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Extreme Rainfall and Streamflow in Niamey City: Trends and Relationship Between Higher Streamflow and Rainfall

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Abstract

Increasing rainfall frequency and intensity, which causes floods, is one effect of climate change. Recent heavy rains have caused regular flooding in several major towns in West Africa. In order to comprehend the cyclical patterns of flash floods and very high rainfall occurrences in Niamey, Niger, between 1982 and 2021. The National Meteorological Direction, the Regional Centre AGRHYMET, as well as the Niger Civil Protection General Direction, provided the flood disaster data used in this research. Five rainfall extreme indices created by the Expert Team for Climate Change Detection Monitoring and Indices (ETCCDI) were studied to define severe rainfall intensity and frequency indices. The Gumbel extreme value distribution was used to estimate the return period of flood and extreme rainfall throughout the period of 5 to 100 years based on the annual maximum daily rainfall. All five severe rainfall indices had an increased trend, except for the continuous wet days (CWD), which revealed a diminishing tendency. During the study period, it was shown that extreme rainfall had both increased in frequency and intensity. An analysis of the flood reports from 1990 to 2020 showed an increase in Niamey. We discovered that a daily maximum of 1-day rainfall and a daily maximum of continuous 5-day rainfall might both reach 163 and 182.2 mm in 100 years from 2020, respectively. Regarding QMax and QX5day, the maximum discharge over five days and the peak discharge may exceed 2722.2 and 14287 m^3/s, respectively. According to the study's findings, floods often occur in Niger, requiring mitigation and adaptation strategies.

Keywords: flood, extreme rainfall, streamflow. the return period, Niamey

INTRODUCTION

In recent decades, flooding has become increasingly recurrent in West African cities, including in Niamey. From 2020 onwards, extreme rainfall caused several floods in Niamey, leaving millions of people homeless, damaging many homes, losing large numbers of livestock and causing loss of life. Against this background, analysis of the frequency of extreme rainfall and flooding in the city of Niamey becomes crucial for flood risk management.

Many regional studies on extreme precipitation and flooding have been carried out in the Western Sahel region, showing that the intensity and the

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frequency of the extreme rainfall has increased over the West African Sahel region [4]. While local studies increasingly reveal that rainfall extremes trends in many West African countries are spatially heterogeneous [6,7,12,13,14]. These local studies have revealed that the increase in flood frequency is likely to be due to changes in land use and land cover and rapid population growth, rather than to extreme rainfall.

STUDY AREA

The capital city of Niger, Niamey (Figure 1), is 255 square kilometers in size and is located between latitudes 2°03 and 2°10 East and 13°28 and 13°35 North. The city is located on a hilltop that overlooks the left bank of the Niger River and an alluvial plain on the river's right bank. It is one of Niger's eight administrative regions, with 1,324,670 inhabitants (*ANNUAIRE STATISTIQUE EDITION 2021*, 2021) (INS, Niger, 2021), comprising 659,422 men and 665,248 women, with a 4.5% annual growth rate in 2020. In the social and environmental domains, this demographic movement leads to a high human concentration that has detrimental impacts on waste management, housing, the accessibility of good drinking water around the city, and health.

Improved living circumstances for the populace will be essential, among other things, to address the already visible repercussions of rising urbanisation.

Today's floods regularly result in the loss of lives, property, and farmland, as well as having an adverse effect on ecosystems, human security, health, and other aspects of daily life. According to Niamey government officials, 57 persons died and 132,528 were impacted by flooding in 2018. 211,000 individuals were impacted by the destruction of 16,375 homes as of the end of September 2019, mostly in the three areas of Zinder (80,534 affected), Maradi (28,847), and Niamey (31,222). (OCHA 2019).

