatures in Rommani.

The mesomediterranean climate with a longer dry season (x.i. between 75 and 100) is found on the lower middle slopes of the Andes, the southern lower slopes of the Rif and all along the west coast from south of Casablanca to Ceuta. The coastal zones have an extremely high atmospheric humidity. In the UNESCO-FAO study it is stated that with identical conditions of precipitation, approximate same lenght of dry period and same number of rainy days, the coastal regions are almost always less arid than areas inland because of the higher atmospheric humidity. As representative stations where chosen: Meknes (M12) with a x.i. of 90 and a climatic class of 6.1311, Rabat (M13) with respectively 90 and 6.1911 and Azrou (M14) with respectively 80 and 6.75.

The variant with a shorter dry season (a x.i. between 40 and 75) is found on the middle slopes of the Atlas and Rif, where it occupies a large proportion of these chains. A representative station is Ifrane (M15) with a x.i. of 45 and a climatic class of 6.75.

The sub-mediterranean climate with a x.i. between 0 and 40 is a mountain climate. In the Rif it comes next below the sub-xeric belt and in the Atlas the transition to the cold climates is from the mesomediterranean. The climate in the middle altitudes is cold with a summer dry season, but only in the Atlas and at the greater heights a cold-axeric climate with a frost period of 5-8 months can be found.

Figure 3 is copied from the guide of the Soil Congress in Morocco 1/ in 1966. It shows the general distribution of crops, pastures and forests in Morocco. Due to shortness of time it has not been attempted to combine this information on actual cropdistribution with the bioclimatic map of UNESCO-FAO or with the data of Papadakis.

The most reliable information on the regional distribution of cropland, pastures and forests is probably that included in a publication of the Moroccan Ministry of Agriculture 2/. It is copied from page 134 of Nuttonsons report in tables 3 and 4 (see next page).

According to the same publication the total fallow area was 1,123,000 ha or 2,7 percent of the country area.

1/ Livret-Guide Congrès de Pédologie Mediterranéenne, Excursion au Maroc. Ministère de l'Agriculture et de la Réforme Agraire, 1966.

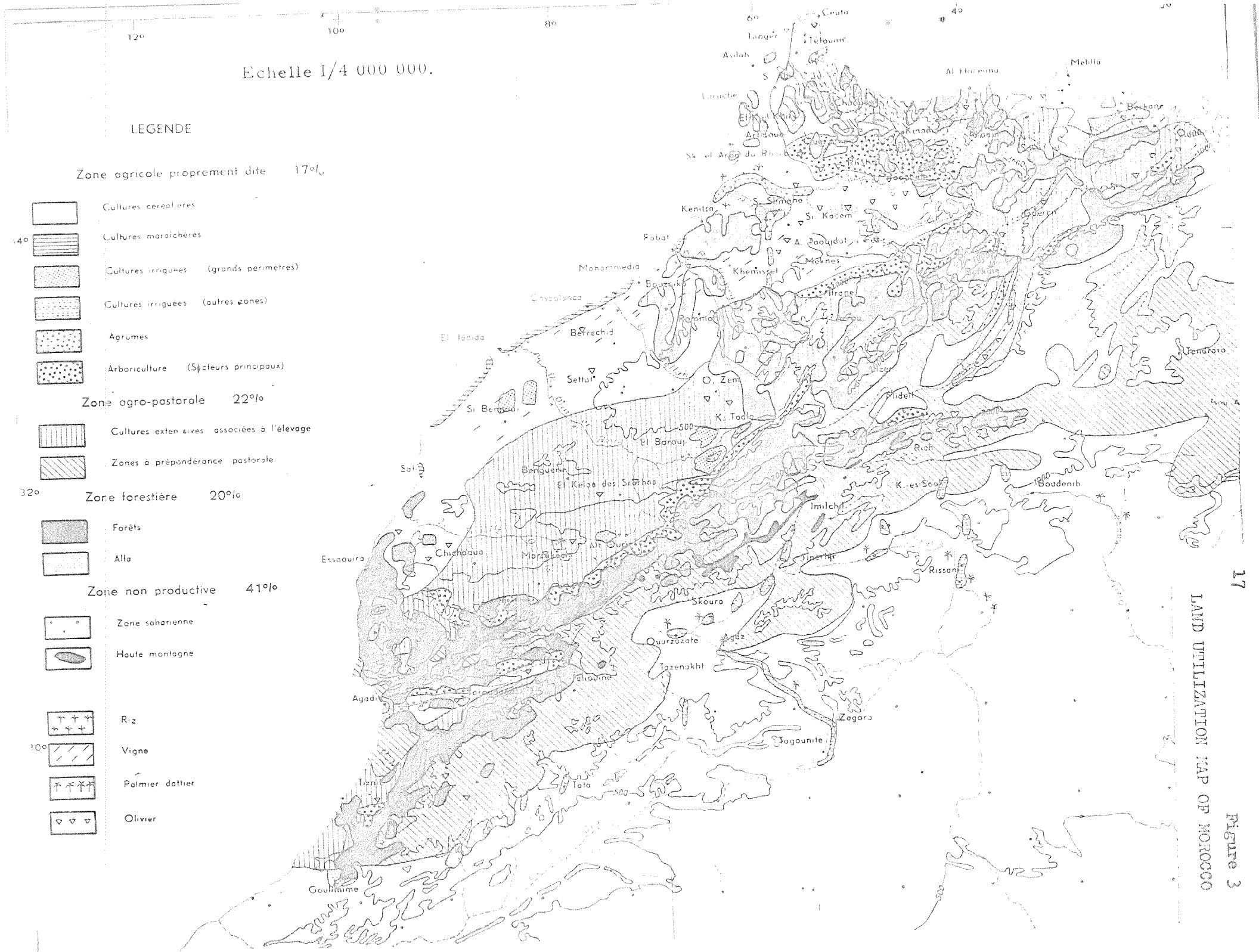
2/ Memento Pratique de l'Agriculture Marocaine, Rabat, 1960

