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IMPACT OF CLIMATIC VARIATIONS ON MATORRALS IN THE SOUTHERN OF TLEMCEN (WESTERN ALGERIA)

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Abstract

The climate of the matorrals on the southern of Tlemcen in north-west Algeria is Mediterranean, characterized by a hot and dry summer and a cool and wet winter. Climatological data show irregular inter and intra annual precipitations and the authors of the rains show a large amplitude. Bioclimatic indices calculated from precipitation and temperature show in most of the logical weather stations a more important drought for the recent period. The comparison of the ombrothermal diagrams of Bagnouls and Gaussen established for each of the periods, shows that the surface between the two curves is always much more important than in the recent period. There is thus clearly accentuation of the drought. The region placed with a clear vertical regression on the Emberger rainfall climatogram. The climatic changes have modified the landscape and are leading to an impoverishment of the region's floristic heritage.

Key words: Climatic indices, Drought, Matorral, Tlemcen, Western Algeria.

Introduction

The matorrals, which undoubtedly cover more than half of the Mediterranean region (Le Houerou *et al.,* 1981) on limestone, occupy huge areas in North Africa and individualized multiple groupings that constitute the most remarkable vegetation structures in the Maghreb, due to their floristic richness (Quezel, 2000).

In Oranie and on the Tlemcen Mountains, a particular settlement occupies an important place in the dynamic phases of the vegetation cover, experiencing rapid regressive transformations linked to the different degradation processes. On this subject (Quezel and Bonin 1980), mention that it is infinitely probable that this regressive evolution of these ecosystems (forests, pre-forestry and matorrals) is underway and may become irreversible.

The general evolution of the climate during the 20th century, at least in its second half, shows a warming trend. The droughts that affected North Africa marked by very noticeable intensities and extensions.

The studies on climate change show that in the Maghreb, global warming is more important than the average, if at the global level, the increase of 0.74°C during the 20th century has been estimated at between 1.5°C and 2°C depending on the regions in the Maghreb, it has also been possible to evaluate a decrease in rainfall which has been between 10 and 20% (Mahi Tabet-Aoul, 2008).

Thus, in recent years, Algeria has experienced very significant climatic variations, undergoing a contrasted balance between the circulation of Saharan air in summer and a polar circulation in winter, thus explaining an arid climate in summer and a humid temperate climate in winter.

The climate of the Tlemcen region is of Mediterranean type is confirmed by several authors Benabadji (1991-1995), Bouazza (1991-1995) Bouazza and Benabadji (2007); have made it possible to recall and specify that the climate of the southern slope of the Tlemcen region is of semi-arid and arid Mediterranean type.

The landscapes of our study area are part of a remarkable regressive dynamic series, which results from the interaction of very diversified factors, notably related to climatology and above all to the deep anthropozoogenic action.

This work analyzes the evolution of temperatures and rainfall in the study area over more than 25 years. The evolution of these two parameters reflects the climatic upheavals experienced in recent years by North Africa and the Greater Maghreb region.

Materials and Methods

This study concerns the Tlemcen region. It is located in the extreme west of Algeria Fig. 1 and crossed by the national road n° 22, linking the North to the South.

Choice of period and duration :

The study area characterized in terms of climate from a series of meteorological data provided by the different stations: Saf-Saf, Ouled Mimoun, Sebdou and El Aricha.

The data from 1913 to 1938 obtained from Seltzer (1946) meteorological compendium, those from 1987 to 2012 provided by the meteorological stations located in the region.

The choice of two series separated by an important interval firstly related to a concern of comparison of these two series relatively different by the rate of precipitation and by the average temperature.

Choice of data and weather stations :

The choice of stations dictated by the general appearance of the relief and by the concern to cover as well as possible all the air of study. For this reason, we have chosen 04 stations:

Results and Discussion

Climate factors:

To better understand the bio climate of the study area, two essential parameters are taken into consideration, namely precipitation and temperature, which are the hinge

Fig. 1: Geographical location of study area.

Table 1: Weather Station Geographic Data.

Weather station	Longitude West	Latitude North	Altitude (m)
Saf-Saf	1°17'	34°52'	592
Ouled Mimoun	1°2'	34°55'	705
Sebdou	1°20'	34°38'	720
El Aricha	1°16'	34°12	1250

Source : N .O.M [1].(Footnotes) [1]N. O.M : National Office of Meteorology.

of the climate Bary and al (1979).

These parameters vary according to attitude, orientation of mountain ranges and exposure.

Precipitation:

Areas receiving more than 400 mm considered semi-arid, sub-humid or humid, depending on the amount of precipitation (Emberger 1930).

Djebaïli (1978) defines rainfall as the primary factor in determining the type of climate. Indeed, it conditions the maintenance and distribution of the vegetation cover on the one hand, and the degradation of the natural environment by the phenomenon of erosion on the other hand, especially in early spring.

The West Algerian region characterized by low rainfall with great inter-monthly and inter-yearly variability, add Bouazza and Benabadji (2002).

Rainfall regimes : table 2

Knowledge of the average annual rainfall is of great interest, but to complete studies of the distribution of rainfall, it is necessary to add that of the rainfall regime, *i.e.* the way in which this total quantity of rain distributed between the different seasons (Angot 1916).

Seasonal regimes :

Defined by Musset in Chaâbane (1993), the method consists in arranging the seasons in descending order of rainfall, which makes it possible to define a seasonal indicator for each station.

