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RECENT EVOLUTION OF CLIMATIC CONDITIONS IN THE LOWER TAFNA WATERSHED (NORTH-WEST OF ALGERIA)

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ABSTRACT

In Algeria, the climatic conditions that have prevailed in the territory for decades have a direct influence on the environment. The aim of this work is to determine the recent evolution of the climate in the Lower Tafna catchment area (North-Western Algeria), by analysing the two periods over a 25-year interval. The study of the different climatic components such as precipitation and annual temperatures during the periods (1913-1938) and (1995-2020) helped us to draw the pluviothermal climagram of Emberger (1955) and the umbrothermal diagrams of Bagnouls and Gaussen (1953), specific to the Mediterranean climate. In terms of average values, temperatures are higher during the new period. Concerning the annual rainfall, the Maghnia station shows a decrease in rainfall while the Beni-Saf station shows an increase in rainfall during the new period.
The analysis of the Emberger rainfall climagram (Q2) informs us that the meteorological stations present a certain dynamic during the new period, passing from the upper semi-arid bioclimatic stage with temperate winter to the lower semi-arid with temperate winter for the Maghnia station and the lower semi-arid with warm winter to the upper semi-arid with warm winter for the Beni-Saf station. The umbrothermal diagrams show that the duration of the summer season is long and dry, characterised by low average rainfall and high heat.
Keywords: Climate change, Lower Tafna, precipitations, temperatures, semi-arid.

Introduction

Climate is a determining factor that comes before any study of the functioning of ecological systems Thinthoin (1948). Emberger clearly emphasised in the course of his work (1930, 1971) that the only common denominator making it possible to define the Mediterranean region is above all of an ecological and more particularly of a climatic nature.

Multiple large-scale climatic events have prompted the world community to take an interest in climate change and its impact on the natural environment.

Algeria's climate is tending towards an increasingly accentuated aridity, as evidenced not only by the rainfall regime but also by the high summer temperatures leading to intense evaporation. Bouazza and Benabadji (2010) agree that the western Algerian region is characterised by low rainfall with high inter-monthly and inter-annual variability.

Since the remarkable work of Seltzer (1946) on the climate of Algeria, several studies have been carried out: Emberger (1955), Bagnouls and Gaussen (1953-1957), Quezel (1957), Gounot (1969), Le Houérou (1969-1975), Stewart (1969), Alcaraz (1969-1982), Emberger (1971), Dahmani (1984), Djebailli (1984), Kadik (1987), Aime (1991), Quezel and Barbero (1993), Mekkioui (1989, 1997), Benabadji and Bouazza (2000), Bestaoui (2001), Hirche and *al*. (2007), Hasnaoui (2008), Merzouk (2010), all these authors agree on the integration of the Algerian climate into the Mediterranean climate.

Temperature and rainfall are the two main elements of the climate (Dajoz, 2006).

This study consists of a bioclimatic approach based on meteorological data, temperatures and precipitation, collected from the meteorological services (O.N.M) in order to see the recent evolution of climatic conditions in the lower Tafna watershed.

Materials and Methods

Located in the northwest of Algeria and 177 km long, the Wadi Tafna has its source in the Tlemcen Mountains at Ghar-Boumaaza (AinadTabet, 1988). This study area covers part of the Wadi Tafna in western Algeria.

The hydrographic network of the Tafna is made up of a large number of wadis and chaâbats which all flow into the Wadi Tafna, either directly or via one of its tributaries.

The Oued Tafna is subdivided into three parts:

- Upper Tafna: the wadi starts in Oueldouriach up to Sidi Medjahed.
- Middle Tafna: from Sidi Medjahed to the gorges of Tahouart towards the village of Hadjeret El-gat.
- Lower Tafna: from the gorges of Tahouart to the sea of Rachgoun, which is the subject of our study.

The climate of the study area is defined using climatic data from two weather stations closest to the study area, namely Beni-Saf and Maghnia (Table 01). The data for the older period from 1913 to 1938 were obtained from the

Seltzer (1946) meteorological compendium and those for the new period from 1995 to 2020 were obtained from the National Office of Meteorology (N.O.M.).

Table 1: Geographical coordinates of meteorological stations (N.O.M.).