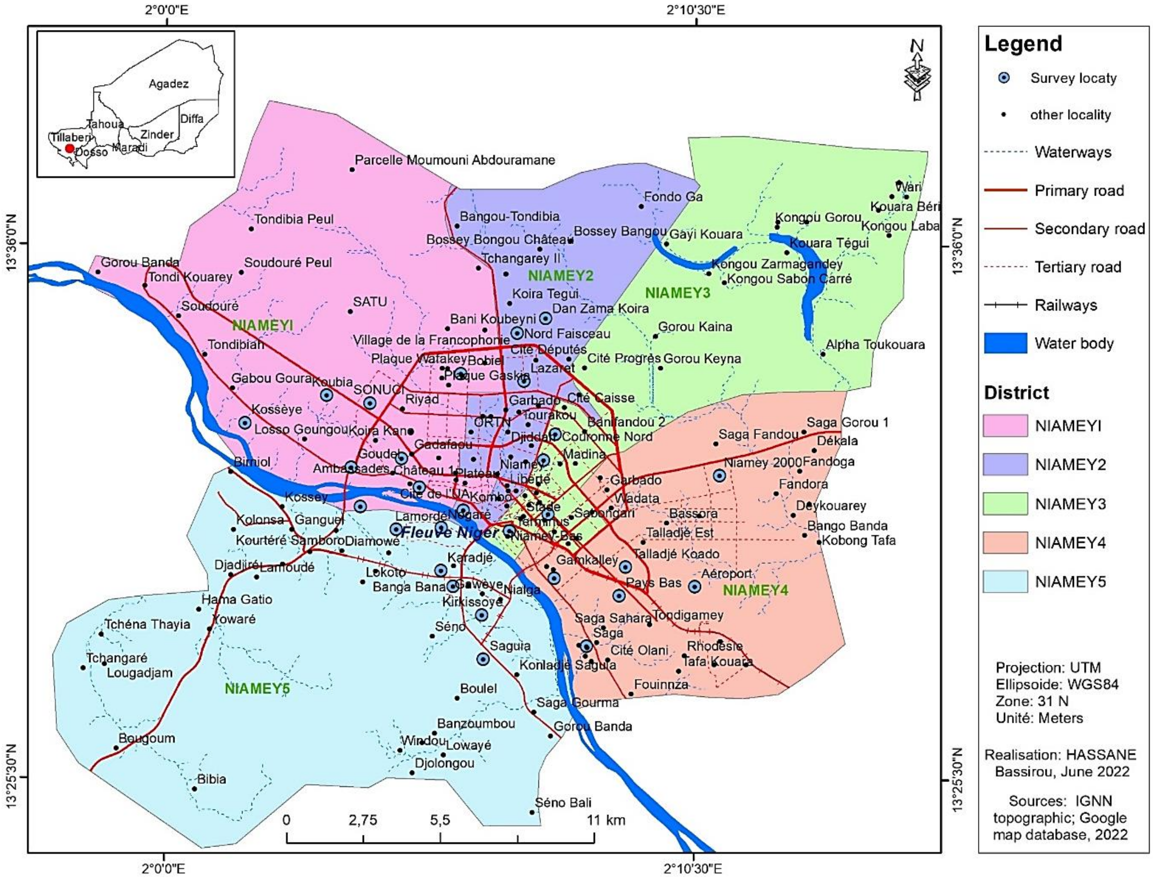

Figure 1. Map of Niamey.

DATA DESCRIPTION

Data used in this work are daily rainfall and streamflow data obtained from Nation Direction of Meteorology Centre in Niger. Rainfall data covers the period 1990–2020 for the rainy season only, while river flow data, which is slightly longer, covers the period 1985–2020. Both precipitation and streamflow time series had no missing data.

METHODS

Trend Analysis

To assess the trends in rainfall indices, streamflow, and the height of streamflow of the meteorological and hydrological station of Niamey City, we select six precipitation indicators from the 27 precipitation and temperature indicators defined and recommended by the team of experts on climate change, and three streamflow indicators [2,3,11]. Table 1 describes indicators used in this work to characterize rainfall and streamflow behavior, including their extremes.

Trends in meteorological and hydrological time series were widely assessed using the modified Mann-Kendall test, which is a non-parametric test used in several studies [2, 16]. The choice of this method is justified by the fact that it takes into account the effect of data [2]. The original Mann-Kendall test was modified to consider the case of autocorrelation time series. In this new version of the Mann-Kendall test, the variance of the statistic is modified to take account of autocorrelation in the series, and the variance is expressed as follows [2]:

$$VAR(s) = \frac{1}{18}\big(n(n-1)(2n+5)\big)\frac{n}{ns^*} \tag{1}$$

Where ns^* is the effective number of observations to account for autocorrelation in the data and $ns^*$is such that:

$$\frac{n}{ns^*} = 1 + \frac{2}{n(n-1)(n-2)}\sum_{s=1}^{n}(n-1) \tag{2}$$

At the 5% significance level, the test is such that the null hypothesis H_0 corresponds to “no linear trend” and the alternative hypothesis H_1 corresponds to the presence of a linear trend in the series.

Extreme Rainfall and Floods Frequency Analysis

Many studies have pointed out that climate and hydrological parameters, including rainfall, temperature, and streamflow, have been changing for a few decades. In this regard, the modelling of daily maximum precipitation and annual maximum discharge should take this trend into account this trend when modelling these variables. In this case, we use the Generalized Extreme Value (GEV) model considering a nonstationary approach Table 1. The GEV model is expressed [5]:

Table 1. Indicators used in this study to characterize rainfall and discharge behaviour.

Index	Name	Unit	Description
R1day	Wet days	Days	Annual number of wet days (day with rainfall ≥ 1 mm)
PRCPTOT	Total wet days rainfall	mm	Annual total rainfall from wet days
R95p	Very wet day	Days	Annual number of days with rainfall ≥ 95th percentile of wet days
R99p	Extreme wet day	days	Annual number of days with rainfall ≥ 99th percentile of wet days
RX1day	Maximum 1-day rainfall	mm	Annual maximum of 1-day rainfall
RX5day	Maximum 5-days rainfall	mm	Annual maximum of consecutive 5-days rainfall
QMin	Annual minimum discharge	m^3/s	The lowest discharge value of the year
QMax	Peak discharge	m^3/s	Annual maximum discharge
QX5day	5-days maximum flow	m^3/s	Moving average of maximum discharge rate over five days

$$GEV(x,\mu(t),\sigma(t),\varepsilon)=\begin{cases} exp\left\{-\left[1+\ \varepsilon\left(\frac{x-\mu(t)}{\sigma(t)}\right)\right]^{-\frac{1}{\varepsilon}}\right\}, & for\ \varepsilon\neq 0 \\ exp\left\{exp\left[\frac{x-\ \mu(t)}{\sigma(t)}\right]\right\} & ,\ for\ \varepsilon = 0 \end{cases} \tag{3}$$

Where $\mu, \sigma\ and\ \varepsilon$ are parameters of location, scale, and shape respectively. In the nonstationary framework the location and scale parameters are function time parameter t. The estimation of shape parameter is highly uncertain, it is not recommended to express this parameter as a function depending on covariates. The parameters are expressed as:

$$\begin{cases} \mu(t) \ = \ \mu_0 + \ \mu_1 t \\ \sigma(t) = \ \sigma_0 + \ \sigma_1 t \\ \quad \varepsilon(t) = \ \varepsilon_0 \end{cases} \tag{4}$$

Where $\mu(t)$ and $\sigma(t)$ are location and scale parameters express as function of covariable time t. $\varepsilon(t)$, the shape parameter was considered constant because of its uncertainty when it is a function of covariates.