This seasonal distribution is particularly important for the development of annuals whose role is often predominant in the vegetation physiognomy.

$Crs = PsX4/Pa$

Ps: seasonal rainfall

Pa: annual rainfall

Crs: Musset Seasonal Relative Coefficient

According to Corre (1961), if the autumn and spring rains are sufficient, they will

Table 2: Average monthly and annual precipitation.

Station	Period	J	F	M	A	M	J	JLY	A	S	O	N	D	P. year (mm)
Saf-Saf	1913-1938	70	72	72	61	48	16	2	3	15	40	70	76	545
	1987-2012	41,99	47,1	50,15	35,1	29,04	6,33	1,24	3,86	14,88	25,55	49,08	40,89	345,21
Ouled Mimoun	1913-1938	71	75	59	48	43	21	3	2	15	54	69	68	528
	1987-2012	40,4	45,3	48,3	33,8	27,9	6,1	1,2	3,7	14,3	24,6	47,6	39,4	332,6
Sebdou	1913-1938	43	41	37	25	34	15	5	7	19	23	35	42	326
	1987-2012	48,59	49,35	43,86	32,29	33,13	10,72	4,79	7,7	19,38	29,62	45,02	44,81	369,26
El-Aricha	1913-1938	29,1	24	32	23,5	22	24,6	7,5	11,7	24,6	28,5	31	27,5	286
	1987-2012	23,3	17,5	28,2	25,2	19,8	5,89	6,46	9,13	15,3	17,8	19,6	10,8	198,98

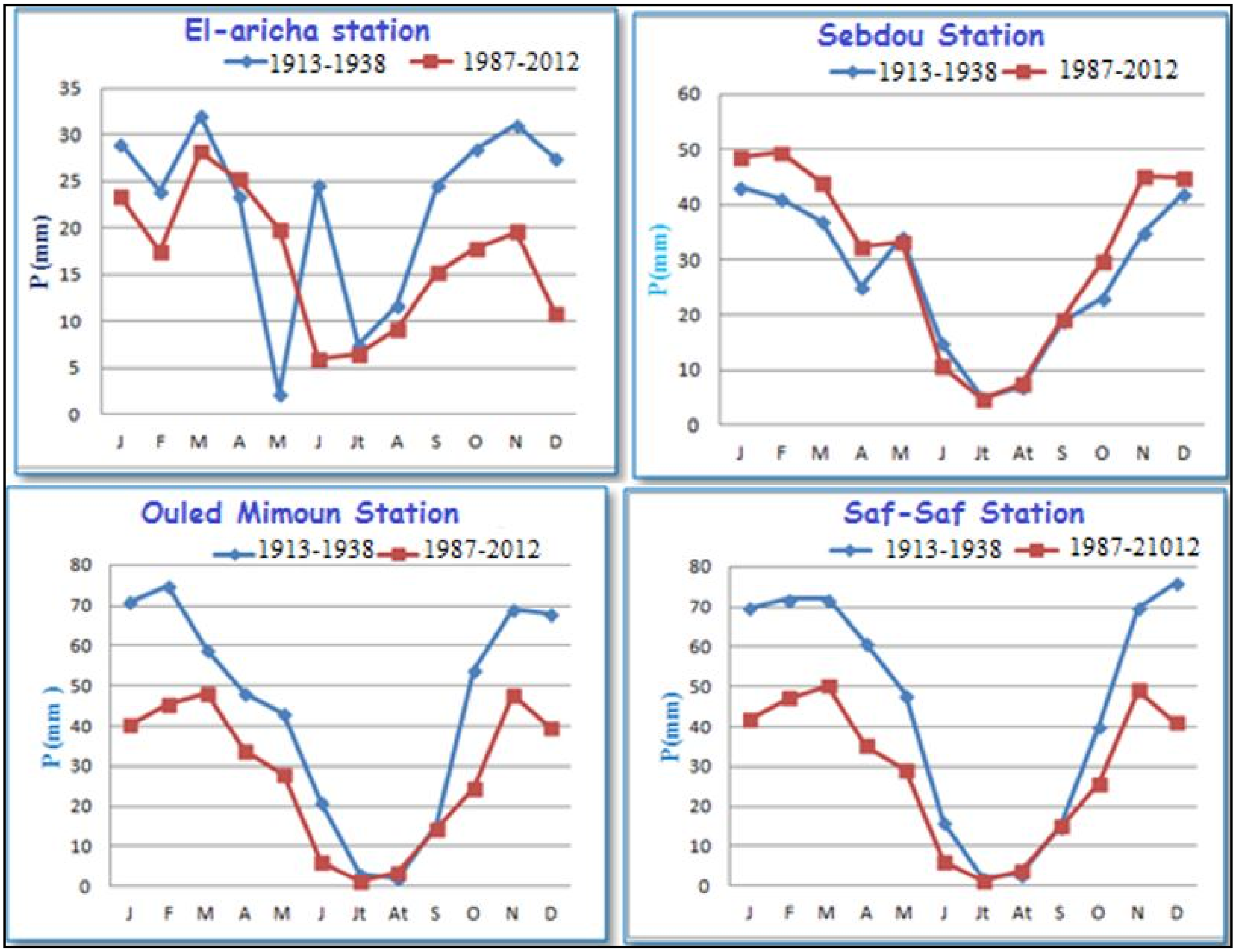

Fig. 2: Average monthly precipitation during both periods.

flourish; if, on the other hand, the amount of rainfall during these two seasons is low, their extension will be poor.

