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RESEARCH ARTICLE

THE BIOCLIMATE OF TLEMCEN AREA (NORTHWEST ALGERIA)

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Abstract

Bioclimate of the Tlemcen region is typically Mediterranean, characterized by two distinct seasons one dry summer and the other rainy winter with some ground therophytisation. Our study is based on two well-defined periods, the ancient from 1913 to 1934 and other recent from 1975-2008. The analysis of the temperature and precipitation allowed us to detect that there was a drop in rainfall and increasing temperature taking into account the two study periods. There are two seasonal patterns, the first is the HAPE type for the two periods (Stations of Hafir, Ouled-Mimoun, Beni-Saf and Ghazaouet) and the second was the type HAPE for the former period becoming HPAE type for the new period (Station of Zenata). Comparing the two periods (old and new), the diagrams of (6) allowed us to suggest that the dry period of the year was extended 2 to 3 months or even 6 months some stations. The pluviothermic climagramme of Emberger (Q_2) revealed that all studied meteorological stations have undergone a shift of one floor or sub-floor. Through this study we can conclude that the region of Tlemcen knows some climate change expressed by the increase in temperature and decrease in rainfall due to several causes such as air pollution and the degradation of the vegetation .

Introduction

The climate is all meteorological phenomena (temperature, atmospheric pressure, wind, rainfall) that characterize the average state of the atmosphere and its evolution in a given location. This is the factor that is placed upstream of any study on the functioning of ecological systems (38).

Scientists have begun to look to the Mediterranean climate of long standing. This interest has led to several studies, we include: (16-21-22-40) and more recently: (28-29-10-24- 26-25-7).

Indeed, its spatial and temporal irregularity involves studies of finer to better understand its evolution and its influence on the distribution of different taxa of vegetation.

(17-1-3) consider a Mediterranean forest, as always subject to a Mediterranean climate. The latter is subdivided into several bioclimatic sets and that depending on the value of annual precipitation or the pluviothermic coefficient of (16-20) and the duration of the summer drought (9), but also according stages of vegetation (26-29).

From (37) and (35), the climate of Algeria noted the Mediterranean diet with two well-marked seasons, very dry, the other relatively wet. This climate tends towards aridity more pronounced.

As part of our study of *Cistus* in the region of Tlemcen, we paid particular attention to the effects of climate (precipitation, temperature) could influence the evolution of the vegetation.

The climate of the region of Tlemcen is the Mediterranean and is characterized by dry summers and rainy winter.

For the region of Tlemcen, several studies have been made on the bioclimate include mainly: (5-11-2-7).

Methodology

To define the climate of the region of Tlemcen, we took into account the reference stations in addition to the study sites. For this, we used the results of previous work and recent results. The comparison between the ancient period (1913-1938) and the recent period (1980-2008) allows us to follow the evolution of the climate of the study area. For the former we have taken the old results of (35) and the new, we used the results given by ONM (National Agency of Meteorology).

Stations are those of Ghazaouet, Beni-Saf near the sea (coastal areas) and those of Ouled Mimoun, Zenata and Hafir inside (Semi-continental areas).

Results and Discussion

Climatic factors

Precipitation

In our study area, the rains usually fall during the wet season (October/May). Rainfall in the region is characterized by inter-annual irregularity and despite their rarity still often violent and fall as shower.

Tables 1 and 2 and figures **(Figure 1, 2, 3, 4 and 5)** express the average rainfall recorded in the various stations during the old and new period. The comparison shows a clear difference between the two eras. This climate change has affected the vegetation dynamics of the study area.

For the earlier period, rainfall was more abundant and more frequent in the study area. This decrease in the amount of water fell resulted in the disappearance of some species allowing the installation of others adapts to extreme climatic conditions, including drought. We always notice a decrease of precipitation of the following stations: Hafir 707 mm, Ouled-Mimoun 528 mm, Zenata 474 mm and Ghazaouet 433.91mm. Overall, the ancient period is characterized by precipitation clearly more important than the recent. Hafir Station marks the largest amount of water fell for the two periods. Zenata Station records superior results during the old period to the new and, for all months except July, although the difference is not very large. At Beni-Saf, the amounts of precipitation for the months of January, February, March, April, May, July, August, September and November are lower compared to the new period. At Ghazaouet, Hafir and Ouled-Mimoun, the amounts of precipitation for all months except August are higher compared to the same month of the new period. It turns out that the months of October and December in ancient times recorded throughout a higher rate in an amount of water. The Mediterranean character of the area that summer is very hot and very little watering. This applies to all stations from the months of May and extends until the end of November for the new period. For the former period the dry season extends from June until the end of September which indicates that the dry season of the new period is greater than that of the old period. Nevertheless it is possible that very few rains take place during the summer while the months of September and October generally have a very minimal rate of precipitation. We can see that the wettest month is November for Beni-Saf and Ghazaouet, Mars for Ouled-Mimoun and Zenata, February for Hafir. For all stations, the months of July and August are the driest. Summer rainfall not exceeding 30 mm throughout the summer for considered both periods.

In our case, we reported a net dominance of dry years. Although often attends to heavy showers, irregularity make that generally our region remains poor water.

The seasonal pattern

Examination of the annual rainfall regime, leads us to a chronogical comparison of two time periods (1913-1938) and (1980-2008).

This is (8) was the first, defined the concept. It involves calculating the sum of precipitation per season and make the classification of stations in order of decreasing rainfall in designating each season by the initial PHE or A, respectively denoting the Spring, Winter, Summer and Autumn.

$$C_{rs} = \frac{P_s \times 4}{P_a}$$

- **P_s:** seasonal precipitation ;
- **P_a:** annual precipitation ;
- **C_{rs}:** Seasonal relative coefficient of Musset.

In the region of Tlemcen, there are two main seasonal patterns: the first is the type of HAPE. This pattern characterizes the Beni-Saf and Ghazaouet stations with rain abundance and drought associated with a second maximum precipitation in autumn and a second minimum in the spring for the old and the new period.

The second is the type HPAE for stations of Ouled-Mimoun and Hafir with a first maximum in winter, a first minimum in summer, a second maximum in spring and a second minimum in autumn for the new period. Zenata station experiencing a seasonal pattern during the early period of HAPE type and for the new period a seasonal pattern type HPAE **(Table 5)**.

This distribution of winter and spring rains, allows plants resumed their biological activity and also helps undoubtedly vegetation to start the summer season with both water reserves in the soil and in the plant.

Temperatures

This factor is very interesting for our study; these changes can influence the onset of forest fires, which is in summer that has the highest fire. One of our concerns in this study is to show the importance of fluctuations and thermal variations in Cistaceae facilities in the region of Tlemcen.

Monthly mean temperatures [(M+m/2)]

The coldest season is from December to March. Average monthly temperatures confirm that January is the coldest month in both periods. They vary between 5.8 °C to Hafir and 12.95 °C to Beni-Saf for the ancient period and 8.28 °C to Hafir and 12.69 ° C to Beni-Saf for the new period. For the higher average temperatures, are located in the month of August. They range from 24.2 °C to Hafir and 26 °C to Zenata for the old period, for the new period 23.98 °C to Ghazaouet and 28.35 °C to Zenata. This comparison between the old and the new time period shows a temperature rise of 25.05 °C to 25.61 °C for Beni-Saf, 26 °C to 28.35 °C for Zenata, 24.2 °C to 24.4 °C for Hafir and we notice a decrease in temperature from 25.2 °C to 24.18 °C for the station of Ouled-Mimoun and 24.25 °C to 23.98 °C to station of Ghazaouet. The temperature increased dramatically but this is not the case for all other stations.

The average temperature of maxima of the hottest month "M"

The study of two periods shows that the highest temperatures are recorded in the month of August for all stations.

July and August coincided with the lack of rain.

The average temperature of the minima of the coldest month "m"

Emberger uses the average minima to express the degree and duration of the critical period of frost in the classification of climates. For all our stations and two periods, January is the coldest month. This average varies between 5.8 °C to Hafir and 12.95 °C to Beni-Saf for the old period and between 8.28 °C to Hafir and 12.69 °C to Beni-Saf for the new period

(23) means by cold season, the period during which temperatures are the lowest of the year and where average temperatures are below 10 °C.

