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RECENT RAINFALL TRENDS BETWEEN 1990 AND 2020: CONTRASTING CHARACTERISTICS BETWEEN TWO CLIMATE ZONES IN BURKINA FASO (WEST AFRICA)

Abstract: The northern region (municipality of Samba) and the southwestern region (municipality of Gaoua) are agricultural production areas, which are however dependent on rainfall. Therefore, knowledge of rainfall characteristics is essential for good agricultural planning. Thus, the objective of this study is to analyse the recent evolution of rainfall between 1990 and 2020 in Burkina Faso. To this end, monthly rainfall data were acquired from the National Meteorological Agency of Burkina Faso. Statistical methods for detecting breaks in time series, standardised rainfall indices, rainfall extremes and rainfall concentration were applied to the data collected. The study shows that annual rainfall totals are increasing between 1990 and 2020, but are marked by alternating wet and dry periods. Moreover, precipitation is more concentrated in a few months (July, August, September) in the northern region since the rainfall concentration index (RCI) is ≥ 25% between 1990 and 2020, and precipitation is more spread over several months (May, June, July, August, September, October) in the southwestern region, since the RCI oscillates between 18.13% and 19.09%, except for the decade 2000-2010 when the RCI is 20.3%. Therefore, the northern region is exposed to extreme precipitation (increase in total wet days (precipitation ≥1 mm) (JP), frequency of intense rainfall (P95(day), intensity of rainy days (SDII (mm/day), maximum daily precipitation (PXJA (mm)) more than the southwestern region (decrease in frequency of intense rainfall, maximum daily precipitation). It is therefore imperative for the national authorities to initiate resilience actions in favour of farmers in the northern region.

Key words: Burkina Faso, rainfall variability, RCI, extreme rainfall

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Introduction

Climate change is a significant variation in climate averages that exists over decades or even longer periods (Gocic & Trajkovic, 2013). It affects all regions of the world (IPCC, 2001; IPCC, 2007; IPCC, 2014). Unlike other continents, in Africa, annual rainfall is a variable usually studied to characterise climate change (Ouédraogo, 2001). West Africa is particularly affected by climate change/variability. Indeed, this area experiences decadal, multi-decadal and centennial variability in rainfall (Onyutha, 2018). The work of Nicholson et al, 2012 adds that this variation continued between 1801 and 1900, marked instead by inter-annual variability in rainfall. However, a major change in the rainfall regime appears to have occurred after 1968 in the Sahelian zone (Nicholson and Palaom, 1993), with a shift to drier conditions a decade later.

Overall, the rainfall recovery was greater in the east than in the west of West Africa, creating a shift in the climatological gradient of east-west rainfall over the area (Nicholson et al., 2018). Nevertheless, other works such as Ibrahim et al., 2021 observe that over the global period 1901-2018, the period 1950-1970 has the wettest years compared to the period 1971-1990 which has the driest years. However, over the last 20 years, a trend towards a return of annual rainfall totals has been observed in different West African areas such as the Middle Niger Basin (Descroix et al., 2013), Senegal (Bodian, 2014), Senegambia (Descroix et al., 2015), the Sahel (Vischel et al., 2015). In Burkina Faso, rainfall and hydrometric regimes have been declining since about 1970. Annual rainfall deficits vary between 10% and 40%, while average annual flows show a deficit of over 20% and sometimes over 60% (Ouédraogo, 2001). Climate variability affects all regions of the country (Ibrahim et al., 2011; Lodoum et al., 2013; Kaboré et al., 2015; Sieza et al., 2019), and the decrease in total annual precipitation is the most significant change (De Longueville et al., 2016). However, most studies (Ouédraogo et al., 2017; Ouédrago, 2013; Paturel et al., 2002) on the characterisation of rainfall variability have taken periods between 1960 and 2014. As a result, there is a temporal gap in knowledge about rainfall trends in Burkina Faso in general and the North and South-West region in particular, which are highly dependent on the rainy season for agricultural production. This study fills this gap by focusing on the period 1990 and 2020.

Data and methods

Geographical location of the study area

The study areas are located in West Africa in general and in Burkina Faso in particular. The municipality of Samba (in the northern region) and the municipality of Dissin (in the south-western region) are located in two different climatic zones, namely the South-Sahelian and the South-Sudanese (Fig. 1).

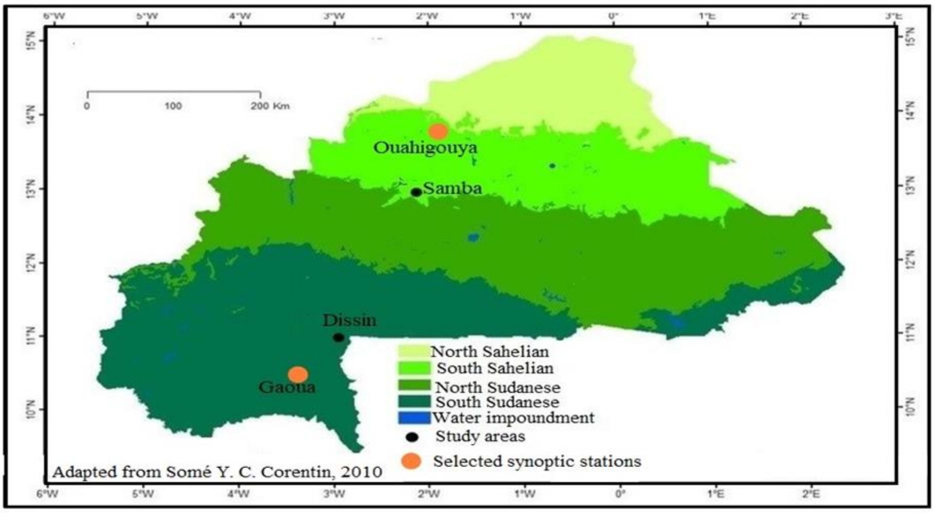


Fig. 1. Location of study sites

Study data

The rainfall data were collected from the National Meteorological Agency of Burkina Faso (NMABF). The study covers two synoptic stations in the north and south-west regions (Tab. 1).