From our results table 4, Fig. 3, we find that the seasonal pattern during the two periods varies between the following types: wsfsu, wfssu and sfwsu.

The first one is of wsfsu type; this regime characterizes the Sebdou and Ouled Mimoun stations with a second maximum of rainfall in spring for the old and new period, and the Saf-Saf station is of wsfsu type for the old period and the El-Aricha station for the new period.

The second is wfssu, indicating the new period of Saf-Saf.

The last type characterizes the old period of El Aricha, with a seasonal fwssu regime.

Temperature :

The temperature is the second constituent factor of the climate influencing the development of vegetation. Average annual temperatures have a considerable

Table 3: Musset Seasonal Relative Coefficient.

Season Station		Winter (W) Ps (mm)	Crs	Spring (S) Ps (mm)	Crs	Summer (Su) Ps (mm)	Crs	Fall (F) Ps (mm)	Crs	Pa (mm)
Saf-Saf	OP	218	1,6	181	1,32	21	0,15	125	0,91	545
	NP	139,1	1,61	70,4	0,81	19,8	0,23	115,3	1,33	345,21
Ouled Mimoun	OP	214	1,62	150	1,13	26	0,19	138	1,04	528
	NP	125,1	1,50	110	1,32	11	0,13	86,5	1,04	332,6
Sebdou	OP	126	1,54	96	1,17	27	0,33	77	0,94	326
	NP	142,75	1,54	109,28	1,18	23,21	0,25	94,02	1,01	369,26
El Aricha	OP	85,1	1,15	70,1	0,94	43,8	0,59	87	1,17	286
	NP	69	1,39	50,89	1,03	30,89	0,62	48,2	0,97	198,98

Table 4: Seasonal Weather Station Regimes.

Station	Pa (mm)	Seasonal plans	
Saf-Saf	545	AP	WSSUF
	345,2	NP	WFSSU
OuledMimoun	528	AP	WSFSU
	332,6	NP	WSFSU
Sebdou	326	AP	WSFSU
	369,26	NP	WSFSU
El -Aricha	286	AP	FWSSU
	198,98	NP	WSFSU

influence on the aridity of the climate.

One of our concerns is to show the importance of thermal fluctuations on the installation and adaptation of species to matorrals.

Average monthly temperatures :

For all four stations, January is the coldest month while August is the warmest month for these stations. Temperatures vary between 5°C in El Aricha and 9°C in Saf-Saf for the old period and with 4.8°C in El Aricha and 9.7°C in Ouled Mimoun for the new period.

The reading of table n° 5 shows us that:

The coldest period is from December to March, the months of July and August considered the hottest months of the year.

