Trend of Precipitation in Algeria: Between Severe Drought and Torrential Rain

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Abstract: In Algeria, water resources, which depend to a large extent on irregular rainfall, remain modest in relation to the deficit and the means of retention. The study of precipitation recorded at several meteorological stations in northern Algeria (1951-1980, 1961-1990 and 2001-2010) shows the evolution of successions of excessive and insufficient rainfall episodes compared to Normal. The intra-annual variability of precipitation is greater for coastal stations than for continental stations. The regionalization, obtained thanks to the isohyets, shows the existence of three regions characterized by different types of precipitation. A superimposition of this map with that of the existing hydraulic retention infrastructures makes it possible to have an idea of the efficiency of the recovery and the retention of rainwater in Algeria.

Keys words: Rainfall · Drought · Regionalization · Hydraulic Infrastructure

INTRODUCTION

Algeria is the largest country in the Mediterranean basin, which are amongst the most vulnerable areas to climate change [1]. Past analyses [2, 3] show that the Mediterranean region, characterized by rainy winters and dry summers, is experiencing increasing temperatures and large changes in the frequency of extreme climatic events for both temperature and rainfall [4].

Climate change characterized mainly by long periods of drought has become a reality in recent decades [5, 6]. Short duration extreme rainfalls are the main cause of flash floods and disasters that may occur suddenly. Due to their torrential character, they also play a significant role in soil erosion and sediment transport.

In climatology and many applications are possible through the use of precipitation data.

These applications depend mainly on the time scale used for recording the data. While annual data can be used to assess climate trends, the analysis at a lower time scale (decennial and daily) reveals an unsuspected number of climatic information: regular monitoring of the water balance; characterization of meteorological events such as the beginning of the rainy season, the presence of dry periods, the forecast of yields, etc.

From the annual precipitation data, we can establish statistics that characterize their spatial and temporal variability and consequently the general climate characteristics [7].

In this study, we discussed two main aspects, namely:

- Inter-annual variability as temporal variability, which can detect trend over time.
- The spatial variability allowing to establish a regionalization (zoning of the climate) and thus to produce maps of zones of homogeneous precipitations.

We use data from stations operating in three different time periods, 1951-1980, 1961-1990 and 2001-2010.

It should be noted that the decade 2001-2010 and the year 2010, as for the years 2005 and 1998, are considered by WMO (2013) [8] as the hottest on the world scale since the availability of meteorological records. In parallel with this increase, a probable increase in precipitation is expected. In recent years, rains have caused severe flooding around the world.

In Algeria, the evolution of temperatures (increase of the minima and maxima) is in conformity with the world situation.

After two decades of drought observed in the eighties and nineties, the beginning of much wetter periods is noted in Algeria and throughout the Maghreb.

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Fig. 1: Map of the studied region

Collection and Formatting of Data
Rainfall Network: The choice of stations is based on three essential criteria:

- Complete or almost complete observations data
- Professional stations
- Uniform spatial distribution

The series of observations of the auxiliary positions being either incomplete or doubtful, we used as much as possible the data collected by the professional stations. However, the imbalance in the spatial distribution of the stations sometimes requires taking into account the data of the auxiliary stations. Overall, the time series considered have gaps during the period 1961-1969. This discontinuity over time has the effect of reducing the period common to the various series to an average duration of 25 years. The main stations are concentrated mainly in the cities shown in Figure 1. The data used in our previous work [5, 6, 7] have been updated by the introduction of data for the period 2001-2010.

Rainfall Data: In order to study the temporal variations of precipitation and generalize the various analysis results, we have created three representative regional series of the northern part of the country: Western region, Central region and Eastern region. We previously selected a number of stations that could together form a homogeneous climatic region. Station Statistical Parameters and regional averages obtained by weighting the data of the stations considered (Table 1).