For most stations we notice an increase in average monthly temperatures during the new period compared to the old. During the ancient period monthly average of the highest temperatures are in August (Beni-Saf, Zenata, Hafir and Ouled-Mimoun), they are between 24.2 °C and 26 °C except for the Ghazaouet station where the average monthly temperature is 33.4 °C which locates in July. Monthly averages are the lowest in the month of January for all the stations; they are between 5.8 °C and 12.95 °C.

During the new period monthly average of the highest temperatures are in August (Beni-Saf, Zenata and Ouled-Mimoun), they are between 24.18 °C and 28.35 °C except for the station of Ghazaouet where the average monthly temperature is 33.4 °C and 25.85 °C which localize in July. For Hafir station, they are between 24.2 °C and 24.9 °C, which are located in the month of July and August. Monthly averages are the lowest in the month of January for all stations; they are between 8.28 °C and 12.69 °C.

Continentality index

The continentality index is defined relative to the average thermal amplitude (M-m). This in turn allows specifying the maritime influence or mainland opposite of a given region.

From (5) four types of climates can be calculated from M and m.

- M - m < 15°C ⟶ Insular Climate ;
- 15°C < M-m < 25°C ⟶ Coastal Climate ;
- 25°C < M-m < 35°C ⟶ Semi-Continental Climate ;
- M-m > 35°C ⟶ Continental Climate.

We observe that the thermal amplitudes of plains stations of sub-coastal and the interior of country are influenced by a much more semi-continental climate (Zenata, Ouled-Mimoun and Hafir), with the exception of the station of Beni-Saf and Ghazaouet, which are influenced by a coastal climate.

Bioclimatic synthesis

Bioclimatic synthesis is an essential step for any project on the environment, it determines by means of its components, the type of climate and vegetation.

The synthesis is made from work of (16-20-6-39).

To make the climate medium data more meaningful, several authors such as: Long; De Martonne; Koppen; Emberger and (9) have proposed the use of climate indices that are only combinations of averages of different components of climate particularly temperature and precipitation.

This bioclimate synthesis highlights the different characteristics of Mediterranean climate. The latter, used for the delimitation of vegetation stages according to (32) and (12).

In fact, according to the amount of water fell annually we can classify bioclimatic stages. Rainfalls tell us about moisture or dryness of the climate.

Subdivision into bioclimatic sub-stages were implemented by (20) followed by (34) based on the average minima of the coldest month.

(31) proposes a classification according to the annual mean temperature (T °) and the mean minima of the coldest months "m".

However, these classifications are complementary; using them, we can classify the study sites.

Climatic factors

The climate is divided into bioclimatic stages:

The sub-humid

Characterize the stations of Hafir, Ghazaouet and Ouled-Mimoun during the early period (1913-1938), due to rainfall reaching respectively 707 mm, 433.91 mm and 528 mm. More specifically, these stations are located respectively in the average sub-humid and lower sub-humid for the last two stations **(Table 9)**.

The semi-arid

This stage characterize the station of Zenata and Beni-Saf during the ancient period (1913-1938), respectively, with an annual precipitation of 474 mm and 371 mm (upper semi-arid).

Hafir Station during the new period (1975-1996) with an annual precipitation of 483.87 mm (upper semi-arid). **(Table 9).**

The arid

The arid stage characterizes the Ouled-Mimoun, Beni-Saf, Ghazaouet and Zenata stations for the new period (1980-2008), respectively, with an annual precipitation of 332.89 mm, 368.37 mm, 344.11 mm and 316.72 mm « upper arid », **(Table 9)**.

The classification according to the average of minima "m"

Thanks to "m", regarded as a fundamental element to restart vegetation. (20) and (34) divided bioclimatic ambiences into six sub-stages according to "m".

Sub-stages are shown in **Table 10**.

As regards the study area values of "m" is between 3.2 °C and 10.77 °C.

The stations of Ouled-Mimoun, Hafir and Zenata are under the influence of a mild winter. By cons, the stations of Beni-Saf and Ghazaouet are influenced by a warm winter for the new period (1980-2008).

The old period (1913-1938), "m" varies between 1.8 °C and 9.1 °C. For Hafir station which is influenced by a cool winter; the station of Beni-Saf by a warm winter and Ghazaouet, Zenata and Ouled-Mimoun stations are in a temperate winter.

This elevation of the "m" has undoubtedly had negative effects to the vegetation in recent years.

Classification of bioclimatic ambiences according to "T" and "m"

This classification has been proposed by (33), based on the following parameters:

- The annual average temperature (T°) ;
- The average of minima of the coldest month (m).

The author retains these parameters as criteria for defining stages of vegetation **(Table 11)**.

These values are expressed in (° C) and thresholds are always approximate as they can vary by more than a degree depending on the altitude, exposure and microclimate.

We note for the new period (1980-2008) and the old (1913-1938) that stations of Ghazaouet, Beni-Saf, Zenata and Ouled-Mimoun always belong to the Thermomediterranean stage.

For cons, the station of Hafir, is for each period in the Mesomediterranean resident with a woodsy vegetation.

De Martonne index

De Martonne tried to define the arid climate by an index that combines the annual average rainfall to annual mean temperature. This index is greatest when the climate is more humid.

(13) defined the index of aridity useful to assess the intensity of drought expressed by the following equation:

$$I = \frac{P(mm)}{T(°C)+10}$$

P: annual average rainfall in (mm).
T: annual average temperature in (°C).

With regard to the new period (1980-2008), the index of De Martonne is between 10.42 (Zenata) to 19.07 (Hafir) in the dry semi-arid with temporary drainage. This scheme involves the predominance of herbaceous, mostly therophyte and drought tolerant species.

The following stations: Ouled-Mimoun and Hafir respectively with an index of De Martonne of 20.38 and 30.04 to the ancient period can put these stations in a temporary flow interval with outer drainage, which confirms the existence of favorable conditions for the establishment of woody vegetation with a non-essential irrigation.

By comparing the values of this index for the two periods, we notice that fall chronologically where increased aridity **(Figure 16)**

Ombrothermic diagrams of Bagnouls and Gaussen

(6) have developed a diagram that allows to identify the duration of the dry period based on a comparison of average monthly of temperatures in °C with those of rainfall in mm, assuming that the dry months when **" P $\geq$ 2T "**.

The study area is situated in a Mediterranean climate, and for all stations, the summer drought period exceeds three months, it undergoes a change increasingly important **(Figure 17, 18, 19, 20 and 21)**.

The ombrothermic diagrams are established for all stations for the early period (1913-1938) and for the new period (1980-2008).

(15) precise that the climate is dry when the temperature curve is above that of precipitation, and wet otherwise.

For the entire study area, climate undergoes a change since the duration of drought following an increasing gradient, as the area between the two curves is increasingly important currently.

The duration of the dry period requires a high evapotranspiration to vegetation and the woody species arrive to survive thanks to their adaptive systems to changing their towers landscape by imposing xerophytic vegetation.

For the old period, all studied stations have 04 months of drought spread from June to September with the exception of the station of Beni-Saf where the duration is 05 months, from May to September. The new period shows duration of drought varies from 5 to 7 months, coinciding with the summer.

It should be noted that with this climate change in parallel, there's changes in the diversity and distribution of vegetation.

Xerothermic index of Emberger

The intensity and the importance of the dry season in a Mediterranean climate led (18) proposed a new index named xerothermic index.

The author suggests this index in addition pluviothermic regime to characterize the Mediterranean climate. It is calculated as follows:

$$Is = \frac{P(mm)}{M(C°)}$$

P: Total average summer precipitation in (mm).

M: Average thermal maxima of the summer (°C).

The author retains the total summer precipitation in (mm) and the average maxima in the same period in (°C) indicating that this index does not exceed "7" for the Mediterranean climate.

