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Trends and variability of extreme climate indices in the Boucle du Mouhoun (Burkina Faso)

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ABSTRACT: The main objective of this study is to analyse the trends and variability of extreme weather indices in the Boucle du Mouhoun region of Burkina Faso. To this end, meteorological data for the period 1991 to 2021 were obtained from the National Meteorological Agency of Burkina Faso. These meteorological data (rainfall, temperature) were integrated into the R-climindex software to generate extreme climate indices (rainfall, temperature). These data were then analysed by means of homogeneity tests (Pettitt and von Neumann ratio), trend tests (Mann-Kendall, Sen's slope) and the frequency of the return period of the extreme climate indices using XLSTAT (Statistical Software for Excel) 2023. The study shows that the precipitation indices are overall homogeneous ($p\text{-value} \geq 0.05$) and that there is no significance ($p\text{-value} \geq 0.05$) for the trend of the extreme precipitation indices from 1991 to 2021. Conversely, the temperature indices are not homogeneous ($p\text{-value} \leq 0.05$), and a significant upward trend was observed for the maximum temperature index ($p\text{-value} \leq 0.05$) and the minimum temperature index ($p\text{-value} \leq 0.05$). The extreme climate indices also show considerable variability over the period 1991-2021. Moreover, the return periods for the occurrence of extreme climate indices are shorter, ranging from 0 to 10 years. It is therefore important that regional authorities in the area develop strategies to consolidate water infrastructures and provide financial support to producers, especially banana producers.

KEY WORDS: variability, climatic indices, trends, return periods, extreme climatic indices.

1. Introduction

Many countries around the world have recently experienced an increase in hydroclimatic extremes such as droughts, floods and heat waves (Wang et al., 2022). The impacts of climate change are more pronounced in developing countries due to lower incomes and adaptive capacities (Georgopoulou et al., 2017; Brouillet and Sultan, 2023). (Asrat and Simane, 2018) also note that farmers, in particular, may find it more difficult to adapt to climate change. In sub-Saharan Africa, climate variability has increased in recent decades (Mairura et al., 2021). It is characterised by

widespread warming, a resumption of monsoon rains and an increase in the frequency of climatic extremes (Sultan and Gaetani, 2016). The observed effects of extreme weather events have increased in recent years (Ayanlade et al., 2022). Since the 1990s, there has been an increase in hydroclimatic events, with a mixture of intense precipitation, long periods of drought and sequences of floods (Salack et al., 2018). Extreme rainfall events have become more frequent and intense in the central Sahel of West Africa (Panthou et al., 2014). This situation has a negative impact on agricultural production. Indeed, the increase in extreme climate events has reduced millet production by 10-20% and sorghum production by 5-15% in West Africa (Sultan et al., 2019). During the dry season, irrigated rice yields in West Africa would fall by 45%. With adaptation, the reduction would be much smaller, around 15% (Van Oort and Zwar, 2017).

Burkina Faso, one of the countries in West Africa, is faced with the occurrence of extreme hydroclimatic events (Yanogo and Yameogo, 2023; Sougué et al., 2023). These events cause serious damage to agricultural production and hydraulic infrastructures (Bossia et al., 2020). Faced with this situation, many rural inhabitants are turning to banana production around small and large dams. The Boucle du Mouhoun region of Burkina Faso has thus become a banana-producing area. In the various villages of the region, particularly Lapara in the Boromo commune, the sale of bananas structures the daily life of the rural population (Yaméogo et al., 2022). Last year, heavy rains caused the Petit Balè dam to burst. This led to flooding. However, few studies have looked at extreme weather events in this region. However, a global study (Galberto et al., 2016) suggests that the recurrence of extreme rainfall has an impact on banana production. Small-scale studies on this topic are not widely used. The main objective of this study is to analyze the trends and variability of extreme weather indices in the Boucle du Mouhoun region of Burkina Faso.

2. Study area

The study area is the Boucle du Mouhoun region in the western part of Burkina Faso (Figure 1).

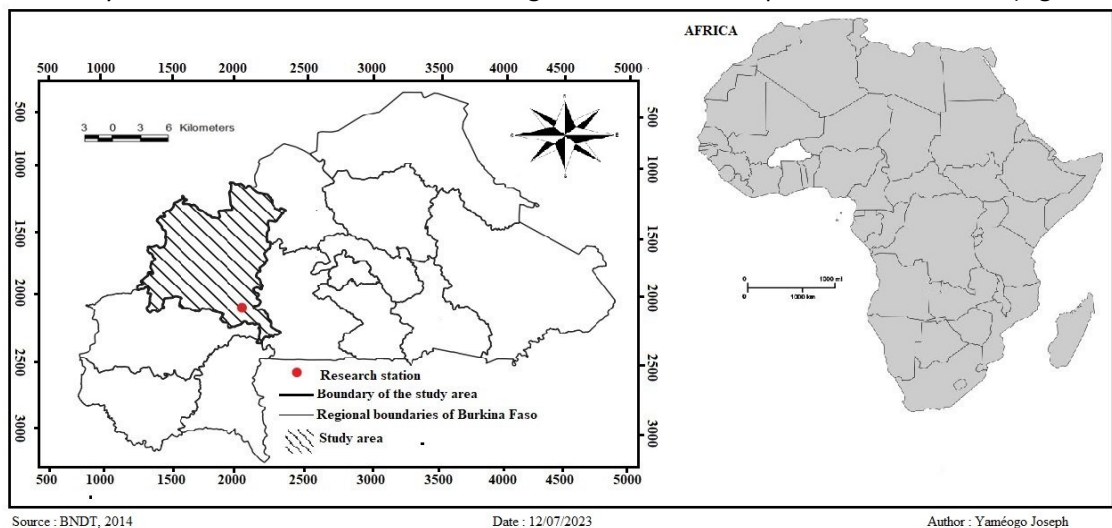


Figure 1 Localization of study site.

The Boucle du Mouhoun region is located in the Sudano-Sahelian zone, but with three (3) climatic variants (MEEVCC, 2021). In the north of the region, the Sudano-Sahelian sector dominates, with average annual rainfall of 500 to 700 mm. In the centre, the northern Sudanian sector, with

average annual rainfall of 700 to 900 mm. In the south, the Southern Sudan sector, with average annual rainfall of 1,000 to 1,400 mm. The synoptic station is located in the North Sudan sector.

