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Pluviometric Regime Evolution in the North of Algeria

تغيرات نظام التساقط المطري في شمال الجزائر

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ABSTRACT: Western Algeria has been experiencing drought since the middle of 1970's, which is characterized by severity and a remarkable persistent of rainfall deficit. The effects of this drought are also felt in the extreme east. The aim of this study is to identify the variations of climate in order to predict and analyze their impact on water resources in future work. The selected study area includes 15 basins of the North of Algeria. Rainfall data from 86 precipitation stations with low precentages of missing data were used in this study. All of these stations' data have been utilized at least over the period 1930-1999/2000, on which the study focused. To explore rainfall variability, long series of rainfall on annual, seasonal, and monthly scales were subjected to statistical tests for detecting breaks in those series. Statiscal methods used are U Buishand, the non-parametric test of Pettitt, the procedure of Bayesian Lee and Heghinian and the procedure of segmentation of Pierre Hubert. The univariate analysis showed a change in the rainfall pattern in the western region since 1975. However, in east of Algeria, no break was detected by the application of these methods.

Keywords: *Rainfall patterns, drought, Statistical test, North of Algeria.*

المستخلص: تتعرض منطقة الغرب الجزائري منذ منتصف السبعينات من القرن الماضي لظاهرة جفاف تميزت بحدة قصوى وديمومة في انخفاض معدلات الأمطار، كما تعرضت الجهة الشرقية لنفس الظاهرة، وإن لم تكن بالحدة نفسها. هدف هذا البحث إلى دراسة التغيرات المناخية والتي ستكون عاملاً أساسياً للتنبؤ وتحليل تأثيراتها على الموارد المائية في الدراسات المستقبلية. تحتوي منطقة الدراسة على 15 حوض تصريف في منطقة الشمال الجزائري، ولانجاز هذه الدراسة تم الاستعانة ببيانات 86 محطة قياس للأمطار جميعها يحتوي على بيانات تغطي الفترة من 1930-1999/2000 على الأقل. ولدراسة هذه التغيرات والتعرف عليها، تم إخضاع البيانات السنوية، والفصلية، والشهرية لتحليل إحصائي باستخدام عدة طرق إحصائية، وهي Statistics U Buishand. the non-parametric test of Pettitt. the procedure of Bayesian Lee and Heghinian and the procedure of segmentation of Pierre Hubert. ولقد أظهرت نتائج التحليلات الإحصائية الأحادية المتغير تغير في نظام الهطول المطري في الناحية الغربية من البلاد ابتداءً من سنة 1975، أما في الناحية الشرقية فلم يلاحظ تغير معنوي في الهطول المطري، إلا أنه قد ثبت تناقص في مستوى التساقطات وإن لم تكن بنفس الحدة التي شهدتها المناطق الغربية والوسطى.

كلمات مدخلية: *أنظمة تساقط مطري، جفاف، طرق إحصائية، الشمال الجزائري.*

INTRODUCTION

The northern part of Algeria is characterized by a Mediterranean climate with a relatively cold and rainy winter, warm and dry summer. The total average rainfall reaches about 400 mm in the west, about 700 mm in the center and about 1000 mm in the east at the coast. This type of climate also predominates the mountain chains of Tell Atlas, where on the eastern summits the total rainfall varies from 800 to 1600 mm, while the values are lower towards the center (700 to 1000 mm) and towards the west (600 mm).

At the plains of the Tell Atlas, the total rainfall varies from about 500 mm in the west, to about 450 mm in the center, and to about 700 mm in the east. The Saharan Atlas is distinguished by a very hot and dry summer, mild in winter with low rainfall.

The region of Western Algeria has been experiencing drought since the middle of 1970's, which is characterized by severity and remarkable persistent of rainfall deficit. The effects of this drought are also felt in the extreme east. The aim of this study is to identify the variations of climate in order to predict and analyze their impact on water resources.