The comparison between the average annual

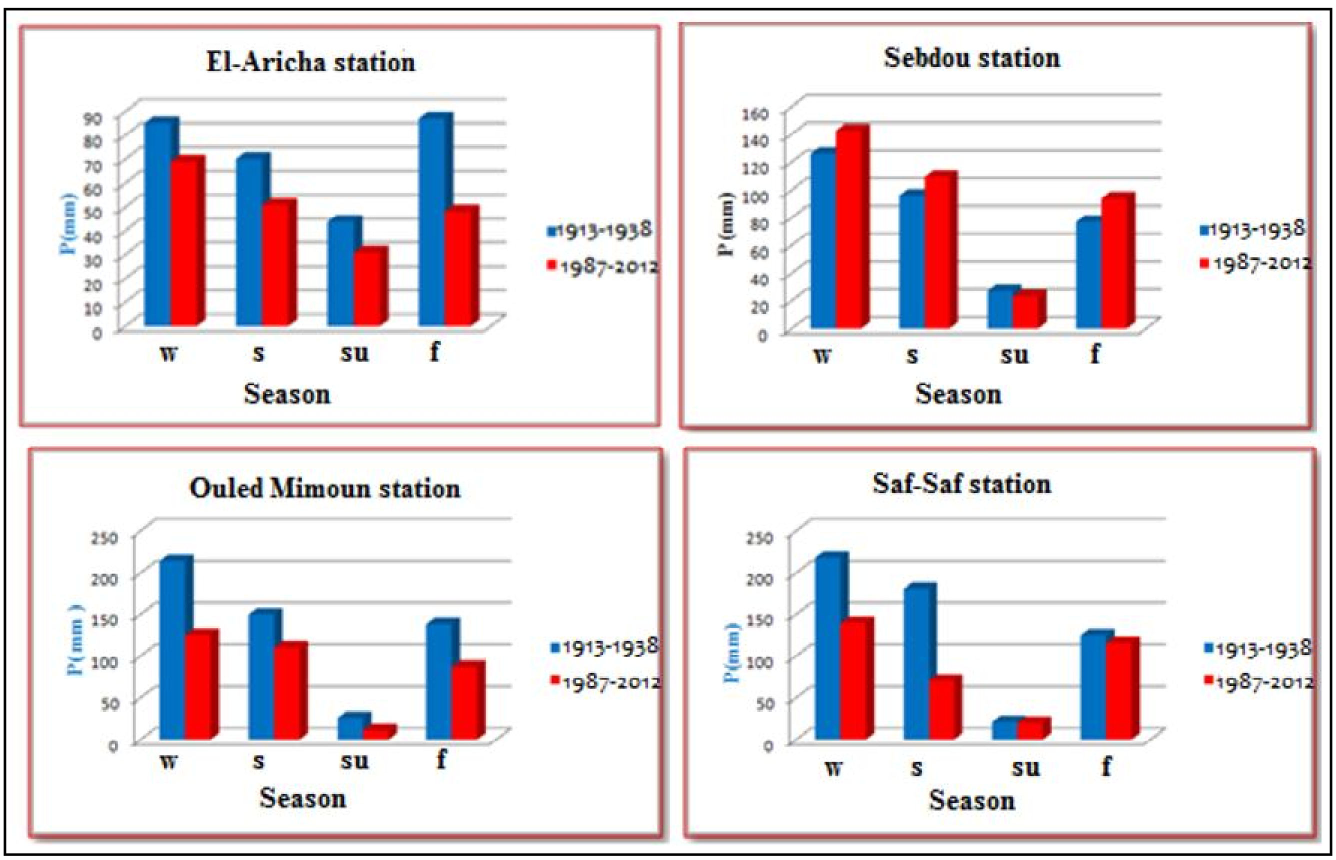

Fig. 3: Seasonal regime.

Table 5: Average monthly and annual temperatures.

Station	Period	J	F	M	A	M	J	Jt	A	S	O	N	D	T⁰C ave. year
Saf-Saf	1913-1938	9	9,5	11,3	14,3	16,8	21,3	24,7	26	22,3	17,9	13,1	10	16,38
	1987-2012	9,14	10,17	12,04	14,1	16,81	19,25	22,15	22,22	19,78	17,21	13,5	9,73	15,50
Ouled Mimoun	1913-1938	8,9	9,8	11,3	14	16,6	20,8	24,4	25,2	21,7	17,2	12,5	9,5	15,99
	1987-2012	9,7	10,8	12,9	15,1	18,2	20,9	24,1	24,1	21,5	18,6	14,6	10,4	16,74
Sebdou	1913-1938	7,5	9,95	8,57	12,25	12,1	21	30,55	23	23,25	18,8	14,5	19,15	16,71
	1987-2012	6,48	7,92	9,33	11,71	14,97	23,74	27,2	28,24	23,82	18,95	14,81	9,76	16,41
El-Aricha	1913-1938	5	5,6	7,85	11,85	15,95	20,35	24,85	24,8	20,05	14,8	7,85	5,2	13,67
	1987-2012	4,8	6,18	9,37	10,9	17,6	21,9	27,7	27	20,7	14,6	8,65	5,5	14,57

temperatures for the two periods allowed us to confirm the presence of a climate change that reflects the increase in average annual temperatures at the stations, especially the of Ouled mimoun and El Aricha.

Thermal amplitudes :

The thermal amplitude has a definite influence on the vegetation; it has a direct action on the biological cycle of the vegetation cover.

It defined by the difference between the extreme maxima on the one hand and the extreme minima on the other. Its value is ecologically important to know; because it presents the extreme thermal limit to which each year the plants must resist (Djabaili 1984).

Continentality Index:

According to Debrach (1959), four types of climates can be calculated from M and m.

