ANALYSIS OF THE FUTURE EVOLUTION OF MAXIMUM CUMULATIVES OF RAINFALL IN THE LOBO BASIN (CENTRAL-WEST OF COTE D'IVOIRE)

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ABSTRACT. – Analysis of the Future Evolution of Maximum Cumulatives of Rainfall in the Lobo Basin (Central-West of Cote D'Ivoire). This work study analyzes the future evolution of the maximum height of rains on three decades (2014-2023, 2024-2033 and 2034-2043). The WeaGETS third-order Markov model and calculation of climate index was respectively used to predict the field of daily rainfall for the period of 2014-2043 and to calculate three climate indices. The medium criterion of Nash 0.93 and the coefficient of determination medium R^2 = 0.9994 for all the stations covering the zone of study shows a good performance of the Markov model. Annual maximum 1-day precipitation (Rx1day) and annual maximum consecutive 5-day precipitation (Rx5day) will decrease during the decades 2014 to 2023 and 2024 to 2033, and will increase from 2033 to 2043. While annual maximum consecutive 3-day precipitation (Rx3day) will know a decrease during the decade from 2024 to 2033 and an increase during the decades from 2014 to 2023 and from 2034 to 2043. Generally, the basin of Lobo will know an increase in these three climate indices over the entire period (2014-2043).

Keywords: evolution, climate indices, WeaGETS, Lobo

1. INTRODUCTION

West Africa is a region where people still face high climatic variability (Sarr and Camara, 2017). This climatic variability refers to the natural variation within or between climates (Kouakou, 2011). It describes the fluctuation of the seasonal or annual values of the climatic parameters (precipitation, temperature,

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etc.) compared to the reference time averages (Servat *et al.,* 1999). Some studies have shown that this change results in increased rainfall and a succession of extreme events (New *et al.,* 2001, Christensen *et al.,* 2007). The consequences of climate variability on the economies of African countries are undeniable, this continent being the most vulnerable (IPCC, 2007).

According to Houghton *et al.* (2001), extreme weather events are expected to become more frequent with global warming. These events have a negative impact on agriculture, livestock and natural resources (Karimou Barké *et al.,* 2015) which are sectors on which most of the West African national economies are based. This is the case of Côte d'Ivoire, whose economic development is based on agriculture. The country is very sensitive to the climatic context (Bigot *et al.,* 2005) because its agricultural sector generally depends on rainfall. In recent decades, it has been subject to climatic variations (Ardoin, 2004, Kouakou *et al.,* 2007). These climatic variations cause the frequency of seasonal lags (confusion on the crop calendar), which has the corollary a regular and effective decline of nearly half of the productions or yields of rain-fed agriculture as well as food crops (Gerald *et al.,* 2009). According to WMO (2009), the sustainability of agricultural and economic conditions depends on our ability to manage the risks associated with extreme weather events. As a result, knowledge of rainfall behavior in the Lobo basin is necessary for sustainable socio-economic development. The present study thus proposes an analysis of the future evolution of the accumulations of precipitations through the computation of the climate indices such as: annual maximum 1-day precipitation (Rx1day), annual maximum consecutive 3-day precipitation (Rx3day) and annual maximum consecutive 5-day precipitation (Rx5day). The data and methods used are presented in the second section. In the third section, the results are presented followed by discussion.