Low values of "I_s" now characterize the Mediterranean climate, confirms the scarcity of rainfall, high temperatures and the extent of the dry season from 4 to 6 months, where an apparent aridity and a very pronounced summer drought.

In Oran (West Algeria), a study conducted by (4), indicates the existence of plant species adapted to a lower index to 2; same author indicates that this index can be less than 1. This figure assumes a dry area far beyond the summer season.

As can be seen above, the I_s values range between (0.39) to Zenata and (1.10) to Hafir. It should be added that this promotes the development of highly diverse plant species and generally dominated by xerophytic species such as: *Ziziphus lotus*, *Calycotome villosa* subsp. *intermedia*, *Chamaerops humilis* subsp. *argentea*.

The pluviothermic quotient of Emberger

(19) established a pluviothermic quotient Q_2, which is specific to the Mediterranean climate. It is frequently used in North Africa and Mediterranean France.

This quotient can locate study sites among the vegetation stages plots on pluviothermic climagramme and also allows assessing the arid Mediterranean regions. The values of Q_2 are especially low when the climate is dry **(Figure 22)**.
From Q_2 (16) has classified the Mediterranean region into five bioclimatic stages (Sahara, Arid, Semi- arid, Sub-humid and Humid).
The quotient (Q_2) was formulated as follows:

$$Q_2 = \frac{1000.P}{(M-m).\left(\frac{M+m}{2}\right)} = \frac{2000.P}{M^2 - m^2}$$

- **P:** Average annual rainfall
- **M:** Average of maxima temperatures of the warmest month (T°K=T°C+273)
- **m:** Average of minima of the coldest month (T°K=T°C+273)

(M+m/2) translates the average conditions of plant life, while (M-m) gives an approximate value of evaporation. This quotient is lower when drought is severe.
In Algeria, (36) has developed a reformulation of the pluviothermic quotient (19) as follows:

$$Q_3 = \frac{1000}{\left(\frac{M+m}{2}\right)+273} . \frac{P}{M-m}$$

(M and m are expressed in absolute degrees °K).

Our stations, (M+m/2) is on average equal to 19.50 °C, these can be reduced to a constant K whose the value for Algeria and Morocco is equal to 3.43 where the new formula:

$$Q_3 = 3{,}43.\frac{P}{M-m}$$

(36) showed that the values of Q_3 and that obtained by the formula Q_2 are somewhat different; the maximum error is less than 2%.

The difference between the results given by Q_3 and Q_2 is greater than 1.7% for all meteorogical stations in Algeria.

Examination of the table above allows us to make the following assumptions:

Most of our stations belong to lower and upper semi-arid bioclimatic stages for both periods studied, with the exception of Hafir station who is under the influence of the lower sub-humid and Ouled-Mimoun station which is under the influence of arid higher.

The coastal stations (Beni-Saf and Ghazaouet) belong to the mild and warm variants and those who have a semi-continental position are in the temperate variant such as: Ouled- Mimoun; Hafir and Zenata. Formula (36) gives values very close to those provided by the Q_2 of Emberger with a difference of 0.23%. This percentage is negligible; if we consider that inaccuracies measures rainfall and temperature can cause the relative errors on the quotient of the order of 10% (34).

Conclusion

Bioclimate of the study area is Mediterranean, which essentially is two bioclimatic stages; semi-arid, which is the most common; the sub-humid and arid are characterized by two very distinct seasons. One winter, short and cold lasts from October to March, characterized by erratic rainfall. Another summer is long and dry another characterized by low rainfall and high temperatures, up to 7-8 months in the coastal and sub-coastal plain whereas at the mountains of Tlemcen it can go up to 6 months.

The bioclimatic study of the area of study allows us to make the following remarks:
- A trend towards aridity of stations and a well pronounced and initiated semi-continentality.
- The classification of bioclimatic ambiences according to the annual average temperature and "m" shows that all stations belong to the Thermomediterranean stage with the exception of the station of Hafir where the type of

climate is Mesomediterranean for both periods. The changing of Hafir station to the thermo-Mediterranean is not excluded in the near future.
- Analysis of thermal data and processing show that the coldest month is "January" with minima temperatures that range between 3.2 °C to 10.77 °C, while the average maxima temperatures of the hottest month vary between 30.8 °C and 33.6 °C (note that the hottest month is August). However, these values are higher in the new period by contributing to the old.
- Comparative study of reference stations for the two periods shows a vertical step of each station directly related to the Q_2 Emberger; Ouled Mimoun Station, despite the relative decline in the value of Q_2 the lower sub-humid to higher arid still with understory in mild winter.
- The current climate of the study area favors the extension of a xerophytic vegetation and especially therophytic. These different adaptations are not valid for all species consequently causing one hand, a regression of the vegetation and even its disappearance in certain cases and secondly an extension and installation of other plant species better adapted to this climate change. This vegetation by drought adaptation plays a role in the spread of repeated fires consequently destroys the landscape.

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Table 1 Climate data from stations in the study area (Recent period 1975-2008).

STATIONS		Moyennes mensuelles des précipitations et des températures												Régimes saisonniers				Types	P (mm) et T° moyenne	M °C	m °C	Q_2
		J	F	M	A	M	J	Jt	At	Sp	Oc	No	Dc	H	P	E	A					
Beni-Saf (80/2008)	P	50,63	58,39	37,35	34,39	24,1	7,07	4,71	3,09	15,89	30,57	62,01	40,17	149,19	95,84	14,87	108,47	HAPE	368,37	30.08	10.77	65, 01
	T	12,69	13,39	14,86	16,36	18,97	22,18	24,7	25,61	22,98	20,18	16,63	14,04						18,55			
Ouled-Mimoun (80/2008)	P	40,46	45,37	48,31	33,81	27,97	6,1	1,2	3,72	14,33	24,61	47,61	39,4	125,23	110,09	11,02	86,55	HPAE	332.89	32.26	3.57	39.84
	T	9,71	10,88	12,92	15,13	18,22	20,91	24,16	24,18	21,54	18,67	14,65	10,43						16,78			
Zenata (80/2008)	P	38,53	43,21	46,01	32,2	26,64	5,81	1,14	3,54	13,65	23,44	45,03	37,52	119,26	104,85	10,49	82,12	HPAE	316,72	33.6	4.3	44.43
	T	12,41	13,56	15,7	17,65	27,16	24,62	28,02	28,35	25,37	21,46	16,74	13,64						20,39			
Ghazaouet (80/2008)	P	42,91	46,84	40,77	27,85	29,29	5,44	1,11	3,6	20,1	33,46	57,97	34,77	124,52	97,91	10,15	111,53	HAPE	344,11	31.16	7.40	45.38
	T	11,5	12,44	14,25	15,91	18,76	22,69	25,85	23,98	23,85	20,15	15,59	12,71						18,14			
Hafir (75/1996)	P	66,9	76	62,07	53,4	40,14	8,65	7,21	9,52	19,52	25,94	53,84	60,68	203,58	155,61	25,38	99,3	HPAE	483,87	32,35	3,2	57,1
	T	8,28	8,79	10,66	12,6	16,08	20,19	24,9	24,4	20,3	16,83	11,72	9,68						15,37			

Table 2 Climate data from stations in the study area (Ancient period 1913-1938).

STATIONS		Moyennes mensuelles des précipitations et des températures												Régimes saisonniers				Types	P (mm) et T° moyenne	M °C	m °C	Q_2
		J	F	M	A	M	J	Jt	At	Sp	Oc	No	Dc	H	P	E	A					
Beni-Saf	P	49	40	37	30	24	9	1	2	15	39	57	68	157	91	12	111	HAPE	371	29,3	9,1	62,85
	T	12,95	13	14,45	15,5	18,35	21,1	24,38	25,05	22,95	19,7	16,35	13,98						18,14			
Ouled-Mimoun	P	71	75	59	48	43	21	3	2	15	54	69	68	214	150	26	138	HPAE	528	32,8	5,2	65,51
	T	8,9	9,8	11,3	14	16,6	20,8	24,4	25,2	21,7	17,2	12,5	9,5						15,9			
Zenata	P	65	62	49	44	38	11	1	4	23	42	68	67	194	131	16	133	HAPE	474	32	6,7	63,97
	T	9,9	10	10,5	13	15	21	24	26	21,5	17	13	10						15,90			
Ghazaouet	P	65,77	49,89	51,03	44,22	35,05	13,34	1,13	1,13	21,54	47,62	66,9	69,17	184,83	130,3	15,6	136,06	HAPE	433,91	29	7	71,35
	T	11,45	11,85	12,9	15,05	17,4	20,6	33,4	24,25	22,15	18,7	15,2	12,35						17,94			
Hafir	P	108	109	106	67	63	20	6	4	28	49	45	102	319	236	30	122	HPAE	707	33,1	1,8	77,77
	T	5,8	6,3	8,3	10,6	14,2	18,4	23,8	24,2	19,8	15	9,5	6,4						13,53			

Table 3 Geographic data from meteorological stations.

