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Research Article

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Evolution of Pluviometric Characteristics in Ader (North Central Niger) from 1951 to 2016

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Abstract Since the late 1960s, West Africa has been facing a phenomenon of climate variability unprecedented on a historical scale. But studies have shown that the rainfall deficit seems to have persisted in the Sahel region until the end of the 1990s. It is in this perspective that the present work, which aims at analyzing rainfall variability in north-central Niger, is situated, in order to judge whether or not the drought persists. The data cover the period 1951-2011 and the approach adopted includes operations such as the criticism and filling of gaps in the data, the calculation of standardized rainfall indices, the detection of breaks in the rainfall series by the application of two tests (PETTITT, BUISHAND). The application of these different tests shows breaks between 1967 and 1970 and the persistence of dry years and wet years. Although several ruptures were detected, the causes deserve special analysis. The results of this work constitute major indicators for the identification of climate risks, but their complement by observations at the local level will make it possible to better characterize climate variability with a view to further reducing the vulnerability of local producers to climate deterioration.

Keywords Ader, rainfall index, climate variability, deficit

Introduction

Abrupt changes in weather patterns are a translation of the occurrence of climate change [1]. In a context of marked climatic deterioration, the characterization of the spatio-temporal variability of climatic parameters and trends is important for sustainable environmental management [15]. Niger, like most Sahelian countries, has experienced significant spatio-temporal variations in climate patterns since the late 1960s, with consequences for agriculture, the main activity of the population.

On a regional scale, Niger has experienced drought since the 1970s [17]; [8]; [21].and [1] and extended into the early 1990s. In Niger, rainfall has varied considerably in recent decades leading to droughts and floods. The occurrence of these extreme events implies a probable change in the stationarity of local weather patterns. Studies by [1] and [1] have shown the existence of strong interannual fluctuations in rainfall in some stations in western and eastern Niger. However, there are still uncertainties about the evolution of rainfall and very few studies exist for stations in north-central Niger.

To overcome this lack and better understand the issues of probable future impacts of climate change in order to reduce the vulnerability of populations, it is necessary to study the temporal evolution of climate on a more general scale, given that the Tahoua region is characterized by the same homogeneous climate regime. It is in this context that the present study is situated, which proposes to analyze the rainfall variability in this zone of Niger.

Data and Methods

Framework of the study

The study area is located in north central Niger. It lies between longitudes 3°56' and 7°20' East and latitudes 13°20' and 16°26' North in the Tahoua region (Figure 1). The main socio-economic activities are agriculture, livestock and fishing. Its climate is sub-Sahelian with rainfall ranging from 350 to 450 mm and average annual temperatures ranging from 15°C to 41°C (DMN, Niger, 2018). It has important natural resources (Maggia, Tarka, etc.) that make it an area of excellence for intensification of agro-sylvo-pastoral production.