Tab. 1: Characteristics of the stations selected in this study

Names of the stations	Climatic zones	Type of station	Type of data collected	Latitude	Longitude	Period of available data
Gaoua	South Sudanese	Synoptic	Monthly rainfall amounts	10.3333	-3.1833	1990-2020
Ouahigouya	South Sahelian	Synoptic	Monthly rainfall amounts	13.5833	-2.4333	1990-2020

Source: National Meteorological Agency of Burkina Faso (NMABF),1990-2020

Methods

Detection of statistical breaks in the rainfall data

The methods used for this study are based on the detection of breaks in time series. In addition, two tests such as Mann-Kendall (MK) test and Pettitt test were chosen for this study, this is because they are widely used to detect the trend and change point in time series of climate and hydrological variables (Jaiswal et al., 2015). Developed by Pettitt (1979), it is a non-parametric test that assesses the occurrence of abrupt changes in the time series. This test is based on the Mann-Whitney two-sample test (rank-based test) (Mallakpour & Villarini, 2016). Let be the time series (xi), with i=1, N; Let be the null hypothesis, i.e. no break in the series. Then, according to Koukponou, 2001, the operationalization of the test assumes that for any time t varying from 1 to N, the series (x), with i=1, t and (xi), with i=t+1, N included in the same population The statistics of the non-parametric test Ut,N for this test can be described as follows (Khoualdia et al., 2014) :

$$U_{t,N} = \sum_{i=1}^{t} \sum_{j=i+1}^{N} D_{ij} \quad (1)$$

$$D_{ij} = sgn(x_i - x_j) \text{ with } sgn(Z) = 1 \text{ si } Z > 0, 0 \text{ si } Z=0 \text{ et } -1 \text{ si } Z<0$$

Let Kmax be the variable defined by the maximum absolute value of U1, N for t varying between 1 and N-1.

If k denotes the value of KN taken from the series studied, under the null hypothesis, the probability of exceeding the value k is given approximately (Koukponou, 2001):

$$\text{Prob } (K_N > K) = 2\exp\left(\frac{-6k^2}{n^2+n^3}\right) \quad (2)$$

For a given first order risk α, if Prob (KN > K) is < α, the null hypothesis is rejected. These equations are integrated into the KronoStat 1.01 software that has been implemented for the calculations.

The Mann-Kendall (MK) test is considered a non-parametric test for identifying trends in climatological and hydro-climatological series data (Wang et al., 2020; Mawonike et al., 2021; Achite et al., 2021). This test not only allows the data to conform to a particular distribution, but also allows data reported as undetected to be included by assigning them a common value lower than the smallest value measured in the data set (Alhaji et al., 2018). The null hypothesis (H0) for this test is that there is no monotonic trend in the time series. While the alternative hypothesis (HA) is that there is a trend (Pohlert, 2020). This trend can be positive, negative or non-zero. The Mann-Kendall test statistic is calculated as follows (Drouiche et al., 2019:168):

Let $x_1, x_2 \ldots x_n$ be a data set in which x_j is given corresponding to time t_j,

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{sgn } (x_j - x_k) \quad (3)$$

With,

$$\begin{cases} \boldsymbol{sgn(x_j - x_i) = 1} \text{ if } \boldsymbol{(x_j - x_i) > 1} \\ \boldsymbol{sgn(x_j - x_i) = 0} \text{ if } \boldsymbol{(x_j - x_i) = 1} \\ \boldsymbol{sgn(x_j - x_i) = -1} \text{ if } \boldsymbol{(x_j - x_i) < 1} \end{cases} \quad (4)$$

Assuming that the data are independent and identically distributed, Kendall (1975) gives E(S) =0, and:

$$Var(S) = \frac{1}{18}[n(n-1)(2n+5) - \sum_{i=1}^{m}(t_i - 1)(2t_i + 5)] \quad (5)$$

where n is the number of data in the series, m is the number of linked of linked groups and ti is the number of data in the group of order i.

If the sample contains ten or more data, the distribution of the test statistic Z below will be approximated by acentred Gaussian:

$$Z = \begin{cases} \frac{s-1}{\sqrt{Var(s)}}, & \text{if } s > 0 \\ 0 & \text{if } s=0 \\ \frac{s-1}{\sqrt{Var(s)}}, & \text{if } s < 0 \end{cases} \quad (6)$$

The null hypothesis H0 (no trend) is rejected when the significance level or the eigenvalue (p-value) is greater than 5%.

PAST, a paleontological statistical software package for teaching and data analysis (Hammer et al., 2001), was used to determine the trend of rainfall data in the study area.