The likelihood ratio test at the 5% significance level is employed to determine which of the two GEV models (stationary and nonstationary) is preferred given the sample of daily maxima rainfall [5]. After selecting a fitted model, the return levels of streamflow are calculated and plotted as well. The return level Z_p associated with the return period $1/p$ is expressed as

$$Z_p = \begin{cases} \mu(t) - \dfrac{\sigma(t)}{\varepsilon}[1-\{-log(1-p)\}^{-\varepsilon}], & for\ \varepsilon\ \neq 0 \\ \mu(t) - \sigma(t)log\{-\ log(1-p)\} \quad , & for\ \varepsilon = 0 \end{cases}$$

Where $\mu, \sigma\ and\ \varepsilon$ are parameters of location, scale, and shape respectively.

Relationship Between Extreme Rainfall and Flood Occurrences

This section consists of analyzing the impact of extreme rainfall on the frequency of floods. The first step consists of analyzing the correlation between extreme rainfall and streamflow and the second step consists of analyzing the impact extreme rainfall on streamflow. To do that we are going to consider extreme rainfall as covariable in the location and scale parameters of flood frequency model Table 2.

Table 2. Scale parameters of flood frequency model

Model	Parameters
M0	$\mu(t) = \mu_0$
	$\sigma(t) = \ \sigma_0$
	$\varepsilon(t) = \varepsilon_0$
M1	$\mu(t) = \mu_0 + \ \mu_1 X_1 + \mu_2 X_2$
	$\sigma(t) = \sigma_0 + \ \sigma_1 X_1 + \ \sigma_2 X_2$
	$\varepsilon(t) = \varepsilon_0$
M2	$\mu(t) = \mu_0 + \ \mu_1 X_1$
	$\sigma(t) = \sigma_0 + \ \sigma_1 X_1$
	$\varepsilon(t) = \varepsilon_0$
M3	$\mu(t) = \mu_0 + \mu_2 X_2$
	$\sigma(t) = \sigma_0 + \ \sigma_2 X_2$
	$\varepsilon(t) = \varepsilon_0$

RESULTS

Climatology Characteristics of Rainfall and Streamflow

We have observed that over the last three decades, the city of Niamey has recorded an average number of wet days (36 days) less than two months. The average wet day interval was between 32 and 41 days. However, 9.7% of the years in the study period (1990, 1991, and 1997) were marked by a total number of rainy days of less than 32. The number of years in which the total number of wet days exceeded 41 is also estimated at 9.7%: 1994, 1999, and 2006. From 1990 to 2020, PRCPTOT ranged between 340.2 and 753.3 mm, with an average value of 514.4 mm, more or less 101.3 mm. The total number of very or extremely wet days was under one and two weeks, respectively. Although the total number of rainy days has been less than two months over the last three decades, the city of Niamey recorded extreme rainfall events that flooded parts of the city during the period studied. For instance, in 1994, 2012, and 2017 RX1day reached 129, 119.2, and 120.5 mm, respectively. The indicator RX1day ranged between 31.6 and 129 mm, with an average value of 64.6 mm. The annual maximum of consecutive 5-days rainfall was between 42.5 and 150mm, with an average value of 88.3 mm. As for streamflow, we also found that the annual maximum of 1-day discharge ranged between 1182 and 2757 m^3/s, with an average value of 1825.9 m^3/s from 1985 to 2020. The annual maximum of consecutive 5-days discharge were between 5910 and 13215 m^3/s, with an average value of 8806.6 m^3/s.

Autocorrelation Test Assessment

We notice that all the time series of discharge indices including, QMin, Qmax and QX5days are suffering of autocorrelation. The plots of PRCPTOT, R1Xday precipitation indices show strong autocorrelation while R1day, R95p and R99p precipitation indices have acceptable autocorrelation (see, Figure 1). The effect of autocorrelation in the rainfall and streamflow indices should be removed by disintegration of the time series.

Trends Analysis

Precipitation indicators such as wet days (R1day), very wet days (R95p), and extremely wet days (R99p) show no significant linear trend with slope values stable at zero (Figure 2(b), (e), (f)). Of these, R95p and R99p are indicators representing the frequency of extreme precipitation, implying that there has been no change in the frequency of extreme precipitation. As far the intensity of extreme rainfall indices as concerned, we detect upward trends in the annual maximum of 1-day rainfall (RX1day), annual maximum of consecutive 5-days rainfall (RX5day) with values equal to 6.2% and 13.9% per decade (Figure 2(h), (i)). We also found that the total wet-day precipitation shows an upward trend with value equal to 3% per decade (Figure 2(c)). As for streamflow, we found that all the discharge indices induced in this work show upward trend trends. We found that the peak flow (QMax) increased by 27.9% per decade (Figure 2(d)). The lowest flow and the annual maximum of consecutive 5-days discharge (QX5day) increased by 1.7% and 0.9%, respectively (Figure 2(a), (g)) Table 3, Figure 3.

Table 3. Preliminary statistics of rainfall and streamflow.