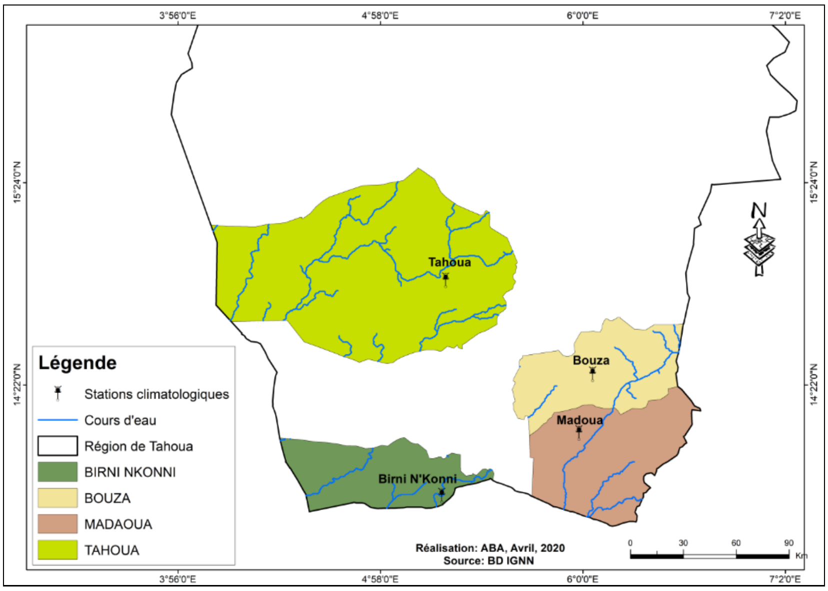

Figure 1: Location of the study area with weather stations

Data and tools

In this study, daily rainfall data from the stations of Birni N'Konni, Madaoua, Bouza and Tahoua (from 1951-2016) and CMIP outputs (2x2) from the study area were exploited. For data processing Xlstat, R and ArcGIS were used.

Methods

Two approaches were used to analyze the temporal evolution of rainfall. These are the standardized SPI index (equation (1), statistical tests of stationarity [19]; [17]; [5]. This is the annual rainfall index, defined as a reduced centered variable [8].

$$IPSa = \frac{(Pa - Pm))}{\sigma P} \quad (1)$$

Where IPSa is the standardized rainfall index for year a, Pa is the rainfall for year a, Pm is the mean annual rainfall (1951-2016), and p is the standard deviation over the same period. This index reflects a rainfall surplus or deficit for the year considered compared to the reference period. Statistical tests and detection of breaks have also been used [5] et [7].

Results

Rainfall variability and breaks in the series

The representation of the reduced centered indices of the interannual average rainfall (1950-2000) in the four stations that are fairly representative of north-central Niger indicates a trend characterized by three major periods. A wet period marked by positive index values, a deficit period marked by negative index values and mixed periods or abrupt alternation between surplus and deficit years. The evolution of annual rainfall values in Bouza is marked by very remarkable interannual fluctuations with a succession of dry and wet periods (Figure 2a). Three main phases are thus highlighted. The periods 1951-1967 and 1998-2008 were wet, with slight deficits in 1954, 1955, 1961 and 1963, while a long dry period was clearly observed from 1968 to the early 1990s. However, it should be noted that from 1990 onwards, there was a semblance of a return to wetter conditions, even though these were characterized by strong interannual variability. From 1968 to 1996, the rainfall deficit coincided with the long drought that affected all of West Africa. In fact, rainfall decreases of 21.54% were recorded at this station. Finally, from the 1990s onwards, there was a rather timid recovery in rainfall, but with very high interannual variability, marked in particular by a severe drought in 2005. The PETTITT (1979) and BUISHAND tests show a downward trend in rainfall with a break in 1967 at the 95% threshold (p-value = 0.04397). The Konni station experienced high interannual variability in rainfall with a wet period between 1951-1959, another deficit period between 1960-1990 and mixed periods (sudden alternation between dry and wet periods) from 1991 onwards (Figure 2b). Statistical analysis shows a downward trend in precipitation and a break in 1970 that is significant in Kendall's test (p-value = 0.01786). Note that this decrease in precipitation is about 21.53%.

As for the Madaoua station, it was marked by strong interannual fluctuations. It has experienced wet periods, the most marked of which are those of 1951-1962 and 1994-2014 (Figure 2c). As for the dry period, it was very long, from 1990 and is marked by strong interannual variability. Finally, at the Tahoua station, the temporal evolution of annual rainfall totals, as illustrated in Figure 2d, shows two very distinct phases. A very wet phase from 1951-1967 is the breaking point (p-value = 0.01786) and another dry phase from 1968 until 2012, which marks a quantitative decrease in rainfall of 24.29%.