Linear regression of rainfall data

It is one of the simplest methods to calculate the trend of data in time series (Nyatuame et al., 2014). The equation of the linear regression line is given by the following formula (Vifan et al., 2022):

$$Y = aX + b \tag{7}$$

Where, X is the independent variable and Y is the dependent variable. a is obtained by calculating the slope, which is the director coefficient of the regression who's positive (+) or negative (-) signs express respectively the increasing and decreasing evolution over time of x and b, a constant such that:

$$a = \frac{(\sum y)(\sum x^2) - (\sum x)(\sum xy)}{N \sum x^2 - (\sum x)^2}$$

$$b = \frac{N(\sum xy) - (\sum x)(\sum xy)}{N \sum x^2 - (\sum x)^2} \tag{8}$$

The coefficient of determination, which is the square of the r (linear regression coefficient), is also associated with the regression line. This coefficient determines how well the regression equation fits to describe the distribution of the points (Kodja, 2018). It is obtained according to Amoussou, 2010, Koumassi, 2014 by the formula R=r2, with

$$\boldsymbol{r} = \frac{\frac{1}{N}\sum(X_i - \overline{X})(Y - \overline{Y})}{\sigma(X).\sigma(Y)} \tag{9}$$

Where: N is the total number of individuals; Xi and Yi are the values of the series. and are the means of the variables. σ(X) and σ(Y) represent the standard deviations.

The R2 value was used to show how strong is the correlation and relationship between the variables X and Y. A value of 1 means that the correlation becomes strong and all points lie on a straight line. On the other hand, a value of 0 means that there is no correlation and no linear X between Y relationship ((Nyatuame et al., 2014).

Standardised Precipitation Index (SPI)

It is the average of the centred and reduced seasonal rainfall totals calculated at each rainfall station for a given season (Kaboré et al., 2017). In addition, it allows the determination of the threshold indicating drought at different time scales (Azzi and Medjerab, 2011). According to Kaboré et al., 2017, the formula for this index is as follows:

$$SPI = \frac{1}{N_i}\sum_{j=i}^{Ni}\left(\frac{p_j^i - \overline{P}_j}{\sigma_j}\right) \tag{10}$$

Where, Pji is the rainfall of year i at station j, Pj the interannual mean rainfall of station j, σj the standard deviation of the seasonal cumulative series at station j, and Ni the number of stations in year i. The SPI index reflects a rainfall an excess or deficit for the year under consideration relative to the chosen reference period (Paturel et al., 1998). McKee et al., 1993, classified it according to the degree of drought (Tab. 2).

Tab. 2. Values of the SPI index

Values of SPI	Drought category	Time in category
0 à -0,99	Slight drought	-24%
-1 à -1,49	Moderate drought	9.20%
1.5 à -1,99	Severe drought	4.40%
<-2	Extreme drought	2.30%

Source: McKee et al.,1993

Indices of climate extremes

The study of extreme precipitation is provided by calculating indices defined by the World Meteorological Organization (WMO) in the framework of the CC/CLIVAR Expert Team on Climate Change Detection, Monitoring and Indices (ETCCDMI) (Kaboré et al., 2017). A total of 27 core indices were proposed by the Expert Team on Climate Change Detection Indices (Peterson, 2005) and included in the RClimDex software (Zhang and Yang, 2004). Eleven (11) indices are used in the analysis of extreme rainfall events (Tab. 3).

Tab. 3. List of the eleven indices used in the analysis of extreme rainfall events

Acronym	Name of the index	Definition	Unit
PTOT	Annual precipitation	Total annual precipitation	mm
JP	Rainy days	Total number of wet days (≥ 1 mm)	Day
SDII	Simple day intensity index	Average water depth per rainy day	mm/day
R10	Rainfall frequency ≥10 mm	Number of days with rainfall ≥ 10 mm	Days
R20	Rainfall frequency ≥20 mm	Number of days with rainfall ≥ 20 mm	Days
CDD	Consecutive dry days	Number of consecutive days with rainfall < 1 mm	Day
CWD	Consecutive wet days	Number of consecutive days with rainfall ≥ 1 mm	Day
PXJA	Daily maximum rainfall	Maximum daily precipitation	mm
Px1Jp	Share of daily maximum rainfall	Proportion of daily maximum precipitation in annual rainfall total	%
P95p	Share of intense rainfall	frequency of intense rainfall	day
P99p	Share of extreme rainfall	Proportion of extreme precipitation in annual rainfall total	%

Source: Ozer et al., 2017

In this study, two levels of rainfall extremes were selected. The first level, highlights the frequencies of extreme rainfall such as: the total number of wet days (rainfall ≥1 mm) (JP), the frequency of intense rainfall (P95(day)). The second level focuses on rainfall intensity with the following indices: rainy day intensity index (SDII (mm/day), maximum daily rainfall (PXJA (mm)). The calculations of the extreme precipitation indices were carried out in the Rclimdex software which was downloaded from the website: http://etccdi.pacificclimate.org/software.shtml.

Rainfall concentration index (RCI)

The rainfall concentration index (PCI) is a useful indicator for estimating monthly rainfall heterogeneity (Kingbo et al., 2022). Many studies (Apaydin et al., 2006; Diouf et al., 2018; Salhi et al., 2019; Quenum et al., 2019; Rawat et al., 2021; Gökçekuş et al., 2021; Pawar et al., 2022) have been conducted using this index. According to De Luis et al., 2011, the operationalisation of RCI is done through the following formula:

$$RCI_{annual} = 100 * \frac{\sum_{i=1}^{12} p_i^2}{(\sum_{i=1}^{12} p_i)^2} \quad (11)$$

Where, Pi is monthly precipitation in the month i RCI. Table 4 below shows the rating scale.