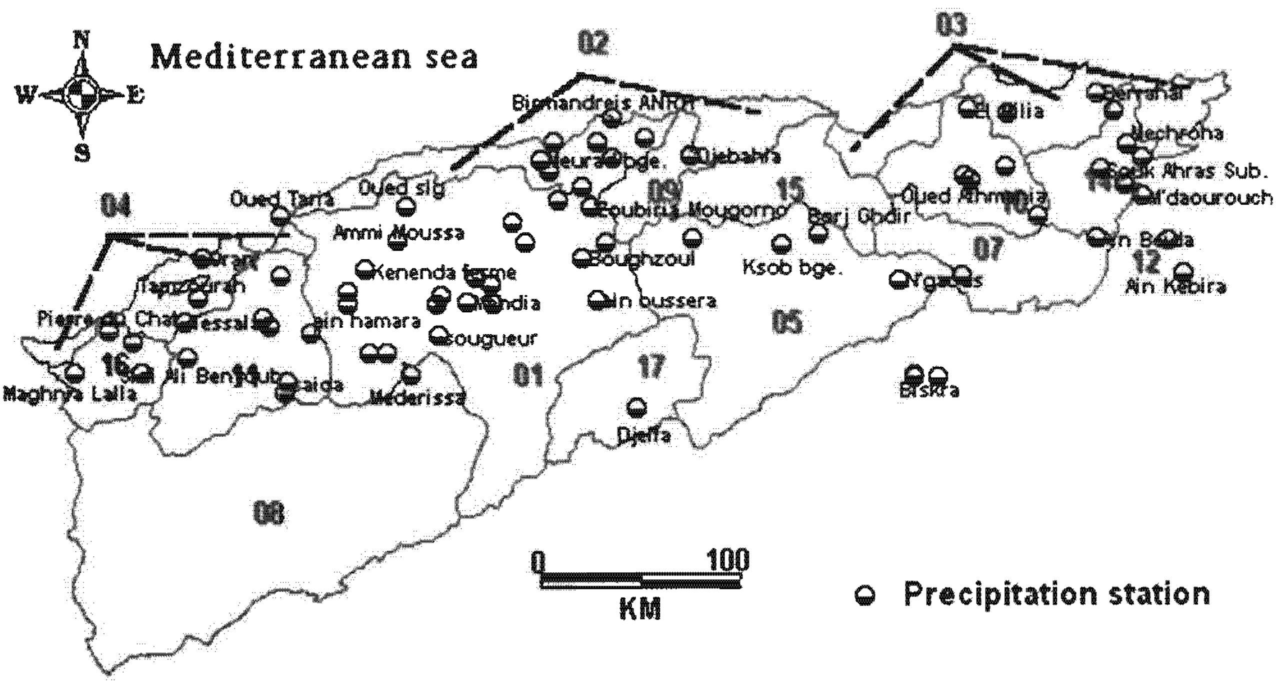
MATERIALS AND METHOD

Study Area

The selected study area lies between longitudes 2° 20' 76 " W and 8° 65' 06" E, and latitudes 32° 73' 44" N and 37° 03' 46" N (Figure 1). It includes 15 major basins, and is characterized by contrasting relief with a total area of about 235273 km^2. Rainfall rates increase from the west to the east, and are concentrated between the period from September to May.

Data

Study of the impacts of climate change in terms of rainfall variation requires a long-term and extensive data series. In order to ensure a good representation of the studied region, 92 rainfall stations with the longest recording periods possible were chosen. Out of these, stations with large number of missing data were rejected (5 years). The final number of the retained stations for the study was 54 rainfall stations distributed throughout the northern of Algeria.



Figs. 1. Studied Areas and the Used Rainfall Stations.

Statistical Methods

We will treat the totality of the information contained in the selected series. The study is conducted by the application of statistical tests for detecting breaks in the series of rainfall at different scales. The choice of methods depends on the robustness of their foundation.

The statistical methods that are used inlcude the statistic U of Buishand (Buishand 1982; 1984) the test of Pettit (Pettit, 1979), the Bayesian method of Lee and Heghinian (Lee and Heghinian, 1977) and the segmentation procedure of Hubert (Hubert, *et al.* 1989; Hubert, 1997).

The power and robustness of these statistical methods have been the subject of the work made by Niel-lubés, *et al.* (1998), and most recently has been the subject of a specific assessment with a decline of 10 years (Hubert, *et al.* 1998) and their application in Algeria (Meddi and Hubert, 2003).

1. Pettitt Test (Pettitt, 1979, in: Aka, *et al.* 1996)

Pettitt considered a sequence of independent random variables $X_1, X_2, \ldots, X_n$. "The sequence is said to have a change point at τ if X_t for t= 1, …, τ have a common distribution function, F_1 (X), and X_t for t = τ +1,…, N have 0 common distribution, F_2 (X), and $F_1(X) \neq F_2(X)$. We consider the problem of testing the null hypothesis of "no-change", H: τ = N against the alternative of "change", A: $1 \leq \tau < N$, using a non-parametric statistic. We make no assumptions about the functional forms of F_1 and F_2 except that they are continuous". Pettitt describes how "a version of the Mann-Whitney statistic can be utilized for the problem in question and derives approximate significance probabilities for testing "no change" against "change".

"Let $D_{ij} = \text{sgn}(X_i - X_j)$ where sgn (X) = 1 if X > 0; 0 if X = 0 and -1 if X < 0, then consider

$$U_{t,N} = \sum_{i=1}^{t} \sum_{j=t+1}^{N} D_{ij}$$

the statistic $U_{t,N}$ is equivalent to a Mann-Whitney statistic for testing that the two samples $X_1, \ldots, X_t$ and $X_{t+1}, \ldots, X_N$ come from the same population. The statistic $U_{t,N}$ is then considered for values of t with $1 \leq t < N$". Pettitt proposed "for the test of H: " no change" against A: "change", the use of the statistic:

$$K_N = \max_{1 \leq t < N} |U_{t,N}|$$

Using the theory of ranks, pettitt gave "the significance probability associated with the value K of K_N approximately by:

$$\text{Pr}ob(K_N > k) \approx 2\exp(-6k^2/(N^3 + N^2))$$

Given a risk, α, of first kind, the null hypothesis is rejected, if the estimated probability of exceeding the value *K* is inferior to α. if so, the series includes a break that takes place at the time τ when K_N is observed.

2. Lee and Heghinian Bayesian Method (Lee and Heghinian, 1977, In: Aka, *et al.* 1996)

The Lee and Heghinian Bayesian method proposes a parametric approach. It requires a normal distribution of values of series. The basic model of the procedure is as follows:

$$X_i = \begin{cases} \mu + \varepsilon_i & i = 1, \ldots, \tau \\ \mu + \delta + \varepsilon_i & i = \tau + 1, \ldots, N \end{cases}$$

Where the ε_i are independent and normally distributed, of zero mean and variance σ^2. τ and δ represent respectively the position in time and the magnitude of a possible change of the mean.

The approach is based on the marginal posterior distributions of τ and δ (Lee and Heghinian, 1977). This study was limited to the posterior distribution of τ. When the distribution is unimodal, the date of the break is assessed by the mode of the posterior distribution of τ. This assessment is more accurate when the dispersion of the distribution is low.

3. The Buishand Statistics (Buishand, 1982, 1984, in: Aka, *et al.* 1996)

Buishand's statistic comes from an original formulation given by gardner (1969): "Gardner's statistic for a two-sided test on ashift in the mean at unknown point can be written as:

$$G = \sum_{k=1}^{N-1} Pk\{S_K/\sigma_X\}^2 \text{ with } S_K = \sum_{i=1}^{N} (Xi - \overline{X})$$

Where Pk denotes the pior probability that the shift occurs just after the K^{th} observation".This formulation supposes that the variance σ^2_x is known. If it is unknown, it can be replaced by the sample standard deviation, D_X, and, if a uniform prior distribution is chosen for Pk, one obtains the statistic U defined by:

$$U = \frac{\sum_{k=1}^{N-1}(Sk/Dk)^2}{N(N+1)} \quad \text{with } D_X^2 = \sum_{i=1}^{N}(X_i - X)^2/N$$

Critical values of the statistic U were first given by Buishand (1982) from a Monte Carlo procedure. Improved critical values are given in Buishand (1984).