Stations	Longitude	Altitude	Latitude	Wilaya
Hafir	1° 26' W	1270	34° 47' N	Tlemcen
Ghazaouet	1° 24' W	4	35° 6' N	Tlemcen
Beni-Saf	1° 21' W	68	35° 18' N	Aïn-Temouchent
Zenata	1° 27' W	285	35° 1' N	Tlemcen
O. Mimoun	1° 30' W	430	34° 50' N	Tlemcen

Figure 1 Average precipitation for the old and the new period at the station of Beni-Saf (1913-1938) and (1980-2008)

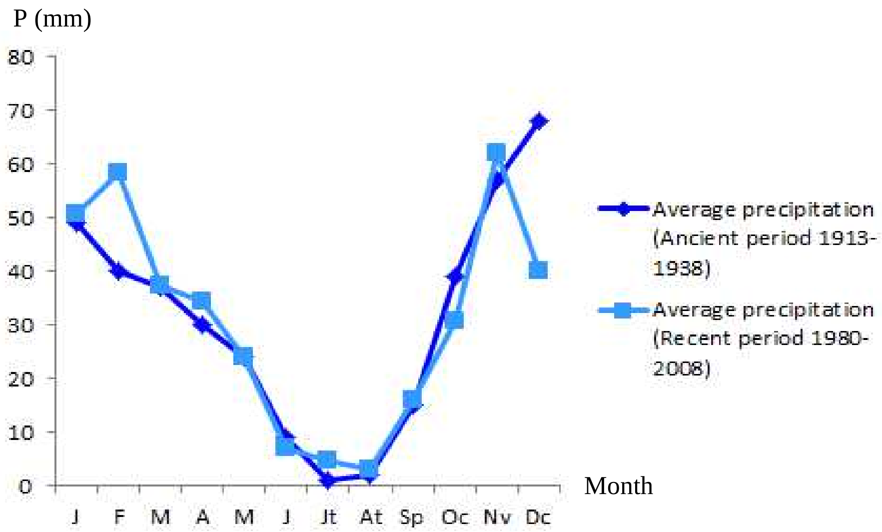


Figure 2 Average precipitation for the old and the new period at the station of Zenata (1913-1938) and (1980-2008).

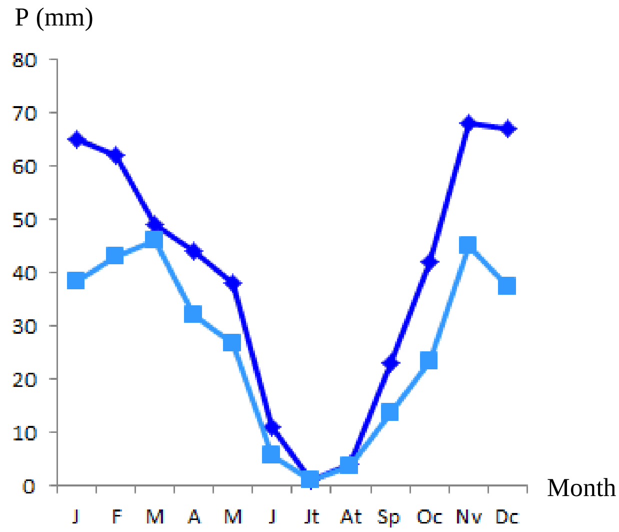


Figure 3 Average precipitation for the old and the new period at the station of Ghazaouet (1913-1938) and (1980-2008).

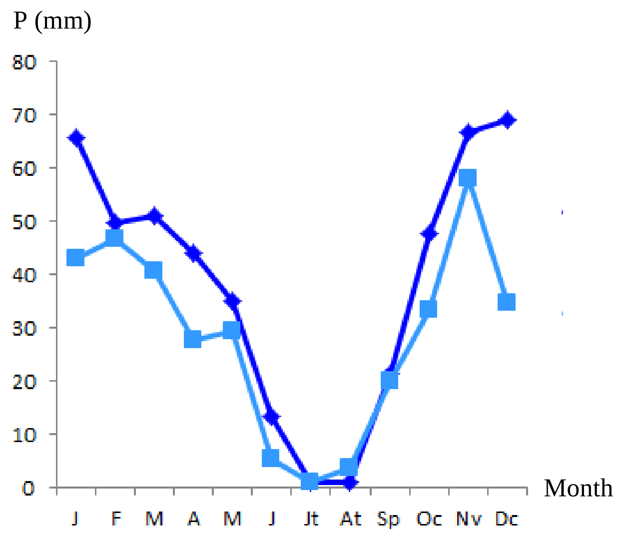


Figure 4 Average precipitation for the old and the new period at the station of Hafir (1913-1938) and (1975-1996).

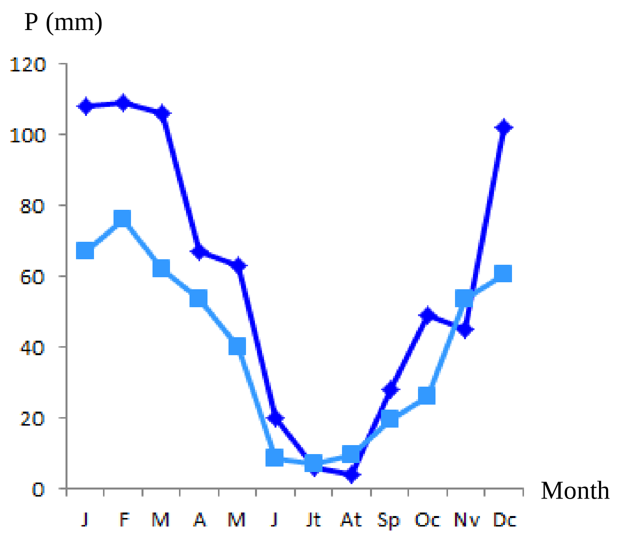


Figure 5 Average precipitation for the old and the new period at the station of Ouled-Mimoun (1913-1938) and (1980-2008).

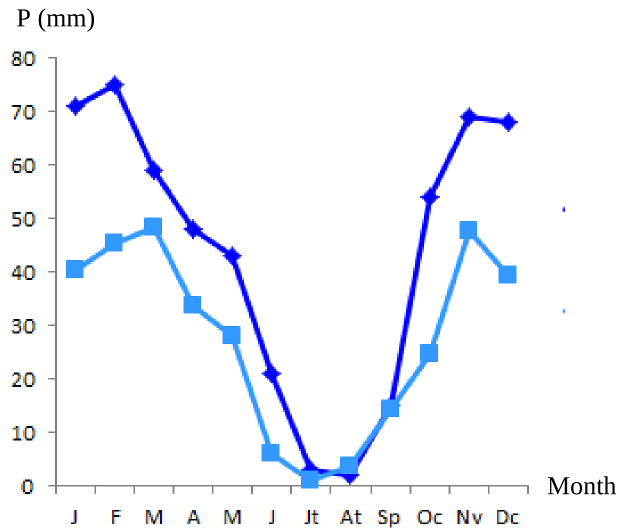


Table 4 Seasonal relative coefficient of Musset during the new period.