3. Data and Methods

3.1. Climatic data

The National Meteorological Agency of Burkina Faso (NMA) was used to collect the rainfall data. The synoptic station of Boromo in the province of Balè, in the Boucle du Mouhoun region of Burkina Faso was used for the study, as it is located in the commune of Boromo. The period considered for the study is from 1991 to 2021, and the rainfall data collected is on a monthly time step. The table below shows the characteristics of the study station.

Table 1 Station characteristics used in this study.

Name of the station	Type de station	Type of data collected	Latitude	Longitude	Period of available data
Boromo	Synoptic	Monthly rainfall ; Monthly temperature	11.75	-2.9333	1991-2021

Source: National Meteorological Agency of Burkina Faso, Boromo, 1991-2021

In order to analyze extreme precipitation events, it is necessary to calculate extreme climate indices. The indices used are those recommended by the World Meteorological Organization's (WMO) Expert Team on Climate Change Detection, Monitoring and Indices (ETCCDMI) (Alexander *et al.*, 2019). 27 indices were listed and calculated using RCLimDex (Vincent *et al.*, 2011), which can be downloaded from the website <http://etccdi.pacificclimate.org/software.shtml>.

These indices are widely used to study extreme events and have been successfully used by several authors in their work analyzing precipitation and temperature extremes in the West African sub-region (Ly *et al.*, 2013; Diedhiou *et al.*, 2018; Yarou *et al.*, 2019), in Asia (Mondal *et al.*, 2022; Zhang *et al.*, 2022), in Europe (Malinović-Milićević *et al.*, 2018; Popov *et al.*, 2019; Gnjata *et al.*, 2021); America (Akinsanola *et al.*, 2020; Ceron *et al.*, 2021; Lagos-Zúñiga *et al.*, 2022). In order to take into account, the sensitivity of extreme climatic events affecting bananas in this study, the indices shown in Table 2 have been used.

Table 2 Extreme rainfall and temperature indices.

Element	Index	Descriptive Name	Definition	Unit
Temperature	TXx	Annual maximum temperature	Annual mean of TX	°C
	TXn	Annual minimum temperature	Annual mean of TN	°C
Precipitation	PRCPTOT	Annual precipitation	Annual total precipitation	mm
	SDII	Simple daily intensity index	Annual precipitation divided by number of wet days	mm/day
	CWD	Consecutive wet days	Maximum number of consecutive wet days (RR ≥ 1 mm)	days
	PXJA	Daily maximum rainfall	Maximum daily precipitation	mm
	R95p	Very wet days	Annual total PRCPTOT when RR>95th percentile	mm

Source: Vincent et al., 2011

3.2. Methods

3.2.1. Trend analysis methods

The Mann-Kendall (MK) test and Sen's slope estimator, linear regression and coefficient of determination (r^2) were used to examine trends in extreme climate indices. The Mann-Kendall test is commonly used to analyze trends in precipitation and temperature time series (Kumar and Sidana, 2017; Sridhara and Gopakkali, 2021). It has even been recommended by the World Meteorological Organization (WMO) (Diress and Bedada, 2021) because its power and significance are not affected by the actual distribution of the data (Hamed, 2009). The Mann-Kendall trend test (Mann, 1945; Kendall, 1975) is based on the correlation between ranks and sequences in a time series (Wang et al., 2020). According to the same authors, for a given time series $\{X_i, i = 1, 2, \dots, n\}$, the null hypothesis H_0 is that it is independently distributed, and the alternative hypothesis H_1 is that there is a monotonic trend. Sen's slope estimator is always associated with the Mann-Kendall (MK) test (Aditya et al., 2021; Frimpong et al., 2022). Sen's slope estimator is used to examine the magnitude of change in the trend of selected extreme climate indices. Linear regression equations and their coefficient of determination (R^2) were also used to capture the trend of the indices over 30 years (1991-2021). XLSTAT (Statistical Software for Excel) 2023 was used to calculate the Mann-Kendall test and to generate the linear regression equations and the coefficient of determination (R^2).

3.2.2. Homogeneity tests

In the study of climate time series, homogeneity of data means the consistency of a series over time and reflects a robust analysis of the data series (Zhang et al., 2011). Two homogeneity tests (Pettitt and von Neumann ratio) were used to assess the homogeneity of the extreme climate index data. These tests, in particular the Pettitt test, detect breaks in the extreme climate index data. Two types of change point detection methods can be distinguished: real-time (or simply online) detection and retrospective detection (Dang et al., 2021). For the detection of change points in extreme climate indices, the retrospective detection method, including the Pettitt test was used in the study. The Pettitt test is a parametric test based on the increasing order (r_i) of the elements in the series (Pettitt, 1979).

The test takes into account the following (Hänsel et al., 2016):

$$U_k = 2 \sum_{i=1}^k r_i - k(n+1), \quad k=1, \dots, n. \quad (1)$$

In addition, the statistics of the Pettitt test are determined by:

$$U_k = \sum_{1 \leq k \leq n} |U_k| \quad (2)$$

According to the test, the null hypothesis is that the data are homogeneous, as opposed to the alternative hypothesis that there is a change in the data (Kocsis et al., 2020). This method is commonly used to find points of change in climate and hydrological datasets (Conte et al., 2019).

The von Neumann ratio is a measure of whether the extreme weather index data are homogeneous or not. Unlike the Pettitt test, the Von Neumann test does not provide any indication of the year of change point (Yildirim and Rahman, 2022). The von Neumann ratio (von Neumann, 1941) is a non-parametric test most often used to detect non-homogeneity over time (Ahmed et al., 2018). The test statistic can be described as (Ahmad & Deni, 2013):

$$N = \frac{\sum_{i=1}^{n-1} ((Y_i - Y_{i+1})^2)}{\sum_{i=1}^n (Y_i - \bar{Y})^2} \quad (3)$$

If the sample or series is homogeneous, then the expected value $E(N) = 2$. If there is a break, then N must be less than 2, otherwise we can say that the sample varies. Otherwise, we can assume that the sample has a rapidly varying mean. XLSTAT 2023 is also used for the Pettitt and von Neumann ratio tests.

3.2.3. Return periods for extreme climate indices

The return periods of extreme climate indices for the period 1991-2021 are determined by frequency analysis. The return period of an extreme climate index is defined as the inverse of the annual exceedance probability (Mohyont & Demarée, 2006). According to Mohyont & Demarée, 2006, the mathematical formula is as follows:

$$RP = \frac{1}{Q (X \geq x^*)} \quad (4)$$

Where:

X^* =Frequency of a rainfall event x^* ;

Q =The amount of rainfall (in mm);

RP =Return Period.

The same formula applies to temperature. We have replaced Q with T for temperature.