In addition to these different methods, the construction of a control ellipse allows an analysis of the homogeneity of the (X_i) series. The Sk variable, which is defined within the framework of Buishand Statistic, follows a normal distribution of zero mean and variance $k(N - k)N^{-1}\ \sigma^2$, k = 0,..., N under the null hypothesis of the homogeneity of the X_i series.

This control ellipse was used here only to estimate visually the importance of the deviations under the null hypothesis of the homogeneity of the series.

Before using these methods concerned with the homogeneity of the series, the correlation test on rank (Kendell and Stuart, 1943; WMO, 1966) was systematically used, enabling an evaluation of random character of the series X_i. This test is based on the calculation of the number of pairs P for which $X_j > X_i$ (j > 1 with i = 1,..., N – 1). Under the null hypothesis, the ω variable is defined as:

$$\omega = \frac{4P}{N(N-1)} - 1$$

Follows a normal disrtribtion with a zero mean and a variance equal to:

$$\frac{2(2N+5)}{9N(N-1)}$$

The alternative hypothesis of this test is a trend.

4. Segmentation of Hubert (Hubert, *et al.* 1989, 1998; Hubert, 1997; Zbigniew, *et al.* 2000).

Given a time series composed of n numerical values: X_i I = 1, 2,...., n. A series XI, $i_1 \le i \le i_2$ where $i_1 \ge 1$ and $i_2 \le n$ is called a segment of the initial series. Each division of the initial series into m segments constitutes an m-order segmentation of this series. Thus, given a particular m-order segmentation of the series, and given i_k, k=1, 2,..., m, the rank in the initial series of the extreme end of the k-th segment (by convention, we will pose i_0=0),

$$i_0 = 0 \prec .... \prec i_k ...... \prec i_{m-1} \prec i_m = n$$

One can note $n_k = i_k - i_{k-1}$ the length of the k-th segment, and X_k its mean (local mean):

$$X_K = \left(\sum_{j=i_{k-1}+1} X_i\right)/n_K \quad \text{Let} \quad d_K = \sum_{i=i_{k-1}+1}(X_i - X_k)^2$$

and define the quantity:

$$D_m = D(i_1, i_2, ..., i_m) = \sum_{k=1}^{k=m}\sum_{i=i_{k-1}+1}^{i=i_k}(X_i - X_k)^2 = \sum_{k=1}^{k=m} d_k$$

as the quadratic deviation between the series and the considered segmentation. This deviation depends only, for a given series, on the adopted segmentation.

For m=1 and m=n, there is only one possible segmentation:

$$D_1 = D(i_1) = n\sigma^2 \quad i_0 = 0 \quad i_1 = n$$

Where σ is the standard deviation of the initial series and:

$$D_n = D(i_1, i_2, ..., i_n) = 0 \quad i_0 = 0 \quad i_1 = 1, ..., i_n = n$$

For any order m between 1 and n, there exist several possible segmentations.

RESULTS AND DISCUSSION

Variability of Annual Rainfall

North Algeria is subject to irregular spatial and temporal variations of rainfall. To characterize this inter-annual variability, we defined the various descriptive characteristics of rainfall series with a common observation period, chosen between the years 1930 and 2000.

To assess the variability of annual rainfall, we used simple climate formulas that are able to give a good information to allow effective representation of the phenomenon. We used the coefficient of variation expressed as a percentage. The coefficient of variation varies between 20% and 49% at Souk Ahras station (in the east of Algeria) and at the level of Biskra station (northern boundary of Sahara), respectively (Figure 2).

To understand the significance of the spatial and temporal relationships between precipitation and their variability, we have studied the relationship between the coefficient of variation and the geographic position of stations, as follows:

1- In the region which lies between meridians 0° 55' W and 1° 60' E, the variability is very important and irregular. The coefficient of variation varies between 25% and 45% at Mederissa station and at Tessala station, respectively. The annual rainfall varies from 280.2 mm at Rechaiga station to 566.1 mm at Aouf station.

2– In the region located between meridians 1° 60' E, and 3° 80' E, the variability is regular and near to normal. The coefficient of variation varies between 24% and 30% at Djebahia station and the station of Algiers, respectively. The rainfall is relatively high with a regional average of 640.8 mm.

3– in the region between meridians 3° 80' E and 6° 07' E, the rainfall is the lowest in studied area and the variability is larger. The rainfall varies between 126.7 mm at Biskra station and 384.4 mm at Borj Ghdir station. The coefficient of variation exceeds 49% at the station of Biskra.

4- Between meridians 6° 07' E and 8° 00' E there is an irregular variability ranging between 20% and 36% at Souk Ahras station and Ain Kebira station, respectively. The annual rainfall is very irregular ranging between 355.1 mm and 1021.7 mm.

The study of the inter-annual variability over the period 1930-2000 for the central and western regions of North Algeria shows that the largest number of deficit years is observed during the 1940's, the 1980's and the 1990's . Between these three major droughts periods, rainfall was generally normal or in excess of the average. At Ain Fekan station, 7 consecutive wet years between the late 40's and early 50's are registered. The driest hydrological year, since 1930, is observed in the early 80's (1982-1983); during this year, the annual rainfall reached a low of 32.5 mm at Oued Taria station. This was the case of several stations in the Maghreb and in the Sahel.

In the extreme east, the variations are not similar to the other two regions. The difference is in that this area has experienced at first an increasing rainfall trend that started in the late 40's and continued until the late 1950's. From that date until the mid-1970, there was a rainfall decreasing trend. It should be emphasized that the second trend is neither exceptional nor characteristic in the east of Algeria.