However, notwithstanding this deterioration in terms of cumulative rainfall, it should be noted that the 1990 and 1994 decades were very rainy for the area. The results of the tests applied are summarized in Table 1 and the analysis shows the presence of two breaks. According to the PETTITT and BUISHAND tests, a break was observed in 1967, 1968 and 1970 respectively in Bouza, Konni and Tahoua, whereas the two tests did not detect any break for Madaoua. It should be noted that all of these breaks occur between 1968 and 1970.

Table 1. Results of the statistical tests applied to the rainfall chronicles

	PETTITT	BUISHAND
Bouza	Rupture 1967 à 99%	Rupture 1967 à 99%
Madaoua	Pas de rupture	Pas de rupture
Konni	Rupture 1970 à 99%	Rupture 1970 à 99%
Tahoua	Rupture 1968 à 99%	Rupture 1968 à 99%

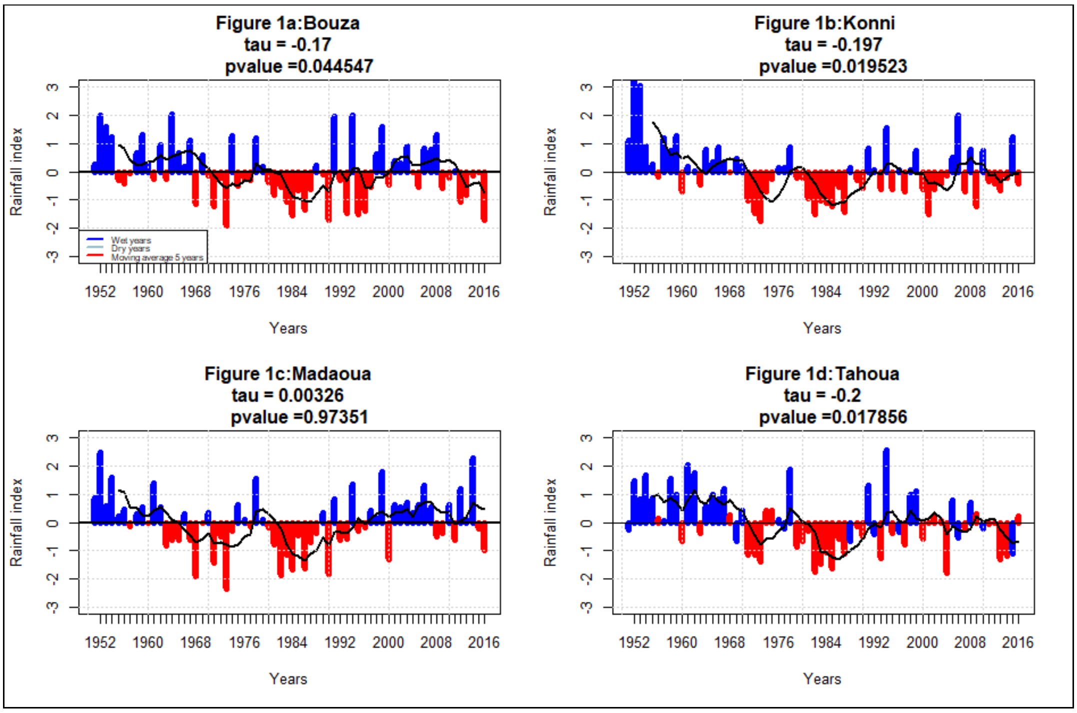

Figure 2: Interannual variability of rainfall between 1951-2016 and 5-year step moving averages

2.2 Evolution of projected rainfall totals

The simulation of seasonal rainfall is one of the main defis of climate simulation in West Africa. In effet, cumulative rainfall during the monsoon season is a key parameter for both the evolution of natural resources (water points, pastures) and agricultural production [16]. Analysis of the results of the homogeneity test [19] of the outputs of four CMIP 5 models reveal significant break years for the study area. Thus, for the CMCC-CM, from 1961 to 2067 an average of 274.924 mm is noted.

However, from 1968 to 2100, an average increase in cumulative rainfall was noted with 346.557 mm, and for the CNRM-CM5, cumulative rainfall was forecast to average 744.868 mm from 1961 to 2058.