Table 3
Regional Distribution of Cropland in Morocco
in 000 ha

Item	Total for Morocco	Oujda Region	Fes-taza Region	Meknes Region	Rabat Region	Chaouia Region	Doukkala Region	Tadia Region	Marrakech Region	Agadir Region	North Zone
Cereals											
Barley	2,100	85	180	70	170	200	170	210	640	225	150
Hard Wheat	1,000	35	170	100	175	165	35	110	145	5	60
Soft Wheat	530	10	30	50	100	110	35	80	105	5	5
Corn	500	1	15	15	35	80	160	4	170	15	5
Legumes											
Peas	75	0.2	7	11	25	18	4	7	1.8	0	1
Chickpeas	80	1	12	10	32	5	4	2	6	0	8
Broad Beans	75	0.5	20	8	20	4	3.5	6	8	1	4
Other Beans	9	1.4	1	0.5	5	0.5	0.2	0.1	0.3	0	0
Lentils	16	0	7	1	0.5	2.5	0.2	2.5	1.2	0.1	1
Industrial and Miscellan. Crops											
Flaxseed	65	0.5	0.5	0.2	10	44	8	0.5	1.3	0	0
Tobacco	1.8	0	0	0.3	1.3	0	0	0	0	0.2	0
Cotton	6.8	0	0	0	0	0	0	5	0	0	1.8
Orchards											
Citrus	48	4.2	2.8	2.7	21.7	1.1	0.4	3.5	3.8	5.6	2.2
Olives	120	2.5	31	11	14.5	0.5	0	10	35.5	11	4
Almonds	70	2	1.2	0.6	0.3	0.2	0	14.1	21	29.4	1.2
Dates	65	2	0	27.7	0	4.6	0	0	11.2	24.1	0
Other	139	2.7	42.2	8.1	16.2	5.7	5.7	11.4	24.8	8.5	14.8
Vineyards	75	8.7	10.1	18.5	17.6		7.2	0.2	1.7	0	5.3

Table 4
Classification of Land, by Use and by Region in Morocco
in 000 ha

Croplands and Land in Temporary Fallow	6,543	233	854	420	887	907	455	396	1,566	475	350
Perman. Pasture Land	9,811	1,624	1,084	2,335	596	282	180	475	1,690	1,545	0
Forest and Esparto"	8,125	1,830	1,280	930	370	210	5	300	350	800	1,550
Other Lands	17,170	232	687	5,171	204	232	55	269	6,904	3,351	65
All Lands	41,649	3,319	3,905	8,856	2,057	1,631	695	1,440	11,010	6,171	1,965


Echelle I/4 000 000.
LEGENDE
Zone agricole proprement dite 17%
Cultures cerealieres
Cultures maraichères
Cultures irriguées (grands perimètres)
Cultures irriguées (autres zones)
Agrumes
Arboriculture (Secteurs principaux)
Zone agro-pastorale 22%
Cultures extensives associées a l'élevage
Zones à prépondérance pastorale
Zone forestière 20%
Forêts
Alfa
Zone non productive 41%
Zone saharienne
Haute montagne
Riz
Vigne
Palmier dattier
Olivier
Tanger
Tetouan
Melilla
Rabat
Casablanca
Meknes
Fes
Oujda
Agadir
Taroudannt
Tiznit
Tata
Goulimine
Zagora
Ouarzazate
Skoura
Tinerhir
Errachidia
Khenifra
Beni Mellal
Essaouira
Safi
El Jadida
Settat
Berrechid
Kenitra
Larache
Taounate
Al Hoceima
Nador
Berkane
Figure 3
LAND UTILIZATION MAP OF MOROCCO
17

A l g e r i a

A large part of the central zone of Algeria has a x.i. between 355 and 365; the true desert. Rain does not occur every year. The sparcity of long term records makes a purely climatic study difficult. The differences in vegetation in the desert zone is in most cases due to edaphic rather than climatic factors (humidity in depressions for instance). A representative station is Reggane (A1) with a x.i. of 360 and a climatic class of 3.21. Some areas have 3.23 depending on the winter severity.

North and south of the true desert desert areas are found with a x.i. between 300 and 355. Representative for this climate is Colomb Béchard (A2) with a x.i. of 355 and a climatic class of 3.23.

A small zone of subdesertic climate with a x.i. between 250 and 300 (long dry season) is bordering the desert on the north, including a part of the region with the "chott". It is also found in some restricted patches in the south of Algeria. A station here is Le Kreidet (A3) with a x.i. of 270 and a climatic class of 3.24. Other areas are perhaps 3.272, due to a more severe winter.

The subdesertic climate with a shorter dry season (x.i. between 200 and 250) is located northwards of the former climate. The Chott-el-Hodna and Chott-ech-Chergui are located in this climate. The correlation of this part of North-West Africa with the climatic classes of Papadakis is difficult. The region of the Chott-el-Hodna in the eastern part of this climate seems to belong to an extension of the 3.24 climate (hot subtropical desert). The western part was classified as belonging to 6.91 (continental semi-arid mediterranean). A part of the southern occurrences belongs to the 3.27 climate. This resembles the 3.24 climate.

Stations, which according to the UNESCO-FAO study are in this climate are Barika (A4) in the east (x.i. 220, climatic class 3.24), and Ain Sefra (A5) in the northwest (x.i. 250, climatic class 3.273).

The xerothermomediterranean conditions (x.i. between 150 and 200) are confined principally to part of the high plateau and to the lips of the Chott-el-Hodna basin. Representative stations are Méchéria (A6) with a x.i. of 150 and a climatic class of 3.272 and Ain Oussera (A7) with a x.i. of 190 and 6.741 as climatic class. Another area has climate 6.912; here lies Sidi Aissa (A8) with a x.i. of 150.

The thermomediterranean climate with a x.i. of 125-150 can be found in the lower Cheliff Valley, parts of the High Plateau and the Saharan Atlas, around the Aurès and on the Nementcha Mountains. For the higher zones Tébessa (A9) with a x.i. of 125 and a climatic class of 6.833 is probably representative, while the lower regions in the Cheliff basin (Mostaganem (A10), x.i. 130) have a climatic class of 6.163.

A climate with a shorter dry season (x.i. between 100 and 125) is bordering the forementioned regions. Also this climate has different climatic classes in the system of Papadakis. The coastal and westerly inland regions, represented by Oran (A11) with a x.i. of 110, have a climatic class of 6.162 to 6.163. More inland (Boghari (A12), x.i. 105) a class of 6.741 is encountered. In a small zone in the Saharan Atlas the class is 6.931 (Aflou (A13), x.i. 110).