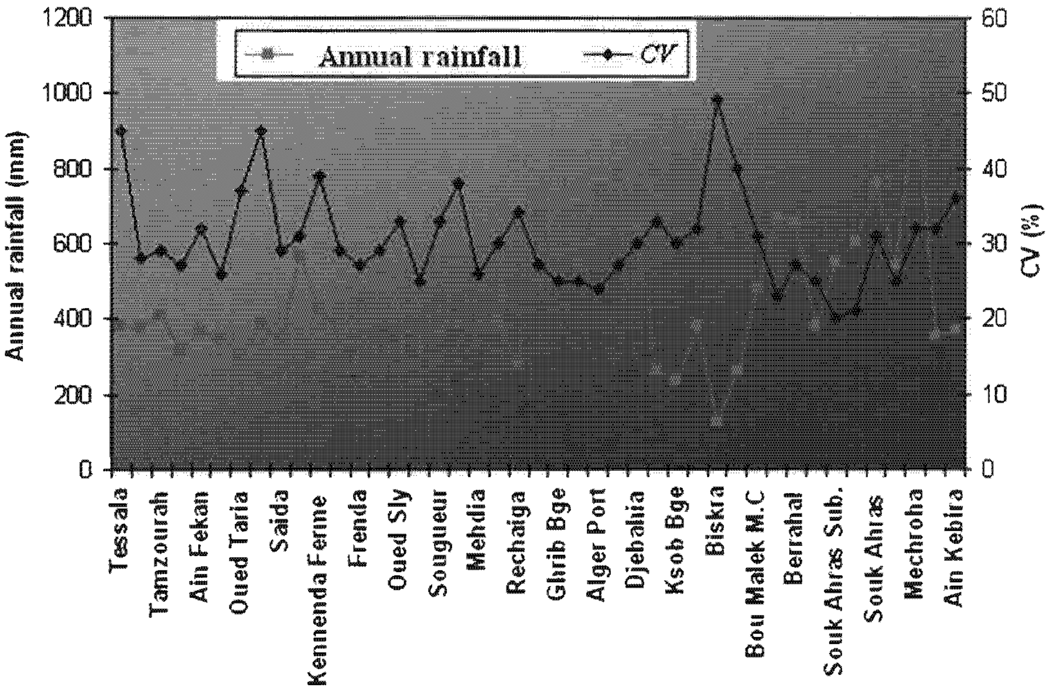
Detection of Discontinuities within Series

Climatic changes of recent decades had a negative influence on water resources (groundwater recharge and dams filling), as well as agricultural yield (Ketrouci, 2002). These changes urged decision-makers to review the types of crops that can adapt to the new climate at certain regions of the country, particularly west of Algeria.

The stationarity or non-stationarity of rainfall series is of great interest for specialists in different water-related disciplines and applications (i.e., hydrology, agriculture, water resource management, etc...). The detection of one or more break in the rainfall series gives information on the evolution and trends of rainfall in a given region. This break can be considered as due to change in the parameters of the probability law of the random variables. In this part, an attempt is made to show this evolution by the determination of the year or years of break in the rainfall series and determine the seasonal and monthly evolution that have influence on vegetative cycle and the renewability of water resources.

Table 1. Descriptive Characteristics of Annual Rainfall Series.

Station	Averagee	Minimum	Maximum	Standard Deviation	CV	max/min
Rechaiga	280.24	104.18	503.45	96.30	0.34	4.8
Mehdia	386.98	203.80	735.20	101.00	0.26	3.6
Sougueur	361.49	115.50	730.50	120.87	0.33	6.3
Dahmouni Trumulet	418.95	176.20	748.40	118.02	0.28	4.2
Colonel Bougarra	335.57	173.30	527.10	83.12	0.25	3.0
Tissemsilet	394.83	169.60	784.70	118.60	0.30	4.6
Boughzoul	195.75	81.30	359.00	62.56	0.32	4.4
Zoubiria Mougorno	540.65	239.10	932.70	137.23	0.25	3.9
Ghrib Bge.	510.77	251.10	868.30	127.54	0.25	3.5
Oued Sly	349.70	129.60	611.10	116.31	0.33	4.7
Sidi Hosni	387.56	129.40	763.70	146.18	0.38	5.9
Ammi Moussa	380.88	192.80	627.50	111.49	0.29	3.3
Kenenda Ferme	423.64	102.90	894.00	165.38	0.39	8.7
Frenda	437.57	237.30	705.10	116.03	0.27	3.0
Ain El Haddid	374.22	169.80	627.00	110.07	0.29	3.7
Meurad Bge.	671.64	366.00	1196.60	183.00	0.27	3.3
Hamiz Bge.	783.91	388.00	1389.50	208.72	0.27	3.6
Alger Port	745.67	439.30	1264.10	180.65	0.24	2.9
Zardesas Bge.	669.87	333.60	1095.80	152.42	0.23	3.3
Berrahal	653.18	261.60	1212.50	179.12	0.27	4.6
Tamazourah	409.62	165.70	720.20	118.24	0.29	4.3
Stidia	363.84	123.90	645.40	121.08	0.33	5.2
Oran	375.80	167.30	661.00	114.36	0.30	4.0
Ain Ouessara	262.57	110.43	556.40	86.64	0.33	5.0
Borj Ghdir	384.40	119.70	783.10	122.67	0.32	6.5
Ksob Bge.	235.56	89.40	403.90	69.64	0.30	4.5
N'gaous	261.85	16.60	653.05	105.85	0.40	39.3
Constantine	511.36	291.00	889.30	117.01	0.23	3.1
Tadjmout 2	157.32	5.50	337.50	75.45	0.48	61.4
Biskra	126.66	14.63	351.10	62.31	0.49	24.0
Biskra secteur	110.22	6.31	238.63	41.38	0.38	37.8
Ain Beida	380.65	160.50	691.50	94.58	0.25	4.3
Mederissa	326.35	159.70	595.50	82.31	0.25	3.7
Djebahia	640.60	335.50	1389.10	193.05	0.30	4.1
Oued Athmania	417.61	119.03	1194.60	173.67	0.42	10.0
Bou Malek M.C.	483.37	204.60	847.15	148.14	0.31	4.1
Sidi Ali Ben Youb	377.56	79.90	621.20	104.30	0.28	7.8
Tessala	440.70	134.30	953.99	161.63	0.37	7.1
Ain El Hadjar	384.00	54.80	997.80	174.44	0.45	18.2
Saida	342.26	157.90	595.60	97.72	0.29	3.8
Oued Taria	304.47	32.50	582.90	113.45	0.37	17.9
Ain Fekan	368.89	166.00	616.60	118.48	0.32	3.7
Aouf M.F.	566.14	205.90	991.20	175.72	0.31	4.8
Bouhanifia Bge.	321.11	135.00	479.00	87.34	0.27	3.5
Mohamadia GRHA	347.94	165.60	515.90	89.56	0.26	3.1
Souk Ahras Sub.	551.39	344.31	922.80	111.58	0.20	2.7
Souk Ahras	757.98	369.80	1389.70	231.77	0.31	3.8
Ain Kebira	365.77	155.90	746.20	133.24	0.36	4.8
Boukhadra	355.11	158.21	761.50	115.16	0.32	4.8
Mechroha	1021.66	298.60	1811.30	326.24	0.32	6.1
Bouchegouf	543.94	279.30	838.56	136.37	0.25	3.0
Ain Berda	606.37	360.60	880.25	127.02	0.21	2.4
Maghnia	397.83	143.90	724.80	142.04	0.36	5.0
Djelfa	263.64	42.30	688.05	114.47	0.43	16.3