However, a cumulative rainfall of 839.78 mm will be observed from 2059 to 2100, i.e. an increase of 95.1 mm. As for the IPSL-CM5A-MR model, it also results in an increase of 31.312 mm between 1961 to 2019 and 2020 to 2100, and the NorESM1-M predicts a breaking point in 2053 with an average accumulation of 650.03 mm which increases to an average of 722.53 mm from 2054 to 2100, an increase of 72.44 mm. In the long term, we note from the comparison of the averages of the various models, the CMCC-CM and IPSL-CM5A-MR underestimate the accumulations; and the CNRM-CM5 overestimates it, thus largely exceeding the current average of the area. For all the above models, it is concluded that the current average signal is not observed, as well as the future evolution not captured with respect to the average of 617.50 mm of observed data over the period 1950 to 2012. Thus, only the NorESM1-M model following RCP 8.5 forcing with a predicted mean annual accumulation of 674.37 mm from 1961 to 1990, confirms the observed mean signal of the data in terms of capturing the future evolution of the mean annual accumulation. Similarly, the comparison of observed and simulated normals (1961-1990) for the models studied reinforces the hypothesis that the NorESM1-M with an observed mean of 643.836 mm shows that the evolution of the current climate in terms of cumulative annual rainfall is captured.

From a trend point of view, the models used show an increase in cumulative rainfall by 2100 and the forecasts show a slight increase in cumulative rainfall by 2020-2049 (Figure 3).