Tab. 4. RCI values and their interpretation

RCI values	Interpretation
RCI<10	Uniform distribution of monthly rainfall over the year
10 ≤RCI<16	Moderate distribution of monthly rainfall over the year
16 ≤RCI<20	Irregular distribution of monthly rainfall over the year
RCI>20	Distributions with monthly variability of rainfall amounts over the year

Source: Oliver, 1980; Michiels et al., 1992

Results

Precipitation trends from 1990 to 2020 between the study stations

The two rainfall stations of Ouahigouya and Gaoua were used for the analysis of annual rainfall. The MK test showed a significant trend (p-value=0.01) towards increasing rainfall for the Ouahigouya station and no significant trend (p-value=0.54) was observed for the Gaoua station (Tab. 5).

Tab. 5: MK and regression model applied to Ouahigouya and Gaoua stations between 1990 and 2020

Stations	Regression model	R^2	S	Z	p-value	Trend	Level of significance
Ouahigouya	y=+8.2077x+592.87	0.254	149	2.51	0.01*	Yes	α= 5%
Gaoua	y=+2.2103x + 1059.3	0.0166	37	0.61	0.54	No	α= 5%

Source: Rainfall data processing, 1990-2020; * if trend at α = 0.05 level of significance

The Pettitt test, however, shows a change point in the time series (1990-2020) at the Ouahigouya station in 2007, and rather no break at the Gaoua station (Tab. 6).

Tab. 6: Result of Pettitt's test applied to Ouahigouya and Gaoua stations between 1990 and 2020

Stations	p-value	Change point	Pettitt's test (Change point of the rain)	Level of significance
Ouahigouya	7.12E-03	Yes	2007	α= 1%
Gaoua	-	No		-

Source: Rainfall data processing, 1990-2020; - No data

The processing of rainfall data with ChronoStat software shows that after the change point in 2007, an ascending phase of rainfall is observed until 2020 (Fig. 2).

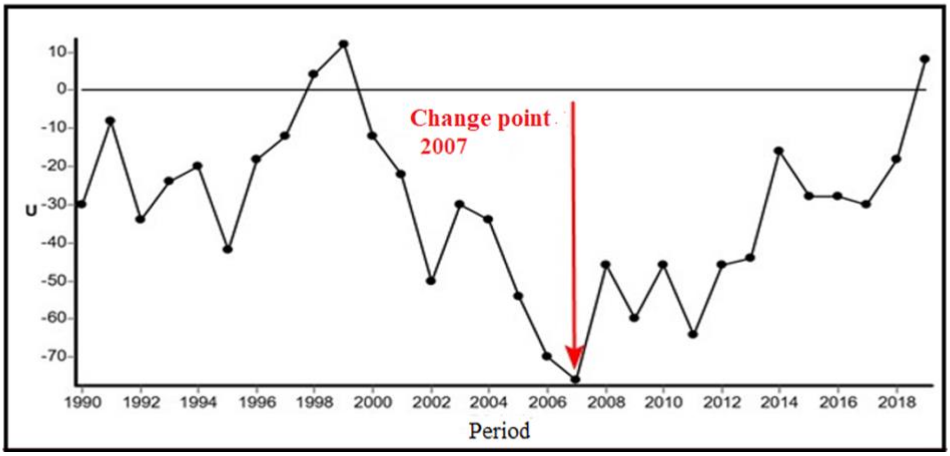


Fig. 2. Change point in the 1990-2020 rainfall series at the Ouahigouya station

However, at the Gaoua station, there is almost no break, but a saw-tooth evolution of the rainfall totals (Fig. 3), which confirms the MK test in Table 5 above of the absence of a break in the rainfall data at the Gaoua station.

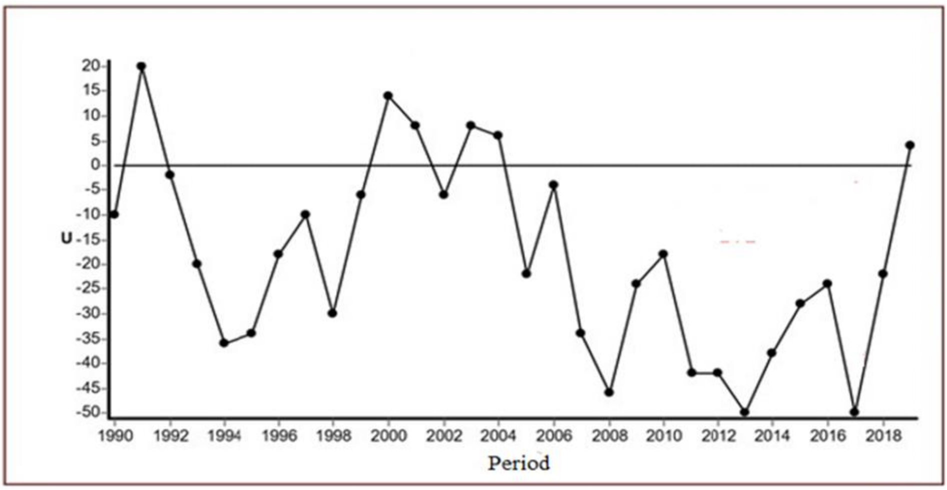


Fig. 3. Unclear break in rainfall data at Gaoua

Interannual variability of precipitation between 1990 and 2020

The processing of rainfall data from the two stations shows a fluctuation in annual rainfall (Fig. 4 and Fig. 5).