In order to operationalize the calculation of the return period, the theoretical probability of each observation has been calculated using the following formulae:

$$P = \frac{m - a + b}{N + 1 - 2a + b} \quad (5)$$

Where, P is probability of exceedance; m is rank, and N is number of years of record. For this study, the Weibull formula has been applied to P . So, $a=0$, and $b=0$. Therefore, the formula for P is now:

$$P = \frac{m}{N + 1} \quad (6)$$

The extrapolation of the return periods of the extreme climate indices was based on the logarithmic regression of the extreme climate indices as follows:

$$Y = a \ln(x) + b \quad (7)$$

Simply replace x with a return period value, which can be in years or days for the CWD index (table 3).

Table 3 Extrapolation of the return periods of the extreme climate indices.

Return Period	Regression equation
50	$a * \ln(50) + b$
75	$a * \ln(75) + b$
100	$a * \ln(100) + b$
125	$a * \ln(125) + b$
150	$a * \ln(150) + b$

Source: Authors, 2023

The return period was calculated using Excel 2023.

4. Results and discussion

4.1. Homogeneity in extreme climatic indices

Overall, the extreme precipitation indices show no temporal breaks between 1991 and 2021, except for the PXJA index, which shows a small break with medium significance ($p \leq 0.5$). The extreme temperature indices show clear breaks between 1991 and 2021. Indeed, the breaks are in 1999 for TXx and in 2001 for TXn (Table 4). The von Neumann ratio test also shows that most of the extreme precipitation indices are homogeneous. Only PXJA is not homogeneous. Extreme temperature indices, on the other hand, are inhomogeneous, with an upward trend in minimum temperatures from 2005 and in maximum temperatures from 2008. Table 4 below shows that the upward trend in maximum temperatures is less pronounced due to low significance ($p \leq 0.5$). This is not the case for minimum temperatures, which show a clear upward trend after 2005 ($p \leq 0.001$).

Table 4 Extreme climate indices applied to Pettitt and von Neumann ratio tests.

Index	Pettitt test			Years of change	Von Neumann ratio test		Interpretation
	k	t	p-value		N	p-value	
Extreme rainfall indices							
PRCPTOT	64	2007	0.775	-	2.17043241	0.687	Homogeneous
CWD	68	1999	0.930	-	2.58579183	0.951	Homogeneous
PXJA	67	1999	0.863	-	1.94299706	0.432*	Non homogeneous
P95	58	1999	0.557	-	2.10448439	0.605	Homogeneous
SDII	72	2005	0.949	-	2.16314945	0.675	Homogeneous
Extreme temperature indices							
TXx	84	1999	0.475*	2008	1.442514	0.064*	Non homogeneous
TXn	165	2001	0.001***	2005	0.97158707	0.001***	Non homogeneous

Source : NMA, 1991-2021 ; Note : **** $p \leq 0.001$; *** $p \leq 0.05$, ** $p \leq 0.01$; * $p \leq 0.5$; - No break

4.2. Trend of extreme climatic indices between 1991 and 2021

The extreme climate indices show different trends between 1991 and 2021, with virtually no clear trend emerging for the extreme precipitation indices (Table 5). However, there is a slight trend for the SDII index (p -value=0.5). However, the trend amplitude (Qi) has a positive value (0.372), indicating an upward trend. The extreme temperature indices show that there is a clear trend (TXx= p -value =0.378; TXn= p -value=0.004) with positive but slightly increasing trend amplitudes (TXx=0.006; TXn=0.026) (Table 5 below).

Table 5 Extreme climate indices applied to the Mann-Kendall and Sen's slope.

Extreme rainfall indices					
Mann-Kendall (MK) test	PRCPTOT	CWD	PXJA	P95	SDII
Tau de Kendall	0.080	-0.078	-0.023	-0.025	0.117
S	35	-33	-10	-11	51
Var(S)	3141.667	3105	3140.667	3141.667	3141.667
p-value	0.544	0.566	0.872	0.858	0.372*
Sen's slope	1.662	-0.050	-0.159	-0.88	0.033

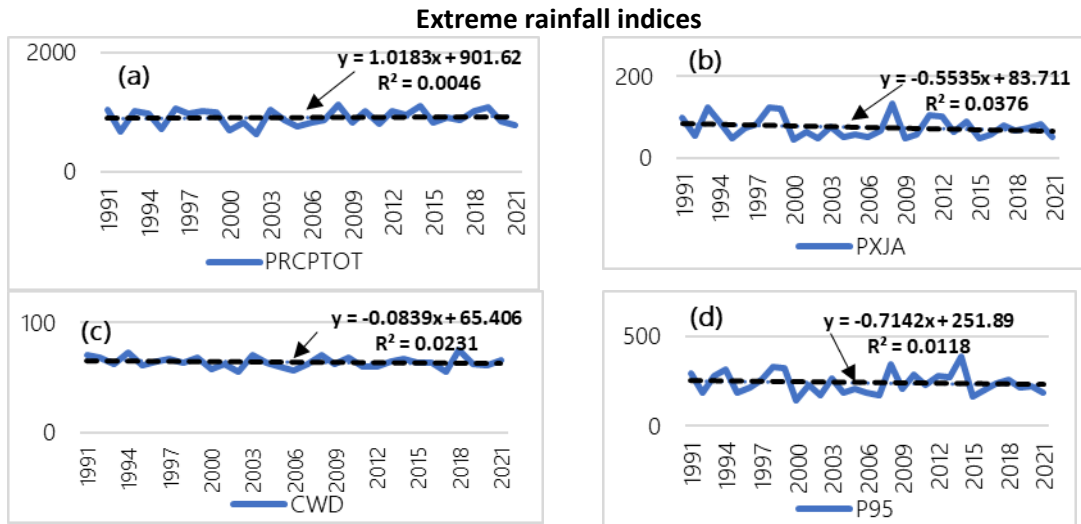
Extreme temperature indices					
Mann-Kendall test	TXx	TXn			
Tau de Kendall	0.118	0.383			
S	48	155			
Var(S)	2842	2839			
p-value	0.378*	0.004***			
Sen's slope	0.006	0.026			

Note : ***Trend is very significant at $\alpha = 0.001$, **Trend is significant at $\alpha = 0.01$, *Trend is significant at $\alpha = 0.05$, * The trend is significant average at $\alpha = 0.5$.

