CLIMATE CHANGE IN NORTHERN AFRICA: TOWARDS A RETURN OF RAINFALL ON THE SOUTHERN MEDITERRANEAN BASIN

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ABSTRACT. **Climate change: towards a return of rain on the Southern Mediterranean basin**. To determine to what extent climate change affects the rainfall recorded on the southern Mediterranean basin, a trend analysis is proposed. This study is based on the chronological graphic method of processing information (MGCTI) of type "Matrice Bertin". Results show an extreme variability of the precipitations and a severe drought, especially for Morocco, observed since 1970s. Finally, a gradual return to humid conditions is observed from the beginning of the 2000s in Algeria and Tunisia and since 2008 in Morocco. This new trend is also confirmed by recent results provided by agricultural data of 2011/2012 and 2012/2013.

Keywords: climate change, trend of precipitation, drought, rain return, Maghreb

1. INTRODUCTION

Climate change is now widely recognized by the scientific community (IPCC, 2013). In its latest report, the IPCC assesses the average trend in global temperature over the period 1880 - 2012 at +0.85° C with an uncertainty between 0.65° C and 1.06° C. The increase over the last decade 2003-2012 amounts to + 0.78° C (for a minimum of 0.72° C and a maximum of 0.85° C). The increase of the minimum temperatures in of the South of the Mediterranean basin, is higher, sharper and affects all regions (Nouaceur et al., 2013).

Most of studies related to the evolution of the precipitation show that climate change is manifested by an intensification of hydrological cycle and a recurrence of extreme events over last decades (New et al. 2001, Christensen et al. 2007, Masei et al., 2007, Tramblay et al, 2012). During the last years, rains generated severe floods around the world. The monsoon rains were extremely strong in India in 2008 and particularly devastating in Pakistan in 2009. In 2010, more than forty cities in the northeastern side of Australia have been affected by

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historic floods (200,000 people were affected). In 2013, the movement speed and violence of the Indian monsoon have been exceptional (more than 5,000 people were killed in deadly flooding) (Bossy, 2013). Moreover, in February 2014, the England observed the worst floods ever recorded for two centuries and wettest winter from over 250 years (Corner, 2014).

The Mediterranean area is recognized as a "hot spot" of climate change. According to the different forecast, it is expected in 2100, an average increase of temperatures from 3 to 4° C, a decrease in precipitation and an intensification of extreme events (IPCC, 2007). The combined effect of climate change and the anthropogenic impact will cause a shortage of water for about 290 million people.

The regions of the Southwestern Mediterranean basin, where signs of change are very significant over the last years, are subject of several discussions. Rainfall records of Marocco in 2009 have shown exceptional and they led to a dam filling to maximum capacity (the degree of filling of the Al Wahda dam, the largest dam of the country, situated on the Ouergha River, was 98.5%). These rains have also ensured a record grain production of 80 million quintals (for the 2009/2010 agricultural year). With average rainfall of 450 mm (+ 20% compared to a normal year), this trend is confirmed for the year 2012/2013 and the cereal production reached a new record with 97 million quintals (Bouziane, 2013).

Regarding Algeria, the situation seems similar. The agriculture year 2008/2009 has been described as very satisfactory, and grain production registered during the year (2009/2010) constitutes a record never recorded, with 61,2 million quintals. The dams also have reached unprecedented levels, with a filling average rates of 72% in 2010 and 81% in 2013 (APS, 2013). In Tunisia, the situation is less clear since the most of areas range between arid and semi-arid conditions. However, this trend is confirmed by an increase in flood. A good example can be illustrated by Sfax city which is flooded twice in 1969 and 1982. In spite of the major managements performed in 1984, the city is again submerged by waters in 2009 and 2013) (Daoud, 2013).

2. DATA AND METHODS

The data of this study concerns three countries (Morocco, Algeria and Tunisia). For Morocco the chosen area is the Middle Atlas (5 stations). In Algeria, we selected 7 stations located in north- east of the country. For Tunisia, 7 stations of the Bizerte–Ichkeul (north–east of the country) are used for this study (Fig. 1).

In order to determine the trend of rainfall, we use chronological graphic method of information processing (MGCTI) of type "Bertin Matrix" (Nouaceur et al, 2013) applied to rainfall. This method aims first to analyze the distribution in space and in time and second to determinate the changes in rainfall cycles.