Rainfall and streamflow indices	**Min**	**Mean ($\pm SD$)**	**Max**
R1day	27	36 (±4.9)	48
PRCPTOT	340.2	514.4 (±101.3)	753.3
R95p	3	7.7 (±2.3)	11
R99p	0	1.5 (±1.3)	6
R1Xday	31.6	64.6 (±23.2)	129
R5Xday	42.5	88.3 (± 29)	150
QMin	0	39.5 (±28)	137
QMax	1182	1825.9 (± 364.3)	2757
QX5days	5910	8806.6 (±1612)	13215

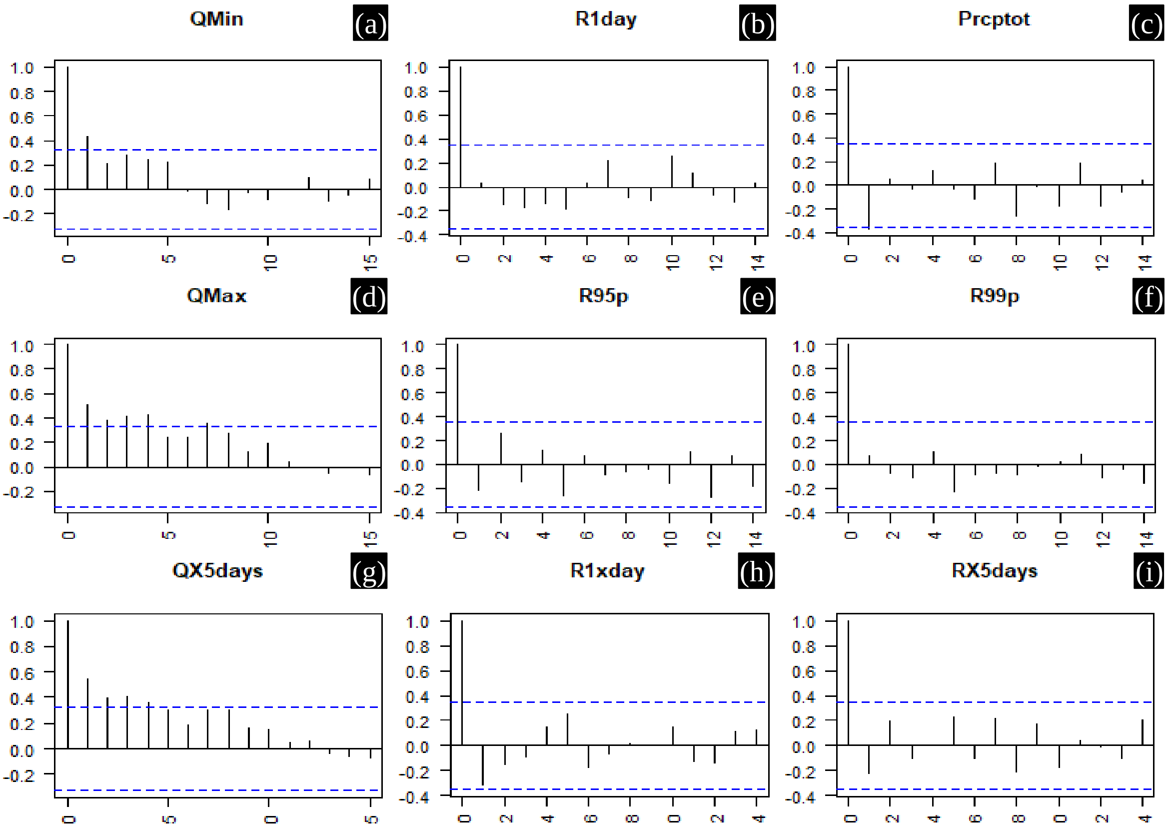

Figure 2. Column 1: The plots denote the autocorrelation of streamflow. Columns 1 & 2: plots corresponding to autocorrelation of rainfall indices.