· M - m < 15°C : island climate

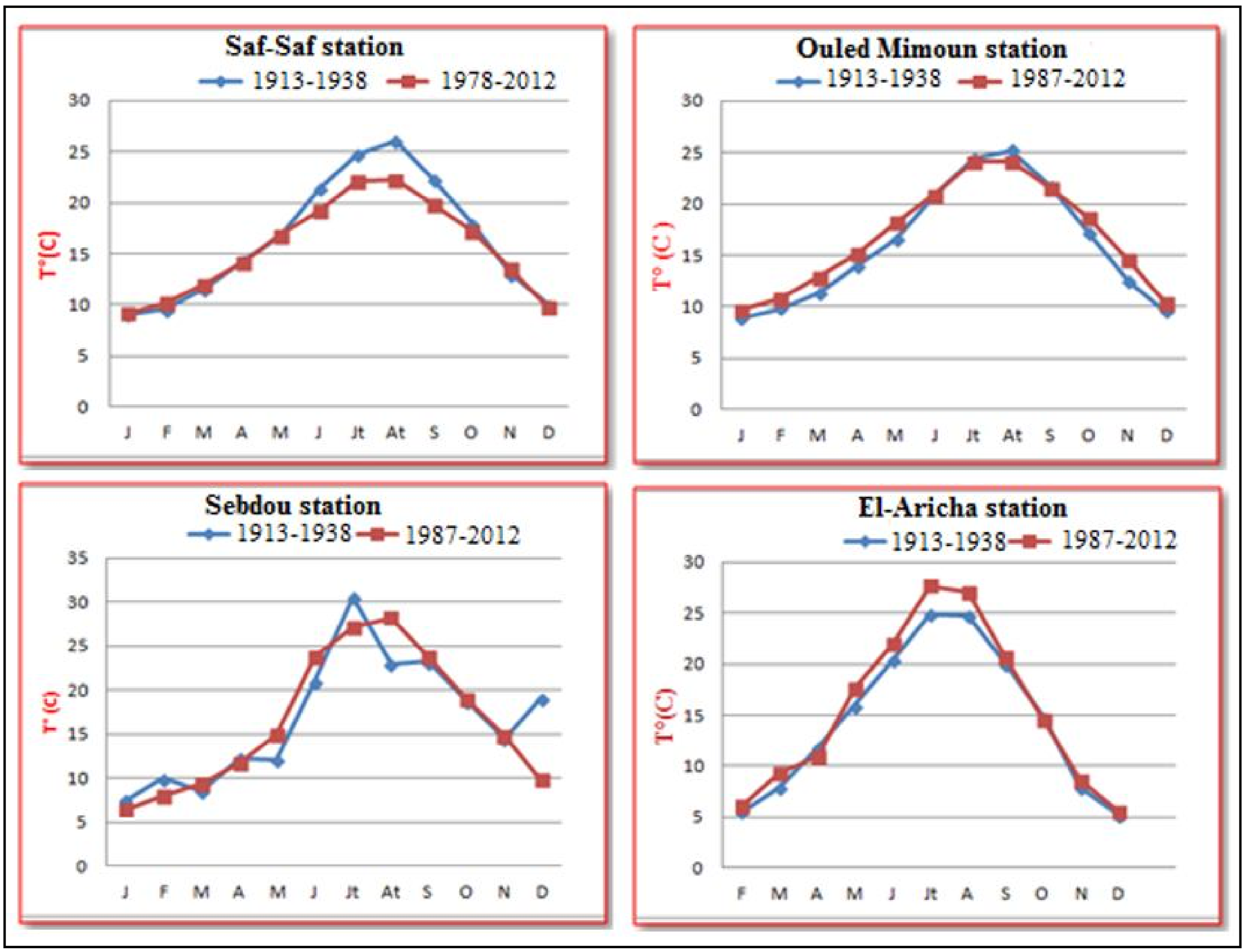

Fig. 4: Average monthly temperatures.

Table 6: Debrach Continentality Index (Old and New Periods).

Station	M°C	m°C	Thermal amplitudes		Climate type
Saf-Saf	32,8	5,8	Old period	27	Semi-continental
	31,25	2,92	New period	28,33	Semi-continental
Ouled Mimoun	33,1	1,8	Old period	31,3	Semi-continental
	32,2	3,5	New period	28,7	Semi-continental
Sebdou	33,88	1,3	Old period	32,58	Semi-continental
	32,35	3,20	New period	29,15	Semi-continental
El Aricha	35.60	-1.5	Old period	37.1	Continental
	32.94	0	New period	32.94	Semi-continental

· 15°C < M-m < 25°C :coastal climate

· 25°C < M-m < 35°C : semi continental climate

This index allowed us to identify stations with continental and semi-continental climates:

All the stations have a semi-continental climate for both periods with the exception of El Aricha which has a continental climate for the old period and a semi-continental climate for the new period.

This semi-continentality leads to the installation of chamaephytes and phanerophytes species characterized by the following species:- *Thymus ciliatus subsp Coloratus.*

- Genista tricuspidata
- Rosmarinus officinalis
- Quercus ilex
- Calicotome intermedia

Wind :

The winds blowing over the zone have various origins depending on their direction (Djabaili 1984).

Winds from the North

In winter, these dry and cold winds penetrate the study area via the Tlemcen Mountains; they favour snowfall at an altitude of over 1,400 metres (Sidi-Djilali). From March-April to October, these winds are hot and sometimes humid because of their passage over the sea; this phenomenon relatively reduces the heat of the summer in the Sebdou area.

Westerly winds

These are the prevailing winds. They blow from southwest to northwest. A large part of the rainfall comes from the forced ascent of these air masses over the Tlemcen Mountains, which allows the area of Sidi Djilali to be relatively wet. They are frequent during the months of November to February.

Winds from the South

Dry and warm, the southerly winds that blow mostly in spring and autumn, sometimes in summer, bring with them a significant amount of sand and silt.

Djebaili in 1984 reported that it is the sirocco, which intervenes with about 15 days in the North and 22 days in the South. This hot current, always dry, is one of the main causes of the near sterility of the high plains. The sirocco is more frequent in the East with 30 days than in the West with an average of 15 d/year. These hot winds blow especially in summer, their maximum frequency occurs in July.

Snow:

Above 600-700 m, snow appears almost regularly every winter where it melts very quickly. It is only on the peaks above 1000 m that snow cover can last (Hadjadj-Aoul 1995) as in the high plains, the snow hardly exceeds 10 cm.

Classification of bioclimatic environments according to "T" and "m":

Rivas Martinez (1981) uses the mean annual temperature "T" with the mean temperature of the minima as a criterion for defining vegetation stages.

· Thermo-mediterranean : T > 16°C and m > + 3°C

· Méso - mediterranean : 12°C < T < 16°C and 0°C < m < + 3°C

Table 7: Vegetation and climate type. (OP Old Period NP New Periods).

Station		T(°C)	m(°C)	Vegetation spreads
Saf-Saf	OP	16,38	4,4	Thermo-mediterranean
	NP	15,48	2.92	Meso- mediterranean
Ouled Mimoun	OP	15,99	1,8	Meso- mediterranean
	NP	16,74	3,5	Thermo- mediterranean
Sebdou	OP	15,69	1,3	Meso- mediterranean
	NP	16,41	3,20	Thermo- mediterranean
El Aricha	OP	13,67	-1.5	Meso- mediterranean
	NP	14,57	0	Meso- mediterranean

· Supra - mediterranean : 8°C < T < 12°C and -32°C < m < 0°C

Based on this scale, we assigned each station its corresponding vegetation stage during the two periods.