Seasons	Winter		Spring		Summer		Autumn		Annual Rainfall	Rainfull regime
Stations	P(mm)	Crs	P(mm)	Crs	P(mm)	Crs	P(mm)	Crs		
Beni-Saf	149,19	1,62	95,84	1,04	14,87	0,16	108,47	1,17	368,37	HAPE
Ghazaouet	124,52	1,44	97,91	1,13	10,15	0,11	111,53	1,29	344,11	HAPE
O.Mimoun	125,23	1,50	110,09	1,32	11,02	0,13	86,55	1,03	332,89	HPAE
Zenata	119,26	1,50	104,85	1,32	10,49	0,13	82,12	1,03	316,72	HPAE
Hafir	203,58	1,68	155,61	1,28	25,38	0,20	99,3	0,82	483,87	HPAE

Figure 6 Seasonal variation depending on precipitation during ancient and the recent period for the station of Beni-Saf.

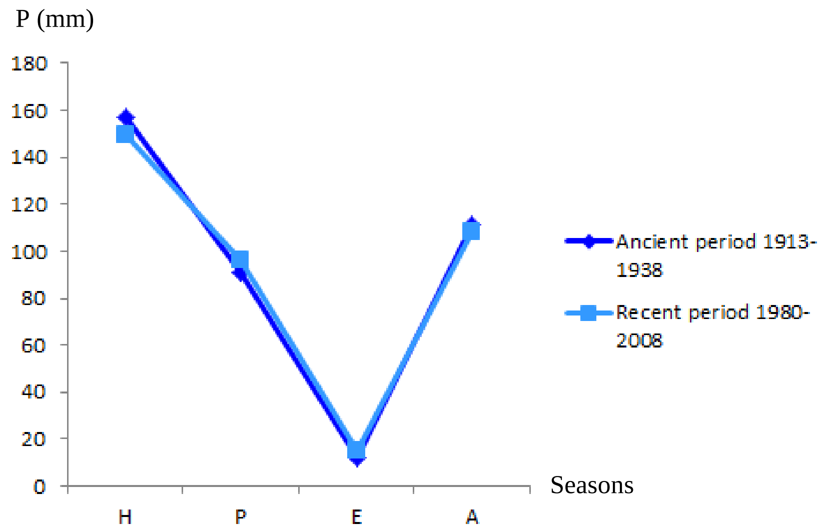


Figure 7 Seasonal variation depending on precipitation during ancient and the recent period for the station of Zenata.

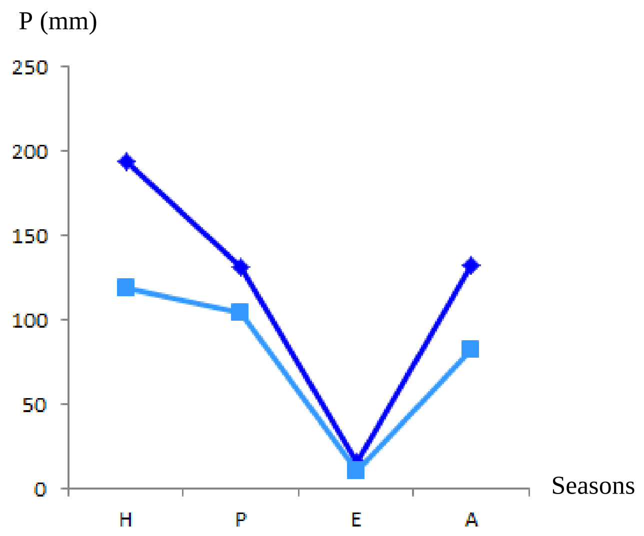


Figure 8 Seasonal variation depending on precipitation during ancient and the recent period for the station of Ghazaouet.

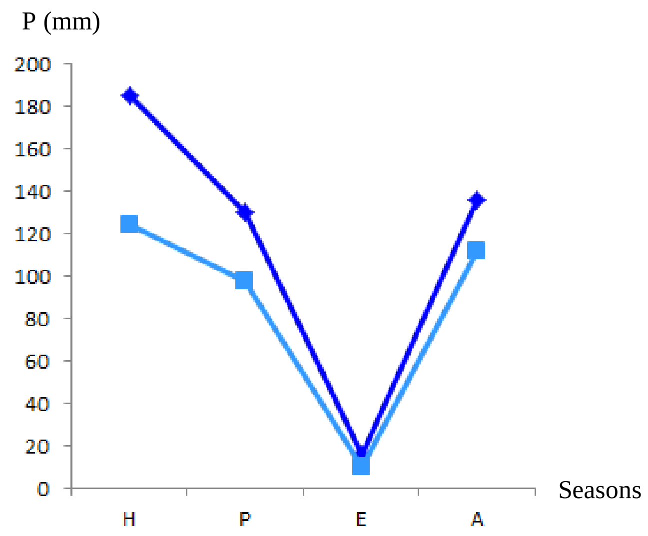


Figure 9 Seasonal variation depending on precipitation during ancient and the recent period for the station of Hafir.

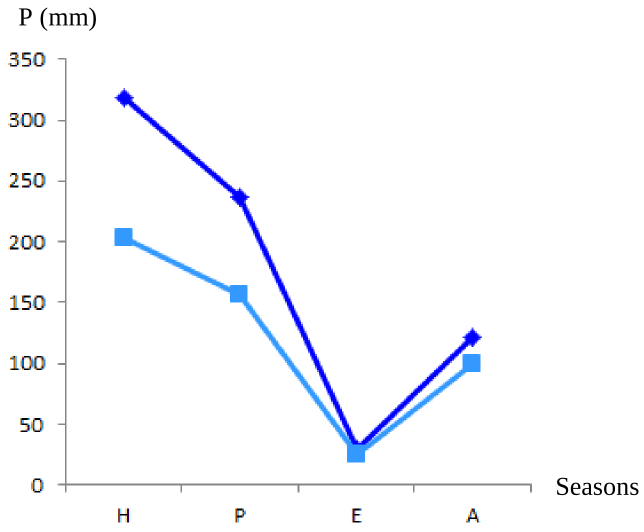


Figure 10 Seasonal variation depending on precipitation during ancient and the recent period for the station of Ouled-Mimoun.

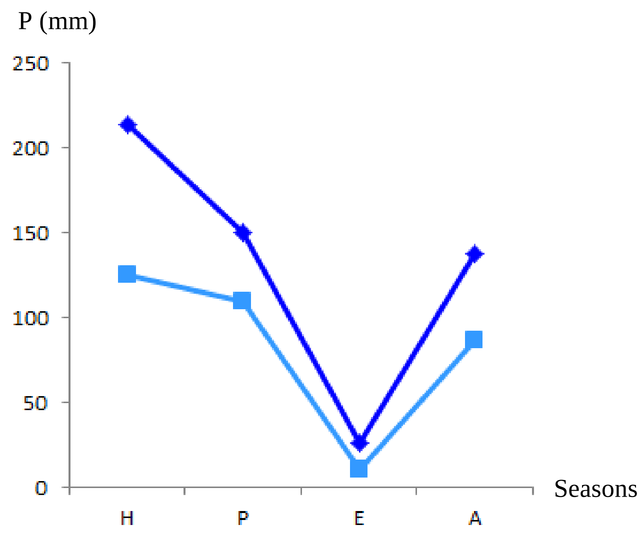


Table 5 Seasonal patterns of meteorological stations

(OP, RP = old and New period).

Stations	Altitude (m)	Rainfall (mm)	Rainfall (mm)	Seasonal pattern	
		OP	RP	OP	RP
Beni-Saf	68	371	368,37	HAPE	HAPE
Ghazaouet	4	433,91	344,11	HAPE	HAPE
O. Mimoun	430	528	332,89	HPAE	HPAE
Zenata	285	474	316,72	HAPE	HPAE
Hafir	1270	707	483,87	HPAE	HPAE

Table 6 Average of temperature maxima of the warmest month

(OP, RP = old and new period).

Stations	Altitude (m)	"M" (°C)		Month	
		OP	RP	OP	RP
Beni-Saf	68	25,05	25,61	August	August
Ghazaouet	4	33,4	25,85	July	July
O. Mimoun	430	25,2	24,18	August	August
Zenata	285	26	28,35	August	August
Hafir	1270	24,2	24,9	August	July

.

