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Trends of Precipitation and Drought on the Algerian Litoral: Impact on the Water Reserves

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Abstract: Rainfall is a fundamental component of climate. Its importance is such that the different climate classifications are based on the average annual or monthly rainfall, combined with the medium and / or temperature extremes. In Algeria, water resources, which depend for largely to a very irregular rainfall and unevenly distribution in space, remain modest relative to the deficit and means of retention (dams, withholding water, etc.). Climate change and especially the drought in recent years, mainly in western countries, further exacerbating the problem. The study of rainfall recorded in hundreds of weather stations in northern Algeria (period 1951-1980 and 1961-1990), shows a succession of episodes of excessive and deficient rainfall compared to normal and that show great variability. The intra-annual variability in precipitation is more important for the coastal stations than for non-coastal stations, this is due to a clearer distinction between dry and rainy seasons for the coastal stations, while the amplitude is smaller rainfall for continental stations by providing rainstorms during the summer. Regionalization, obtained by tracing the isohyets shows the existence of three distinct regions characterized by different rainfall patterns. An overlay of this map with that of existing water infrastructure allows us to have an idea about the effectiveness of recovery and retention for the different regions of the Algerian coast.

Key words: Rainfall • Drought • Regionalization • Water infrastructure • Algeria

INTRODUCTION

The continuation of dry spells in the Mediterranean has become a climatic reality during the last decade [1,2]. Many applications are possible for the data of precipitation in climatology and agro climatology. These applications depend mainly on the time scale used in data recording. If annual data can be used to assess climatic trends, analysis at lower time scale (decadal and daily), reveals an unsuspected number of climate information directly usable in agriculture: regular monitoring of water balance; characterization a number of weather events such as the start of the rainy season, occurrence of dry spells, forecasting returns, etc. From the data of annual rainfall, we can establish statistics that characterize their spatial and temporal variability and consequently the general characteristics of climate [3,4]. In this study we addressed two main aspects, namely:

- The inter-annual variability as temporal variability, which can detect the trend over time.
- The spatial variability in order to establish a regionalization (zoning climate) and thus produce plots of rainfall maps

We felt stations whose operation covers two different periods, namely the period 1951-1980 and 1961-1990.

Collecting and Formatting Data

Rainfall Network:

The Choice of Stations Is Based on Three Essential Criteria:

- Data complete observations or almost complete
- Professional Stations
- Uniform spatial distribution

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Fig. 1: Maps of the main meteorological stations used in our studies

The series of observations of auxiliary positions are either incomplete or questionable; we have used as much as possible the data collected by professional stations. However, the imbalance in the spatial distribution of stations sometimes requires taking into account the auxiliary data items. Overall, the series considered, there are shortcomings in the period 1961-1969. This gap in time has the effect of reducing the period common to the different series to an average of 25 years.

Rainfall Data: Among all the available stations we selected 42 stations for the period 1951-1980 (Figure 1). To study the temporal variations in precipitation and generalize various results of analysis, we established three regional series representing the northern part of the country: Western Region, Central Region and Eastern Region. We first selected a number of stations forming a homogeneous climatic region. The different stations selected and the statistical parameters are summarized in (Table 1) for the western region, (Table 2) for the central region and (Table 3) for the eastern region.

The regional average is obtained by the weighted average of the stations considered (Table 4).

Table 1: Statistical parameters of representative stations of the western region

West Region	Oran Baudens	Oran Port	Oran Sénia	Boutlelis	El Braya
Observation Period	1877-1915	1904-1951	1925-1984	1941-1984	1925-1962
Number of years of actual obs..	39	47	54	30	30
Average (mm)	384.9	392.0	395.5	390.7	394.0
Standard deviation	114.7	140.4	115.9	147.2	127.3
Coefficient of variation (%)	29.8	35.8	29.3	37.6	30.4

Table 2: Statistical parameters of stations representing the Central Region

Central Région	Alger Port	Dar El Beida	INA El Harrach	Alger Université	Bouzaréah
Observation Period	1844-1942	1936-1982	1908-1968	1913-1968	1940-1980
Number of years of actual obs.	99	45	58	56	65
Average (mm)	650.4	692.4	658.2	735.8	761.4
Standard deviation	153.0	167.3	148.2	162.5	163.0
Coefficient of variation (%)	23.5	24.2	22.5	22.0	21.4

Table 3: Statistical parameters of representative stations of the Eastern Region

East Région	Annaba Port	Cap de garde	Ben M'hidi
Observation Period	1907-1955	1931-1961	1926-1980
Number of years of actual obs..	44	27	48
Average (mm)	763.0	728.3	686.6
Standard deviation	159.2	147.8	151.7
Coefficient of variation (%)	20.8	20.2	22.0

Table 4: Weighted averages of stations considered

	West Region	*Central Région*	*East Région*
Regional average (mm)	392.8	695.3	724.3
Regional Standard deviation (mm)	127.8	158.0	153.0

RESULTS AND DISCUSSION

Using these standardized regional series (for each year the total annual is replaced by the average z-scores of stations in operation) has a number of advantages. They minimize the local effects on rainfall distribution, to overcome the existing gaps in the series taken individually, thus increasing the length of the resulting series.