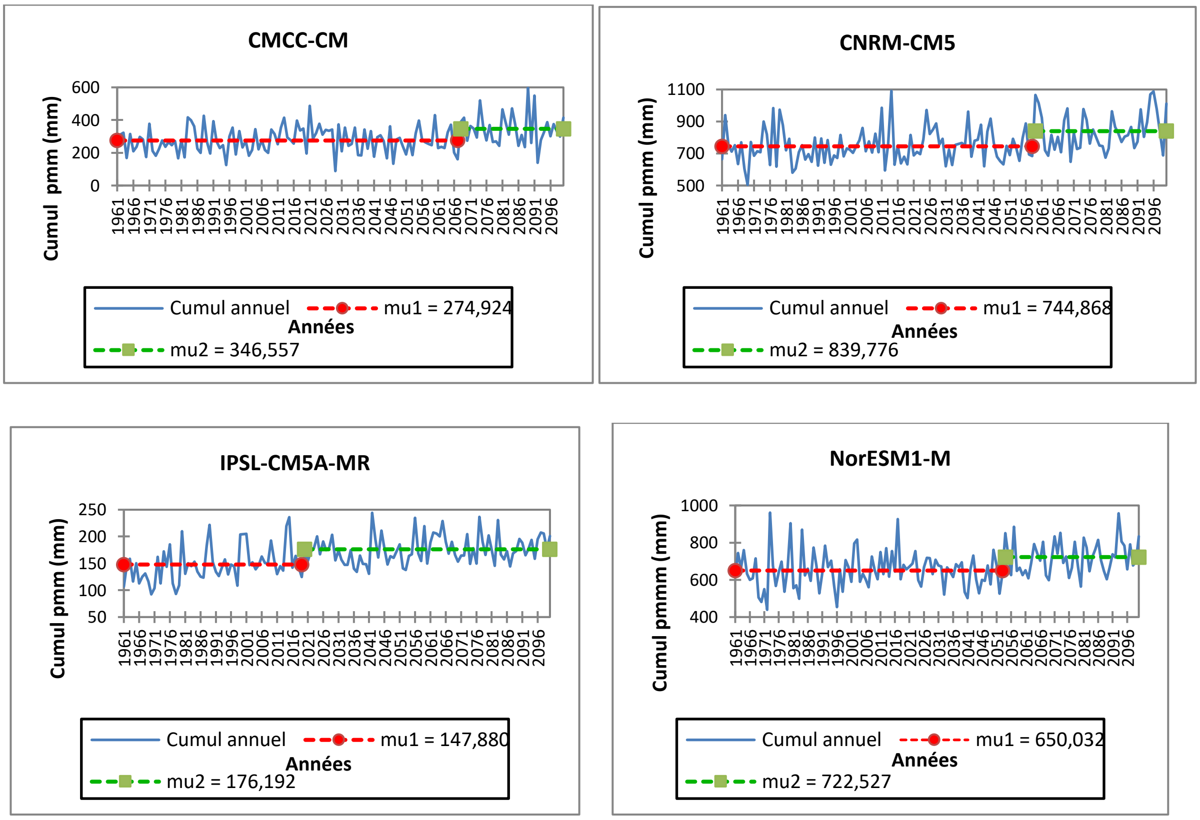

Figure 3: Results of the breakage test for the various rainfall model outputs for Central-Northern Niger

3. Discussions

Through the analysis of annual rainfall series, this work has focused on characterizing the recent trend, in order to determine the evolution of the climatic deterioration that began in the late 1960s.

Wet periods alternate with dry and mixed periods.

In sum, the analysis of rainfall trends in north-central Niger shows that cumulative rainfall has been declining on average since the end of the 1960s. Standardized anomalies show three major phases in the evolution of the climate, namely a wet phase from 1961 to 1968 or 1969; a phase of persistent dry years (1969-1997) and finally a mixed period from 1998.

However, in general, the moving average curves, which are a good indicator of major interannual fluctuations [18], show very distinct periods. These different results that reflect this climatic crisis corroborate the conclusions of [10] who showed a change in rainfall observed in the Sahel between the periods 1951-1970 and 1971-1990. Other studies and works in the Sahelian region confirm these results, particularly in terms of droughts in the West African Sahel during the periods 1970-1990, and have evoked episodes of strong rainfall deficits, clear breaks and or spatio-temporal variability [3]. [10]; [13]; [17]; [8]. Similarly, the decreases in cumulative rainfall in Bouza, Konni and Tahoua of 21.54%, 21.53% and 24.29%, respectively, are related to the results of [2] who noted deficits of 20 to 25% in the Sahelian zone. Indeed, even though no break was detected in Madaoua, it should be noted that the average annual precipitation amounts collected remain lower than before 1970 (1951-1970), with rates of variation between the two wet periods (1951-1963) of 6.7% and 8.44% for the period 1991-2016.

Finally, all the results agree on the occurrence of strong interannual fluctuations in rainfall and a downward trend in rainfall (succession of dry periods and wet periods). North-central Niger, apart from the great drought recorded during the 1970s and 1973, experienced significant dry periods between 1980 and 1985, and then 1990 and 2005. These periods of drought can be interpreted as manifestations of the great drought that affected West Africa from the late 1960s to the mid-1990s [5] and [6]. From the recovery to wetter conditions from 1990 onward, the results are consistent with the findings of [9] who noted that since the late 1990s conditions were wetter in the eastern Sahel and that drought was receding slightly in the central Sahel, while the western Sahel, in contrast, was still experiencing dry conditions.

The work of [1] also points to an improvement in rainfall since the mid-2000s. However, they judge that the situation has not returned to that of the years 1951-1970. Similarly, the outputs of the NorESM1-M and CNRM-CM5 models capture the signal currently observed in terms of cumulative annual rainfall and predict increases in cumulative rainfall, which bodes well for farmers in terms of reducing the risk of drought, even though, in the Sahelian zone, it is the great variability in time and space that makes production activities difficult in certain years.

Conclusion

This study reveals that over the past sixty years, this region of Niger has experienced strong climatic variability with a succession of dry and wet periods. The analysis of observed rainfall shows that there is a significant downward trend in rainfall, while forecasts indicate an increase in terms of annual accumulations.

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