Figs. 2. Relation Between Annual Rainfall and Cefficient of Variation.

Annual Scale

Applied to each post, generally, the results of these tests are consistent in the recognition of a disparity in the series, even if the date of break for several tests differs, sometimes, by few years. To interpret these results, we have sketched a map on which we show the obtained results (Figure 3). In the eastern region of Algeria, and more specifically, the area between longitudes 6° E and 8° E no significant break could be detected in spite of the decrease in annual rainfall during the last two decades of the last century.

Moreover, any break in the rainfall regime has been highlighted by a similar study conducted in the central region of Tunisia using the same statistical tools (Kingumbi, *et al.* 2001). For the rest of the Algerian territory and for all the tests, the point of change occurred during the decade 1970-1980, and since then the drop in the annual rainfall has become more clear and a reality.

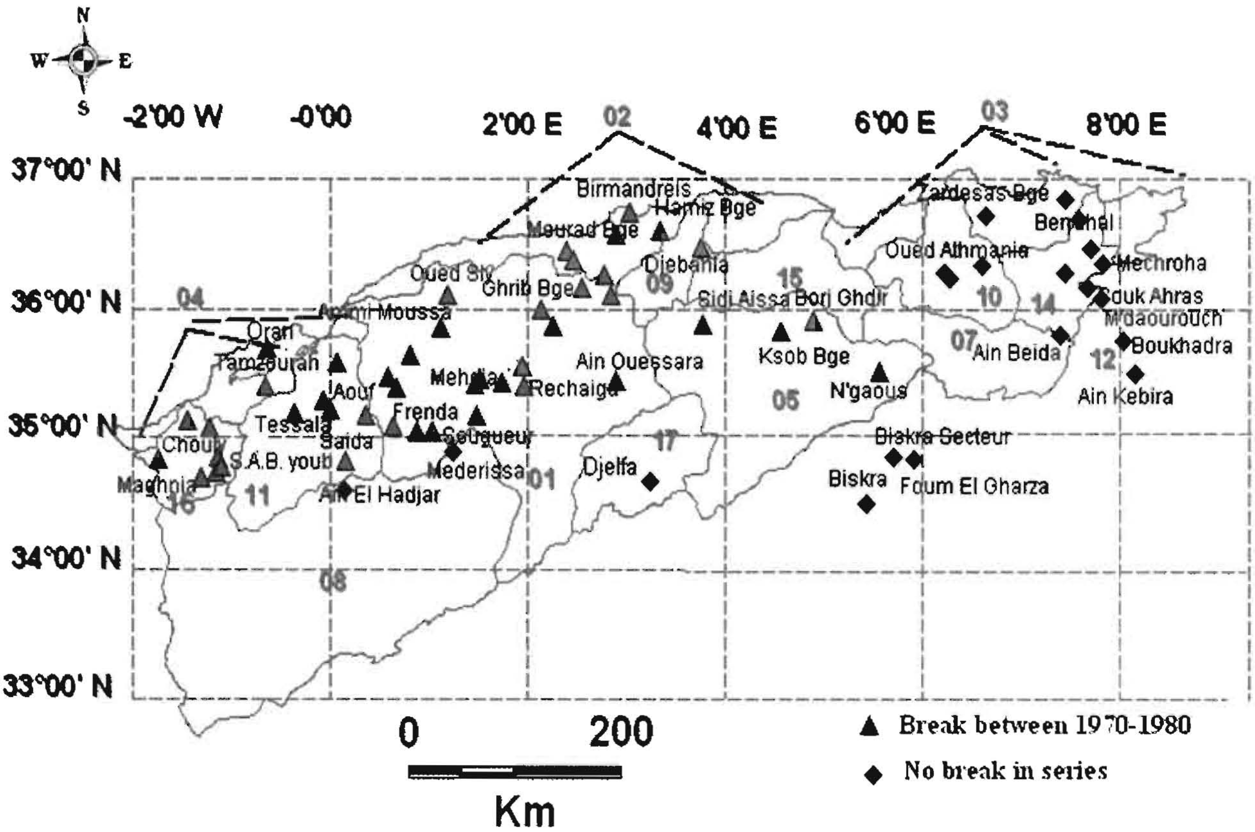
Seasonal Scale

In a hydrological year, tests for detecting breaks were used for the seasonal rainfall to understand their contribution in the reduction of the annual rainfall. For the series of rains of autumn and summer, no significant rupture was detected. The rainfalls of winter and spring contribute to the evolution of the rainfall regime.

