Climate Change in Tafilalet Region (South-East of Morocco, West Mediterranean Part): Trend Analysis

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ABSTRACT

The Errachidia-Tafilalet region is located in the southeast of Morocco. It is a part of the great watersheds Ziz (14400 km²) and Rheris (12,600 km²). The study area is bounded by the watershed Guir to the east, the Algerian border in the south, the mountains of the High Atlas to the north and the mountains of the Anti-Atlas in the southwest. The region’s natural environment is marked by the arid climate. The precipitations are low and the evapotranspiration is high up to 4000 mm / year.

This study aims to understand the climate change in this region and its impact for the characterization of the local drought (deficit, intensity and duration), and the changing climatic parameters (rainfall at different scales, temperature) identified by means of time series. According to the studied period, the data analysis expresses a decrease in rainfall and an increase in temperature. The data also show certain alternating wet and dry periods with durations nearly variable in time and space.

Keywords: Precipitation, Temperature, trend, impact, climate change.

1. INTRODUCTION

Several regions of Morocco were faced with dry periods series since the early 1980s and have had a significant impact on the country’s economy [1,2].

Various studies of future climate projections using climate models show that Morocco is one of the countries most likely to be threatened by climate change, and will record a reduction in cumulative rainfall in the coming decades [3]. Indeed, Morocco's climate warmed significantly over the period 1961-2008. A general trend toward drying is observed. Most annual trends are between 0.2 ° C and 0.4 ° C per decade [1,2] and the reduced rainfall is almost universal throughout the Moroccan territory.

Other studies report that during the positive phase of the North Atlantic Oscillation (NAO), characterized by the digging of the Icelandic depression and swelling/intensification of the anticyclone of the Azores; precipitation would be reduced in Morocco as in southern Europe. Conversely, the negative phase would generate precipitation over it and over northwest Africa [1,2].

Similarly, the study of climate change across Morocco conducted by Born et al. (2008)[4] using the climate classification showed that the Moroccan climate tends to warmer and drier conditions over the last century [5].

In Morocco, the characterization of the precipitation regime to regional and local levels is crucial for the climate change and adaptation. In fact, the rainfall is very important to a particular socio-economic value and many sectors depend on it including water resources and agriculture [1,2]. Indeed, water is of vital importance in the plain of Tafilalet. These regions populations have been harnessed for centuries to mobilize countless works appropriate to their context. Thus, perennial surface waters are derived over water by thresholds while the raw water is mobilized through diversion dams, sometimes of large dimensions or by conventional leads. As for groundwater, it is mobilized by Khettaras which are underground, draining groundwater by gravity, and it is by private pumping (wells) that they developed in recent years of drought.

The climate of the study area is mostly arid (Fig. 1). This is an environment which the runoff is rare. Any change will increase the acuity of the problem and make it more severe. Of course the change in terms of quantity is not going to be important, but it will relatively be more intense in terms of quality, and rarity will amplify the phenomenon.

This climate is also characterized by annual irregularity. Precipitation generally decreases going towards the south.

The aim of this work is to study the climatic parameters (precipitation, temperature) and understand the climate of this region by a spatiotemporal statistical analysis (study of climate trends).
2. DATA AND METHODS

This work’s purpose is to analyze climate changes observed in the region of Errachidia-Tafilalet. This analysis will focus on the recordings provided by the various stations of the study area (Table 1).

Table 1: The different stations covered in the study area

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Station</th>
<th>X(m)</th>
<th>Y(m)</th>
<th>Z(m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ziz</td>
<td>Foum Zaabel</td>
<td>579 700</td>
<td>174 650</td>
<td>1230</td>
</tr>
<tr>
<td></td>
<td>Barrage Hassan Addakhil (BHA)</td>
<td>586 450</td>
<td>155 330</td>
<td>1 130</td>
</tr>
<tr>
<td></td>
<td>Errachidia</td>
<td>591 230</td>
<td>148 970</td>
<td>1028</td>
</tr>
<tr>
<td></td>
<td>Errachidia (DMN)</td>
<td>594 554</td>
<td>148 942</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Radier Erfoud</td>
<td>615 000</td>
<td>101 880</td>
<td>823</td>
</tr>
<tr>
<td></td>
<td>Taouz</td>
<td>634 100</td>
<td>35 700</td>
<td>680</td>
</tr>
</tbody>
</table>

Precipitation measurements are made with a significant regularity. Rarely noted gaps in the monthly series. The rainfall observation period is generally longer than that of other climate parameters (temperature, wind speed, humidity, and evaporation).