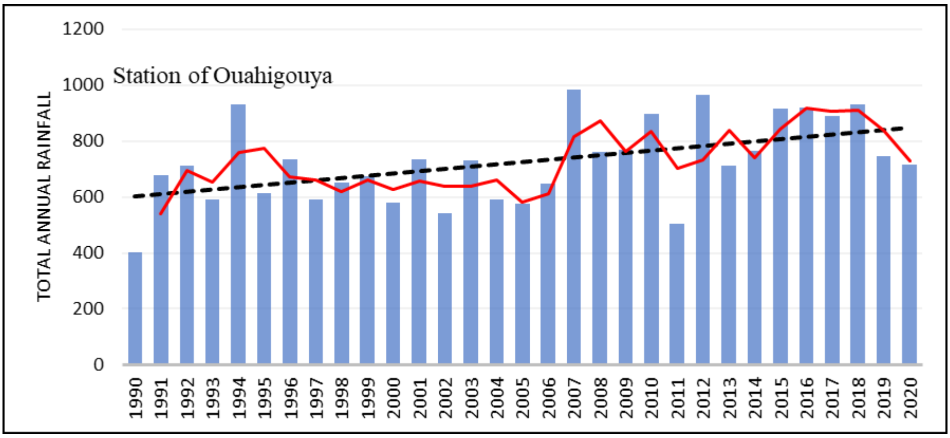


Fig. 4. Evolution of the annual rainfall totals in the Ouahigouya station

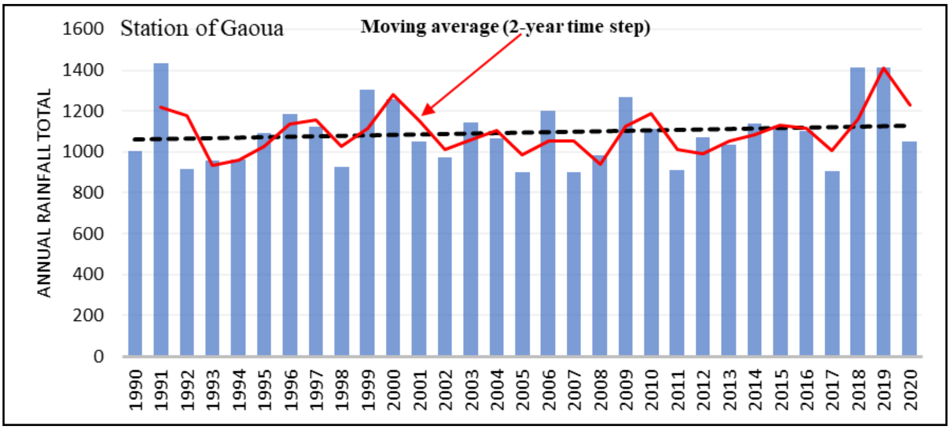


Fig. 5. Evolution of the annual rainfall totals in the Gaoua station

Figure 4 and Figure 5 show that the trend lines have positive slopes (y=+8.2077x+592.87 for Ouahigouya; y= +2.2103x + 1059.3 for Gaoua (Tab. 5)). This means that annual rainfall totals are increasing. However, the coefficients of determination are very low (R2=0.2536 for the Ouahigouya station (Tab. 5), R2=0.0166 for the Gaoua station (Tab. 5)), and therefore the statistical significance of the upward trends is low.

The standardised index (SPI) shows that the annual change in rainfall between 1990 and 2020 is also punctuated by wet and dry periods (Fig. 6).

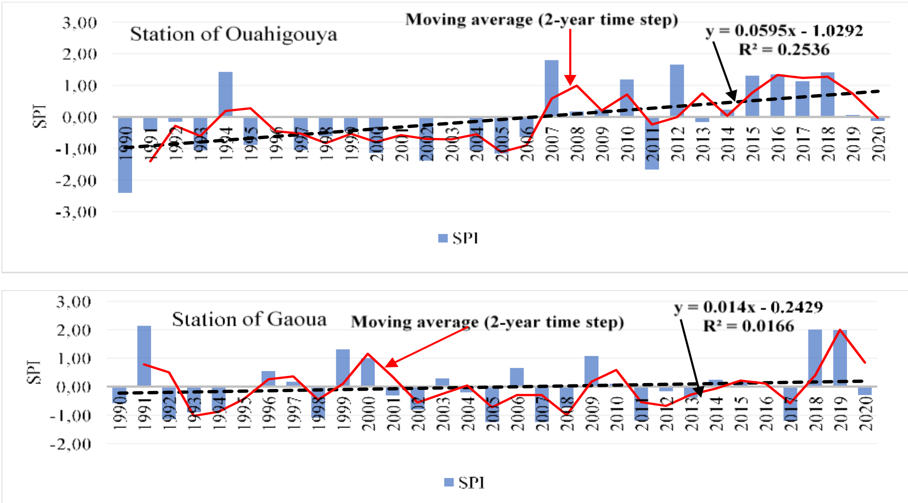


Fig. 6. Interannual evolution of the standardised rainfall index of the two study stations

Figure 6 shows that the interannual variability of rainfall at the Ouahigouya station highlights two distinct rainfall periods: 1990-2005, which corresponds to a dry period, and 2006-2020, which corresponds to a wet period. However, the moving averages (2- year time step) show variations between each period. On the other hand, at the Gaoua station (rural municipality of Dissin), the two decades (1990-2000; 2000-2010) are generally dry phases (with 55% of the indices negative and 45% positive). However, in the decade 2010-2020, a succession of dry and wet phases is observed. The trend lines also show that both stations experience a moderately high increase in wet periods for the Ouahigouya station (R2=0.2536) and a small increase in wet periods for the Gaoua station (R2=0.0166).