Stations	Latitude N	Longitude W	Altitude (m)	Wilaya
Béni-Saf	35°18'N	1°21'W	68m	Ain-Temouchent
Maghnia	34°52'N	1°47'W	426m	Tlemcen

Site nº1 "Maghnia"

This site is located on the eastern slope of the lower Tafna at an altitude of approximately 222 m, with a longitude of 1°38' West and a latitude of 34°55' North (Figure 01).

Site nº2 "Béni-Saf"

This site has a longitude of 1°27' West and a latitude of 35°28' North. Exposed to the north-west of the lower Tafna, this site is located at an altitude of 13 m (figure 01).

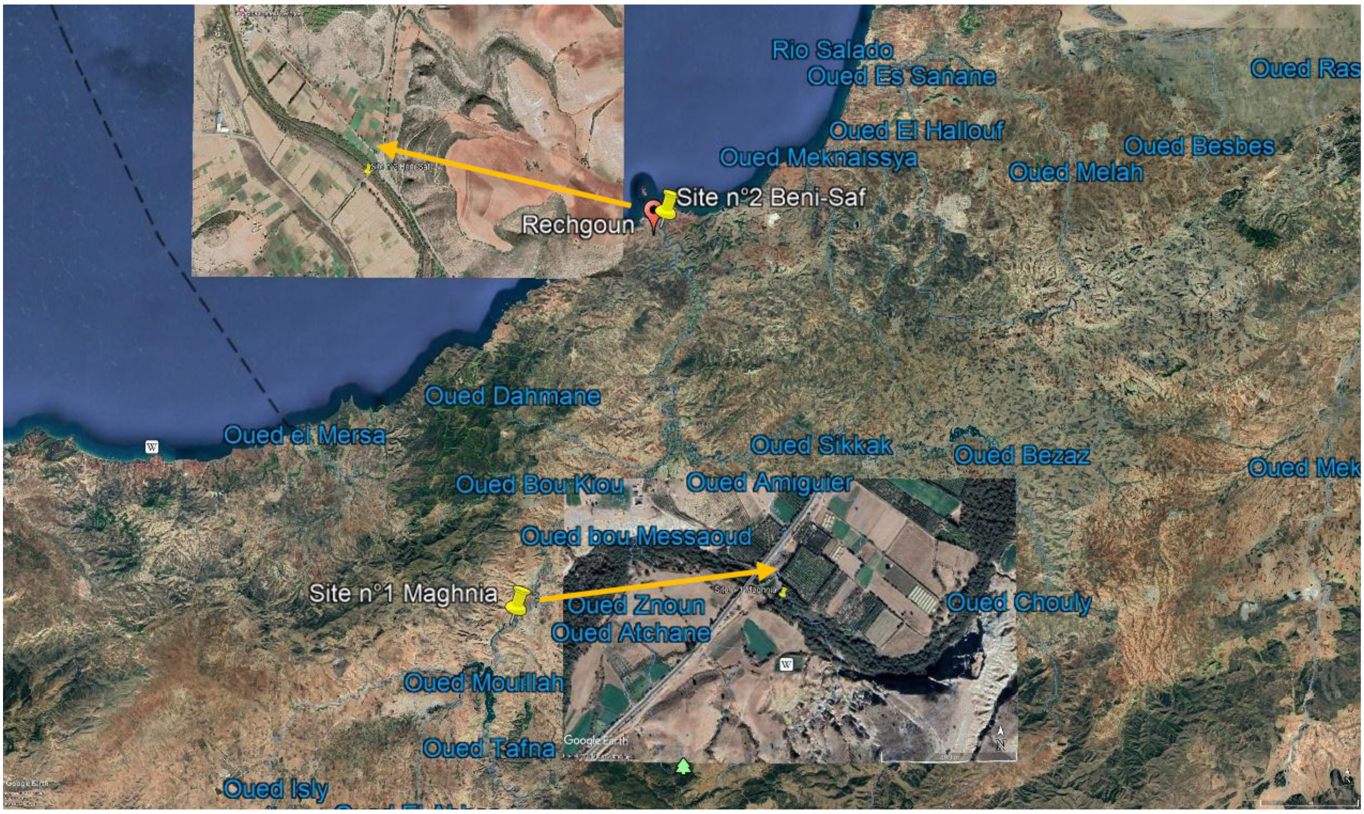


Fig. 01: Geolocation of sites by LAND-SAT satellite image (Google Earth Professional, 2021).

The objective of this bioclimatic analysis is to compare the old and new climatic periods of the study region over a 25-year period in order to highlight the recent evolution of the climate in this region of the Lower Tafna catchment area, located in the northwest of Algeria.