The climate is mesomediterranean with a x.i. of 75-100 in the Tlemcen region, the Ouarsenis and the Constantine area. Representative in the first region is Tlemcen (A14) itself, with a x.i. of 90 and a climatic class of 6.161. Just outside the Ouarsenis lies Medea (A15) with a x.i. of 100 and a climatic class of 6.132. The last region is represented by Constantine (A16) with a x.i. of 95 and a climatic class of 6.192 inland and by Bône (A17) with a x.i. of 90 and a climatic class of 6.141 on the coast.

The lower parts of the Kabylia mountains have a shorter dry season and a x.i. of 40-75. Some restricted areas in the Auris and the Ouarsenis have also this climate. It is represented by Alger (Algiers) (A18) with a x.i. of 75 and a climatic class of 6.141.

In the hill country of the Ouarsenis, Kabylia and the South Philippeville region the climate is submediterranean with a x.i. of less than 40. Some very restricted areas receive heavy rainfall and have a sub-dry period only.

There are no areas of cold climate except the mountain crests. On the coast, frost is an extremely rare phenomenon though heavy snowfall can damage the indeciduous foliage of trees by breaking the branches.

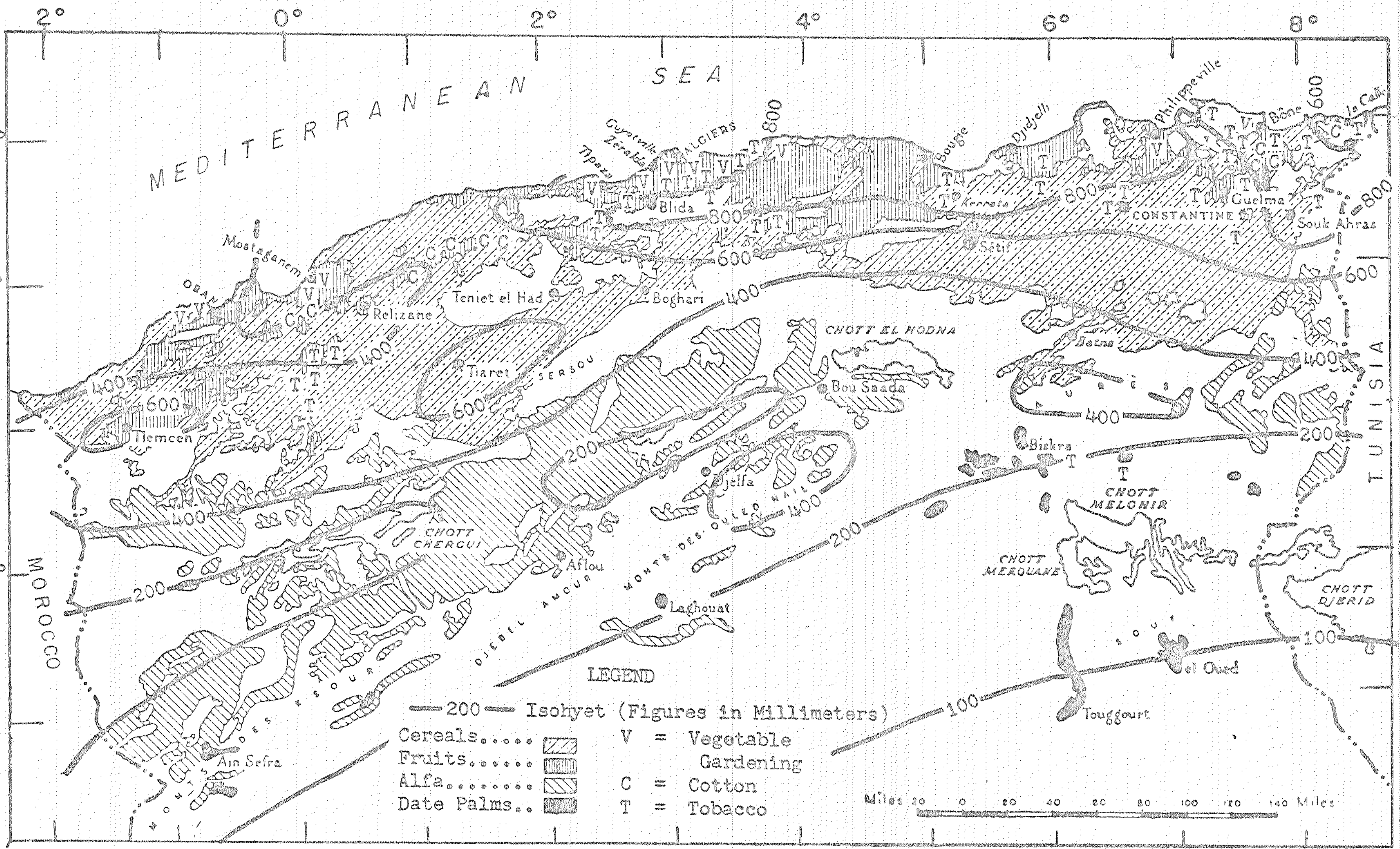
The map of crop distribution in relation to annual rainfall, figure 4, is taken from page 308 of Nuttonson's report.

Table 5 1/ shows the land use of North and South Algeria; in table 6 1/ the land use of North part is divided according to administrative subdivisions.

Table 5
Land Use Data of Algeria

	North Algeria		South Algeria		Total Algeria	
	in 000 ha	in %	in 000 ha	in %	in 000 ha	in %
Land used for agriculture	13274	45.9	29176	14.0	42450	17.9
Forest exploitation	2419	8.4	5	0.0	2424	1.0
Alfa zones	3037	10.5	-	-	3037	1.3
Uncultivated	10155	35.2	179490	86.0	189645	78.8
Total	28885	100.0	208671	100.0	237556	100.0

1/ derived from : L'Algérie Agricole, Numéro spécial, La Statistique Agricole, Ministère de l'Agriculture et de la Réforme Agraire, 1966.



CROP DISTRIBUTION AND ISOHYETS MAP OF ALGERIA (NORTH)

Figure 4

Table 6

Land Use Data of Algeria by Administrative Subdivisions

in 000 ha

	Land used for agriculture	Forest exploitation	Alfa zones	Total area of zones
Alger	182	43	-	276
Medea	2946	347	518	5001
El Asnam	803	269	-	1314
Tizi Ouzou	383	132	-	603
Oran	1014	349	216	1672
Mostaganem	919	129	21	1123
Tiaret	1497	173	796	2600
Tlemcen	386	159	224	812
Saïda	207	143	584	5630
Constantine	1247	23	53	2031
Batna	1533	189	269	3722
Annaba	991	306	258	2382
Sétif	1166	157	98	1719
Total North Algeria	13274	2419	3037	28885
South Algeria	29176	5	-	208671
Total Algeria	42450	2424	3037	237556

Note on slope classes and soil conservation in North Algeria

In a recent publication of Greco 1/ results are given of a topographic survey on the repartition of slope categories rainfall zones.