The results are in contrast with the work of Tazen *et al.* (2018) in Burkina Faso (case of the Centre region). In fact, the P95, CWD and SDII indices show trends as the p-value < 5%. Similar results were obtained by Agyekum *et al.* 2022 between Burkina Faso and Ghana. Indeed, the study also shows an upward trend in observed days with heavy and very heavy rainfall (R10 mm and R20 mm), very wet and extremely wet days (R95p and R99p), but a downward trend in consecutive wet and dry days (CWD and CDD). In Mali, similar observations were made by Fofana *et al.*, 2022 with regard to PRCPTOT (upward trend, p-value=0.006). However, in the study area, PRCPTOT showed no trend according to the Mann-Kendall test (p-value=0.544 > 5%). In Ethiopia, on the other hand, rainfall trends are almost similar to those in the study area, with both increasing and decreasing trends observed in the time series studied (Shigute *et al.*, 2023). This point was also made by Adeyeri *et al.* 2019 around Lake Chad (between Niger and Nigeria).

4.3. Temporal characteristics of extreme climatic indices

The extreme climate indices over the period 1991-2021 are highly variable (figure 2).



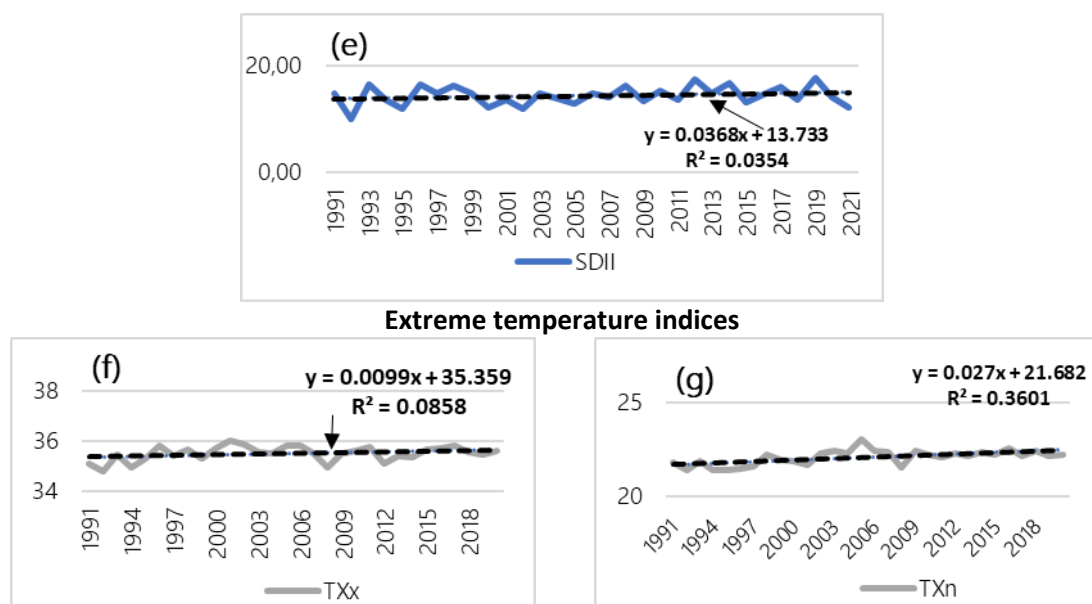


Figure 2 High variability of extreme climate indices over the period 1991 to 2021 (Source : National Meteorological Agency of Burkina Faso, Boromo, 1991-2021).

Two trends can be seen in Figure 2: first, in the case of extreme precipitation indices, a decrease is observed for CWD, P95 and PXJA, while an increase is observed for PRCPTOT and SDII. The second concerns extreme temperatures, where the indices show a significant increase between 1991 and 2021. However, Table 6 shows that the decade 2001-2010 corresponds to an overall decrease in precipitation indices. Conversely, the 2011-2021 decade shows an increase in extreme precipitation indices. This is in contrast to the extreme temperature indices, which show an increase in the 2001-2010 decade and a slight variability between TXx (decrease) and TXn (increase) in the 2011-2021 decade.

Table 6 Decade-by- decade trends in extreme climate indices.

Index	1991-2000	2001-2010	2011-2021
Extreme rainfall indices			
PRCPTOT	926.24	886.06	939.3
CWD	65.7	63	63.54
PXJA	85.39	65.29	81.37
P95	253.93	226.66	240.76
SDII	14.09	13.99	14.83
Extreme temperature indices			
TXx	35.36	35.63	35.55
TXn	21.73	22.28	22.29

Source: National Meteorological Agency of Burkina Faso, Boromo, 1991-2021

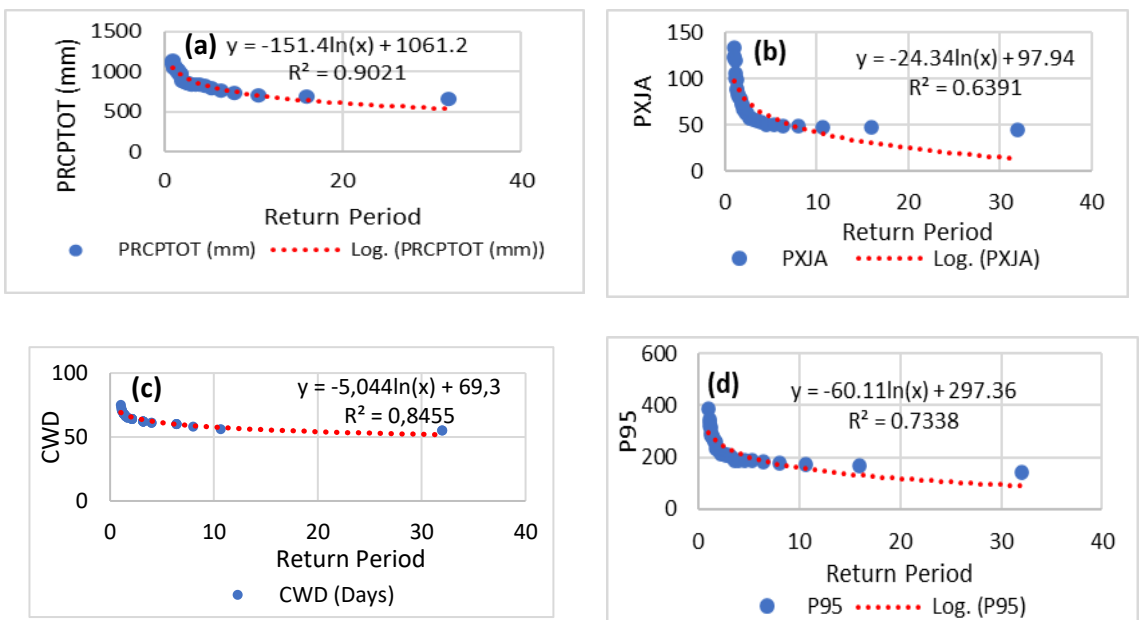
Results on the variability of extreme climate indices were also observed by Ly et al. 2013 in Sahelian West Africa. The authors found that indices such as CWD (maximum 5-day rainfall) increased between 1960 and 2010. Diatta et al. (2020) also found similar results for the variability of extreme climate indices (CDD, CWD, R10mm, R20mm, Rx1day, Rx5day, Prcptot and SDII).