In order to assess the climate in the study area, we take into consideration

- Interpretation of climatic factors based on data from meteorological stations,
- Determination of the bioclimatic stage of the study sites based on Emberger's (1955) rainfall-thermal climagram and after calculation of the rainfall-thermal quotient Q_2 specific to the Mediterranean climate.

$Q_2=2000P/(M^2m^2)=1000P/(M+m/2)(M-m)$

P: average annual rainfall in mm;

M: average of the maxima of the warmest month;

m: average of the minima of the coldest month;

M and m: expressed in absolute degrees °K; (T+273°K).

- The dry period by means of the umbrothermal diagram of Bagnouls and Gaussen (1953), who consider that a month is biologically dry if the total monthly precipitation expressed in millimeters is equal to or less than twice the average temperature expressed in degrees Celsius, "P≤2T".

P: average precipitation for the month in mm,

T: average temperature of the same month in °C.

Results and Discussion

The climatic parameters make it possible to characterize the different climates of the region under study. We used bioclimatological tools such as climagrams and diagrams, models for representing and comparing climate.

Table 02 : Average monthly and annual rainfall.

Stations	Periods	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	P (mm)
Maghnia	OP(1913-1938)	60	52	49	41	37	10	1	4	22	35	49	58	418
	NP(1995-2020)	35.5	25.5	28.9	32.3	20.1	5.6	3.9	10	15.4	31.5	41.9	33.4	284
Béni-Saf	OP(1913-1938)	49	40	37	30	24	9	1	2	15	39	57	68	371
	NP(1995-2020)	58.7	35.2	33.0	50.5	18.2	19.8	19.5	4.7	24	41.5	62.9	43.7	411.7

OP: old period NP: new period

Table 03 : Monthly and annual average temperatures.

Sites	Periods	Jan	Feb	Ma	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	T Moy (°C)
Maghnia	OP (1913-1938)	9.00	10.2	12.20	14.65	18.10	21.70	25.90	26.40	22.91	18.11	12.90	9.80	16.82
	NP (1995-2020)	10.2	11.1	13.3	15.7	19.3	23.7	27.3	27.6	23.8	19.9	14.6	11.3	18.1
Béni-Saf	OP (1913-1938)	12.95	13	14.45	15.50	18.35	21.10	24.38	25.05	22.95	19.70	16.35	13.98	18.15
	NP (1995-2020)	13.4	13.8	15.1	16.7	19.3	22.6	25.1	25.9	23.6	20.3	16.3	14.3	18.9

Annual regime

Examination of the annual precipitation regime leads us to a chronological comparison of the two periods. The distribution of rainfall is irregular at both stations (Table 02).

- For the old period (1913-1938), the average rainfall is 418 mm for the Maghnia station and 371 mm for Béni-Saf.
- For the new period (1995-2020), the Maghnia station has an average rainfall of 284 mm and 411.7 mm for Béni-Saf.

The histogram of annual variations in precipitation (Figure 02), shows a decrease in the amount of precipitation relatively important in the site of Maghnia with a value of loss of 134 mm while a slight increase on the site of Béni-Saf was noticed that is to say a rate of 40.7 mm of increase during these 25 years.

In general, the comparison of the two weather stations shows above all the permanent irregularity of rainfall.

According to Halimi (1980) rainfall patterns are influenced by two groups of factors:

- Geographical factors: altitude, latitude, distance from the sea, orientation of the slopes.
- Meteorological factors: air masses, center of action, trajectory of depressions.

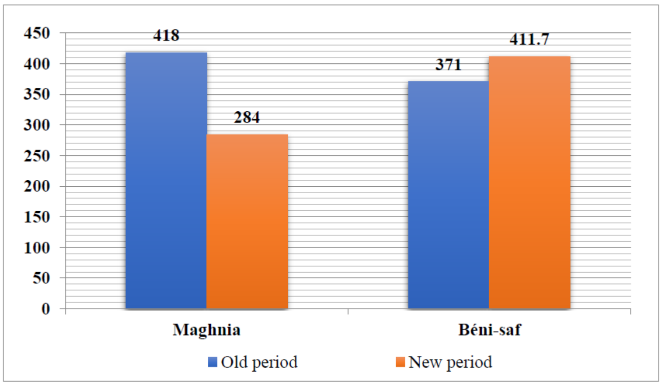


Fig. 02: Annual rainfall variations during the two periods

Monthly patterns

The analysis of the average monthly rainfall data allows a better visualization of the distribution of the quantities of water recorded at the level of each meteorological station and for each month throughout the year.