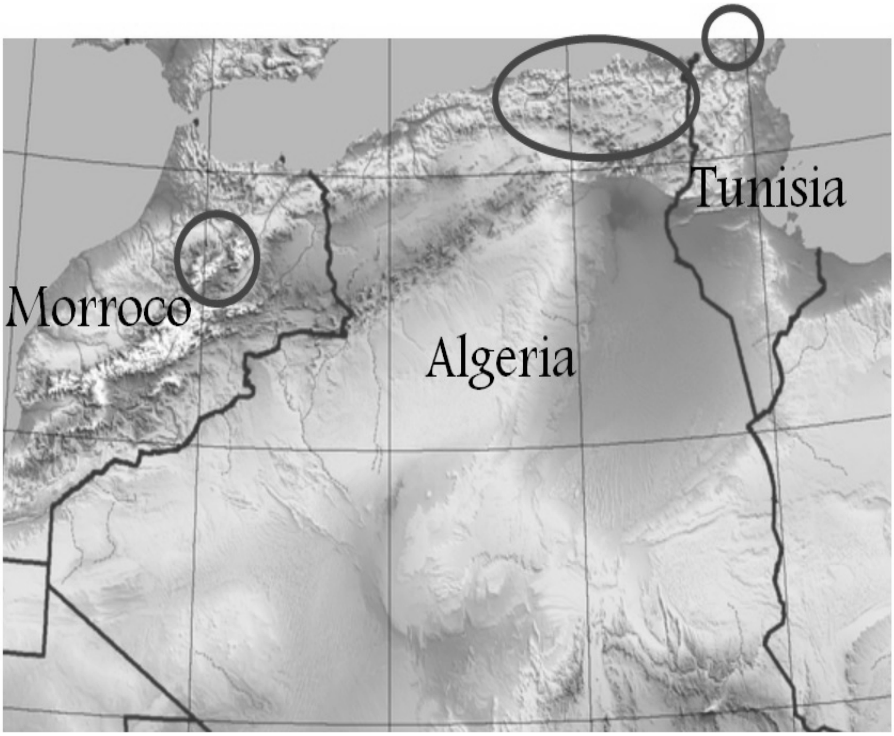

Fig. 1. Map of study area localization.

A classification per year relative to limit values (Q1, Q2, median, Q3 and Q4) is performed for all stations and for the full time series (Table 1). The years with cumulative rainfall lower than the limit value of 1 (Q1) are considered very dry. Those situated between Q1 and Q2 are considered dry. Years, having rainfall height between the second quintile and the median, are normal with a dry trend. Between the median interval and Q3, the years are normal with a wet trend. Between Q3 and Q4, years are classified as wet. Finally, years with cumulative rainfall higher than Q5 are considered very wet.

After this first step, a recording of values through a range of colours is done (the varying colour depending on the position of the rainfall cumulative compared to the limit values). This first treatment is followed by a procedure for reordering (permutations of columns) in order to obtain a classification that show a homogeneous coloured structure (Bertin matrix). This procedure allows us to visualize the evolution of the rainfall according to two dimensions (space and time).

To determine the ruptures and the characteristic periods, a second procedure is performed. It is to assign a number ranging from 1 (very dry year) to 5 (very humid) following the characters already determined and allocated to each year. The sum of the numbers of all stations for each year is centred reduced, allowing thus obtain an index that varies from +1.80 for a very humid year to -1.80

for a very dry year. The result is projected on a graph to show first the rainfall variability on a regional scale and second to determine the dates of breaks and changing trend.

3. RESULTS

For Algeria, the MGCTI matrix shows an organization of rainfall with three characteristic periods (Fig. 2):

– a high variability between 1970-1986, and no trend over this period;
– the second period is ranges between 1987 and 1995. It shows a significant decrease of wet conditions (very high conditions of dryness are recorded during 1989, 1993 and 1994);
– the third period (1996 - 2012) shows wet conditions. However, a return of severe dry conditions is recorded in 2000 and 2001 (the regional index indicates respectively -1.79 and -1.65). These dry conditions decrease in 2006, 2007 and 2008. Finally 12 years with positive regional indices are observed over this long period of 17 years.

For Morocco, the MGCTI shows a structure more organized, with changing trend well defined (Fig. 2):

– a wet phase between 1970 and 1980. The annual rainfalls are marked by an upward trend. The indices recorded on this first period are all positive, except for 1974 (during five years, an index higher than +1 is noted);
– a long drought is observed from 1981 to 2007. The negative indices reach -1 for 9 years. Finally, from twenty-seven years of this period, only 6 years are into the "wet" case (1982, 1987, 1989, 1996, 1997 and 2003);
– the last phase (2008-2010) shows humid conditions (the indices are exceeding +1). During the last two years, very wet conditions are observed in all stations.