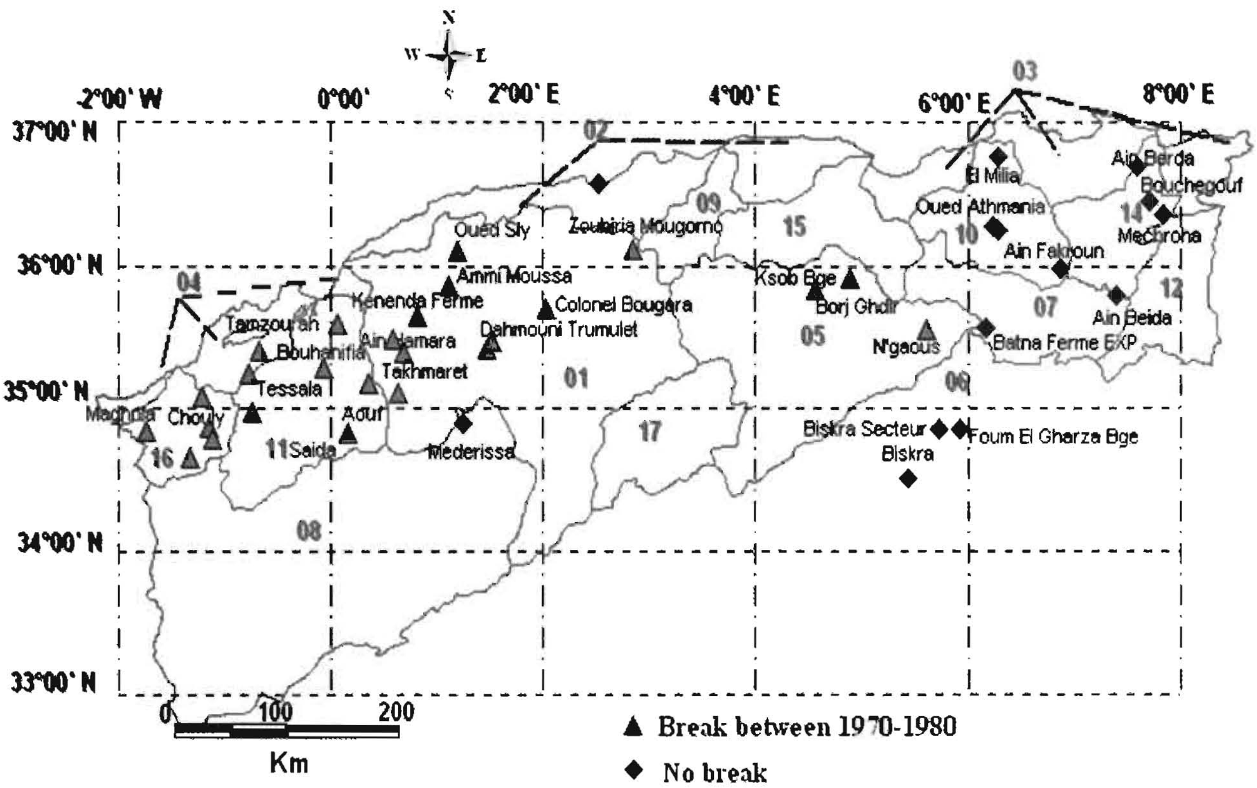
The tests for detection of breaks in the series of rainfall of winter shows a break, for the majority of stations in 1973, which confirm the decline and changes in the rainfall pattern during this decade. The winter rain has been reduced between 40% and 70%. To interpret these results, we have also sketched a map on which we present the obtained results (Figure 4). These rains are responsible for the decline in annual rainfall in the area between longitudes 2° 00 ‘W and 6 ° 00’ E.

The rainfall rate of spring (Figure 5) show discontinuity between the years 1974 and 1980 for most of the rainfall stations. These rainfall rates have seen a considerable decrease up to 80% for the station of Sidi Ali Ben Youb; rainfall deficits during this season are considerable and important. It is important to note that, at this scale, the East of Algeria, specifically, the area between meridians 1° 60’ and 8° 00’ E, had experienced the break of the stationary of the time series. From this analysis, it was concluded that:

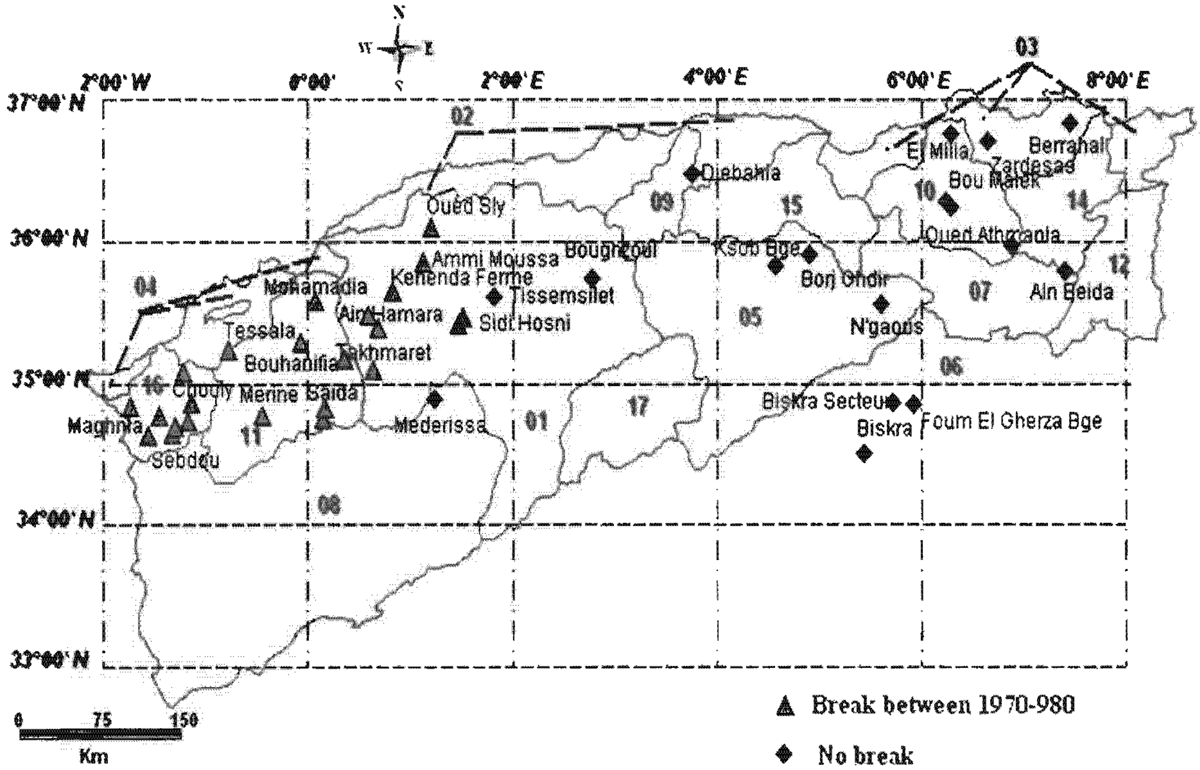
- The rainfalls of winter and spring are responsible for the decline of the annual rainfall in the area between meridians 2° 00’ W. and 1° 60’ E.
- Only the spring rainfalls reflect the fluctuations recorded in the area between meridians 1°60’ and 6° 00’ E.
- From the 6th Meridian East, no break in the seasonal rainfall is recorded.



Figs. 3. Cartographic Sketch of the Results Obtained on an Annual Scale.



Figs. 4. Cartographic Sketch of the Results Obtained for Winter Season.



Figs. 5. Cartographic Sketch of the Results Obtained at the Seasonal Scale – Spring Season.

The decrease in the total rainfall explains the consequences experienced by farmers and other water users (i.e., drinking water). In the agriculture, this negative development has had a negative impact on the development of the area between longitudes 2° W and 6° E. These findings should help policy makers to make decisions on the nature of agricultural practices in the region affected by this phenomenon.

Monthly Scale

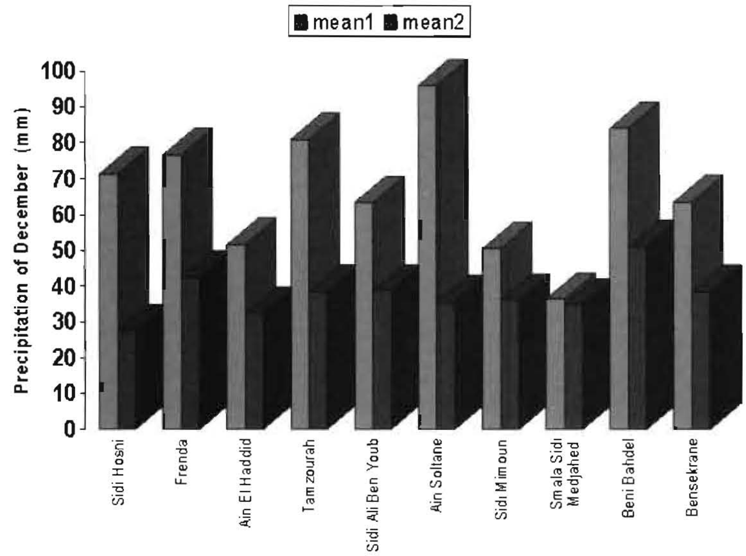
The contribution of the rainalls of winter and spring in reducing rainfall is presented above. To better define this decrease at a more finer scale, a study on a monthly scale to detect the change is conducted by applying all the methods described above for all months of the year. The results indicated that the winter rainfalls, including the rainfalls of December and January, and the rainfalls of spring (March and April) have seen a break of the stationarity of the rainfall series, as follows:

- The rainfall for the month of December showed a decline between 5% and 63% (Figure 6).
- The rainfall of January have recorded a huge deficits ranging between 33% and 53% (Figure7).
- The rainfall deficits in March ranged between 37% and 69%; and In April, the deficits have exceeded 67% (Figure 8).

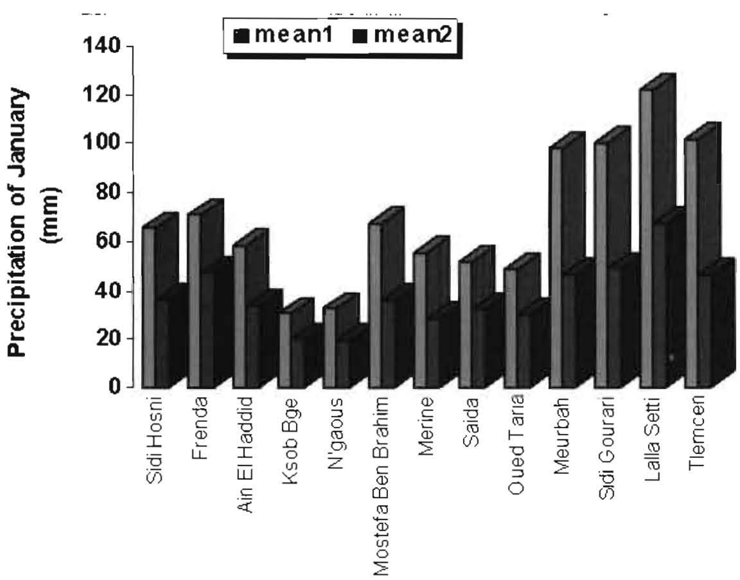
CONCLUSION

The study of detection of breaks in the rainfall indicated a change in the rainfall pattern during the decade 1970-1980 for most of the rainfall stations in North Algeria, as well as in the area in the extreme east of Algeria, between 6° W longitude and 8° W. The change in pluviometric regime, developed in Algeria during the 70's and 80's, has spared the east of the country. However, it is the role of climatologists and meteorologists to find the causes of these changes to explain this phenomenon.