The analysis of Table 02 and Figure 03 shows a low rainfall rate and permanent irregularity. Generally speaking, the wettest period for the two former stations was from November to April. On the other hand, July is the driest month. For the new period, the recorded rainfall differs greatly from the data for the old period. There is a significant decrease in rainfall for the Maghnia station, except for the Béni-Saf station, where the new period remains slightly higher. The wettest period is also the same and still extends from November to April. July remains the driest month for the Maghnia station, while August is the driest month of the year for the Béni-Saf station.

The distribution of the quantities of water recorded at each station is as follows

Maghnia :

- For the old period (1913-1938): the maximum monthly rainfall is 60 mm during the month of January and the minimum is 1 mm in July.
- For the new period (1995-2020): the maximum monthly rainfall is 41.9 mm during the month of November and the minimum is 3.9 mm in July.

Béni-Saf :

- For the old period (1913-1938): we note 68 mm as maximum rainfall for the month of December and 1 mm as minimum in July.
- For the new period (1995-2020): rainfall varies from 62.9 mm recorded for the month of November to 4.7 mm for the month of August.

The latitude and altitude of the stations have a direct relationship with the amount and frequency of rainfall. This was confirmed by Chaâbane (1993).

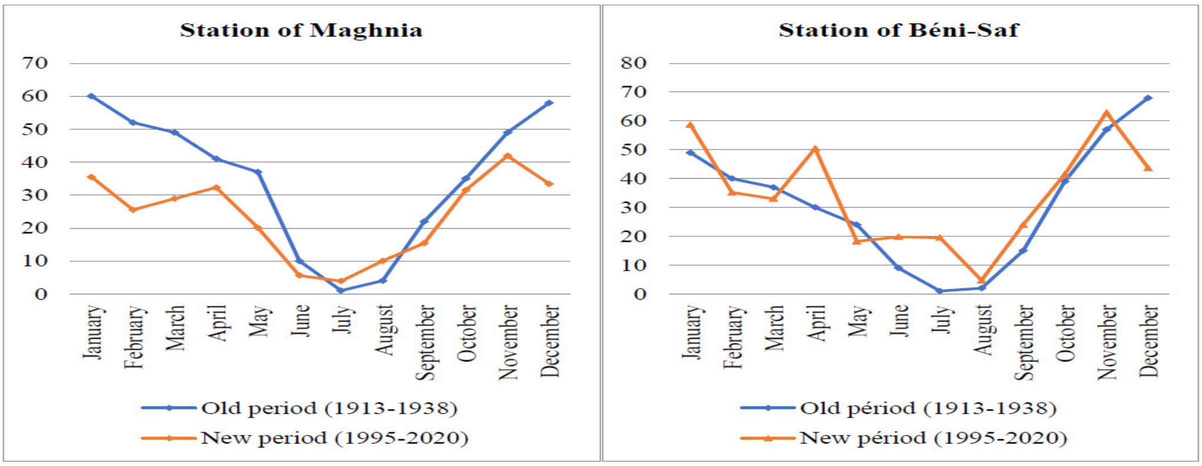


Fig. 03: Monthly rainfall variations during the two periods

Average monthly temperatures

The data in **Table 03** allow us to advance the following results:

- The average monthly temperatures in the Maghnia site range from 9 °C to 26.40 °C during the old period and from 10.2 °C to 27.6 °C during the new period.
- Concerning the site of Béni-Saf, the average monthly temperatures vary between 12.95 °C and 25.05 °C for the older period whereas in the new period the average temperatures are between 13.4 °C and 25.9 °C.
- For all weather stations, the coldest month is January in both periods.
- July and August are considered the warmest months of the year.
- The comparison between the average annual temperatures of the two periods allowed us to confirm the presence of an evolution that shows an increase in average annual temperatures of about 1.28 °C and 0.75 °C respectively for the stations of Maghnia and Béni-Saf.

Umbrothermal diagrams of Bagnouls and Gaussen

The interpretation of the diagrams shows the following results **(Fig. 04)**:

- The dry season for the station of Maghnia extends from mid-May to mid-October during the old period, i.e. 5 months of drought, and from mid-April to October for the new period, equivalent to 6 and a half months of drought.
- For the station of Beni-Saf, the dry season extends from mid-April to mid-October for the older period about 6 months of dryness and from May to mid-October or 5 months and a half for the new period.