The Lobo basin (Fig. 1) is located in the west-central part of Côte d'Ivoire between longitudes 6°05' and 6°55' West and latitudes 6°02' and 7°55' North. Most of the basin belongs to the region of Upper Sassandra. It covers the departments of Daloa, Issia, Vavoua and Zoukougbeu; the extreme north belongs to the department of Séguéla; while it overflows in the South, on that of Soubré. It is characterized by two types of climate: the equatorial climate of moderate transition (Baoulean climate with two seasons) which is observed in the northern half of the basin and the equatorial climate of transition (Attiean climate with four seasons) which is observed in the extreme south. Two major types of terrain share the basin. These are the plains with altitudes between 160 and 240 m, located in the south of the basin and the plateau occupying most of the basin correspond to altitudes varying between 240 and 320 m (Yao, 2014). The soils are essentially modal or moderately desaturated ferralitic type with modal remakes and overlapping from schists and granites (Perraud, 1971).
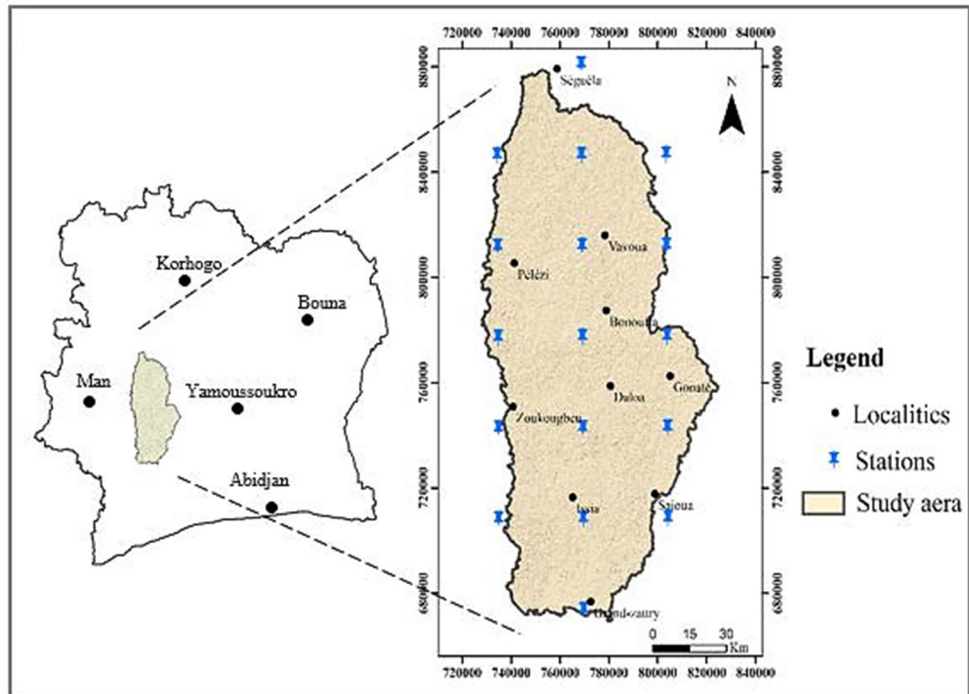
Fig.1. Localisation of the Lobo basin

2. MATERIAL AND METHODS

2.1. Material

2.1.1. Data

For this study, daily rainfall data from 17 stations covering the Lobo watershed for a period of 30 years from 1984 to 2013 were used. These data are obtained from the National Environmental Prediction Centre's (NCEP) Climate Prediction System (CFSR) reanalysis repository and are available on the Soil and Water Assessment Tool (SWAT) website (*http://globalweather.tamu.edu/*). They were used as a reference for the forecasting of daily data from 2014 to 2043.

2.1.2. Software

The software used is of several types:
- XLSTAT 2016 was used to store and statistically process rainfall data;

- Matlab 2014 for the prediction of daily precipitation data;
- ClimPACT 2 Master running under the environment of the statistics software 'R' version 3.1.2, for the calculation of daily time step climate indices.

2.2 Methods

The method used to predict daily precipitation fields from 2014 to 2043 is based on the WeaGETS Markov chain 3 method and the method used to analyze maximum cumulative precipitation is based on the climate index method (Aguilar *et al.*, 2009; Hountondji *et al.*, 2011 and N'Guessan Bi, 2014) proposed by the expert team on climate change detection and indices (ETCCDI).

2.2.1. Markov model of order 3 of WeaGETS

WeaGETS is a versatile Matlab-based stochastic daily time generator that produces daily precipitation, a series of maximum and minimum temperatures (Tmax and Tmin) of unlimited length. First, second and third order Markov models are provided to generate the occurrence of precipitation, and four distributions (exponential, gamma, asymmetric normal and mixed exponential) are available to produce a daily precipitation amount. Precipitation generating parameters have options to smooth using Fourier harmonics following the Richardson approach (1981) and to correct the low frequency variability of precipitation and temperature following the spectral correction method of Chen *et al.* (2010). Details of the method are found in the work of Chen *et al,* 2011 and Chen *et al.,* 2012.