4.4. Characterization of the return periods of extreme climatic between 1991 and 2021

Figure 3 below shows that the return periods of the extreme weather events (PXJA, PRCPTOT, P95, CWD, TXx, TXn) are relatively short, as most of the extreme weather indices (PXJA, PRCPTOT, P95, SDII, TXx, TXn) have return periods between 0 and 10 years. However, only the CWD index has a return period expressed in days, which is also short as the return period varies between 0 and 10 days during the rainy season. However, the trend lines are usually negative. This means that when the extreme weather indices fall, the return periods are long. The high coefficients of determination (R^2) show that this trend is strong. However, the SDII is the exception to the rule, as it increases over the years. Overall, the return periods of the climate indices in the area are between 0 and 10 years. This means that they will continue to occur in the coming years.

Several other studies in Africa converge with the results of this study. In Africa, extreme mean annual temperatures have shorter return periods (4 to 7 years) than maximum annual temperatures (6 to 10 years) (Turasie, 2021). In the Pra River catchment in Ghana, (Osei et al. 2021) found almost similar results to our study, with return periods of the CWD index ranging from 6 to 20 days over a 10-year period. In Kigali, Rwanda, the return periods of extreme maximum rainfall are increasing and vary between 5 and 50 years (Singirankabo and Iyamuremye, 2022). In Senegal, on the other hand, return periods of extreme rainfall tend to be between 100 and 150 years over the period 1951-2005. In the northeastern region of Brazil, return periods for the occurrence of intense rainfall events (IRE) are shorter, ranging from 5 to 10 years (Oliveira and Lima, 2019).

Extrapolation of the return periods from 50 to 150 years for the extreme climate indices shows a significant change in the indices (Figure 4). The extreme precipitation indices (PXJA, SDII) increase with the return periods. Conversely, PRCPTOT, P95, and CWD decrease with return periods. The same is true for the extreme temperature indices, which show a decrease in extreme temperatures over the years (return periods).



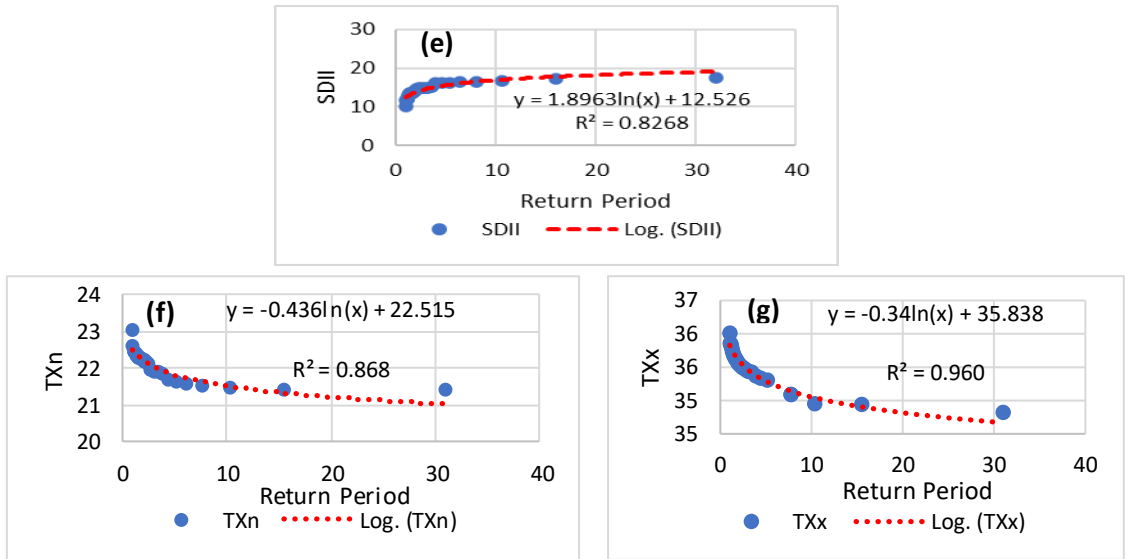
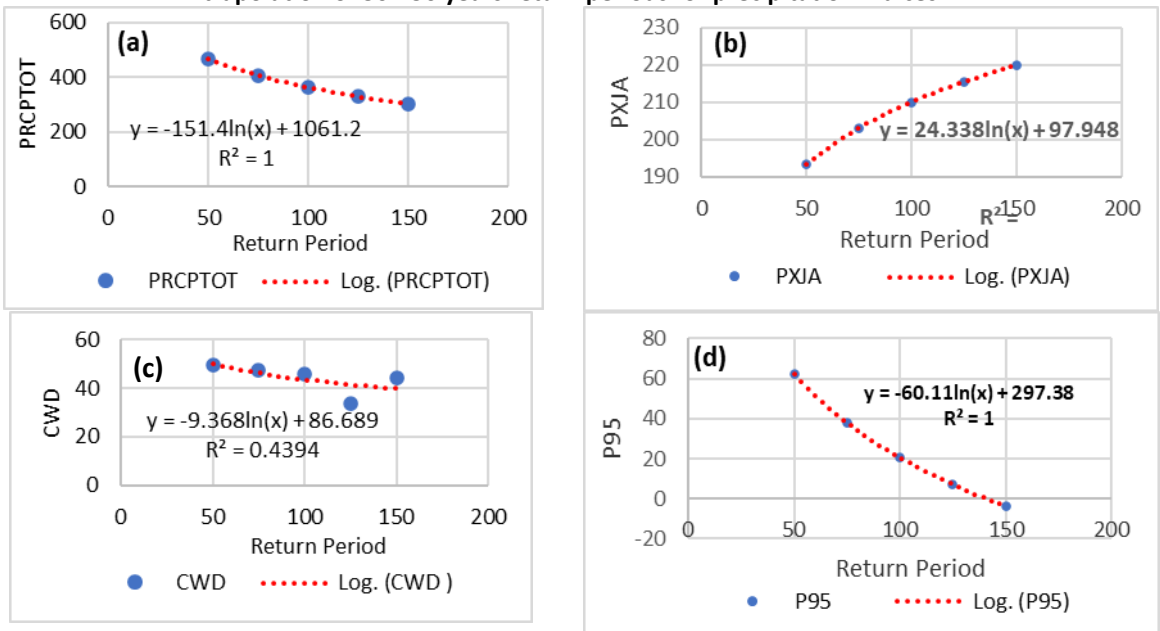
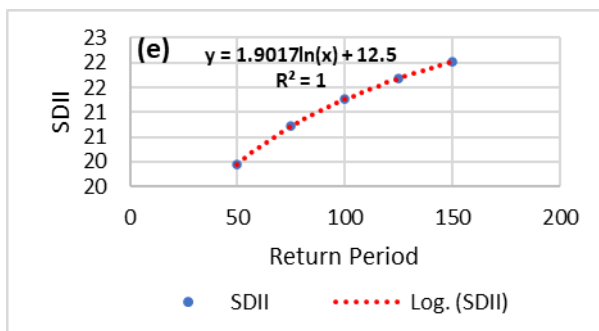