These results confirm that the study area is under the influence of the Mediterranean climate, with each station studied had a more or less intense season depending on its position in relation to the sea, its altitude and its geographical position. The dry period lasts from 5 and a half to 6 and a half months, and generally coincides with the summer period.

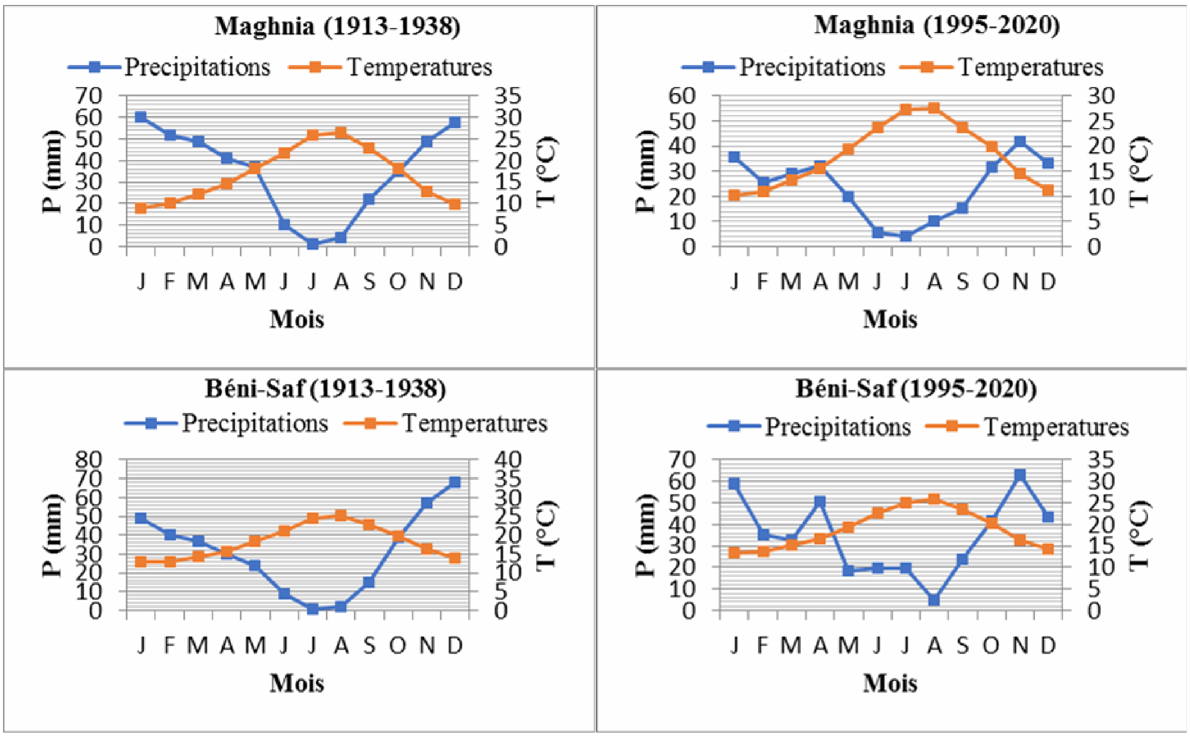


Fig. 04: Umbrothermal diagrams of Bagnouls and Gaussen

Emberger rainfall quotient

The calculated values of Q_2 (Table 04) oscillate between 49.98 (Maghnia) and 62.85 (Beni-Saf) during the old period and 33.56 (Maghnia) and 74.30 (Béni-Saf) for the new period.