The vegetation stage is different from one station to another between meso-mediterranean and thermo-mediterranean.

Bagnouls and Gaussen ombrothermal diagrams:

This is still one of the most widely used graphical representations today. It takes into account the monthly averages of precipitation (p in mm) and temperature (t in °C) and gives a relative expression of the summer drought

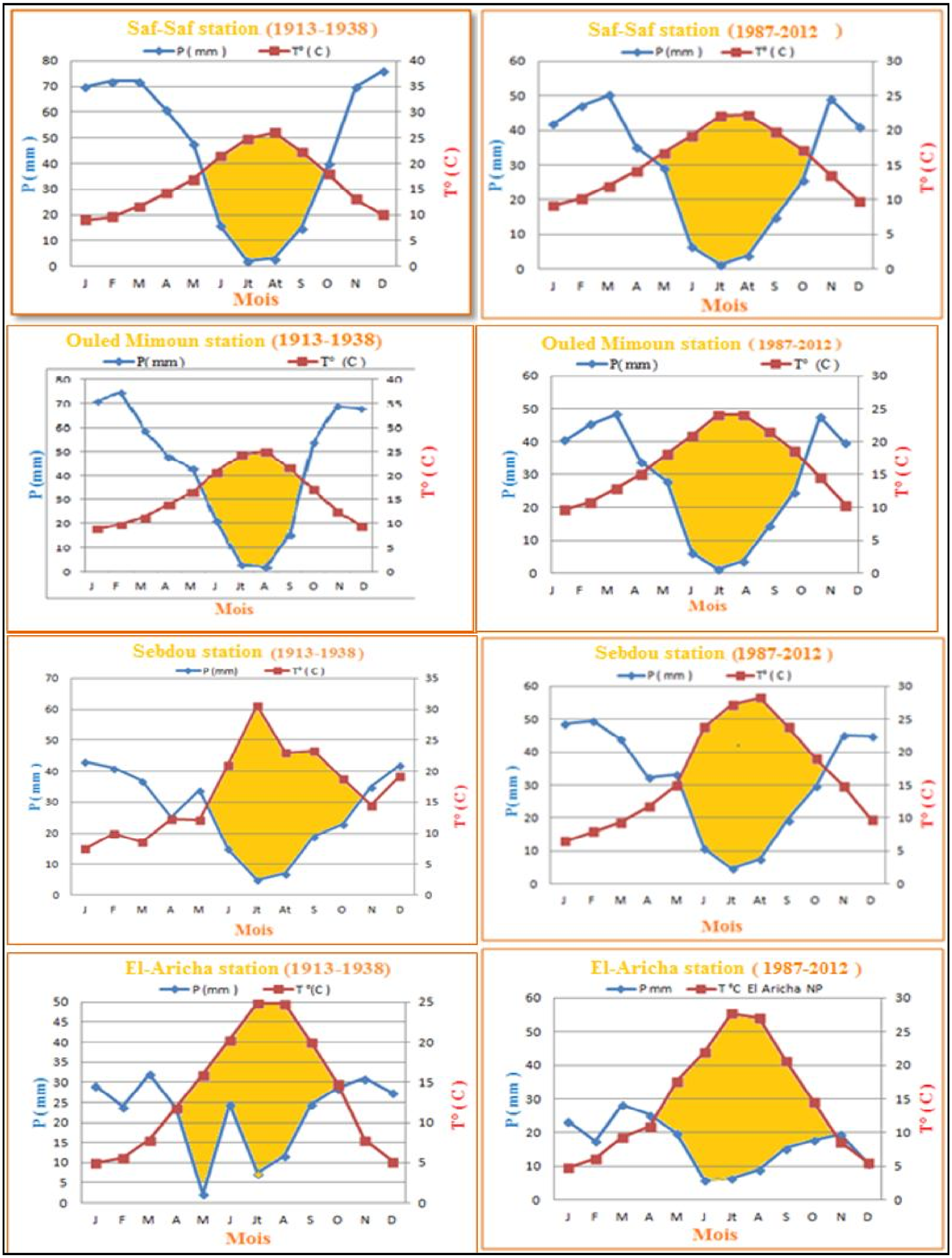

Fig. 5: Ombrothermal diagrams of the different stations.

in duration and intensity (Bagnouls and Gaussen 1953).

Bagnouls and Gaussen (1953), add that a month said to be biologically dry if "the total monthly precipitation expressed in millimeters is equal to or less than twice the average monthly temperature, expressed in degrees centigrade". This formula (P less than or equal to 2T) makes it possible to construct ombrothermal diagrams showing the intensity and duration of the dry season based on the intersections of the two curves.

The comparative analysis of the plots Fig. 5 shows that the dry period centered in the months of June, July and August (A.P.) and lengthens towards spring or towards autumn during late rains (N.P.). This period spread over several months, so we can see that the current dry period is longer than the old one. The drought thus accentuated.

On the ground this results in important modifications of the floristic composition; thus modifying the landscape by imposing a xerophitic vegetation such as:

Genista tricuspidata

-Atractylis humilis subsp caespitosa

Centaurea nicaensis

According to Dimitrakopoulos and Mitsopoulos (2006) in the Mediterranean basin extended summers (from June to October and sometimes longer); with a possible absence of rain and average daytime temperatures well above 30°C reduce the water content of forest litter to less than 5%.