We note that the calculated coefficients of variation are in the same order for different stations in a same region. This gives each group of stations a character of “climatic homogeneous region”. In addition, the coefficient of variation is a parameter characterizing the dispersion; we conclude that high rainfall variability exists in the western region. There is also some similarity in the evolution over time of precipitation of Central and Eastern regions. The chronology of the annual values shows that the wettest year in the western region has been observed in 1935 with a total rainfall of 719 mm. The maximum observed at the Center was 1132 mm in 1854 against a total of 1019 mm in the east in 1915. However, it is necessary to further analyze the series in order to identify the essential characteristics [1].

Generally, a year (i) is considered abnormally dry, if the ratio of its average total rainfall x_i is such:

$$r_i = \frac{x_i}{x_j} \leq 1 - \alpha Cv_j \qquad (1)$$

X_j and Cv_j are respectively the average and the coefficient of variation of the regional series (j) considered. The parameter α depends on the specifics of the study; its value is increased by unity. In the same way we can define a wet year and a normal year. the above relation is defined for each region and for two different values of alpha. the lower and upper limits, which identify a given character, are calculated.

The distribution of coefficient of variation (Table5) and frequencies expressed as a percentage (Table 6), are given for the three characters:

For (α = 0.5), we notice that a same character is found, in approximately equal proportions, in the three regions considered.

For α = 1, we see a significant difference between the frequencies of normal years and dry years from west to east regions. This is due to the time effect, comparing the common period 1910-1980 we found for (α = 1) the following frequencies (Table 7):

The time remaining without effect on the results, we can conclude that a difference of rainfall between western and eastern regions exists. A few similarities between the East and Central appear also. The percentage of dry years in the East (25%) where the total average of 700 mm per year is higher than the western region. This may seem contradictory, as it must be noted that the thresholds values that allowed the counting of dry years are specific to each region. Thus one year considered as dry in the East (annual total <571 mm) is not necessarily regarded as such in the west where the lower limit is 277 mm.

Table 5: Estimated coefficient of variation

	West Région		Center Région		East Région	
	α = 1	α = 0.5	α = 1	α = 0.5	α = 1	α = 0.5
Lower limit	277	341	537	616	571	648
Upper limit	532	468	853	774	878	801
Coefficient of variation Cv_j	0.315	0.227	0.21			

Table 6: Estimating the frequency distribution of the three characters

	West Région		Center Région		East Région	
	α = 1	α = 0.5	α = 1	α = 0.5	α = 1	α = 0.5
Dry years	11	33	14	30	25	39
Normal years	76	40	69	40	59	34
Wet years	13	27	17	30	16	27

Table 7: Calculations of the frequency distribution of the three characters for the period 1910-1980

	West Région	Center Région	East Région
Dry years	14	14	25
Normal years	75	68	59
Wet years	11	18	16