Evolution of extreme rainfall between 1990 and 2020

Statistical processing of the rainfall data from the study stations made it possible to draw up a profile of the variation in the frequency of extreme rainfall from 1990-2020 (Figure 7). The total number of wet days (rainfall ≥1 mm) (JP) increased in the Ouahigouya stations and decreased in the Gaoua station. As for the number of days with rainfall ≥ 95th percentile (P95), the trend lines show that they decrease over the years (1990-2020) for the Gaoua stations. On the other hand, the Ouahigouya station shows an increase in the frequency of extreme rainfall.

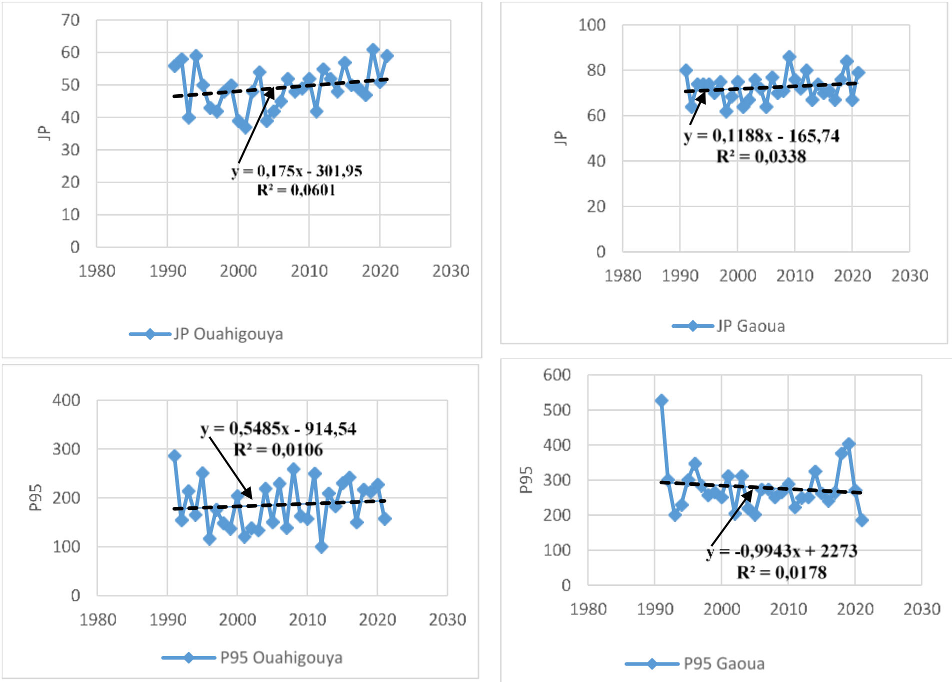


Fig. 7. Variation in the total number of wet days (precipitation ≥1 mm) and the frequency of intense rainfall between 1990 and 2020

With regard to rainfall intensity between 1990 and 2020, Figure 8 below shows that it also undergoes marked variations. The rainy-day index (PXJA) is increasing at the Ouahigouya station, and decreasing at the Gaoua station, with negative slopes. However, all stations show an increase in the maximum daily rainfall (SDII) between 1990 and 2020. This shows the variability of rainfall intensity in the climatic zones, with a higher climatic risk (flooding) in the South-Sahelian zone than in the South-Sudanese zone of Burkina Faso.

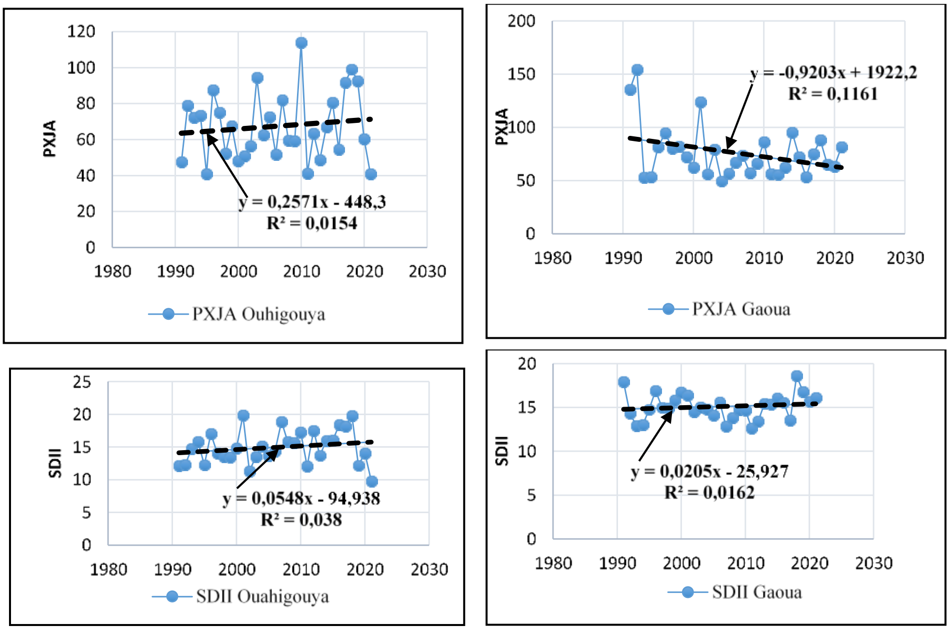


Figure 8. Evolution of the rainy-day index (PXJA) and the maximum daily rainfall (SDII) between 1990 and 2020

Changes in rainfall concentration between 1990 and 2020

Over the period 1990 and 2020, the monthly rainfall concentration evolves strongly in a sawtooth pattern, and the trend lines have negative slopes (for the Ouahigouya station: y= - 0.0284x + 24.027; for the Gaoua station: y= = - 0.0447x + 17.414) (F. 9). This results in a decrease in the concentration of precipitation during the wet months between 1990 and 2020.