Results and Comments: Use of standardized regional series (for each year the annual total is replaced by the average of the reduced center variables of the stations in operation) minimizes the local effects on rainfall distribution, alleviating existing gaps in individual series and thus increases the length of the resulting series. The coefficients of variation calculated are of the same order of magnitude for the different stations of the same region. This gives each group of stations the character of a "homogeneous climatic region". Moreover, the coefficient of variation being a parameter characterizing the dispersion, one can conclude to a great variability of the precipitations in the western region. Some similarity in the evolution over time of rainfall in the Center and East regions has been observed. The chronology of annual values shows that the wettest year in the western region was observed in 1935 with a total of 719 mm. The maximum recorded at the Center was 1132 mm in 1854, compared to a total of 1019 mm in the East in 1915. However, it is necessary to deepen the analysis of the series in order to identify the essential characteristics [9]. It is generally accepted that a given year i is abnormally dry if the ratio of its rainfall totals xi to the mean is such that:

$$r_j = \frac{X_i}{X_j} \leq 1 - \alpha Cv_j \qquad (1)$$

X_j and Cv_j are respectively the mean and the coefficient of variation of the regional series j considered. The parameter α depends on the specificities of the study; its value is increased by the unit. In the same way, we can define a rainy year and a normal year. Given the above relationship, for each region and for two different values of α, lower and upper limits are determined which identify a given character.

Table 1: Weighted Average rainfall of the considered stations

	West region	Central region	East region
Regional average (mm)	417.5	759.7	815.3
Regional standard deviation (mm)	139.6	201.3	168.1

Table 2: Estimated values of the coefficient of variation of regional series

	West region		Central region		East region	
	$\alpha = 1$	$\alpha = 0.5$	$\alpha = 1$	$\alpha = 0.5$	$\alpha = 1$	$\alpha = 0.5$
Lower limit	245	376	578	674	581	655
Upper limit	545	478	823	795	866	823
Coefficient of variation Cvj	0.325	0.235	0.218			

Table 3: Estimation of the frequency distribution of the three characters

	West region		Central region		East region	
	$\alpha = 1$	$\alpha = 0.5$	$\alpha = 1$	$\alpha = 0.5$	$\alpha = 1$	$\alpha = 0.5$
Dry years	13 %	37 %	13 %	30 %	25 %	40 %
Normal years	75 %	42 %	67 %	40 %	59 %	34 %
Rainy years	15 %	21 %	20 %	30 %	16 %	26 %

Table 4: Frequency Distribution calculations of the three characters for the period 1910-2010

	West region	Central region	East region
Dry years	35	23	30
Normal years	38	49	41
Rainy years	27	28	29

The frequency distribution of the 03 characters is given in Table 2. For $\alpha = 0.5$, a given character is found in equal proportion in the three regions. For $\alpha = 1$, a noticeable difference between normal years and dry years frequencies from the western region to the eastern region is noted. This being due to the effect of period, the comparison on the common period 1910-1980 gives, for $\alpha = 1$ the frequencies reported in Table 3.

Since the period has no effect on the results, we can conclude that there is a difference in the rainfall pattern between the West and the East of the country and a few similarities between the East and the Center. The percentage of dry years in the East (25%) averaging 700 mm per year is higher than that in the West region. This may seem contradictory, so it should be noted that the threshold values allowing the counting of dry years are specific to each region. As a result, a dry year in the East (annual total <571 mm) is not necessarily considered as such in the West where the lower limit value is 277 mm.

Rainfall Trend 1990-2010: In order to characterize the rainfall of the last decade, we have opted for the balance method consisting of a comparison of the annual rainfall averages of the different stations to their respective normal's. Thus, almost all the stations in the West region have a significant rainfall deficit compared to normal. This deficit is reduced in the Center region to become a rainfall surplus in the East region.

The variability of precipitation can be summarized by the frequency distribution of dry, normal and rainy periods.

- The three regions show a succession of rainfall deficit and surplus periods.
- The ascending phases confirm the great inter-annual variability of rainfall in the west of the country.
- For the Center and East regions, the ascending or descending phases do not have this aspect.

The analysis of the completed data confirms a beginning of decreasing phase towards the year 1940, date common to all the northern part of the country. As for the last years, this decrease is felt from 1975, especially in the West of the country. Even more recently, the various observations confirm the downward trend in precipitation, particularly in the western region, hence the particular interest we place in the study of rainfall during the 1990-1999 and 2001-2010 decade for the three regions considered (Table 4).