Table 7 Average of minima of the coldest month

(OP, RP = old and new period).

Stations	Altitude (m)	"m" (°C)		Month	
		OP	RP	OP	RP
Beni-Saf	68	12,95	12,69	January	January
Ghazaouet	4	11,45	11,5	January	January
O. Mimoun	430	8,9	9,71	January	January
Zenata	285	9,9	12,41	January	January
Hafir	1270	5,8	8,28	January	January

Figure 11 Average temperatures for the old and the new period at the station of Beni-Saf (1913-1938) and (1980-2008).

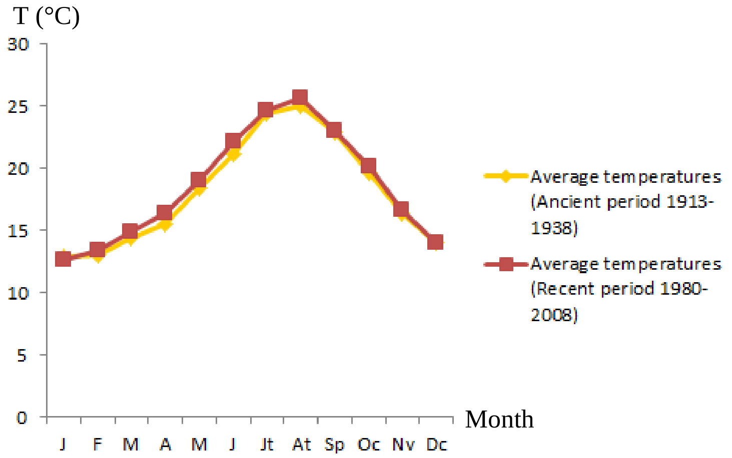


Figure 12 Average temperatures for the old and the new period at the station of Zenata (1913-1938) and (1980-2008).

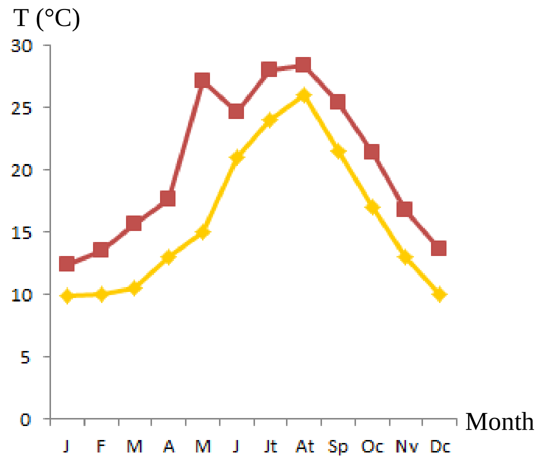


Figure 13 Average temperatures for the old and the new period at the station of Ghazaouet (1913-1938) and (1980-2008).

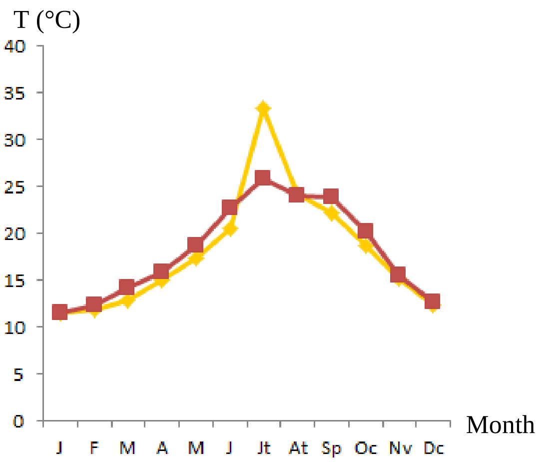


Figure 14 Average temperatures for the old and the new period at the station of Hafir (1913-1938) and (1975-1996).

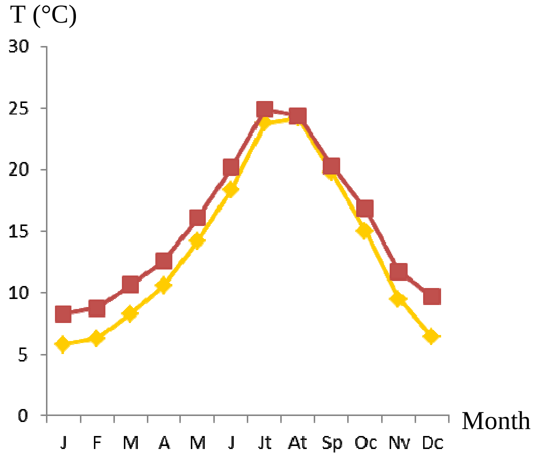


Figure 15 Average temperatures for the old and the new period at the station of Ouled-Mimoun (1913-1938) and (1980-2008).

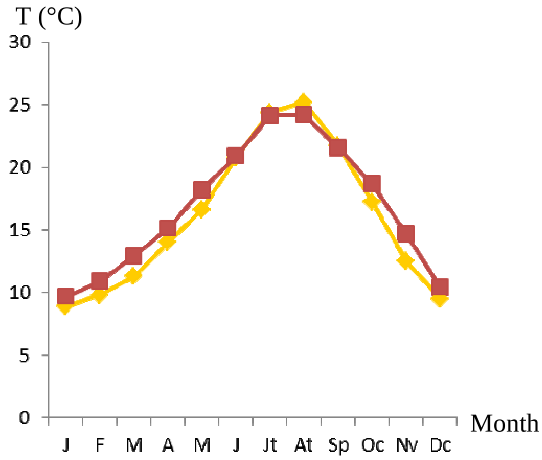


Table 8 Continentality index of Debrach.

Stations	Period	Thermal amplitude	Type of climate
Beni-Saf	(1980-2008)	19,31	Coastal Climate
	(1913-1938)	20,2	Coastal Climate
Ghazaouet	(1980-2008)	23,76	Coastal Climate
	(1913-1938)	22	Coastal Climate
Zenata	(1980-2008)	29,3	Semi-Continental Climate
	(1913-1938)	25,3	Semi-Continental Climate
Ouled-Mimoun	(1980-2008)	28,69	Semi-Continental Climate
	(1913-1938)	27,6	Semi-Continental Climate
Hafir	(1975-1996)	29,15	Semi-Continental Climate
	(1913-1938)	31,3	Semi-Continental Climate

Table 9 Classification of meteorological stations according to bioclimatic stages depending on precipitation.

Stations	Period	P (mm)	Bioclimatic stages
Beni-Saf	(1913-1938)	371	Upper Semi-arid
	(1980-2008)	368,37	Upper Arid
Ghazaouet	(1913-1938)	433,91	Lower Sub-humid
	(1980-2008)	344,11	Upper Arid
Zenata	(1913-1938)	474	Upper Semi-arid
	(1980-2008)	316,72	Upper Arid
O. Mimoun	(1913-1938)	528	Lower Sub-humid
	(1980-2008)	332,89	Upper Arid
Hafir	(1913-1938)	707	Average sub-humid
	(1975-1996)	483,87	Average Semi-arid

Table 10 Classification of sub-stages according to the minima temperature of the coldest month.

Average of Minimum of the coldest month	-3	0	3	7	11
Sub-Stage	Cold	Cool	Temperate	Warm	

Table 11 Classification of bioclimatic stages according to the average temperature "T" and the average temperature of the minima in the coldest month.