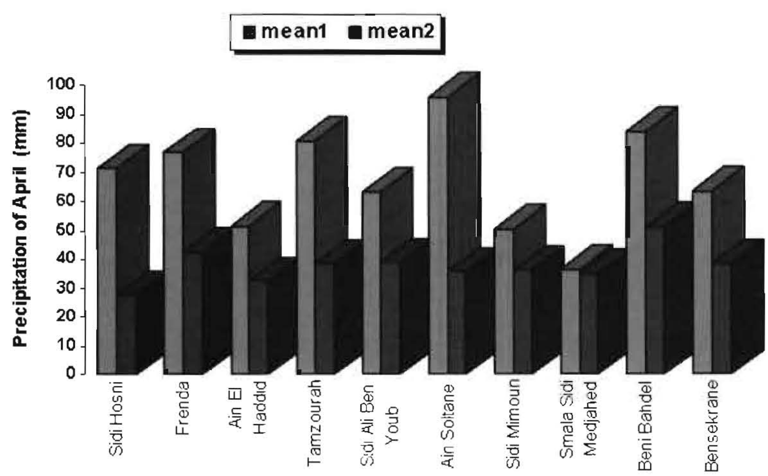
The application of statistical tests to seasonal rainfalls, enabled the conclusion that it is the rainfall of the winter and spring which recorded a break in the series during the decade 1970-1980. At the monthly level, the months of the two rainy seasons that have registered the most significant and the most important decreases are the months of December, January, March and April.



Figs. 6. Variations of Both Average (Before and After Break) of Rainfall, December.



Figs. 7. Variations of Both Average (Before and After Break) of Rainfall, January.



Figs. 8. Variations of both Average (Before and After Break) of Rainfall, April.

REFERENCES

Aka, AA, Servat, E, Paturel, JE, and **Kouamé B** (1996) Analysis of the temporal variability of runoff in Ivory Coast : Statistical approach and phenomena characterization. *Hydrological Sciences Journal* **41** (6): 959-970.

Buishand, TA (1982) Some methods for testing the homogeneity of rainfall records. *Journal of hydrology* **58** (1/2): 11-27.

Buishand, TA (1984) tests for detecting a shift in the mean of hydrological time series. *Journal of hydrology* **73** (1/2): 51-69.

Hubert, P, Carbonnel, JP, and **Chaouche, A** (1989) Segmentation des séries hydrométéorologiques-application à des séries de précipitation et de débits de l'Afrique de l'Ouest. *Journal of hydrology* **110** (3/4), 349-367.

Hubert, P (1997) Change points in Meteorological Time Series. Extrait de. *In* : **Subba, TR, Priestly, MB,** and **Lessi, O (eds)**, *Applications of Time Series Analysis in Astronomy* and Meteorology. Chapman and Hall Edition, London, UK, pp 399-412. Available at: http://www.adsabs.harvard.edu./abs/1998ASA-.15..361r

Hubert, P, Servat, E, Paturel, JE, Kouame, B, Bendjoudi, H, Carbonnel, JP, and **Lubes, H** (1998) La procédure de segmentation, dix ans après. *In:* **Eric S, Hughes, D, Fritsch, JM, and Hulme, M, (eds),** *Water Resources in Africa During the XXth. Century.* IAHS Publication No. 252, International Association of Hydrologyical Sciences (IAHS), Institute of Hydrology, Wallingford, Oxfordshire, UK, pp267-273. (In French Lang.)

Ketrouci, K (2002) *La sécheresse dans l'Ouest Algérien et son impact sur le rendement du blé dur. Mém.* De magistère-Centre Universitaire de Mascara, de Mascara, Algeria. p108. (In French Lang.).

Kingumbi, A, Bargaoui, Z, Bourges, J, and **Hubert, P** (2001) Evolution récente des series pluviométriques en Tunisie centrale. In : *Séminaire International Sur l'Hydrologie des Regions Méditerranéennes (Montpellier),* PHI-V/DTH No.51, UNESCO, Paris, France. pp 346-355. (In French Lang.).

Lee, AES, and **Heghinian, S** (1977) A shift of the mean level in a sequence of on dependant normal random variables: A Bayesian approach. *Technometrics,* **19** (4) : 503-506.

Lubes, H, Masson, JM, Servat, E., Paturel, JE, and **Boyer JF** (1994) Caractérisation de fluctuations dans une érie chronologique par application de tests statistiques. *Etude Bibliographique, Rapport No. 3,* Programme ICCARE. ORSTOM, Montpellier, France. (In French Lang.).

Lubes H, Masson JM, Servat E, Paturel JE, and **Servat E** (1998) Variabilité climatique et statistique : Etude de simulation de la puissance et de la robustesse de quelques tests utilisés pour vérifier l'homogénéité de chroniques. *Revue des sciences de l'eau,* **3**: 383-408. (In French Lang.)

Meddi, M, and Hubert, P (2003) Impact de la modification du régime pluviométrique sur les ressources en eau du Nord-Ouest de l'Algérie. *Hydrology of the Mediterranean and Semiarid Regions.* IAHS publication No. 278, International Association of Hydrologyical Sciences (IAHS), Institute of Hydrology, Wallingford, Oxfordshire, UK, 1-7. (In French Lang.).

Pettit, AN (1979) A non-parametric approach to the change-point detection. *Applied Statistics* **28**: 126-135.

Zbigniew, W, Kundzewicz, and **Alice R** (2000) *Detecting Trend and other Changes in Hydrological Data.* World Climatie Programme: Water. WCDMP-45. WMO/TD-No.1013.

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