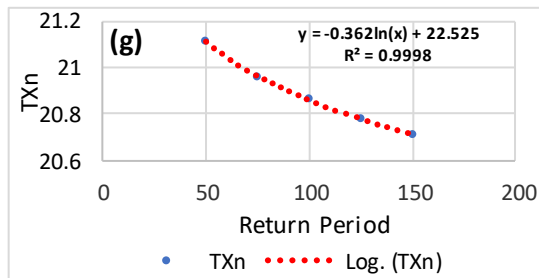
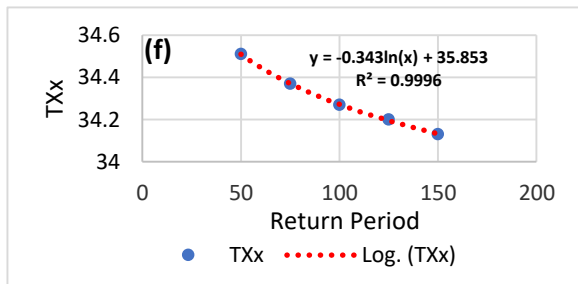
Figure 3. Return periods for extreme climatic indices between 1991 and 2021 (Source: National Meteorological Agency of Burkina Faso, Boromo, 1991-2021)

Extrapolation of 50-150 years return periods for precipitation indices





Extrapolation of return periods from 50 to 150 years for temperature indices



Source: National Meteorological Agency of Burkina Faso, Boromo, 1991-2021

Figure 4. Extrapolation of return periods from 50 to 150 years for extreme climatic indices

Figure 4 shows two (02) trends in the extreme precipitation indices: on the one hand, there is a decrease in PXJA and SDII, and on the other hand, PRCPTOT, P95 and CWD increase between 50 and 150 years. As for the temperature indices, there is a steady decrease in TXx and TXn.

5. Conclusion

The extreme precipitation indices are largely homogeneous, except for the SDII which shows a break, while the extreme temperature indices show breaks over the period 1991-2021. The trend of the extreme climate indices is upward for the extreme temperature indices and both upward (PRCPTOT, SDII) and downward (PXJA, P95, CWD) for the extreme precipitation indices. In addition, the extreme climate indices are highly variable between 1991 and 2021. The return periods of the extreme weather indices vary between 0 and 10 years. This implies that the trends in extreme weather indices will continue over the next decade. It is therefore important that measures are taken to help banana growers near the dams in the Mouhoun loop to avoid production losses.

References

- Adeyeri, O. E., Lawin, A. E., Laux, P., Ishola, K. A., & Ige, S. O., 2019. Analysis of climate extreme indices over the Komadugu-Yobe basin, Lake Chad region: Past and future occurrences. *Weather and climate extremes*, 23, 100194. <https://doi.org/10.1016/j.wace.2019.100194>.
- Agyekum, J., Annor, T., Quansah, E., Lamptey, B., & Okafor, G., 2022. Extreme precipitation indices over the Volta Basin : CMIP6 model evaluation. *Scientific African*, 16, e01181.