Bioclimatic stages	Annual average temperatures (°C)	"m" average (°C)
Thermomediterranean	> 16	> 3
Mesomediterranean	12< T <16	0 <m <3
Supramediterranean	8< T <12	-3 <m <0

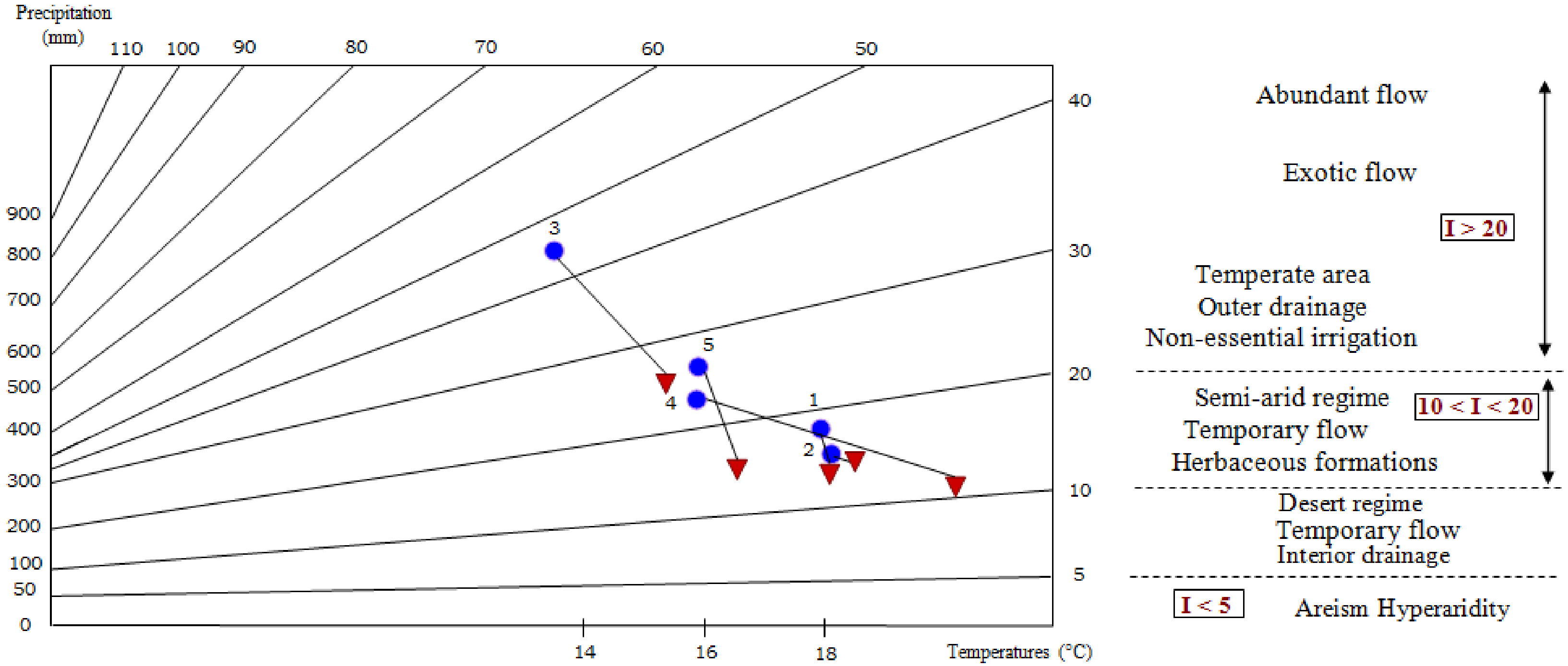
Table 12 Vegetation stages and climate types.

Stations	Periode	T (°C)	m (°C)	Vegetation stages
Beni-Saf	O	18,14	9,1	Thermomediterranean
	R	18,55	10,77	Thermomediterranean
Ghazaouet	O	17,94	7	Thermomediterranean
	R	18,14	7,40	Thermomediterranean
Zenata	O	15,90	6,7	Thermomediterranean
	R	20,39	4,3	Thermomediterranean
Ouled-Mimoun	O	15,9	5,2	Thermomediterranean
	R	16,78	3,57	Thermomediterranean
Hafir	O	13,53	1,8	Mesomediterranean
	R	15,37	3,2	Mesomediterranean

Table 13 Aridity index of De Martonne.

Stations	Period	De Martonne index	Type of climate
Beni-Saf	(1913-1938)	13,18	Dry Semi-arid
	(1980-2008)	12,90	Dry Semi-arid
Ghazaouet	(1913-1938)	15,53	Dry Semi-arid
	(1980-2008)	12,22	Dry Semi-arid
Zenata	(1913-1938)	18,30	Dry Semi-arid
	(1980-2008)	10,42	Dry Semi-arid
Ouled-Mimoun	(1913-1938)	20,38	Temperate area with outer drainage
	(1980-2008)	12,43	Dry Semi-arid
Hafir	(1913-1938)	30,04	Temperate area with outer drainage
	(1975-1996)	19,07	Dry Semi-arid

Figure 16 Aridity index of De Martonne



Legend

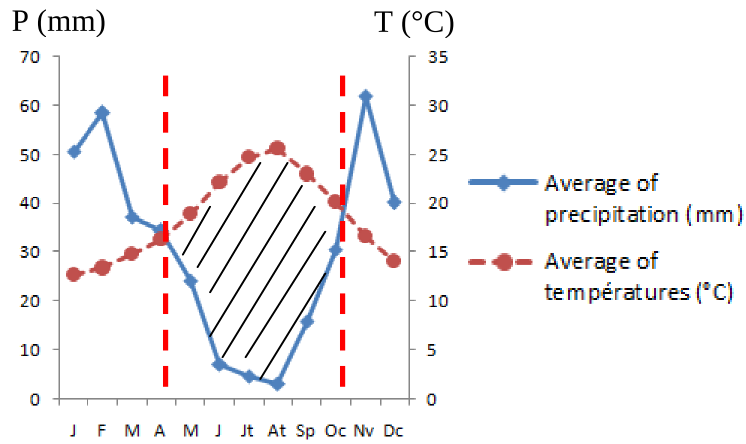
1: Ghazaouet 2: Beni-Saf 3: Hafir 4: Zenata 5: Ouled-Mimoun

● Ancient period (1913-1938)

▼ Recent period (1975-2008)

Figure 17 Ombrothermic diagrams for the station of Beni-Saf (1913-1938) and (1980-2008).

Ancient period (1913-1938).



Recent period (1980-2008).

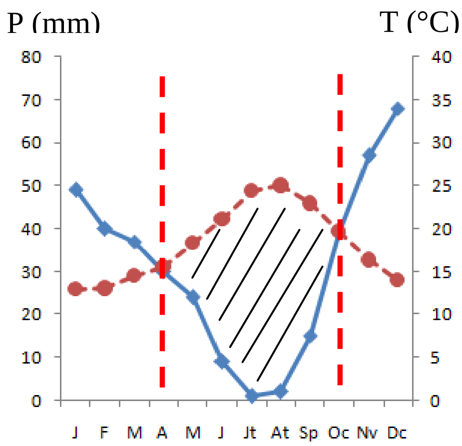
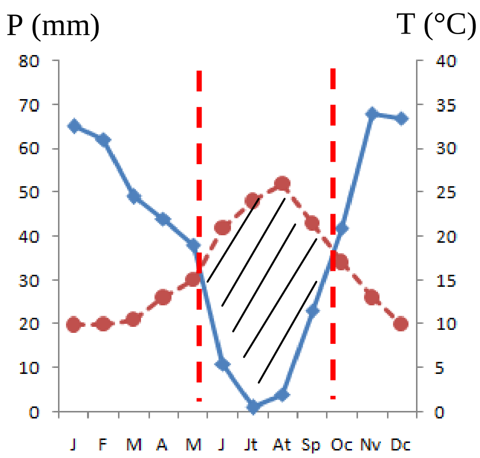


Figure 18 Ombrothermic diagrams for the station of Zenata (1913-1938) and (1980-2008).

Ancient period (1913-1938).



Recent period (1980-2008).