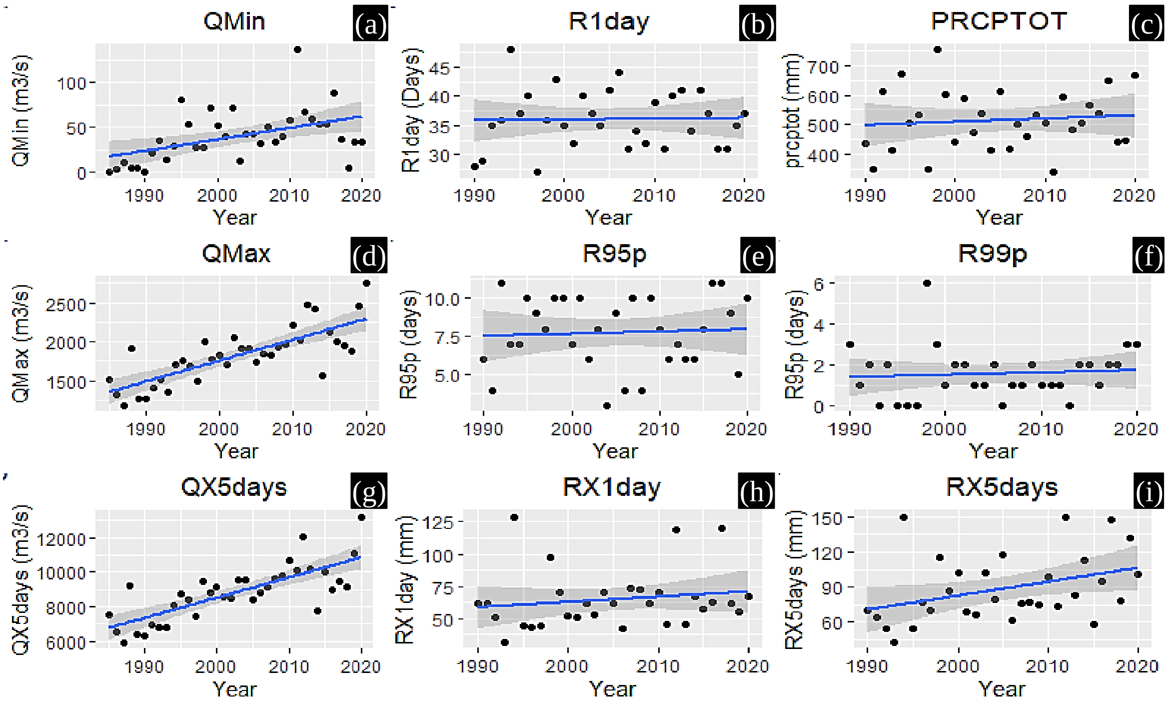

Figure 3. Trends in rainfall and discharge indices given as changes per year in QMin (a), R1day (b), PRCPTOT (c), QMax (d), R95p (e), R99p (f), QX5days (g), RX1day, RX5days (i). First column: plots (a, d, g) represent trends in discharge indices. First and second columns: plots (b, c, d, f, h, i) represent the trends in rainfall indices.

Rainfall and Streamflow Anomalies

From 1990 to 2020, we found that 1991, 1997, and 2011 were droughts years, while 1994, 1998, 2017, and 2020 were wet years in Niamey. Apart from these years, the other years are marked by alternations of slight drought and humidity considered to be neutral years. Regarding the standard flow index, we found that the flow is characterized by two hydrological periods (drought and wet) divided into four phases. A period of negative anomalies, during which there were years of meteorological and hydrological droughts that occurred concomitantly. This period corresponds to a single phase of hydrological drought over the period 1990–2020 and occurred between 1990 and 1999. A second period of positive flow anomalies was characterized by three moisture phases: The first phase corresponds to the resumption of the wet period from 2000 to 2005, reaching a peak in 2010. Between 2006 and 2013, there was a second phase, with higher humidity over the study period, during which a meteorological drought occurred in 2011. From 2016 onwards, a final phase of moisture has been resumed until 2020, with some years considered wet weather years.

MODELLING OF EXTREME RAINFALL AND HIGHER DISCHARGE

Estimation of Parameters

Table 4 shows that the p-values of the deviance are lower than 5%, implying that the nonstationary models of rainfall and streamflow outperform the stationary models respectively. For RX1day and RX5day models, the location parameter is expressed as a function of time, while the scale and shape parameters were considered constant. As for QMax and QX5day, only the shape parameter was considered constant, and the location and the scale parameters depended on the time parameter.

Return Levels of Daily Maxima Streamflow

We found that in 100 years from 2020, a daily maximum of 1-day rainfall and daily maxima of consecutive 5-days rainfall could reach 163 and 182.2 mm, respectively. As for QMax, and QX5day, the peak discharge and the daily maximum of 5-days discharge could also reach 2722.2 and 14287 m^3/s, respectively Table 5 and Figure 4.

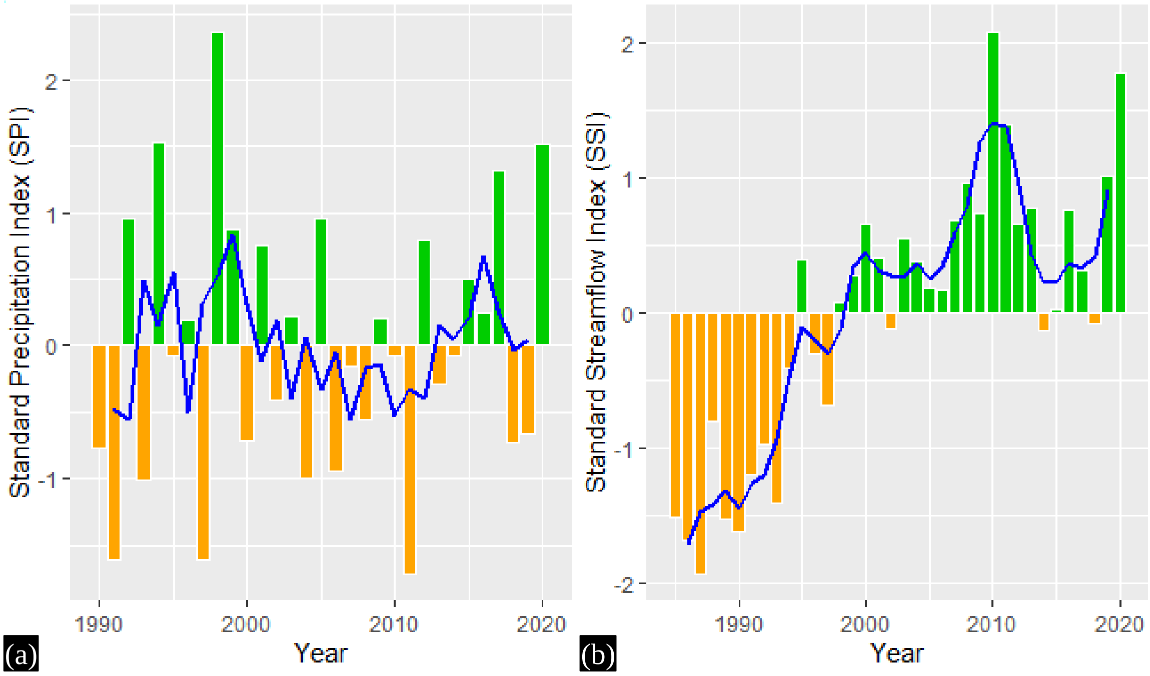

Figure 4. (a) plot-a represents the standard precipitation index and (b) plot-b denotes the standard streamflow index. The blue line denotes the 3 years moving average of SPI and SSI in plot-a and plot-b respectively.