Table 7
Areas of Slope Classes by Rainfall Zones in North Algeria
in 000 ha

zone and rainfall in mm.	slope classes 0-3%	3-12,5%	12,5-25%	over 25%	totals
humid and subhumid zone					
over 600	368	1239	2139	1335	5081
500-600	235	675	934	63	1957
400-500	1544	1388	1507	98	4537
semi-arid zone					
300-400	5409	1387	538	224	7558
arid zone					
200-300	4334	810	326	95	5565
100-200	2742	229	90	52	3113
totals	14632	5728	5584	1867	27811

Note on Potential Land Use in North Algeria

On the basis of the study of 28.4 million ha in North Algeria it was estimated that 12.8 million or about 45% of the total area is in need of soil conservation. Of these 12.8 million ha 9.3 million are in the cultivated or cultivable lands, 2.1 million need (re)forestation and 1.4 million ha grazing land are in need of conservation. With the implementation of conservation measurements, the potential land use of North Algeria could be(in million ha):

Table 8
Potential Land Use Data of North Algeria (in million ha)

cereals and industrial crops	3.0	
forage crops	2.4	9.3
fruit trees	3.7	
irrigated areas	0.2	
forests		3.7
cultivated pastures	1.4	12.9
semi extensive grazing land	11.5	
built on areas	0.9	2.5
wasteland	1.6	
total		28.4

1/ Greco, J., L'Erosion, la Défense et la Restauration des Sols, Le Réboisement en Algérie. Publication du Ministère de l'Agriculture et de la Réforme Agraire, Alger, 1966.

The ultimate division of the 9.3 million ha is foreseen as in table 9:

Table 9
Potential Cropland Area of North Algeria
in relation to 1959 data
in million ha

	1959	potential
cereals	2.93	2.59
dry pulses	0.07	0.28
misc. crops	0.03	0.08
grapes	0.36	0.40
fruit and olive trees	0.20	1.78
fruit trees (semi-forest)	-	1.5
forage crops	0.08	2.4
	3.67	9.3
fallow	3.00	0.3

Irrigation is not included in the study.

T u n i s i a

As in Morocco, no true desert is found in Tunisia. The desert with a x.i. between 300 and 355 occupies the southern third of the country, including the "chotts". Representative stations in the northern part are Tozeur (T1) with a x.i. of 335 and Kebili with 325. The climatic class of both stations is 3.23. In the south Fort Saint has a x.i. of 350, near to the true desert.

Parallel to this zone runs the area with a sub-desertic climate with a long dry season and a x.i. of 250-300. Gafsa (T2), with a x.i. of 295 and a climatic class of 3.24 is representative. The zone with a shorter dry season and a x.i. between 200 and 250 is the area around the Golf of Gabès and from there running inland and along the coast to Lybia. The island of Djerba has also this climate. Representative stations of the coastal areas are Gabès (T3) with a x.i. of 220 and Djerba with 210. The climatic class of both is 3.43.

There is a broad belt of xerothermomediterranean climate (x.i. 150-200) south of the Tébessa mountains going to the sea. Stations in this zone are El Djem (T4) with a x.i. of 170 and Kairouan with 180. The climatic class of both is 6.812.

Bordering the xerothermomediterranean is a belt of thermomediterranean climate with a relatively long dry season and a x.i. between 125 and 150. The belt runs from west to south, reaching the coast south of the Golf of Hammamet. Sousse (T5), on the coast, has a x.i. of 130 and a climatic class of 6.833. Characterized by a shorter dry season and a x.i. between 100 and 125 are areas in the rest of the northeast and the Medjerda valley. Béjà (Bedja) (T6), representative for inland, has a x.i. of 110 and a climatic class of 6.1311 while

Tunis (T7), lying near the coast, has also a x.i. of 110, but a climatic class of 6.171. The difference in the climatic class is mainly due to the higher summer temperatures inland.

The mesomediterranean climate with a x.i. between 75 and 100 is represented by a rather extensive region north of the Tébessa mountains down to the coast along the lower south and east slopes of the Medjerda mountains. Stations in this region are Thala (T8) with a x.i. of 90 and a climatic class of 6.1322 and Le Kef which has also 90 as x.i., and, depending on the severity of the winter, 6.1311 or 6.1322 as climatic class.