De Martonne's aridity index:

Based on essentially geographical considerations, De Martonne (158), defined the aridity of the climate by the quotient.

Table 8: De Martonne Aridity Index.

Station	Periods	P mm	T+10°C	DE Martonne index.
Saf-Saf	1913-1938	545	26,35	20,68
	1984-2009	345.2	25,48	13,54
Ouled Mimoun	1913-1938	528	25,99	20,31
	1984-2009	332,6	26,74	12,43
Sebdou	1913-1938	326	25,69	12,68
	1984-2009	369,26	26,41	15,60
El Aricha	1913-1938	286	23,67	12.53
	1984-2009	198,98	24,57	8.05

$I = P / (T + 10)$

P : Average annual rainfall (mm)

T : Average annual temperature (C)

Aridity increases as the index value decreases.

At the global level, De Martonne proposed six main types of macroclimates ranging from arid desert areas (I < 5) to humid areas with predominantly forest (I > 40).

For the old period (1913-1939), this index goes from 12.53 mm/°C at El-Aricha to 20.68 mm/°C at Saf-Saf.

For the new period (1987-2012), this index goes from 8.05 mm/°C at El-Aricha to 13.54 mm/°C at Saf-Saf, their regime is of semi-arid type Fig. 11, which induces the predominance of herbaceous plants in the floristic procession of the matorrals of the south of Tlemcen.

Emberger Xerthermic Index:

According to Godron in Daget the summer drought is the first discriminating feature of the Mediterranean.

Table 9: Drought Indices at Resorts.

Station		PE (mm)	M(°C)	Is
Saf- Saf	Old period	20	32,8	0,60
	New period	19.98	31,2	0,64
Ouled Mimoun	Old period	20	32,8	0,60
	New period	19,2	32,2	0,59
Sebdou	Old period	31	33,88	0,91
	New period	31,87	32,35	0,98
El Aricha	Old period	43,8	35.60	1,23
	New period	30,89	32.94	0,93

It expressed using the Emberger coefficient.

$I_s = PE / M$

Where PE is the sum of the average summer precipitation and M is the average maximum temperature of the warmest month.

These low drought index values table 9 confirm the scarcity of rainfall, high heat and the extent of the dry season.

On this subject, Bouazza (1995) has highlighted a list of species in relation to the drought index *Chamaerops humilis* 0.54 < Is < 0.80.

Calycotome intermidea 0.52 < Is < 0.77

Ampelodesma mauritanicum 0.80 < Is < 1.28

Thymus ciliatus subsp. *Coloratus* 0.40 < Is < 0.71

Quercus ilex 0.69 < Is < 1.28

Juniperus oxycedrus subsp *oxycedrus* 0.56 < Is < 1.38

Emberger Quotient :

It is particularly suitable for Mediterranean regions where it allows distinguishing different bioclimatic stages.

In these regions, Emberger noted that the thermal amplitude (M - m) is an important factor in plant distribution. Indeed, Emberger's index takes into account