Table 4. Estimation parameters of rainfall and streamflow models

Variable	Model	Model parameters	Log-likelihood
RX1day	Stationary	$\mu(t)$ = 54.1 $\sigma(t)$ = 14.8 $\varepsilon(t)$ = 0.12	134.5
	Nonstationary	$\mu(t)$ = 43.7 + 0.6t $\sigma(t)$ = 12.5 $\varepsilon(t)$ = 0.25	131.8
	Deviance		*5.43*
	P-value of deviance		*0.01*
RX5day	Stationary	$\mu(t)$ = 74.7 $\sigma(t)$ = 21.8 $\varepsilon(t)$ = 0.04	145.3
	Nonstationary	$\mu(t)$ = 59.9 + 0.97t $\sigma(t)$ = 19.2 $\varepsilon(t)$ = 0.08	142
	Deviance		*6.61*
	P-value of deviance		*0.01*
QMax	Stationary	$\mu(t)$ = 61.9 $\sigma(t)$ = 43.4 $\varepsilon(t)$ = 0.11	262.4
	Nonstationary	$\mu(t)$ = 1615 + 11.9t $\sigma(t)$ = 5.7 - 6.6$\times 10^{-4}t$ $\varepsilon(t)$ = 0.16	255.6
	Deviance		*13.5*
	P-value of deviance		*0.001*
QX5day	Stationary	$\mu(t)$ = 8217 $\sigma(t)$ = 1496.1 $\varepsilon(t)$ = - 0.17	316.2
	Nonstationary	$\mu(t)$ = 8201.7 + 34.7t $\sigma(t)$ = 7.5 – 0.02t $\varepsilon(t)$ = - 0.04	311.7
	Deviance		*8.9*
	P-value of deviance		*0.011*

Table 5. Return period and associated return level of daily maxima streamflow.

Return period (Year)	RX1day (mm)	RX5day (mm)	QMax (m^3/s)	QX5day (m^3/s)
5	76.4	106.1	2198.6	10743.4
10	91.5	122.8	2350.2	11646.8
25	115.3	145.4	2517.3	12745.6
50	137.1	163.4	2625.9	13531.3
100	163	182.2	2722.2	14287.0

Impact of Extreme Rainfall Upon Flood Frequency

Figure 5 shows that the correlation between the frequency of the annual maximum of 1-day discharge and an annual maximum of consecutive 5-days discharge and an annual maximum of 1-day rainfall and

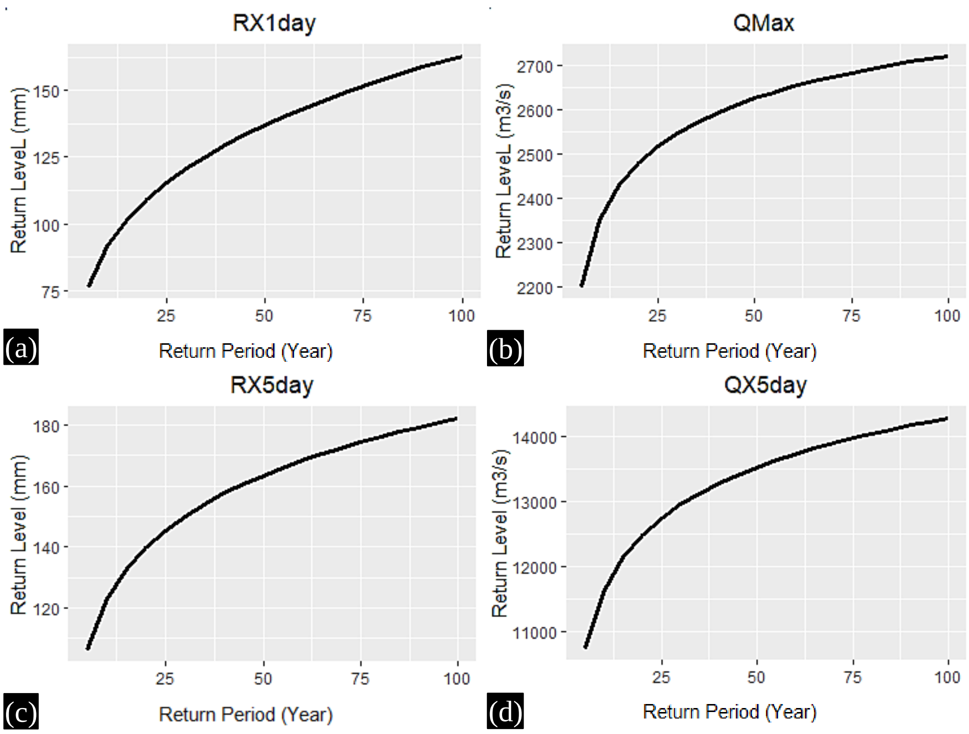

Figure 5. Return level as a function of the return period. The first column represents the return level plot of the annual maximum of 1-day rainfall and the annual maximum of consecutive 5-days rainfall with respect to return periods. The second column represents the return level plot of the annual maximum of 1-day discharge and annual maximum of consecutive 5-days discharge with respect to return periods.