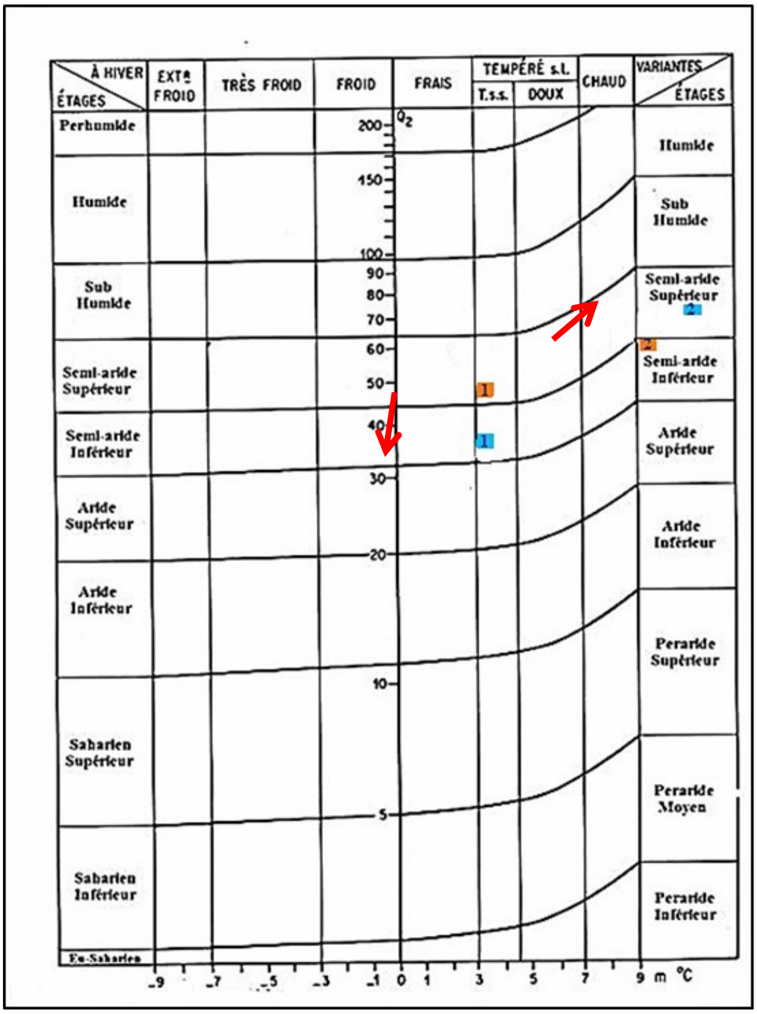
The pluviothermal climagram (Figure 05), shows a difference in climate between the weather stations in the study area, which are positioned asfollows:

- The station of Maghnia evolves from the upper semi-arid stage with temperate winter to the lower semi-arid bioclimatic stage with temperate winter during the new period.
- The Béni-Saf station changes from the lower semi-arid with warm winter in the old period to the upper semi-arid with warm winter in the new period.

Several fundamental factors influence the climatic characteristics of the study region during this study period, namely: the geographical location, the pivotal position between the Sahara and the Mediterranean, the altitude, and the transformation of green areas into concrete areas.

Table 04: Table showing bioclimatic stages

Stations	Periods	M (°C)	m (°C)	P (mm)	Q_2	Bioclimaticfloors
Maghnia	**OP**	32.07	3.3	418	49.98	Upper semi-arid to temperate winter
	NP	32.3	3.2	284	33.56	Lower semi-arid to temperate winter
Béni-Saf	**OP**	29.3	9.1	371	62.85	Lower semi-arid to warm winter
	NP	29.6	10.7	411.7	74.30	Upper semi-arid to warm winter



Old period **1.** Maghnia

New period **2.** Beni-Saf

Fig. 05: Emberger rainfall pattern (Q2)

Conclusion

Within the framework of this study and for a better analysis of the impact of climatic variability on the Lower Tafna catchment area, we considered it useful to analyse and compare the various climatic components of the old and new periods. This comparison is based on an average of 25 years, a necessary and sufficient time condition for a reliable characterization of the climate of the region studied.

From this bioclimatic study, we can see that the climate has changed for all sites and we can draw the following conclusions:

The climate of the study area is Mediterranean. Generally speaking, the climate is relatively dry throughout the region, with low and irregular rainfall not exceeding 420 mm per year. This deficit undoubtedly affects the environment.

According to Emberger's (Q2) rainfall climagram, the weather stations belong to the semi-arid bioclimatic stage, characterized by a temperate or warm winter.

The duration of the summer season is long and dry, characterized by low average rainfall and high temperatures, which can last from 5.5 months to 6.5 months.

According to Combourieu Neboutand *et al.* (2009) the drought induces a strong summer/winter seasonal contrast in the hydrological cycle. The last few decades have been marked by several heat waves associated with droughts that are sometimes unprecedented in historical records.

The study of bioclimatology is necessary because this discipline provides information on the influence of climatic factors and their impacts on water resources and the environment.

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