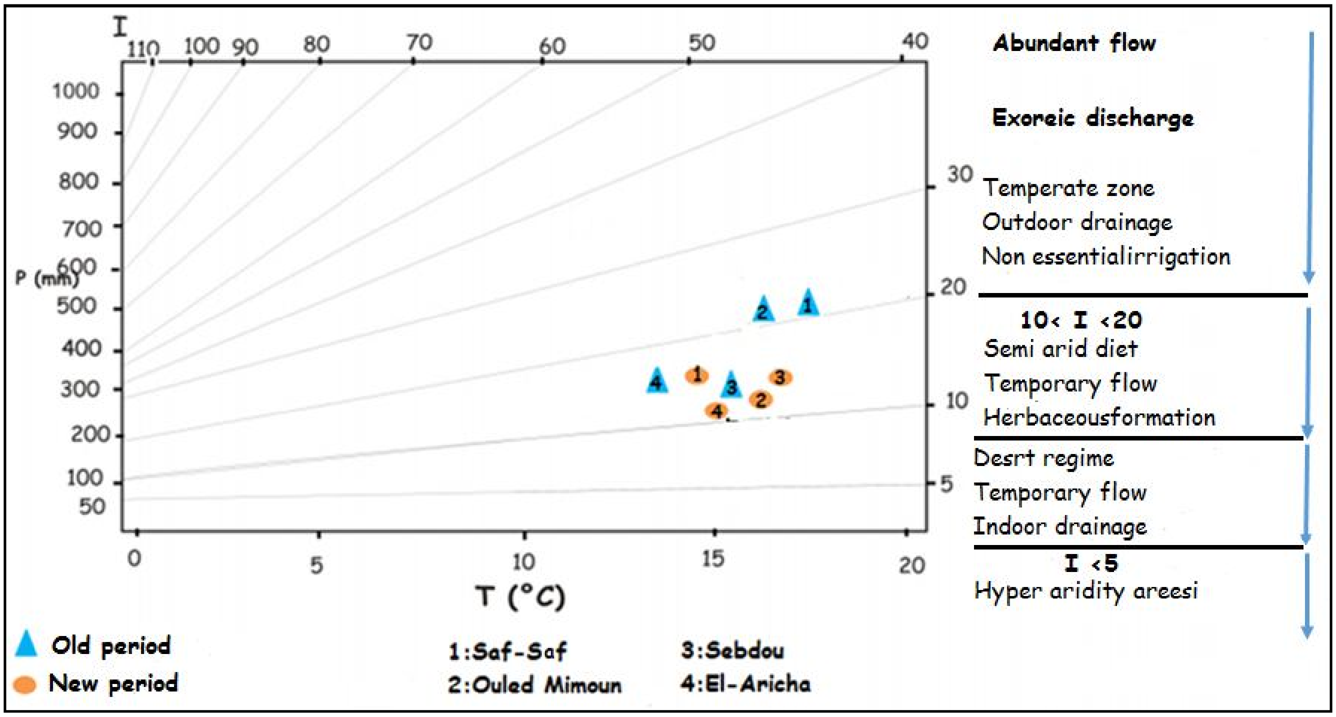

Fig. 6: DE MARTONNE Aridity Index.

the annual precipitation P, the average of the temperature maxima of the hottest month (M in °C) and the average of the temperature minima of the coldest month (m in °C) Dimitrakopoulos and Mitsopoulos (2006).

The Emberger index Q2 given by the formula

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

P: average annual rainfall

M: average of the highest month's maximums (T+273°K)

m: average of the minimums of the coldest month (T+273°K)

According to the Emberger climagram Fig. 7 there is a difference between the stations in the area; these are marked by more aridity with a harsh winter.

Table 10: Emberger Quotient.

Station		Q_2	Etages bioclimatiques
Saf-Saf	Old period	70,68	Subhumide in temperate winter
	New period	41,98	Semi-arid in cool winter
Ouled Mimoun	Old period	65,52	Subhumide in temperate winter
	New period	39,84	Semi-arid in temperate winter
Sebdou	Old period	34,43	Semi-arid in temperate winter
	New period	43,56	Semi-arid in cool winter
El Aricha	Old period	26,57	Semi-arid in cold winter
	New period	20,86	Arid in cool winter

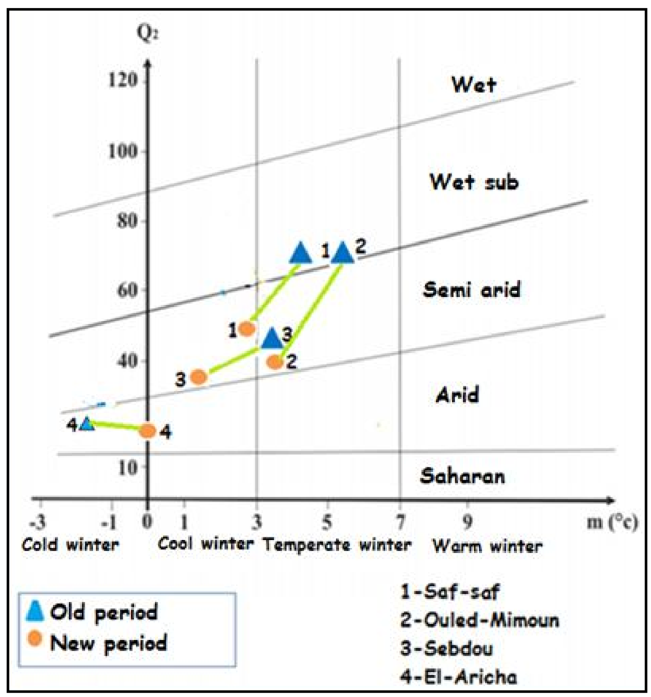

Fig. 7: Emberger Climogram.

The reading of the rainfall climate diagram shows that :

- El-Aricha station goes from semi-arid to cold winter to arid to cool winter.

- The station of Sebdou moves from semi-arid to temperate winter to semi-arid to cool winter.

- The station of Ouled-Mimoun underwent a shift from the subhumid bioclimatic stage to temperate winter to semi arid to cool winter.

- Finally, the station of Saf-Saf went from sub humid to temperate winter to semi-arid to cool winter.

Conclusion

Recent studies on global change have shown that the Mediterranean region can be subject to complex climatic variations.

According to Velez (1999), climatic conditions were particularly unfavorable during the 1980s, characterized by extremely severe droughts, which strongly affected all the countries of the Mediterranean basin, especially Morocco, Algeria, Portugal, Spain and France.

The simple interpretation on a macro or mesoscale and comparisons between remote stations could be made.

This work allowed confirming the warming trend and especially the drying up, aridification, and their impact on the floristic procession of matorrals in the study area.

The first long, dry season generally begins in May and lasts until October, while the second short, wet season characterized by monthly rainfall oscillations with short dry spells and rainfalls.

Seasonal rainfall shows that, overall, the autumn (A) and winter (H) seasons are the wettest.

According to Debrach's (1959) thermal classification, we have two types of climate, namely semi-continental and continental.

Benabadji and Bouazza (2000) point out that the effects of the xerothermic summer attenuated by relative humidity, especially when a forest or forest meadow cover exists.

Le Houerou (1971) underlines, in the light of this, the consequences of the climate that are at the origin of one of the essential mechanisms of the degradation of Mediterranean vegetation in general.

Faced with this climatic evolution, the response of plants will obviously not be unequivocal and species, or even populations, will react individually.

According to Huntley (1991), three non-mutually exclusive possibilities must be considered:

- A reduction of the plant cover;

- A migration or a modification of its range;

- Adaptation to new environmental conditions through an evolutionary response.

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