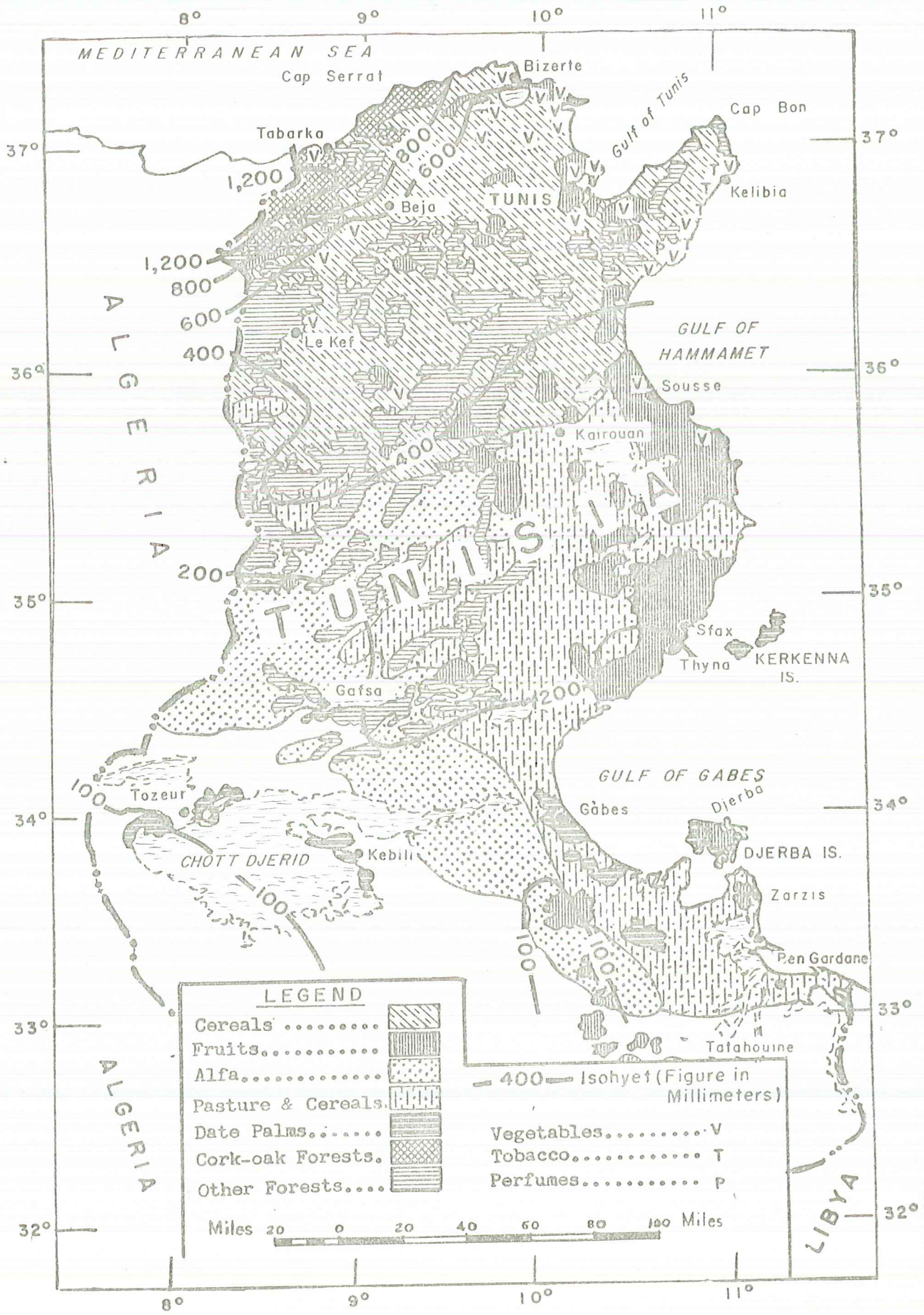
A shorter dry season and a x.i. of 40-75 is found in a small area west of Maktar and on the slopes of the Medjerda mountains, on the north reaching the sea. An inland station is Maktar (T9) with a x.i. of 75 and a climatic class of 6.1322 and on the coast Tabarka (T10) with 65 as x.i. and 6.151 as climatic class. The difference in the climatic class is due to the higher summer temperatures and the lower winter temperatures inland.

Near the coast, on the Medjerda mountains, the climate is sub-mediterranean with a x.i. between 0 and 40. It is the best watered region of Tunisia. As in Algeria cold climate conditions are not found (i.e., no monthly average is below $0^{\circ}C$).

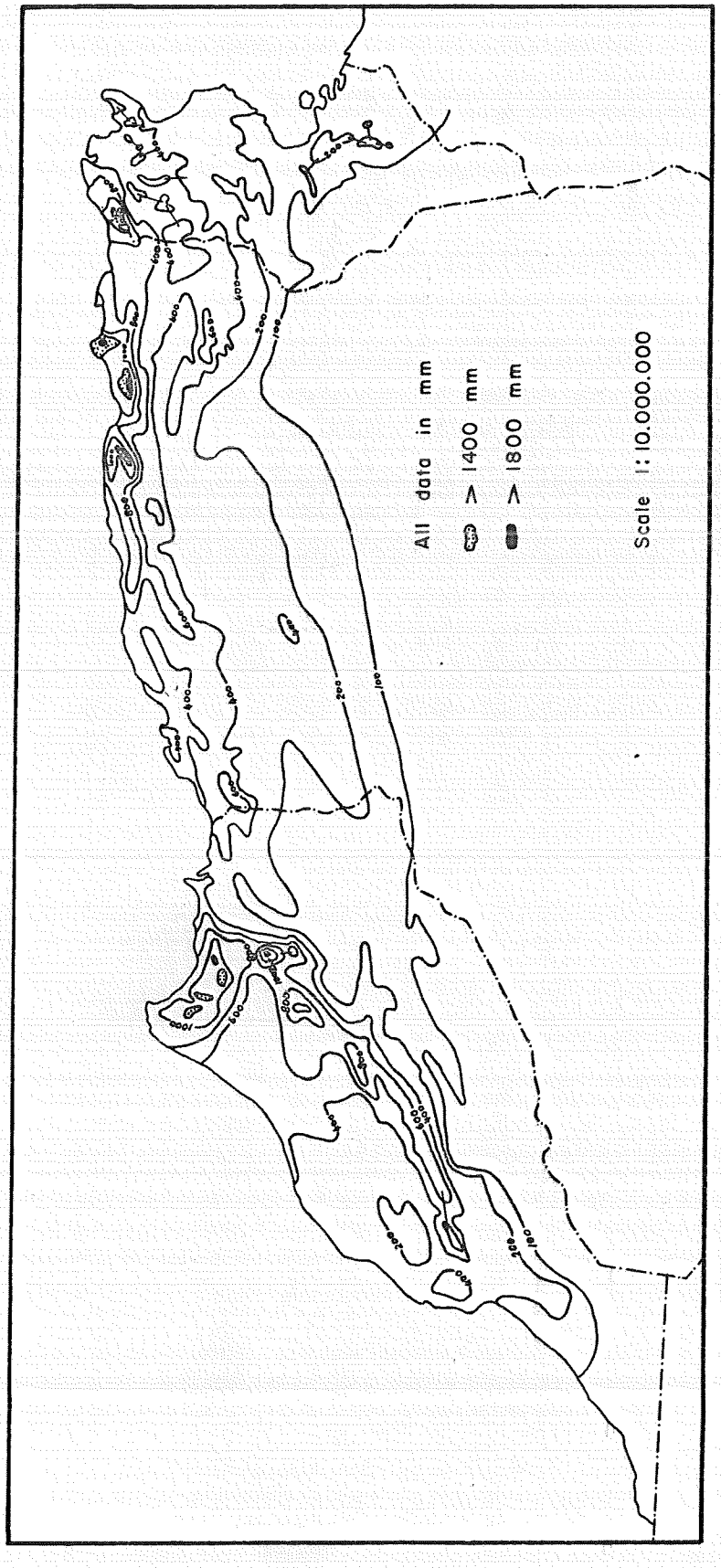
Figure 5, taken from the report of Nuttonson (page 535) shows the distribution of crops and forests in relation to the annual rainfall.