- Ahmad, N. H., & Deni, S. M., 2013. Homogeneity test on daily rainfall series for Malaysia. *MATEMATIKA : Malaysian Journal of Industrial and Applied Mathematics*, 141-150.
- Ahmed, K., Shahid, S., Ismail, T., Nawaz, N., & Wang, X. J. (2018). Absolute homogeneity assessment of precipitation time series in an arid region of Pakistan. *Atmósfera*, 31(3), 301-316. <https://doi.org/10.20937/ATM.2018.31.03.06>
- Akinsanola, A. A., Kooperman, G. J., Pendergrass, A. G., Hannah, W. M., & Reed, K. A. , (2020). Seasonal representation of extreme precipitation indices over the United States in CMIP6 present-day simulations. *Environmental Research Letters*, 15(9):1-12.
- Alexander, L.V., Fowler, H.J., Bador, M., Behrangi, A., Donat, M.G., Dunn, R., Funk, C., Goldie, J., Lewis, E., Rogé, M. and Seneviratne, S.I., 2019. On the use of indices to study extreme precipitation on sub-daily and daily timescales. *Environmental Research Letters*, 14(12) :1-11.
- Asrat, P., & Simane, B., 2018. Farmers' perception of climate change and adaptation strategies in the Dabus watershed, North-West Ethiopia. *Ecological processes*, 7(1): 1-13.
- Ayanlade, A., Oluwaranti, A., Ayanlade, O.S., Borderon, M., Sterly, H., Sakdapolrak, P., Jegede, M.O., Weldemariam, L.F. and Ayinde, A.F., 2022. Extreme climate events in sub-Saharan Africa : A call for improving agricultural technology transfer to enhance adaptive capacity. *Climate Services*, 27, 100311.
- Bossa, A. Y., Hounkpè, J., Yira, Y., Serpantié, G., Lidon, B., Fusillier, J. L & Diekkrüger, B., 2020. Managing new risks of and opportunities for the agricultural development of West-African floodplains : Hydroclimatic conditions and implications for rice production. *Climate*, 8(1):1-11.
- Brouillet, A., & Sultan, B., 2023. Livestock exposure to future cumulated climate-related stressors in West Africa. *Scientific Reports*, 13(1), 2698.
- Ceron, W.L., Kayano, M.T., Andreoli, R.V., Avila-Diaz, A., Ayes, I., Freitas, E.D., Martins, J.A. and Souza, R.A. (2021). Recent intensification of extreme precipitation events in the La Plata Basin in Southern South America (1981–2018). *Atmospheric Research*, 249, 105299.
- Conte, L. C., Bayer, D. M., & Bayer, F. M. (2019). Bootstrap Pettitt test for detecting change points in hydroclimatological data : case study of Itaipu Hydroelectric Plant, Brazil. *Hydrological Sciences Journal*, 64(11), 1312-1326.
- Dang, C., Zhang, H., Singh, V. P., Zhi, T., Zhang, J., & Ding, H., 2021. A statistical approach for reconstructing natural streamflow series based on streamflow variation identification. *Hydrology Research*, 52(5), 1100-1115. <https://doi.org/10.2166/nh.2021.180>
- De Longueville, F., Gemenne, F., & Ozer, P. (2015). Perception des changements de précipitation et migration au Burkina Faso. In *28e Colloque International de l'Association Internationale de Climatologie*. ULG-Université de Liège, Belgium.
- Diedhiou, A., Bichet, A., Wartenburger, R., Seneviratne, S.I., Rowell, D.P., Sylla, M.B., Diallo, I., Todzo, S., Touré, N.D.E., Camara, M. and Ngatchah, B.N., 2018. Changes in climate extremes over West and Central Africa at 1.5°C and 2°C global warming. *Environmental Research Letters*, 13(6) :1-12.
- Diress, S. A., & Bedada, T. B. (2021). Precipitation and temperature trend analysis by Mann Kendall test : the case of Addis Ababa methodological station, Addis Ababa, Ethiopia. *African Journal on Land Policy and Geospatial Sciences*, 4(4), 517-526.
- Fofana, M., Adoukpe, J., Larbi, I., Hounkpe, J., Koubodana, H.D.N., Toure, A., Bokar, H., Dotse, S.Q. and Limantol, A.M., 2022. Urban flash flood and extreme rainfall events trend analysis in Bamako, Mali. *Environmental Challenges*, 6, p.100449.
- Frimpong, B. F., Koranteng, A., & Molkenhain, F., 2022. Analysis of temperature variability utilising Mann–Kendall and Sen's slope estimator tests in the Accra and Kumasi Metropolises in Ghana. *Environmental Systems Research*, 11(1), 1-13.

- Georgopoulou, E., Mirasgedis, S., Sarafidis, Y., Vitaliotou, M., Lalas, D.P., Theloudis, I., Giannoulaki, K.D., Dimopoulos, D., Zavras, V., 2017. Climate change impacts and adaptation options for the Greek agriculture in 2021–2050 : a monetary assessment. *Climate Risk Management*, 16, 164-182. Available at : <https://doi.org/10.1016/j.crm.2017.02.002>.
- Gnjato, S., Popov, T., Ivanišević, M., & Trbić, G., 2021. Changes in extreme climate indices in Sarajevo (Bosnia and Herzegovina). *Glasnik Srpskog geografskog društva*, 101(2), 1-21.
- Hamed, K. H., 2009. Exact distribution of the Mann-Kendall trend test statistic for persistent data. *Journal of hydrology*, 365(1-2): 86-94.
- Hänsel, S., Medeiros, D. M., Matschullat, J., Petta, R. A., & de Mendonça Silva, I., 2016. Assessing homogeneity and climate variability of temperature and precipitation series in the capitals of north-eastern Brazil. *Frontiers in Earth Science*, 4,1-29. doi: 10.3389/feart.2016.00029. <https://doi.org/10.1016/j.envc.2022.100449>.
- Kendall, M.G., 1975. *Rank Correlation Methods*. 4th Edition, Charles Griffin, London.
- Kocsis, T., Kovács-Székely, I., & Anda, A., 2020. Homogeneity tests and non-parametric analyses of tendencies in precipitation time series in Keszthely, Western Hungary. *Theoretical and Applied Climatology*, 139(3-4), 849-859.
- Kumar, S., & Sidana, B. K., 2017. Climatic variability and its impact on rice and wheat productivity in Punjab. *Journal of Agrometeorology*, 19(4), 359-362.
- Lagos-Zúñiga, M., Balmaceda-Huarte, R., Regoto, P., Torrez, L., Olmo, M., Lyra, A., Pareja-Quispe, D. and Bettolli, M.L., 2022. Extreme indices of temperature and precipitation in South America : trends and intercomparison of regional climate models. *Climate Dynamics* :1-22.
- Ly, M., Traore, S. B., Alhassane, A., & Sarr, B., 2013. Evolution of some observed climate extremes in the West African Sahel. *Weather and climate extremes*, 1, 19-25.
- Mairura, F.S., Musafiri, C.M., Kiboi, M.N., Macharia, J.M., Ng'etich, O.K., Shisanya, C.A., Okeyo, J.M., Mugendi, D.N., Okwuosa, E.A. and Ngetich, F.K., 2021. Determinants of farmers' perceptions of climate variability, mitigation, and adaptation strategies in the central highlands of Kenya. *Weather and Climate Extremes*, 34, 100374. <https://doi.org/10.1016/j.wace.2021.100374>.
- Malinović-Miličević, S., Mihailović, D. T., Radovanović, M. M., & Drešković, N. (2018). Extreme precipitation indices in Vojvodina region (Serbia). *Journal of the Geographical Institute "Jovan Cvijić" SASA*, 68(1), 1-15.
- Mann, H. B., 1945. Nonparametric tests against trend. *Econometrica: Journal of the econometric society*, 245-259.
- Ministère L'Environnement, DE L'Economie Verte Et Du Changement Climatique (MEEVCC)., 2021. La neutralité en matière de dégradation des terres dans la région de la boucle du Mouhoun, situation de référence, tendances, cibles et mesures associées, rapport final,36.
- Mohymont, B., & Demarée, G. R., 2006. Courbes intensité-durée-fréquence des précipitations à Yangambi, Congo, au moyen de différents modèles de type Montana. *Hydrological sciences journal*, 51(2), 239-253. <https://doi.org/10.1623/hysj.51.2.239>
- Mondal, S.K., Huang, J., Wang, Y., Su, B., Kundzewicz, Z.W., Jiang, S., Zhai, J., Chen, Z., Jing, C. and Jiang, T., 2022. Changes in extreme precipitation across South Asia for each 0.5 C of warming from 1.5 C to 3.0 C above pre-industrial levels. *Atmospheric Research*, 266,105961.
- Oliveira, D. H. M. C., & Lima, K. C., 2019. What is the return period of intense rainfall events in the capital cities of the northeast region of Brazil ? *Atmospheric Science Letters*, 20(10), e934.
- Osei, M. A., Amekudzi, L. K., Omari-Sasu, A. Y., Yamba, E. I., Quansah, E., Aryee, J. N., & Preko, K., 2021. Estimation of the return periods of maxima rainfall and floods at the Pra River Catchment, Ghana, West Africa using the Gumbel extreme value theory. *Heliyon*, 7(5), 1-13.