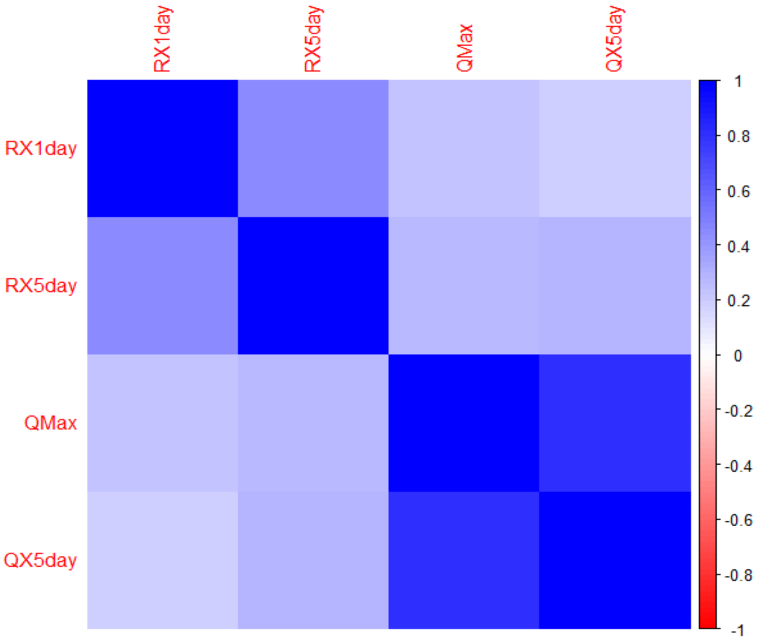

Figure 6. Correlation plot between Rainfall and discharge indices, including RX1day, RX5day, QMax and QX5day.

an annual maximum of consecutive 5-days rainfall are not strong, ranging from 0 to 0.4. In addition to correlation analysis, we modelled QMax and QX5day as functions of RX1day and RX5day. We found that the stationary models of QMax and QX5day outperformed the nonstationary models, implying that the upward trends in past floods frequency could not be due to extreme rainfall variability.

DISCUSSION

Understanding the evolution of trends in flooding and extreme events is important for the management of natural disasters such as floods. Analysis of the frequency and intensity of extreme precipitation revealed that extreme precipitation has become more frequent, but that no trend was observed in the intensity of extreme precipitation. In the light of some local studies (Sougué et al., 2023) have shown that downward trends in rainfall indices outnumber upward ones [7]. We also found that flood frequency has increased in Niamey. According to Tramblay et al. (2020), the annual maximum flow does not show a monotonic pattern, but rather global trends downwards before 1980 and upwards thereafter, particularly in West and South Africa [15]. These findings corroborate our results about the trends in the annual maximum of the peak discharge and annual maximum of consecutive 5-days discharge in Niamey.

Furthermore, it was found that extreme precipitation has no impact on flood frequency in Niamey, as the relationship between flood frequency and extreme precipitation frequency is not sufficiently strong, and the results of non-stationary generalized extreme value model with location and scale parameters as a function of extreme precipitation revealed that extreme precipitation has no impact on recent upward trends in flood frequency. In Burkina Faso, it was found that the recent increase in floods was due to land use and land cover, rapid growth of population rather than extreme rainfall. In Mali, it was also found that over 50% of floods were not due to extreme rainfall. According to the same authors, changes in land use and land cover and the increase in impervious surfaces are indicated as factors that increase the frequency of floods. However, according to the study by Aich et al. (2015) [1], the results are less clear but show that climate change and land use and land cover are drivers of increased flooding; however, their shares cannot be quantified. A complex model is therefore needed to assess the impact of land use, land cover and extreme precipitation on flood frequency and intensity.

We also show that a non-stationary generalized extreme value model with a time parameter as a covariate outperforms the stationary generalized extreme value model, implying that the stationarity assumption should be considered with caution when modelling the frequency of extreme precipitation events and the frequency of peak discharge.

The lack of long-term data was this study's main drawback. It should go without saying that in the future a research based on land use changes will need to be taken into consideration in order to emphasise the influence of land use changes on the incidence of flash floods in the studied regions given that land use changes affect how often floods occur. The upward trend in floods may be explained by either the little increase in precipitation between 1990 and 2020 or the rise in exposed soil as a result of urbanisation. Similar conclusions were drawn from a study of floods in Ouagadougou, where the frequency of floods rose from 1961 to 2015 despite the fact that the quantity of rainfall that triggered the floods was not very high. As a consequence, the land-use changes—whose investigation is beyond the scope of this work—might be included as a factor in addition to rainfall in causing the flood. For undeveloped countries like Niger where there is a dearth of rainfall data, the research of climate change impact issues using CHIRPS satellite data may be an alternative [8]. A recent study that used CHIRPS data and a study carried out in Ghana in the Vea catchment by Larbi et al. (2018) between 2016 and 2018 provide evidence for this. It is apparent that the rain is becoming harder and heavier if the authors are not specific and certain about when it rains in West Africa. The growing extreme rain fall indices, including RX1Day, RX5Day, and R99P, which are heading higher, corroborate this. People need to be informed that the rain is becoming more intense and that this might cause a number of issues, including flooding. The quantity of precipitation falling on the ground rises due to soil erosion, highlighting the flood. Historical flood statistics from the Civil Protection Directorate and the EM-DAT database illustrate this impact of damages. This paper gives specifics on the dams' ages before outlining the immediate steps that must be taken to lessen the consequences of flood catastrophes. The flood in the Niamey area is thought to have been caused by the orange alert level (580-619 cm) hight, which is not a large quantity. Since we are aware of how important rain is in causing floods, every time it rains, we should take early action to ease the problem. Decision-makers will be aware and able to put required and efficient flood mitigation measures in place for predicted and future floods, which will benefit the public. Gutters and other drainage systems need to be maintained in excellent shape because water will find another route to flow if the bed-water is blocked by a faulty drainage system or a poorly built property.