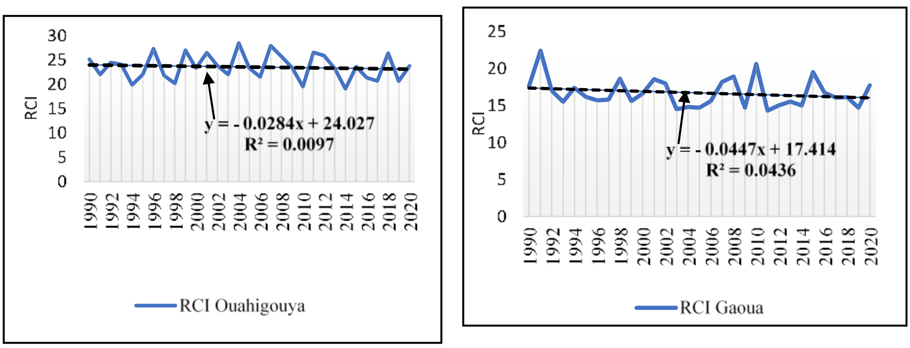


Figure 9: Regressive dynamics of monthly rainfall concentration between 1990 and 2020

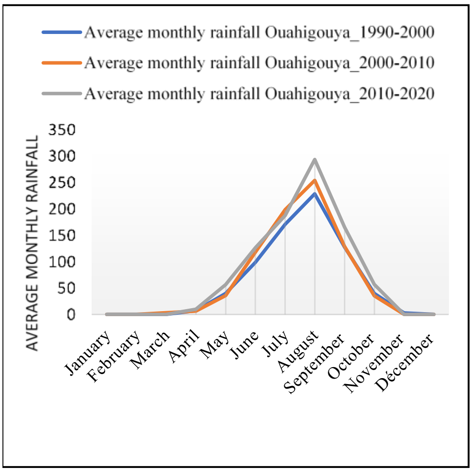
Furthermore, the average RCI per decade (1990-2000; 2000-2010; 2010-2020) of the Ouahigouya station is higher than that of the Gaoua station (Tab. 7).

Tab. 7. Average RCI between surveyed stations from 1990 to 2020

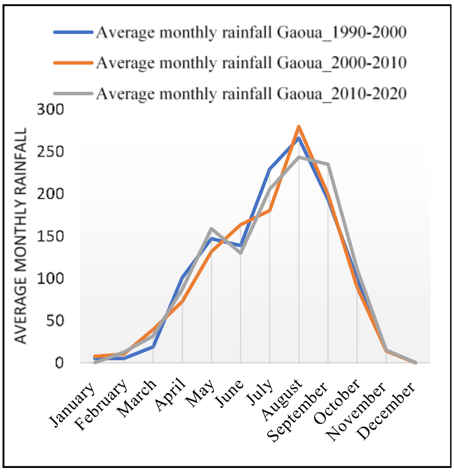
Stations	Average RCI Decade 1990-2000	Average RCI Decade 2000-2010	Average RCI Decade 2010-2020	Average RCI Decade 1990-2020	Climate domains
Ouahigouya	25.73%	26.56%	25.07%	25.80%	South Sahelian
Gaoua	18.84%	20.30%	18.13%	19.09%	South Sudanese

Source: ANMB data, 1990-2020

This table shows that the average RCI between 1990 and 2020 at the Ouahigouya station is very high, which implies a poor distribution of rainfall during the rainy period, since the RCI ≥25%. On the other hand, for the Gaoua station, the monthly distribution of rainfall is more spread out over several months, due to an RCI varying between 18.13% and 19.09%, except for the decade 2000-2010, where an RCI=20.3% is observed. The analysis of rainy months by decade confirms the results of the average RCI, as short rainy periods (July, August, September) are observed at the Ouahigouya station and a long rainy period (May, June, July, August, September and October) at the Gaoua station (Fig. 10).



Station of Ouahigouya



Station of Gaoua

Fig. 10. Decadal trends in monthly precipitation between 1990 and 2020

Figure 10 also shows that between 1990 and 2020 there was an increase in rainfall during the month of August, and a disruption of the pre-wet season periods for the Gaoua station between the decades (1990-2000; 2000-2010; 2010-2020).

Discussion

Discussion will focus on trends in annual rainfall totals and extreme rainfall events that characterise recent rainfall variability in West Africa.

Trends in annual rainfall

The 1970s and 1980s were the worst periods in the Sudano-Sahelian countries of West Africa (Niger, Mali and Burkina Faso). These periods were characterized by a drastic reduction in annual totals rainfall. In Burkina Faso, the decline in annual rainfall reached 20% in 1970 (Ibrahim et al., 2014). This put the rural population of the country in food crisis. Recent rainfall data analysed show an increase in annual rainfall. The trend lines show positive slopes, but the coefficients of determination (R2) are low. This shows that the increasing of observations trends in rainfall are weak. Furthermore, wet phases between the mid-decade 2000-2010 and the decade 2010-2020 were observed over the study areas. in addition to this, the breaks in 2006 (Pettitt test) for the Ouahigouya station and a small break in 2017 for the Gaoua station confirm an increase in rainfall after the break periods. In sum, a recovery in cumulative rainfall is therefore observed between 1990 and 2020 in the study areas.