For Tunisia, the rainfall values recorded in the Northern Tunisia shows an important variability (Fig. 2). The MGCTI matrix also reveals different trends:

– a wet phase between 1970 and 1976;
– a long dry period of 25 years (1977-2001) interspersed with short wet period (1979-1980, 1990-1992, 1996 -1997). During this phase, negative indices were higher than - 95 (partial dryness) for 11 years;
– a wet period between 2002 and 2011 during which only one year (2008) has recorded a negative index.

Table 1. Features of studied stations.

Tunisia							
Stations	Sejenane Délégation	Ras El Ain	Djebel Essama	Chaab Eddoud	Koussat El Bey	Tinja Her	Sidi Salem
Average	839,74	524,81	717,70	612,27	459,15	599,81	669,92
Median	816,40	506,70	727,50	579,50	442,50	585,20	668,10
Q1	659,00	362,00	510,20	497,10	305,30	478,30	530,20
Q2	786,50	479,95	685,60	531,20	433,50	555,30	623,55
Q3	885,50	563,95	771,41	640,20	484,50	642,70	709,00
Q4	1075,00	666,20	862,60	775,10	614,40	722,00	807,40
Max	1287,50	843,20	1198,50	873,80	822,00	881,70	977,70
Min	402,00	232,30	323,80	338,70	205,80	243,90	404,40
Standard deviation	218,84	148,85	194,67	141,02	142,49	146,70	152,94
Algeria							
Stations	Dar El Beida	Annaba	Skikda	Béjaïa	Constantine	Biskra	Tébessa
Average	643,46	651,26	735,23	797,89	524,88	127,71	378,03
Median	683,52	614,60	729,80	780,80	491,90	125,98	370,35
Q1	475,40	531,10	615,90	631,00	401,80	69,07	276,45
Q2	606,00	584,40	666,30	749,00	470,00	93,90	346,70
Q3	712,80	648,00	754,00	819,80	514,20	132,80	406,80
Q4	783,60	773,00	854,40	969,20	662,90	188,00	498,30
Max	1169,00	1126,00	1148,20	1373,41	868,20	295,00	0,00
Min	280,00	409,00	491,60	320,00	253,30	47,00	199,00
Standard deviation	186,30	152,12	156,29	205,63	149,21	59,39	108,19
Morocco							
Stations	Ifrane	Fez	Taza	Sefrou	Meknes		
Average	947,00	474,49	586,35	533,98	548,98		
Median	878,60	466,80	534,70	523,50	527,30		
Q1	720,50	364,60	426,50	368,20	401,80		
Q2	832,40	433,50	496,40	480,90	496,30		
Q3	979,70	504,90	557,60	592,83	553,30		
Q4	1143,90	622,49	752,40	701,60	696,80		
Max	1865,70	761,10	1203,30	921,68	1147,40		
Min	583,20	206,90	328,20	227,49	181,50		
Standard deviation	269,82	141,84	196,32	170,08	190,58		