2.2.2. Calculation method for indices

The calculation of climate indices takes place in two steps (Balliet *et al.,* 2017):
✓ **Quality control (QC) of the data used**
The principle is as follows:
   - replace the maximum daily temperature of the incorrect values with -99.9, if lower than the minimum daily temperature;
   - it is not possible to have more than 365 to 366 daily observations per year;
   - the month of February should not have more than 28 observations in any given year;
   - missing or negative data (for precipitation) are replaced by -99.9 before quality control by the software.
✓ **Calculates climate indices**
To analyse the future evolution of the maximum cumulative rainfall, we calculated the indices. In this study, three indices climate (R1xday, Rx3day and Rx5day) will be the subject of our study.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Annual maximum 1-day precipitation (Rx1day)

The Rx1day index indicates the annual maximum 1-day precipitation. The mean values of this index (Fig. 2) will range from 48.11 mm to 56.23 mm over the period 2014 to 2023. From 2024 to 2033, the mean values of R1day will range from 45.60 mm to 55.82 mm, a decrease of 0.73 mm/year. From 2024 to 2023, the maximum total rainfall on a rainy day will be between 44.48 mm and 112.83 mm, an increase of 2.6 mm/year. The general trend of the Rx1day index over the entire study period in the Lobo basin is increasing. The highest mean values will be observed in 2020, 2025 and 2041 respectively over the decades 2014 to 2023, 2024 to 2033 and 2034 to 2043.
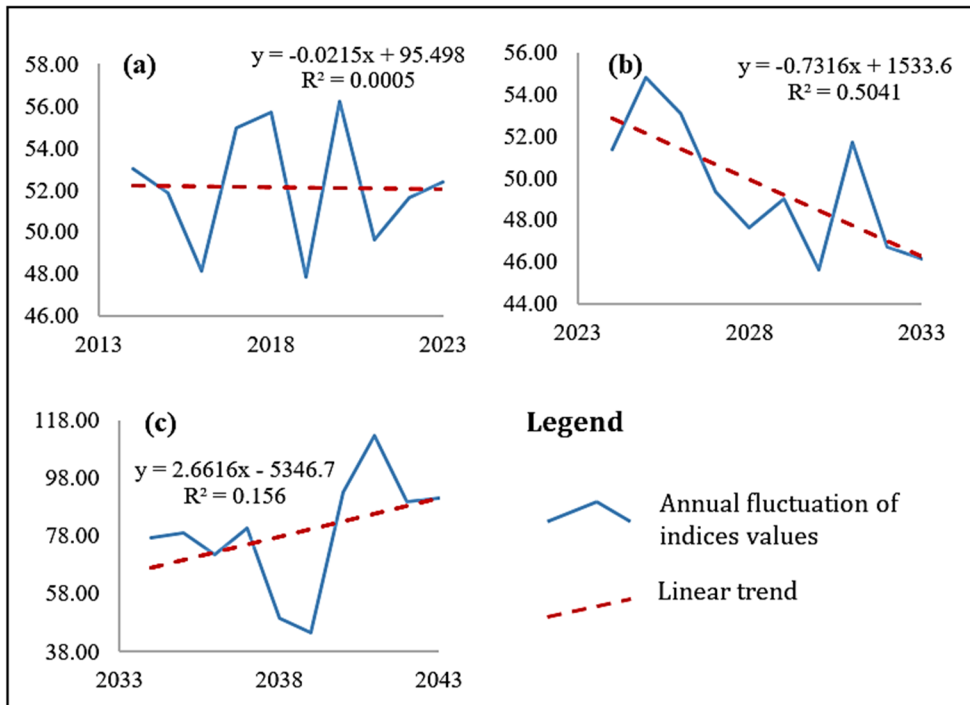
Fig. 2. Annual variation and linear trend in Rx1day index values in the Lobo basin in 2014-2023 (a), 2024-2033 (b) and 2034-2043 (c)

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3.1.2. Annual maximum 3-day precipitation (Rx3day)