CONCLUSION

The study has investigated the temporal variability of rainfall and discharge characteristics as well as the impact of extreme rainfall on the frequency of flood frequency in Niger. In contrast to large-scale studies that concluded that extreme rainfall has become more frequent and intense in West Africa, our results show a more nuanced picture because we found that only the frequency of extreme precipitation has upward trends. No significant trend was observed in the intensity of the extreme in Niamey. Our results show upward trends in flood frequency and these trends are not linked only to extreme precipitation events.

This research might be used as a resource to educate decision-makers about the forthcoming flood. With this knowledge, actions might be made quickly and appropriately to lessen the potential harm that a flash flood can inflict. Since there have been no prior studies conducted in this area in Niamey, the key challenge throughout this research has been the limits of the data that is now accessible, particularly based on historical flood information in Niamey. Given that rainfall has not been the primary cause of the flood in Niamey, land-use changes have a significant impact and should be further examined in the flood research that will be conducted in the future.

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Conflict of Interest Statement

The authors say they have no competing interests.

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REFERENCES

1. Aich, V., Liersch, S., Vetter, T., Andersson, J. C., Müller, E. N., & Hattermann, F. F. (2015). Climate or land use? —Attribution of changes in river flooding in the Sahel zone. Water, 7(6), 2796–2820.
2. Amichiatchi, N., Soro, G. E., Hounkpè, J., Goula Bi, T. A., & Lawin, A. E. (2022). Evaluation of Potential Changes in Extreme Discharges Over Some Watersheds in Côte d'Ivoire. Hydrology 2023, 10, 6.
3. STATISTICAL YEARBOOK EDITION 2021. (2021). 2016–2020.

4. Bigi, V., Pezzoli, A., & Rosso, M. (2018). Past and future precipitation trend analysis for the City of Niamey (Niger): An overview. Climate, 6(3), 73.
5. Coles, S. (2001). An introduction to Statistical Model of Extreme Values (1st ed.). Springer-Verlag London.
6. Fofana, M., Adounkpe, J., Larbi, I., Hounkpe, J., Koubodana, H. D., Toure, A., Bokar, H., Dotse, S.-Q., & Limantol, A. M. (2022). Urban flash flood and extreme rainfall events trend analysis in Bamako, Mali. Environmental Challenges, 6, 100449.
7. Klassou, K. S., & Komi, K. (2021). Analysis of extreme rainfall in Oti River Basin (West Africa). Journal of Water and Climate Change, 12(5), 1997–2009.
8. Niger: Floods - Jun 2021 available :https://reliefweb.int/disaster/fl-2021-000127-ner
9. Panthou, G., Vischel, T., & Lebel, T. (2014). Recent trends in the regime of extreme rainfall in the Central Sahel. International Journal of Climatology, 34(15), 3998–4006.
10. Sa’adi, Z., Shahid, S., Ismail, T., Chung, E.-S., & Wang, X.-J. (2019). Trends analysis of rainfall and rainfall extremes in Sarawak, Malaysia using the modified Mann–Kendall test. Meteorology and Atmospheric Physics, 131(3), 263–277.
11. Sillmann, J., Kharin, V. V., Zhang, X., Zwiers, F. W., & Bronaugh, D. (2013). Climate extremes indices in the CMIP5 multimodel ensemble: Part 1. Model evaluation in the present climate. Journal of Geophysical Research: Atmospheres, 118(4), 1716–1733.
12. Sougué, M., Merz, B., Sogbedji, J. M., & Zougmoré, F. (2023). Extreme Rainfall in Southern Burkina Faso, West Africa: Trends and Links to Atlantic Sea Surface Temperature. Atmosphere, 14(2), 284.
13. Ta, S., Kouadio, K. Y., Ali, K. E., Toualy, E., Aman, A., & Yoroba, F. (2016). West Africa Extreme Rainfall Events and Large-Scale Ocean Surface and Atmospheric Conditions in the Tropical Atlantic. Advances in Meteorology, 2016, 1940456. https://doi.org/10.1155/2016/1940456
14. Tazen, F., Diarra, A., Kabore, R. F. W., Ibrahim, B., Bologo/Traoré, M., Traoré, K., & Karambiri, H. (2019). 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, 12(S1). https://doi.org/10.1111/jfr3.12507
15. Tramblay, Y., Villarini, G., & Zhang, W. (2020). Observed changes in flood hazard in Africa. Environmental Research Letters, 15(10), 1040b5.
16. Yue, S., & Pilon, P. (2004). A comparison of the power of the t test, Mann-Kendall and bootstrap tests for trend detection/Une comparaison de la puissance des tests t de Student, de Mann-Kendall et du bootstrap pour la détection de tendance. Hydrological Sciences Journal, 49(1), 21–37.