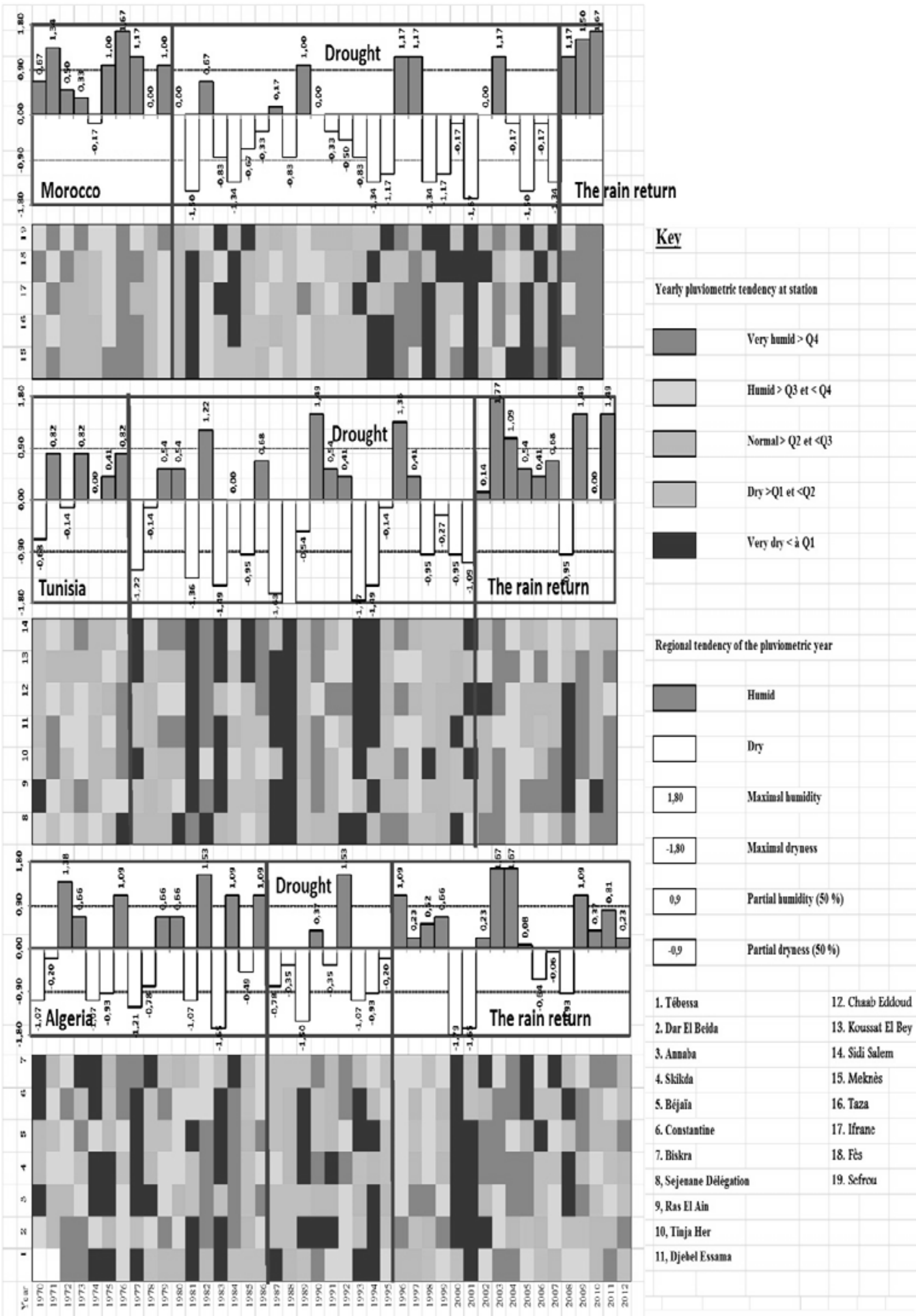

Fig. 2. Chronological graphic method of information processing (MGCTI) (Morocco, Algeria and Tunisia, 1970-2012).

4. CONCLUSION AND DISCUSSION

The evolution of the rainfall in North-eastern of Algeria is marked by three different phases alternating between drought and humid period. Since 2002, the data attest a return to wetter conditions despite the persistence of extreme variability with brief dry and very dry years (2006 and 2008).

For the Moroccan rainfall, the highlight is the persistence of droughts and their extension in time. After the wet period of 1970-1980, a drought over a period of 27 years (1981 and 2007) is detected. Finally, the last phase of the time series clearly stands by indices with record values that may indicate the beginning of a new trend (2008, 2009 and 2010).

For Tunisia, the values show high variability, characteristic of the Mediterranean climate. The drought between 1977 and 2001 is less intense than this observed in Morocco. However, it is distinguished by a regular return with wet conditions every two or three years. Finally, there is a return of the rainfalls in 2002 (confirmed across central Maghreb).

The analysis of rainfall data recorded in this large region of southern Mediterranean shows a significant variability of this climate parameter. This distinctive character to the Mediterranean climate reflects the vulnerability of this zone, called "hot spot" of global climate change. This investigation also helped to highlight the severity of the long period of drought in the region between 1980 and 2007. During this period of scarcity, rainfall totals have reached their lowest level in Morocco.

Finally, new rainfall conditions are recorded from 2002 (Algeria and Tunisia): they show a new climate trend. These new conditions are observed later, from 2008, in Morocco. These conditions called "return of the wet period" are confirmed by the agricultural assessments of 2011/2012 and 2012/2013 (DEPF, 2012) and information on the rates of dams filling. This assumption is supported by the evidence of the impact of different global climate oscillations (North Atlantic Oscillation; El Niño Southern Oscillation) in most of continents and particularly on the African continent (López-Moreno et al, 2011). Forecasts vary from one model to another, but an increase in precipitation and extreme weather events could take its place in the global dynamics of climate change (IPCC, 2007).

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