The Rx3day index corresponds to the annual maximum 3-day precipitation. The mean values of this index (Fig. 3) will range from 69.21 mm to 79.66 mm over the period 2014 to 2023. From 2024 to 2033, the mean Rx3day values will range from 70.61 mm to 80.95 mm, a decrease of 0.31 mm/year. From 2024 to 2023, the maximum total precipitation on three consecutive rainy days will be between 62.83 mm and 181.13 mm, an increase of 5.27 mm/year. The general trend of the Rx3day index over the entire study period in the Lobo basin is increasing. The highest mean values will be observed in 2018, 2031 and 2041 respectively over the decades 2014 to 2023, 2024 to 2033 and 2034 to 2043.
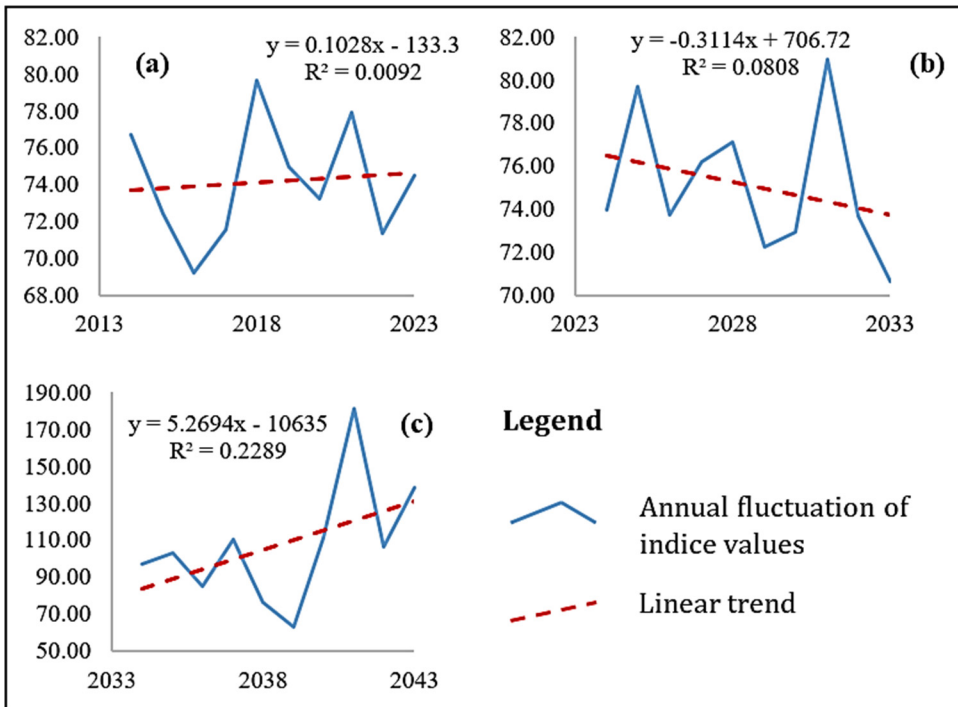

Fig. 3. Annual variation and linear trend in Rx3day index values in the Lobo basin in 2014-2023 (a), 2024-2033 (b) and 2034-2043 (c)

3.1.3. Annual maximum 5-day precipitation (Rx5day)

The Rx5day index is the annual maximum 5-day precipitation. The mean values of this index (Fig. 4) will range from 92.34 mm to 101.04 mm over

the period 2014 to 2023. From 2024 to 2033, the mean Rx5day values will range from 90.03 mm to 101.96 mm, a decrease of 0.13 mm/year. From 2024 to 2023, the maximum total precipitation on five consecutive rainy days will be between 73.93 mm and 234.68 mm, an increase of 6.44 mm/year. The general trend of the Rx5day index over the entire study period in the Lobo basin is increasing. The highest mean values will be observed in 2018, 2031 and 2041 respectively over the decades 2014 to 2023, 2024 to 2033 and 2034 to 2043.
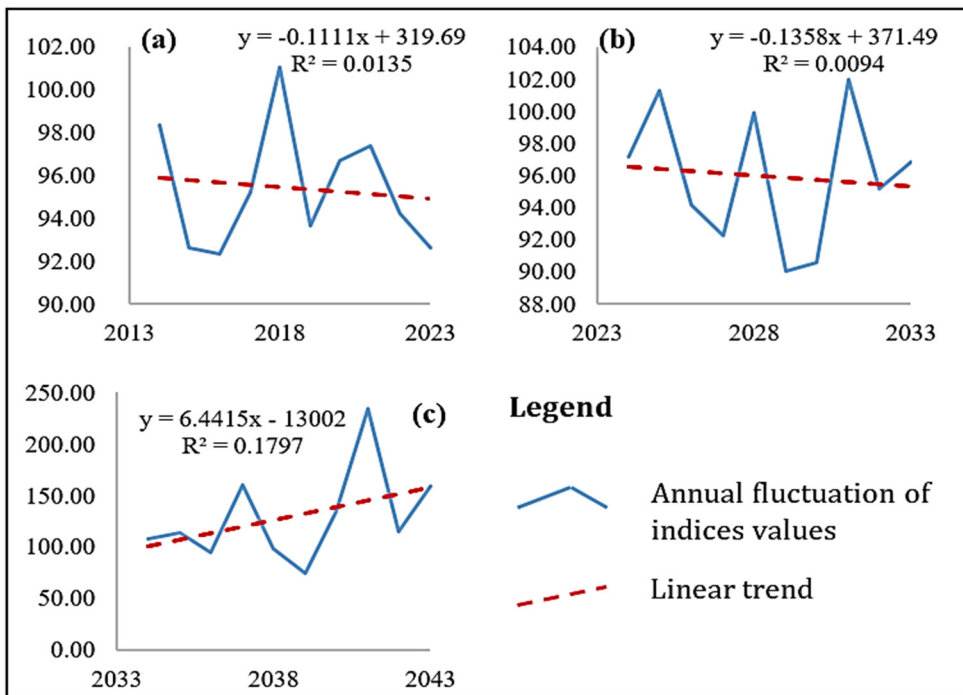