(1951-1980)   (1961-1990)   (2001-2010)

Fig. 1: Annual average rainfall distribution for the three Periods

Plotting the Rainfall Map: The purpose of the plot is to represent the spatio-temporal variability of the relative rainfall at three different periods, namely 1951-1980, 1961-1990 and 2001-2010, in order to highlight the trend of this parameter. The interpolation method used is kriging [10], which however has the disadvantage of not involving the rainfall gradient of altitude which takes into account objectively the influence of the relief. Since the rains that fall in Algeria are for the most part of orographic origin, the annual quantity of precipitation collected by a given station depends on the altitude or, more generally, the topography of this station. The notion of altitude gradient gradient is then used. This is why the search for a law according to which the height of rain varies with altitude has resulted in 03 possible representations corresponding to 03 natural regions: the coastline, the Atlas Tell, the Saharan Atlas with the Sahara.

Rainfall Map Analysis: Figures 1 represent the annual average distributions of the respective precipitation of the two periods considered. The isohyets in both cases have a similar configuration and indicate a general tendency to decrease precipitation. The average annual rainfall increases in two main directions, namely from West to East and from South to North. The looser network of isohyets on the western part shows the greater variability of precipitation. The comparison with the pluviometric map of Algeria drawn up by P. SELTZER for the period 1913-1938 [11] highlights the following points:

- The configurations of the isohyets are quite similar.
- However, there is a significant decrease in the average annual rainfall in the east of the country.

Despite an intra-annual variability in the Mediterranean context, the analysis of the evolution of this parameter in the various stations reveals a structure of values structured in three periods:

- The first period, from 1951 to 1980, is considered normal with a wet tendency. However, it contains 47% of wet and very wet years, 33% of dry and very dry years and only 20% of normal years
- The second, from 1961 to 1990, showed a significant decline in wet years to 43%, while dry years accounted for 44% and normal years 13%. The years 1993, 1994, 2000 and 2001 stand out with a very high percentage of stations in the dry year to very dry (100% in 1993 and more than 80% in 1994)
- The period from 2001 to 2010 is characterized by an increase in wet years to 52% and normal years (18%). It is also marked by the lowest percentage of dry years. The years 2005 and 2006 deviate from the general characteristics of the period and turn out to be dry.

The analysis of the minimum and maximum temperatures in Algeria proves the existence of real climatic changes during the studied periods. While for precipitation, a wet period occurs from 1970 to 1986 and a strong drought then established for nearly fifteen years, from 1987 to 2002.

Since 2003, we have seen a return to more abundant rainfall with more rainy episodes. These phenomena have been particularly frequent over the last decade.

Heavy rainfall causes floods and cause material damage or even loss of life. The Bab El Oued disasters in November 2001 where precipitation of 159.4 mm were observed in less than 48 hours and Ghardaia in 2008, lead respectively to 800 and 43 deaths [12, 13].

CONCLUSION

The study of precipitation over northern Algeria shows a succession of excess and deficit rainfall episodes relative to normal and which testify to their great variability. The intra-annual variability of precipitation is greater for coastal stations than for inland stations, this is due to a clearer distinction between dry and rainy seasons for coastal stations, while the rainfall amplitude is smaller. For continental stations by bringing storms during the summer. Regionalization shows the existence of three distinct regions characterized by different rainfall patterns, with a similarity between the central and eastern regions. Average annual rainfall increases in two main directions, from west to east and from south to north. The looser network of isohyets on the western part shows the greater variability of precipitation. Compared to the rainfall map for the 1951-1980 period, the second map shows a general downward trend in rainfall. The great inter-annual and intra-annual variability of rainfall justifies a better knowledge of our water potential and their rational use.

After nearly two decades of drought, the return of rains is confirmed over a large part of the country. High rainfall, very comfortable in terms of the availability of water resources, is less so for the management of rainwater runoff and vulnerability to urban floods, especially when rainfall is intense.

This situation has revealed a new risk of flooding, overflowing hydraulic dams. For these structures, it is a question of switching from the management of water scarcity to that of excess, whereas they are now very silted.

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