Kaboré et al. (2019) also notice an increase in rainfall events in the north-central region of Burkina Faso, which are more pronounced in the Sahelian zone than in the Sudano-Sahelian zone of the country. Furthermore, De Longueville et al., 2016 find that most stations have recorded a recovery in rainfall in recent years in Burkina Faso. Similar results have been obtained by other authors in West Africa. Indeed, in Senegal, similar results have been obtained, with wet conditions from 1999 (Pettitt) or 2003 (Lee and Heghinian; Hubert), although annual rainfall remains below pre-1970 levels (Badian, 2014). Descroix et al., 2015 also notice an increase in rainfall in Senegambia between 2000 and 2010, although the recovery of rainfall in the Niger basin has slowed. In the Sahelian zone of West Africa, the rebound in rainfall after the drought of the 1980s took place in the 1990s, with interannual fluctuations until 2010 (Biasutti, 2019).

Trends in extreme rainfall

The extreme rains retained for the study are of two (02) orders: the frequencies of extreme rains such as: the total number of wet days (rainfall ≥1 mm) (JP) (y=0.175x-301.5), the frequency of intense rains (P95 (day)) (y=0.5485x-914.54), and the intensity of the rains whose indexes are: the intensity of the rainy days (SDII (mm/day), the maximum daily rainfall (PXJA (mm)). The South-Sahelian zone (municipality of Samba) is more affected by extreme rainfall than the South-Sudanese zone (municipality of Dissin). Indeed, trend lines with positive slopes for the total number of wet days, frequency of intense rainfall (P95/day), intensity of rainy days (SDII (mm/day) and maximum rainfall (PXJA (mm) (y=0.2571x-448. 3) were observed in the Sahelian South against only an increase in the total number of wet days (rainfall ≥1 mm) (y=0.1188x-165.74) and the increase in the intensity of rainy days (SDII (mm/day) (y=0.205x-25.927) in the Sudanese South (municipality of Dissin).

Other studies conducted in Burkina Faso seem to corroborate the results of this study. Thus, daily rainfall intensity has changed significantly in 73% of the stations, with values ranging from -9.6% to 7.6% per decade (Sougué, et al., 2023). Thus, there is a downward trend in daily rainfall intensity in southern Burkina Faso, while in northern Burkina Faso there are both upward and downward trends (Sougué, et al., 2023). Panthou et al. (2014) also observe an increase in extreme rainfall in the Sahelian zone of West Africa. These authors found that between 2001 and 2010, the Sahelian rainfall regime is characterised by a sustained deficit in the number of rainy days, while at the same time the occurrence of extreme rainfall increases (Panthou et al., 2014). Thus, the proportion of annual rainfall associated with extreme rainfall increased from 17% in 1970-1990 to 19% in 1991-2000 and 21% in 2001-2010 (Panthou et al., 2014). In Niger, between 1950 and 2014, there was an increase in extreme rainfall as a proportion of maximum daily rainfall (PXJA/mm) and a reduction in wet days, rainy days (Ozer et al., 2017).

According to Sylla et al., 2016, most West African countries will experience shorter rainy seasons, widespread torrid, arid and semi-arid conditions, longer dry periods and more intense extreme rainfall events. On the other hand, in coastal West Africa, particularly in Côte d'Ivoire, especially in the Zanzan region, the daily rainfall intensity index (PXJA) is rather decreasing (Kouman et al., 2022) in contrast to the study areas. However, in Nigeria, all climatic zones are affected by extreme rainfall. Thus, the maximum consecutive 5-day rainfall (RX5day) and daily rainfall intensity (SDII) increased over the three climatic regions of Nigeria, namely the Guinean coast, sub-Sahelian and Sahelian regions (Dike et al., 2020). At the same time, heavy rainfall days (R20mm) increased significantly over the Guinean coast and sub-Sahelian regions while the frequency of wet days (RR1) increased marginally (Dike et al., 2020). Another study covering almost all West African countries such as Mali, Nigeria, Senegal, Togo, Burkina Faso, Mauritania, Guinea, Niger and Ghana confirm the results on the increase of extreme rainfall between 1960 and 2010. Indeed, during the period 1960 and 2010, the daily intensity index (DII) and 5-day maximum rainfall (Rx5day) had regional increasing trends, while during the period 1981 and 2010, in addition to the DII and Rx5day having increasing trends, the extreme rainfall (1-day maximum rainfall (Rx1day), proportion of intense rainfall in total annual rainfall (R95P) proportion of extreme rainfall in total annual rainfall (R99P), number of consecutive days with rainfall < 1 mm (CDD), number of consecutive days with rainfall ≥ 1 mm (CWD), number of days with rainfall ≥ 10 mm (R10mm), number of days with rainfall ≥ 20 mm (R20mm)) have occurred over the region and all West African countries are affected (Barry et al., 2018). The various studies both in West Africa and in the study, areas reveal an occurrence of extreme rainfall that affects Sahelian West Africa more than the Guinean or near coastal areas of West Africa.

Conclusion

Rainfall is a key variable in agricultural production in Burkina Faso. Its recent evolution (1990-2020) is marked by an increase in total annual rainfall regardless of the climatic zone. However, the alternation of wet and dry periods is more marked in the southern Sudanian zone than in the southern Sahel. Furthermore, extreme rainfall occurs in both the southern Sahelian and southern Sudanian zones. However, it is increasing in the southern Sahelian zone. It can therefore be said that the recent evolution of rainfall is contrasted between the climatic zones (southern Sahelian; southern Sudanian) studied. In addition, farmers have had more difficulty growing cereals in the South Sahelian zone, where rains are short and accompanied by extreme rains, whereas in the South Sudanian zone, the distribution of rains is spread out and extreme rains increase slowly or even decrease.

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