Figure 5

CROP DISTRIBUTION AND ISOHYETS MAP OF TUNISIA



MEAN ANNUAL RAINFALL IN NORTH-WEST AFRICA



APPENDIX II

Explanation of Climatic Classes, according to Papadakis 1/

3. Desert

Cropping is impossible without irrigation, but mediterranean deserts provide some grazing in winter.

3.2 Hot Subtropical Desert
Semi-tropical or hot subtropical, absolute and mediterranean desert (3.21, 3.23). Although these climates are non-frostless, subdivisions 3.21-3.26 allow the cultivation of citrus and in most parts even sugarcane and banana can be grown. Cotton and rice are important crops. In 3.21 winter is to warm for wheat and other cryophylous crops; it can be grown but it is marginal; the other subdivisions, 3.23, 3.24 and 3.27 have winters sufficiently cool for wheat and other cryophylous crops. Climates 3.24 and 3.27 provide some grazing in winter.

3.43 In this semi-hot subtropical mediterranean desert winter is sufficiently mild for citrus and in some parts of the region banana and sugarcane can be grown. Also cotton and rice are suitable crops. Some grazing is provided in winter.

6. Mediterranean

Characterized by dry summers and more or less humid winters; as a consequence winter cereals and legumes, grapes, olives, figs, almonds are the principal rain-fed crops.

6.1 Subtropical Mediterranean
Without irrigation winter crops (wheat, barley, oat, Faba, chickpea, etc.), olives, grapes, almonds and figs can be grown. With irrigation cotton, citrus, deciduous fruits, early and late vegetables of very good quality can be produced. Parts with very mild winters can support sugarcane and bananas.
In 6.13, a hot subtropical, dry mediterranean climate, citrus can be grown, also early and late vegetables. Some areas, where the dry season begins in May (6.1312) conditions are difficult for rainfed maize, but good for wheat. Climate 6.131 has a mild ("citrus") winter and can be subdivided into:
6.1311, where the dry season begins with June,
6.1312, where the dry season begins with May and
6.1313, where the dry season begins with April.
In Climate 6.132 the winter is less mild ("oat-winter")
In 6.14, a semi-hot subtropical climate with 3 or less dry months some maize is grown without irrigation when the dry season starts in July.
In climate 6.15, semi-hot subtropical, moist mediterranean, with 4 or more dry months the dry season begins with June.

1/ Climates of the World and their Agricultural Potentialities; edited by the author, 1966.

In climate 6.16, semi-hot subtropical, dry mediterranean, the humidity index quotient annual rainfall and annual potential evapotranspiration is more than 0.44. In 6.17 this quotient is less than 0.44.
In climate 6.19, also semi-hot subtropical, dry mediterranean, the average daily minimum of all months is lower than 20°C. This climate with its cool nights is very suitable for maize and beans.
A subdivision is made according to the humidity index, which is more than 0.44 in 6.191 and less in 6.192.

6.74 Warm continental, dry mediterranean climate with a humidity index of less than 0.44; winter cereals are the principal rainfed crops. It is the region of grapes, olives and figs. Also rice can be grown. Maize needs irrigation.

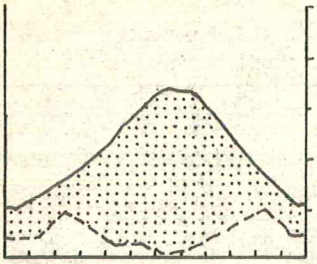
6.75 semi-warm continental, moist mediterranean climate with 3 or less dry months; winter cereals are important and maize can be grown without irrigation. Grapes and figs can also be grown.

6.8 Subtropical Semi-arid Mediterranean
In these climates winter cereals suffer considerably from drought. Where the dry season begins with April wheat and other winter cereals can be grown, but it is hazardeous. Where it starts with March cropping without irrigation is practically not feasible. Summercrops are virtually excluded. With irrigation winter crops, cotton and other summercrops, deciduous fruits, vegetables etc. yield very well.
In 6.81, hot subtropical with an annual humidity index of less than 0.22, citrus can be grown also. In 6.811 the dry season begins with April or later; in 6.812 with March or earlier.
In 6.83 hot or semi-hot subtropical and a annual humidity index of more than 0.22 the dry season begins with April (6.833); citrus can be grown.

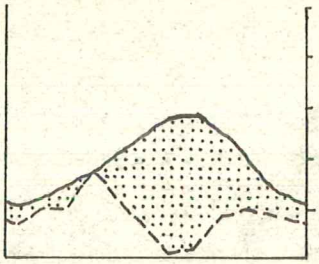
6.93 In this climate, winter cereals suffer from drought when the dry season starts with April (6.931); cropping without irrigation is not advisable. Potatoes can be grown under irrigation.

APPENDIX III.