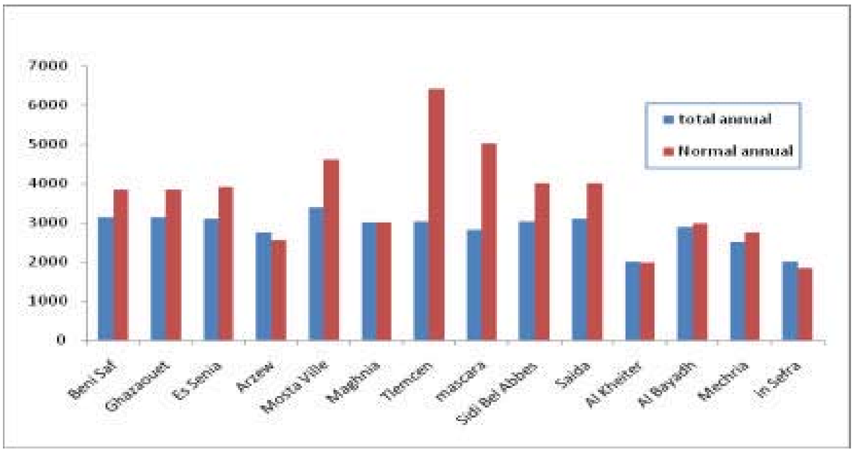

Fig.1: Assessment of rainfall in the West

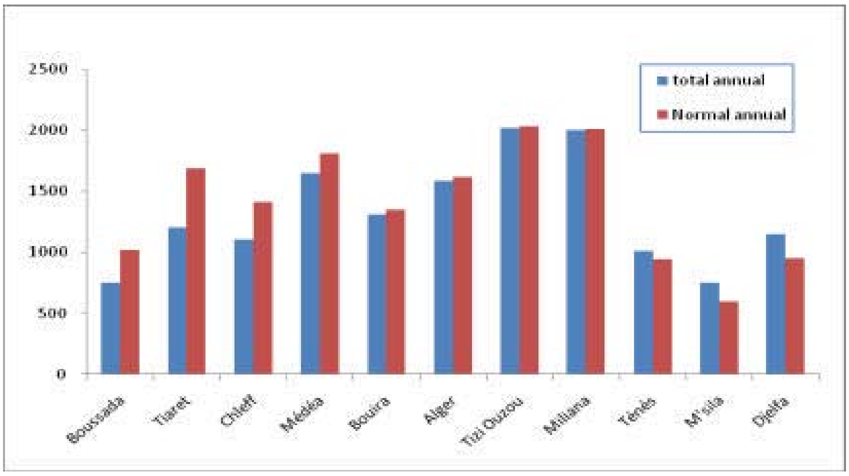

Fig. 2: Assessment of rainfall in the Center

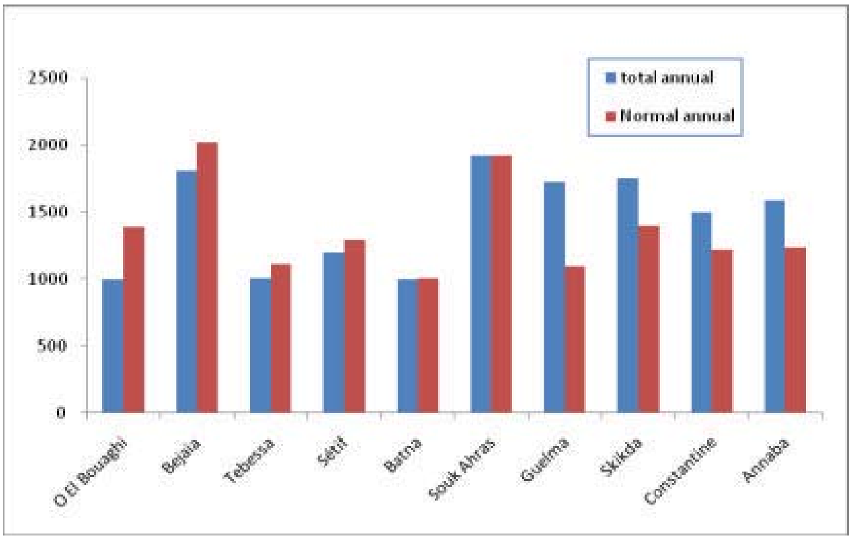

Fig. 3: Assessment of rainfall in the East

Fig. 4: Distribution of average annual rainfall (period 1951-1980)

Fig. 5: Distribution of average annual rainfall (1961-1990)

Finally, the variability of rainfall can be summed up by the frequency distribution of dry periods, normal and wet.

- For the 3 regions we observe a succession of deficits and surplus periods.
- The saw tooth phases confirms the high inter-annual variability of precipitation in the west.
- For Central and eastern regions the different phases do not present this aspect.

Analysis of these data shows an early phase of decreasing towards the year 1940, common throughout the northern part of the country. As in recent years, this decline is being felt from 1975, particularly in western region. More recently, various observations confirm the downward trend in rainfall including western region, where the particular interest that we attach to the study of rainfall during the decade 1990-1999 for the three regions. Trend rainfall decade 1990-1999:

To characterize the rainfall in the last decade, we have opted for the method of assessment based on a comparison of average annual precipitation and the normal data for the different stations.

Thus almost all stations of the western region (Figure 1) have a significant rainfall deficit compared to normal. This deficit is absorbed in Central region (Figure 2) to turn into surplus rainfall in eastern region (Figure 3), especially for coastal stations (station of Annaba in particular).

Tracing the rainfall map: The purpose of maps is to represent the spatial and temporal variability of rainfall in two different periods, namely 1951-1980 and 1961-1990, to highlight the trend of this parameter.

The kriging interpolation method is used [5]. However this method has the disadvantage of not involve the rainfall gradient of altitude, which reflects objectively the influence of terrain.