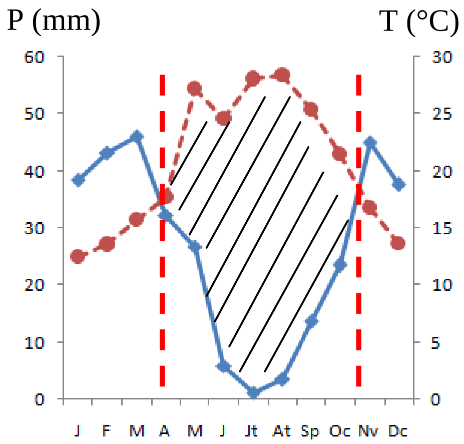
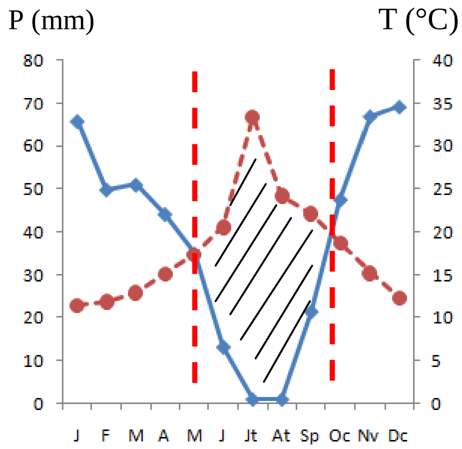


Figure 19 Ombrothermic diagrams for the station of Ghazaouet (1913-1938) and (1980-2008).

Ancient period (1913-1938).



Recent period (1980-2008).

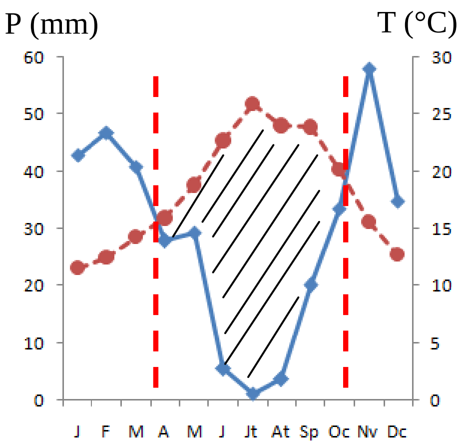
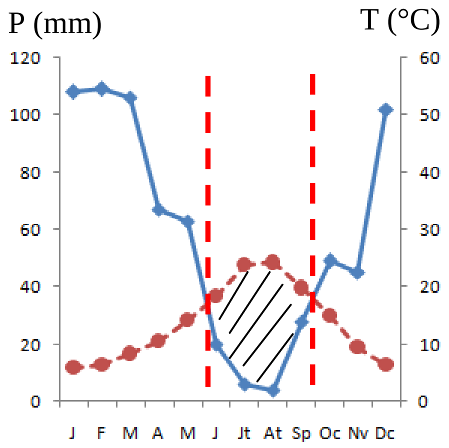


Figure 20 Ombrothermic diagrams for the station of Hafir (1913-1938) and (1975-1996).

Ancient period (1913-1938).



Recent period (1975-1996).

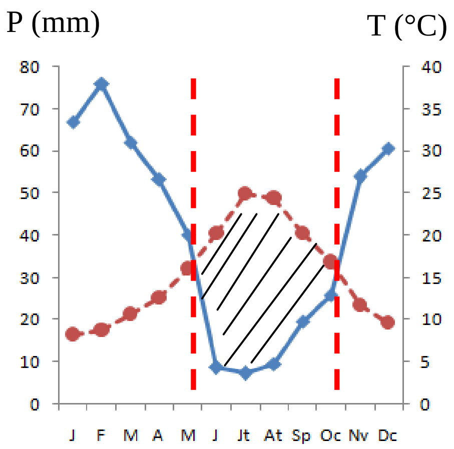
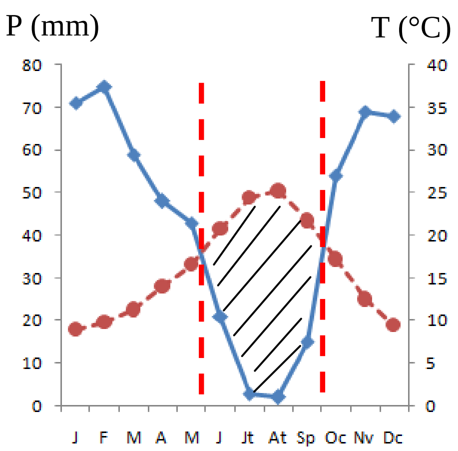


Figure 21 Ombrothermic diagrams for the station of Ouled-Mimoun (1913-1938) and (1980-2008).

Ancient period (1913-1938).



Recent period (1980-2008).

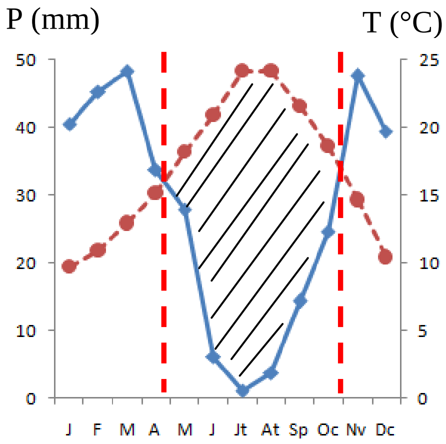
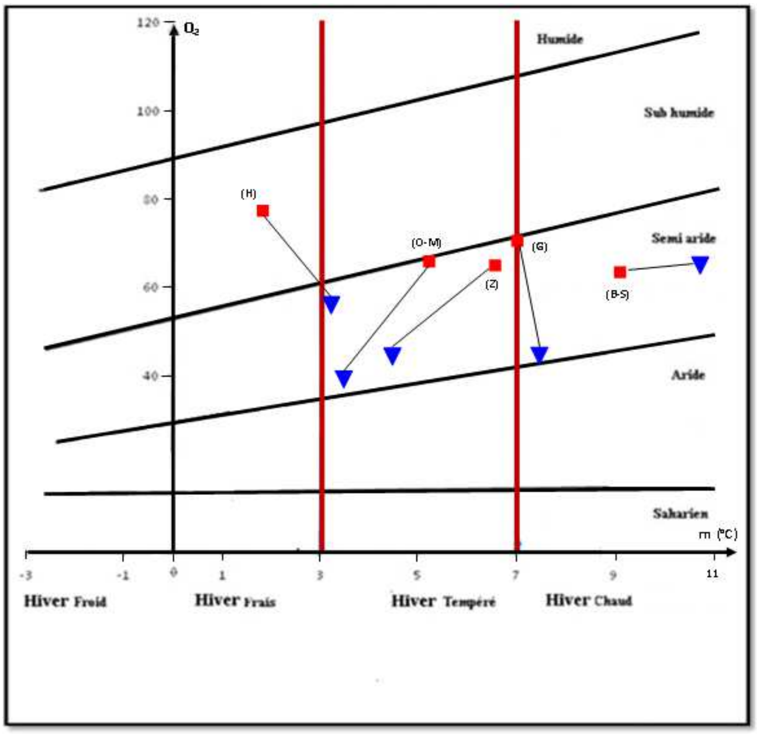


Table. 14 Xerothermic index of Emberger.

Stations	P (mm)	M (C°)	I_s = P/M
Beni-Saf	14,87	24,16	0,62
Ouled-Mimoun	11,02	23,08	0,48
Ghazaouet	10,15	24,17	0,42
Zenata	10,49	27	0,39
Hafir	25,38	23,16	1,10

Figure 22 Pluviothermic climagramme of Emberger (Q_2) of meteorogical stations.



H : Hafir ; **O-M** : Ouled-Mimoun ; **Z** : Zenata ; **G** : Ghazaouet ; **B-S** : Beni-Saf

● Ancient period (1913-1938)

▼ Recent period (1975-2008)

Table 15 Pluviothermics climagrammes of Emberger and of Stewart.

Stations	M		m		Q_2		Q_3	
	OP	RP	OP	RP	OP	RP	OP	RP
Beni-Saf	29,3	30,08	9,1	10,77	62,85	65,01	62,99	62,56
Ghazaouet	29	31,16	7	7,40	71,35	45,38	67,65	53,64
Zenata	32	33,6	6,7	4,3	63,97	44,43	64,26	42,94
Ouled-Mimoun	32,8	32,26	5,2	3,57	65,51	39,84	65,61	41,36
Hafir	33,1	32,35	1,8	3,2	77,77	57,1	77,47	53,02