The longest time series are those of Errachidia, Radier Erfoud stations (47 and 46 years).

For National Meteorological stations, the longest run is that of Errachidia (30 years) with continuous data between 1973-2003. The series of National Meteorology stations of Errachidia shows no gaps.

The average annual rainfall is 177 mm in Foum Zaabel station further north of the study area and 45.3 mm in Taouz station.

The average rainfall ranges from year to year between 186.9 mm at Foum Zaabel and 48.9 mm at Taouz.
Maximum temperatures are high during the hot months of summer and the minimum temperatures are very low during the cold months of winter.

The average annual temperature ranges from 18.3 °C at Foum Zaabel and 22.3 °C at Taouz. Monthly average temperatures range from -2.3 °C for the coldest month (January) at the Foum Zaabel station upstream of the plain and a maximum of 45 °C for the warmest month (July) to Taouz further south.

The data analysis method used is the chronological graphic method of information processing (MGC[76x700]TI)[11]. Applied to temperature and precipitation data, this method will initially analyze the spatial and temporal distribution of meteorological parameters, and then secondly it will determine the dates of changes in trends.

3. RESULTS AND DISCUSSION

3.1 Precipitation

Monthly rains are characterized by a highly variable rainfall from one year to the other, reflecting erratic rainfall. They show two important episodes: rainy October-November and April-May (Fig. 2).

The annual rainfall regime is characterized by two wet seasons of fall and spring separated by rapid minimum winter season on low and a long summer season very marked by drought [6].

The annual variation of rainfall is recorded for strongly different periods, the interannual average rainfall increases from South to the North. It is of 48.9 mm at Taouz and reaches 186.9 mm at Foum Zaabel.

To get a better idea of the interannual variability of rainfall, changes in annual rainfall, deviations from the mean and trends for each station; the method MGCTI was used for each station.

3.1.1 Foum Zaabel Station

The comparison of values below the axis 0 and those above (anomalies) (Fig. 3) shows that the number of rainfall deficit years is generally more important than the number of humid years. The highest deficits are -119%; -107%; -114% and -107% for the respectively years 1983, 1985, 1998 and 2000 in Foum Zaabel.

The humid years for all stations in the study area are recorded upstream of the plain (Foum Zaabel and Errachidia). At its south, this exes of humidity is relatively small except in 2008, which remained a fairly wet year (+ 204% in Taouz).

Fig3: Evolution of the annual rain and deviation from the average in Foum Zaabel station.

The general trend of rainfall in the Foum Zaabel station is negative. It was - 0.1 mm/year for the 20-year moving average (M20) and -0.5 mm/year for the average mobile 5 years (M5). However, one can notice that it tends to vanish from 2007 (rain back) (Fig. 4).

3.1.2 Dam Hassan Addakhil Station (BHA)

This region is characterized by a long drought period (from 1996 to 2005) with a maximum of -101%
deficit in 2000 (Fig. 5). The rainfall excess years are fewer and are + 120%, + 132% and + 145% respectively for 1979, 1989 and 2008. The trend is negative and rainfall is around 1mm / year (M5) (Fig. 6).

3.1.3 Errachidia Station

Errachidia station represents the longest time series. Three periods of drought are distinct: from 1957 to 1963, from 1980 and 1988 and from 1996 to 2005 (Fig. 7). The least profitable years are: 1957, 1961, 1983 and 2000 with respective gaps of -98%, -86%, -89% and -87%. The highest positive deviation is in 1995 (+ 178%). The general trend of precipitation is negative (Fig. 8). It is -0.3mm / year (M20) and - 0.2 mm / year (M5). This is a less pronounced trend as Barrage Hassan Addakhil. Yet the two stations are close to one another. This difference in trend can be explained by the fact that, at Errachidia, the moving average trend is calculated over a longer time series.

3.1.4 Erfoud Station

Erfoud station is located further south of Tafilalet region. It also represents the longest time series of the region. The deviation from the average shows a distinct drought (1996-2005) (Fig. 9). The evolution of the annual rainfall hardly exceeds 150mm / year except in 2008 when it reached 185.2mm. The most deficit years record values close to the half (55%) in 1983. The most over-year rainfall is 1974 (+77%). The deviation from the average in 2008 was 120% (exceptional year). The general trend of precipitation is negative. It is -1.2 mm / year (M20) and - 0.9 mm / year (M5) (Fig. 10).
Fig 9: Evolution of the annual rain and deviation from the average in Erfoud Radier station.