In fact, rain falling in Algeria is in the majority orographic [6] the annual quantity of collected precipitation by a given station depends on the altitude or more generally of the topography of this station. We shall then introduce the concept of altitude rainfall gradient.

Therefore the search for a law by which the amount of rain varies with altitude led to three possible representations corresponding to three natural regions: the coast, the Tell Atlas and the Sub Saharan region.

Maps Analysis: The distributions of average annual rainfall of the two periods are shown on Figures 4 and 5. The isohyets present in both cases a similar configuration and show a general trend of declining rainfall. The average annual rainfall increases along two main directions namely from west to east and from south to north. The network of isohyets on the western part reflects the greater variability in precipitation. The comparison with the rainfall map of Algeria compiled for 1913-1938 by P. Seltzer (Seltzer, 1946) highlights the following points:

- The isohyets configurations are quite similar.
- There was however a significant decline in the average annual rainfall in the east.

Algeria has 57 major dams on five watersheds. They have a capacity of 6.8 billion m^3 (Remini, 2009). However, the amount of fresh water potential is reduced by several factors: poor management, siltation, droughts, etc.

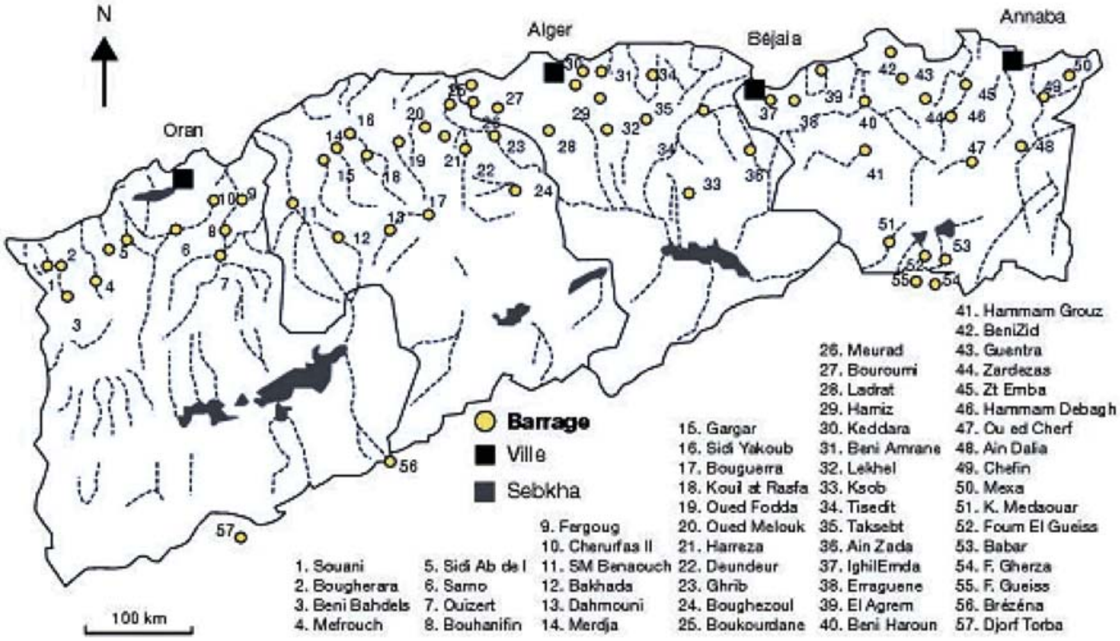

Fig. 6: Distribution of dams in northern Algeria (Remini, 2009)

Overlaying maps of rainfall (Figure 1 and 2) and the distribution of dams map in northern Algeria (Figure 6) shows a fairly large disparity between the two.

Climate change makes the current provision of dams unfavorable for optimal restraint of rain.

CONCLUSION

The study of rainfall in the north of Algeria shows a succession of episodes rainfall excess and deficit compared to normal and that show great variability. The intra-annual variability in precipitation is more important for the coastal stations than for hinterland stations; this is due to a clearer distinction between dry and rainy seasons for the coastal stations, while the amplitude is smaller rainfall for continental stations by providing rainstorms during the summer. Regionalization shows the existence of three distinct regions characterized by different rainfall patterns, but with a similarity between the central and eastern regions. The average annual rainfall increases along two main directions, namely from west to east and from south to north. The isohyets network on western part reflects the greater variability in precipitation. Compared to map rainfall over the period 1951-1980, the second map shows a general trend of declining rainfall. The great variability between annual and intra annual precipitation warrants a better understanding of our potential and water use efficiency.

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