- Owusu, V., & Yiridomoh, G. Y., 2021. Assessing the determinants of women farmers' targeted adaptation measures in response to climate extremes in rural Ghana. *Weather and Climate Extremes*, 33, 100353.
- Panthou, G., Vischel, T., Lebel, T., 2014. Recent Trends in the Regime of Extreme Rainfall in the Central Sahel. *Int. J. Climatol*, 34, 3998-4006.
- Pettitt, A. N., 1979. A non-parametric approach to the change-point problem. *Journal of the Royal Statistical Society : Series C (Applied Statistics)*, 28(2), 126-135.
- Popov, T., Gnjato, S., Trbić, G., & Ivanišević, M., 2019. Analysis of extreme precipitation indices in the east Herzegovina (Bosnia and Herzegovina). *Journal of the Geographical Institute "Jovan Cvijić" SASA*, 69(1), 1-16.
- Salack, S., Saley, I. A., Lawson, N. Z., Zabré, I., & Daku, E. K., 2018. Scales for rating heavy rainfall events in the West African Sahel. *Weather and climate extremes*, 21, 36-42.
- Shigute, M., Alamirew, T., Abebe, A., Ndehedehe, C. E., & Kassahun, H. T., 2023. Analysis of rainfall and temperature variability for agricultural water management in the upper Genale river basin, Ethiopia. *Scientific African*, 20, e01635. <https://doi.org/10.1016/j.sciaf.2023.e01635>.
- Singirankabo, E., & Iyamuremye, E., 2022. Modelling extreme rainfall events in Kigali city using generalized Pareto distribution. *Meteorological Applications*, 29(4), e2076.
- Sougué, M., Merz, B., Sogbedji, J. M., & Zougmore, F., 2023. Extreme Rainfall in Southern Burkina Faso, West Africa: Trends and Links to Atlantic Sea Surface Temperature. *Atmosphere*, 14(2), 284. <https://doi.org/10.3390/atmos14020284>
- Sridhara, S., & Gopakkali, P., 2021. Trend and change point detection of seasonal rainfall for effective crop planning over southern transition zone of Karnataka, India. *Journal of Agrometeorology*, 23(3), 316-323.
- Sultan, B., Defrance, D., & Iizumi, T., 2019. Evidence of crop production losses in West Africa due to historical global warming in two crop models. *Sci. Rep.*, 9 :1-15.
- Tazen, F., Diarra, A., Kabore, R. F. W., Ibrahim, B., BologoTraoré, M., Traoré, K., & Karambiri, H., 2018. Trends in flood events and their relationship to extreme rainfall in an urban area of Sahelian West Africa: The case study of Ouagadougou, Burkina Faso. *Journal of Flood Risk Management*, e12507. doi :10.1111/jfr3.12507
- Turasie, A. A., 2021. Exceedance and Return Period of High Temperature in the African Region. *Climate*, 9(4), 53.
- Van Oort, P. A., & Sander, J. Z., 2017. Impacts of climate change on rice production in Africa and causes of simulated yield changes. *Global change biology*, 24, n°3 :1029-1045. doi: 10.1111/gcb. 13967.
- Vincent, L. A., Aguilar, E., Saindou, M., Hassane, A. F., Jumaux, G., Roy, D., Booneeedy, P., Virasami, R., Randriamarolaza, L. Y. A., Faniriantsoa, F. R, Amelie, V., Seeward, H & Montfraix, B., 2011. Observed trends in indices of daily and extreme temperature and precipitation for the countries of the western Indian Ocean, 1961-2008. *Journal of Geophysical Research, Atmospheres*, 116(D10).
- Wang, F., Shao, W., Yu, H., Kan, G., He, X., Zhang, D., Ren, M. and Wang, G., 2020. Re-evaluation of the power of the mann-kendall test for detecting monotonic trends in hydrometeorological time series. *Frontiers in Earth Science*, 8 :1-14.
- Wang, S., Ancell, B., Yang, Z. L., Duan, Q., & Anagnostou, E. N., 2022. Hydroclimatic extremes and impacts in a changing environment: Observations, mechanisms, and projections. *Journal of Hydrology*, 608, 127615.
- Yaméogo, J., Sanou, K., Yanogo, P. I., 2022. La recomposition des systèmes de culture dans les bananiers autour du barrage de petit Balé : cas du village de Lapara dans la commune de Boromo, au Burkina Faso. *Akofena, Spécial n°09, vol.1, Décoloniser la recherche scientifique*

- en Lettres et Sciences Humaines : épistémologie, théorie, empirisme et perspectives, Université Houphouët Boigny, Côte d'Ivoire : 271-286.
- Yanogo, I. P & Yaméogo, J., 2023. Recent rainfall trends between 1990 and 2020 : contrasting characteristics between two climate zones in Burkina Faso (West Africa). *Bulletin of the Serbian Geographical Society*, 103(1) : 87-106. <https://glasniksgd.rs/index.php/home/issue/view/107>.
- Yarou, H., Obada, E., Biao, E. I., Badou, D. F., & Alamou, E. A., 2019. Variabilité Des Extrêmes Pluviométriques Récents Dans Le Bassin Béninois Du Fleuve Niger (1960-2016), Bénin. *Rev. Ivoir. Sci. Technol.*, 34 : 112-126.
- Yildirim, G., & Rahman, A., 2022. Homogeneity and trend analysis of rainfall and droughts over Southeast Australia. *Natural Hazards*, 112(2), 1657-1683.
- Zhang, H., Wang, F. T., & Zhou, P., 2022. Changes in climate extremes in a typical glacierized region in central Eastern Tianshan Mountains and their relationship with observed glacier mass balance. *Advances in Climate Change Research*.
- Zhang, X., Alexander, L., Hegerl, G.C., Jones, P., Tank, A.K., Peterson, T.C., Trewin, B. and Zwiers, F.W., 2011. Indices for monitoring changes in extremes based on daily temperature and precipitation data. *Wiley Interdisciplinary Reviews : Climate Change*, 2(6) :851-870.