Fig. 4. Annual variation and linear trend in Rx5day indices values in the Lobo basin from 2014-2023 (a), 2024-2033 (b) and 2034-2043 (c)

3.2. Discussion

This work highlights the analysis of the future evolution of maximum cumulative rainfall in Lobo basin (west-central of Côte d'Ivoire). The precipitation data used in this study are obtained from the National Environmental Prediction Centre's climate prediction system reanalysis repository. Several studies have been conducted using CFSR data, indicating their validity (Mo *et al.,* 2011; Najafi

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et al., 2012; Dile and Srinivasan, 2014). These data have the advantage of better reflecting the rainfall event measured by satellites, as shown in the work of Fuka, *et al.,* 2013. The methodological approach is based on the use of daily rainfall indices of extremes proposed by ETCCDI experts who have the advantage of describing the particular characteristics of extremes. Also, Markov chains, widely used for precipitation analysis (Chèze and Jourdain, 2003; Cazacioc and Cipu, 2004) describe daily precipitation fields well. They have the advantage of taking into account the memory effect. The works of Stern *et al.,* 2006 and N'Guessan Bi, 2014 came to the same conclusion. These results are consistent with the work of Wilks (1998), Chen *et al.* (2012), Lennartsson *et al.* (2008) and Allard *et al.* (2015). This study forecasts an increase in the Rx1day, Rx3day and Rx5day indices, which correspond respectively to the cumulative precipitation for 1, 3 and 5 days in one year. It shows a general upward trend for the coming decades (2014-2043). These results are similar to the work of Vu Thi Van Anh (2016), Sarr and Camara (2017), IPCC (2007) and Fredolin T. *et al.* (2018). In their study on future changes in precipitation extremes, Vu Thi Van Anh *et al.* (2016) showed that maximum precipitation of one, three and five days at all stations in Vietnam is increasing. Sarr and Camara (2017) predict an increase in these indices over much of West Africa and these results support the IPCC (2007) projections that predict an increase in extreme weather events over the coming decades. Fredolin T. *et al.* (2018) in their work on most of Indochina and northern Myanmar have reached the same conclusions. This projection of extreme rainfall in the future will lead to certain types of natural disasters related to water resources in the Lobo basin, such as floods.

4. CONCLUSION

Analysis of the future evolution of maximum cumulative precipitation in the Lobo basin has shown that over the next three decades (2014-2043):
- the annual maximum 1-day precipitation (Rx1day) will increase by 1.26 mm/year or 12.6 mm/decade;
- the annual maximum 3-day precipitation (Rx3day) will increase by 1.65 mm/year or 16.5 mm/decade; and
- the annual maximum 5-day precipitation (Rx5day) will increase by 1.73 mm/year or 17.3 mm/decade.

The results of this study could enable policy makers to put in place the adaptation strategies needed for better water resource management and natural disasters. They can therefore help to increase the resilience to climate change of certain human activities such as agriculture, which is a very important source of food and income for the people of Côte d'Ivoire.

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