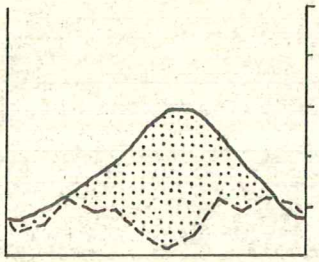
OMBROTHERMIC DIAGRAMS OF SELECTED METEOROLOGICAL STATIONS IN MOROCCO



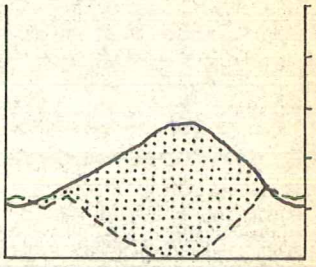
M 1 FIGUIG



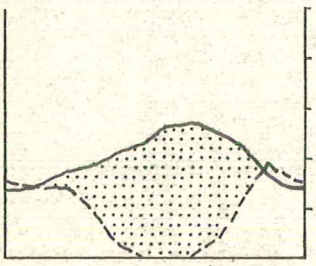
M 2 GUERCIF



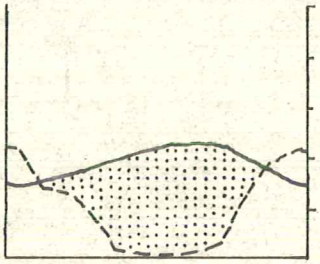
M 3 BOUARFA



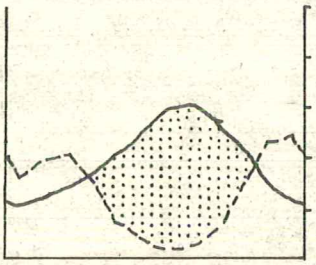
M 4 CHICHAOUA



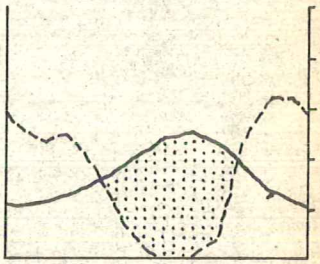
M 5 TAROUDANT



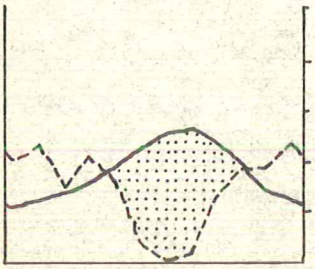
M 6 AGADIR



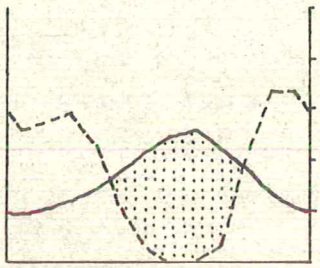
M 7 EL BOROUJ



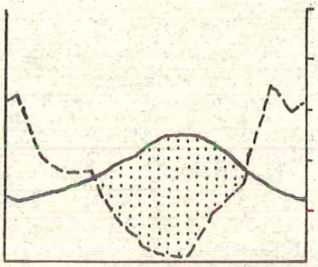
M 8 SETTAT



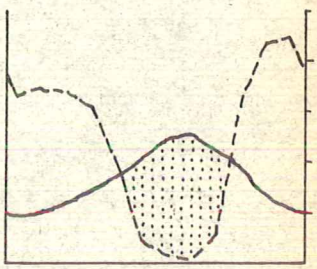
M 9 BERKANE



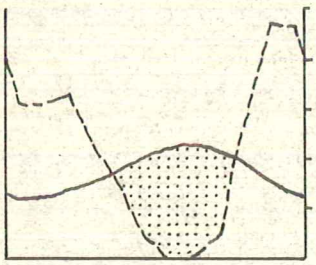
M 10 ROMMANI (MARCHAND)



M 11 MELILLA



M 12 MEKNES



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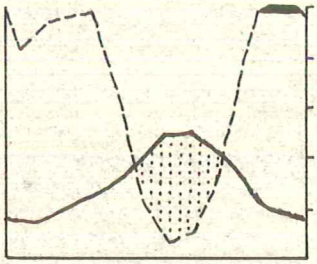

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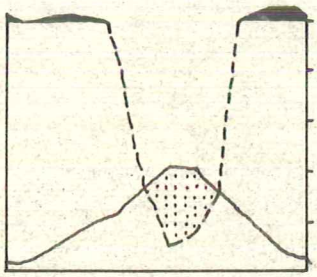
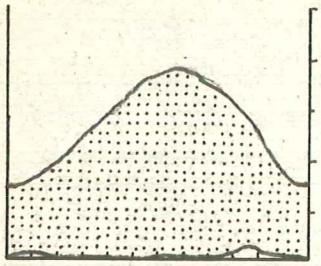


M 15 IFRANE

APPENDIX III

OMBROTHERMIC DIAGRAMS OF SELECTED METEOROLOGICAL STATIONS IN ALGERIA



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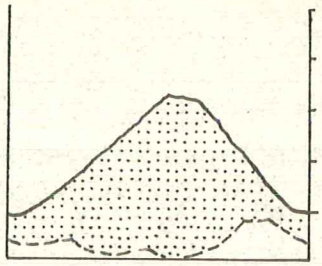

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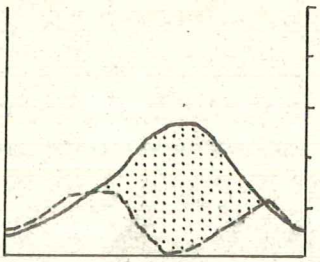

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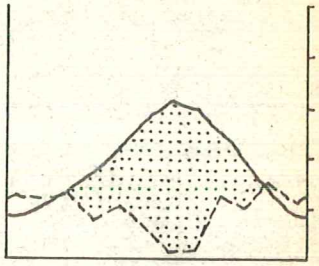

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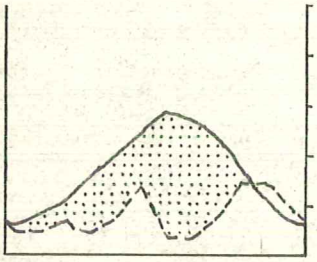

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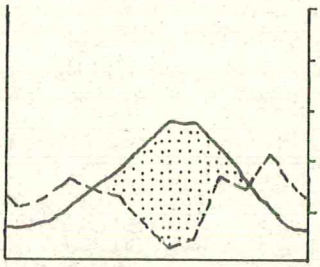

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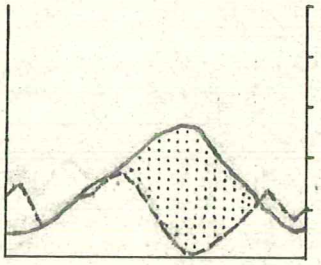
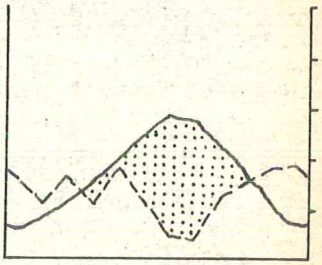


A 7 AIN OUSSERA



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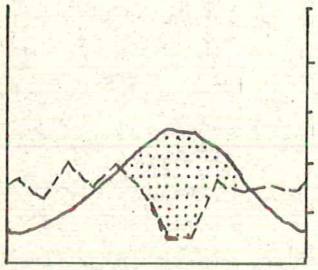

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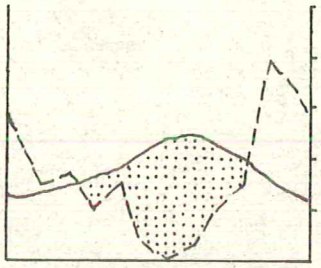
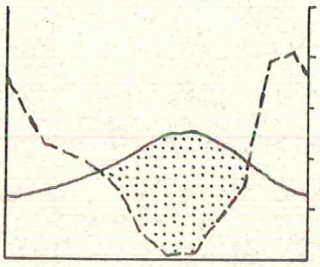