Fig 10: Trend of rainfall in Erfoud Radier station.

3.1.5 Taouz station

Taouz is at the extreme south station of the studied area. The rainfall is very low. The average is 48.85 mm (1970-2008) (Fig. 11). Deficit years out number with maximum grazing the -50%. In contrast, the humid years are few and rarely exceed + 50% (+ 53% in 1974 and + 152% in 2008). The trend is positive (Fig. 12). It is 0.02 mm / yr (M5) and 0.1 mm / year (M20).

However, it remains to note that the positive trend in Taouz is the result of a trend calculated over a period incorporating more recent recordings (up to 2011).

Fig 11: Evolution of the annual rain and deviation from the average in Taouz station.

Fig 12: Trend of rainfall in Taouz station.

The analysis of trends and deviations from the mean in the various stations of the region shows that:

- The trends observed on moving averages of 5 years, 10 years, 15 years and 20 years at the entire region are negative. They range between -0.1 and -1.2 mm / year.

- The wettest years are:
  - 1979/1980 for Foum Zaabel and Dam Hassan Addakhil stations with averages which are 310 mm and 243.7 mm respectively;
  - 1989/1990 for the same stations with 301.3 mm and 255.8 mm;
  - 1995/1996 for Foum Zaabel, Errachidia Hassan Addakhil dam stations with 406.7 mm, 270 mm and 269.4 mm respectively.

- The difference between the annual average and the rainfall variation from year to year shows in general:
• The number of successive years of drought can reach 10 years.

➢ The deficit / excess analysis relative to normal indicates that they can reach values between 50% to over 100%.

3.2 Temperatures

Average annual temperatures are relatively high and confirm the arid climate (Fig. 13). They go up from Foum Zaabel in the north towards Taouz further south and are respectively in the range of 18.3 °C and 22.3 °C.

Temperatures have very significant seasonal variations with very hot summers and very cold winters. It has low daytime temperatures while the night temperatures rarely exceed 0 °C.

Fig13: Average monthly temperatures of different stations of studied region.

Generally, in the Tafilalet region from upstream to downstream, the patterns are without exception on the rise with values around 0.03 °C / year except for the Hassan Addakhil dam station which are of the order of 0.2 °C / year. In the latter, records are of lower duration (up to 2003-2004) (Fig. 14, 15, 16 and 17).

Fig14: Trends in annual temperatures in Foum Zaabel Station.

Fig15: Trends in annual temperatures in Hassan Addakhil dam station.

Fig16: Trends in annual temperatures in Erfoud station.
The temperature’s trends recorded in Taouz and Erfoud are relatively higher than those of the Foum Zaabel station located in further north (Fig 14, 15, 16 and 17). This difference may be due to the presence of hot, dry air masses from the Sahara.

Many researchers have shown, from the rainfall series, a drought phase that began in the 1970s "break" and is linked to a significant decrease in annual rainfall in the Maghreb countries. MEDDI et al. (2007) [7] detected a sizeable reduction in rainfall in Algeria, around the year 1980.

In Morocco, AMRAOUI et al. (2004) [9] have confirmed, through the study of rainfall deviations from the average annual rainfall of Morocco (1934-2000 period), an irregular rainfall and showed a significant decrease in contributions since 1980. SEBBAR et al. (2011) [10] reaffirmed by the application of the standardized precipitation index (IPS) the existence of this phase of drought from 1970.

This break in rainfall patterns at the national and regional scale corresponds to the signal of global climate change [8], appears at the Tafilalet region by a slight reduction in annual rainfall totals (no break). Associated with lower totals, drought seems to be more persistent in time. Thus, we see that 65% of years of Errachidia’s rainfall series are in deficit.

**4. CONCLUSION**

According to the study period, the trend curves express a decrease in rainfall and an increase in temperature. We also note a certain alternating wet and dry periods with durations nearly variable in time and in space. Therefore, we cannot be categorical on climate change unless if we are dealing with a longer climatic data recording time, a more general context and a fairly high density of recording stations. In addition, the rain’s return which started in the last decade is characterized by more precipitation and is accompanied by a greater number of extreme rainfall events [11].

This new rainy stage coincides with an increase in floods as a type of disasters, in the region and throughout the country.

The increased frequency of flooding confirms that rainfall cycles are now characterized, among others, with a more intense rain. A comparative study of the future number of rainy days, the number of thunderstorm days and the flow rate at Oued Ziz would inform us about the torrential wet phase of this latter.

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**REFERENCES**


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