A 10 MOSTAGANEM



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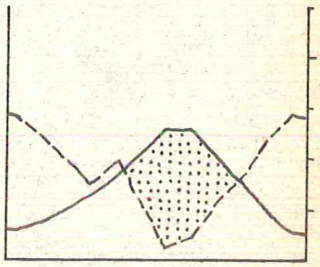

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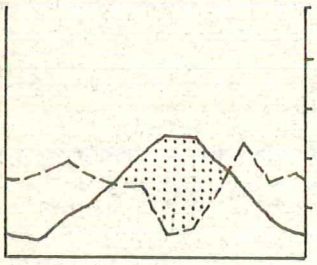

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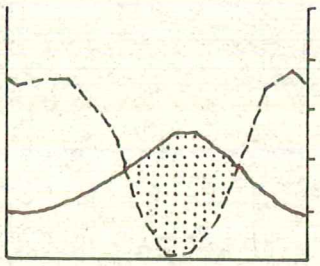

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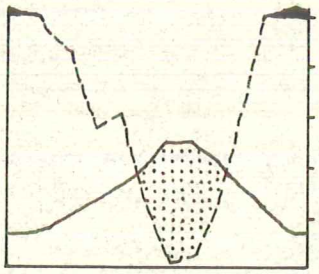

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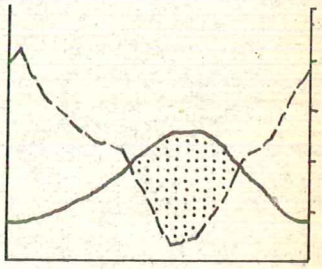

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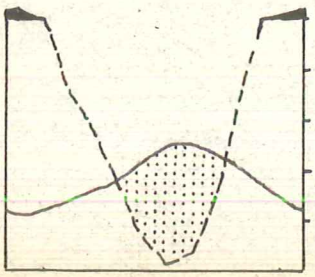

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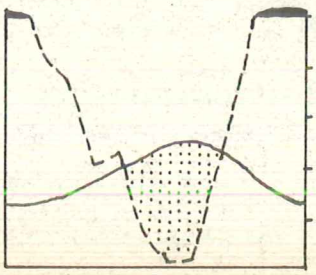
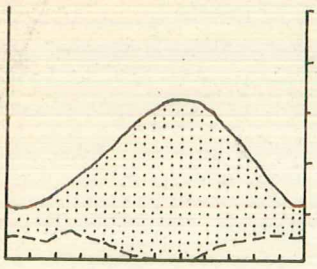


A 18 ALGER

APPENDIX III

OMBROTHERMIC DIAGRAMS OF SELECTED METEOROLOGICAL STATIONS IN TUNISIA



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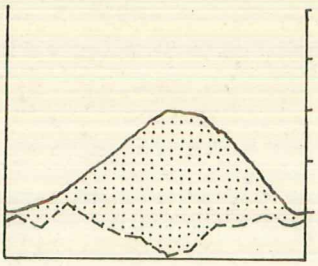

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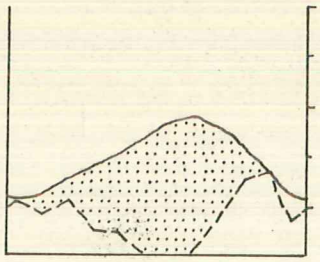

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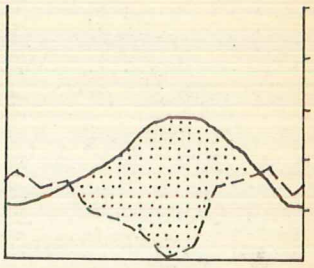

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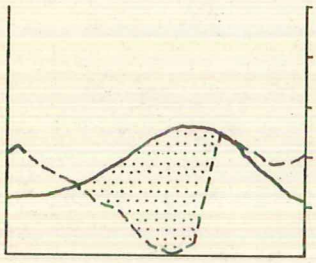

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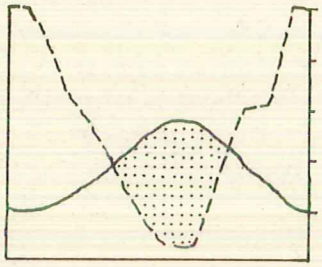

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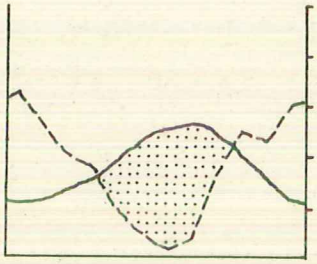
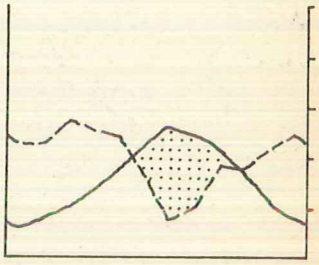


T 7 TUNIS



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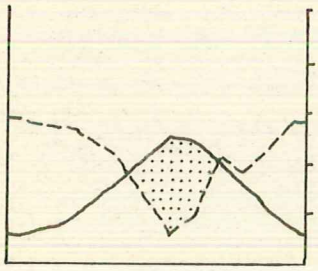

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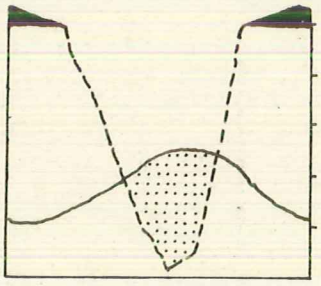
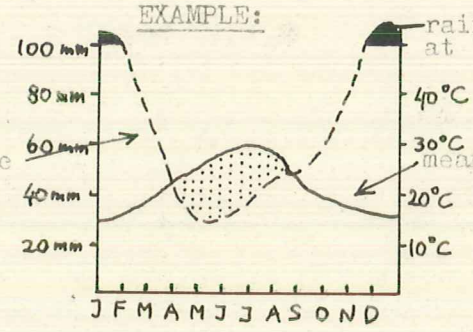


T 10 TABARKA

EXAMPLE:



rainfall over 100 mm at 1/10 of the scale

rainfall line

mean temperature line

months of the year

regarded as dry