

Characterization of Dry and Wet Conditions in the Koliba-Corubal Basin for the Historical Period (1981-2024)

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Received: 📅 2026 Feb 22

Accepted: 📅 2026 Mar 13

Published: 📅 2026 Mar 24

Abstract

Koliba /Corubal basin, located between Guinea and Guinea-Bissau, is a key region in West Africa due to its major role in freshwater supply. However, climate variability and climate change are severely impacting the management of its water resources. This study aims to analyze the historical climatic conditions of the basin between 1981 and 2024, focusing on trends in extreme rainfall and temperatures. To this end, climate indices such as the SPI (Standardized Index of Precipitation) will be used. Precipitation Index) and the SPEI (Standardized Precipitation Evapotranspiration Index (SPI) is used to assess dry and wet periods, as well as changes in the distribution of extreme temperatures (such as hot days and nights). The results indicate moderate trends in precipitation, with a slight increase in moderate rainy days, but no significant changes in the frequency of extreme precipitation events. In contrast, minimum and maximum temperatures showed an increasing trend, with potential implications for water management and agriculture. Analysis of the SPI and SPEI indices across various timescales revealed an increased trend toward prolonged dry conditions, particularly over the long term (12 to 24 months), highlighting a predisposition of the basin to severe drought periods. This study provides essential information for sustainable water resource management, aiming to strengthen climate change adaptation strategies in the region.

Keywords: Koliba Corubal Basin , Extreme Rainfall, Extreme Temperatures, Climate Change, SPI, SPEI

1. Introduction

Climate variability and its effects on water resources are crucial issues in semi-arid regions, where the impact of extreme events, such as droughts and floods, is increasingly pronounced due to climate change. These events have profound repercussions on water resource management, agriculture, and food security. West Africa, and in particular the Koliba /Corubal basin, located between Guinea and Guinea-Bissau, is especially vulnerable to these changes [1,2]. This basin, although relatively small, is a vital water source for Guinea-Bissau, and understanding its hydrological dynamics in the face of climate change is essential [3]. Climate change is affecting the frequency, intensity, and duration of extreme weather events in this region, including intense rainfall, prolonged periods of drought, and heat waves. A study of historical climate trends in the Koliba /Corubal basin can provide valuable information to anticipate these effects and help formulate adaptation strategies [4]. The variability of rainfall and temperatures can indeed modulate hydrological flows, with direct impacts on available water resources. Satellite data, such as those from the CHIRPS system for precipitation and ERA5 reanalyses for temperatures, offer accurate and extensive coverage for these climate studies [5,6].

In this context, the use of climate indices such as the SPI (Standardized Precipitation Index) and the SPEI (Standardized Precipitation The Evapotranspiration Index allows us to track trends in drought and humidity over time, taking into account the combination of precipitation and evapotranspiration [7,8]. These indices are widely used in the analysis of the impacts of climate change, as they incorporate not only variations in precipitation, but also thermal factors that influence evapotranspiration [9]. In addition, extreme temperature indices, such as TX90p, TN90p, and their annual equivalents, provide a comprehensive assessment of heat waves and exceptionally hot nights, two phenomena that are expected to intensify under the influence of global warming. Koliba /Corubal basin , although relatively small, is characterized by significant climate variability, marked by a single rainy season and a prolonged dry period. Recent climate trends show a slight increase in minimum and maximum temperatures, as well as changes in rainfall patterns affecting both dry and wet periods. The role of the West African monsoon, along with the interaction between local and global weather systems, contributes to this variability. Monthly maximum temperatures can reach up to 40°C during the hot season, while minimum temperatures

can drop to 10°C during the cool season, thus accentuating the thermal variability in the region [10].

The need to assess past climatic conditions and project future trends is all the more pressing in light of global climate projections. Studies such as those by the IPCC (2021) and van Vuuren show that warming trends are expected to continue to intensify, altering water cycles at global and regional scales [11]. In this context, analyzing historical climate data and simulating future impacts using climate models, such as those from CMIP6, allows for a better understanding of the risks associated with hydroclimatic changes in vulnerable areas like the Koliba /Corubal basin [3,12]. The objective of this study is to characterize the historical climatic conditions of the Koliba /Corubal basin between 1981 and 2024, with a focus on trends in extreme precipitation and temperature. We will use standardized climate indices, such as the SPI and SPEI, to analyze dry and wet periods. Furthermore, we will examine the impact of extreme temperatures on local climatic conditions using time series from reanalysis data, such as

those from the ERA5 project, to provide an assessment of climate trends and their implications for water resources in the basin [13].

This analysis is essential for the sustainable management of water resources, as it allows for a better understanding of long-term climate trends and the development of strategies adapted to the specific conditions of the Koliba /Corubal basin [12,14]. The results obtained could also be used to improve drought management policies, hydraulic infrastructure planning, and long-term adaptation strategies to climate change at the regional and national levels [11].

2. Study Area

The Koliba -Corubal catchment area is located between 11° N and 12° 30' N and between 12° W and 14° 30' W. It is shared between Guinea (84.5%) and Guinea-Bissau (15.5%), covering an area of 20,876.4 km² at the Tché-Tché hydrometric station (see figure 1).

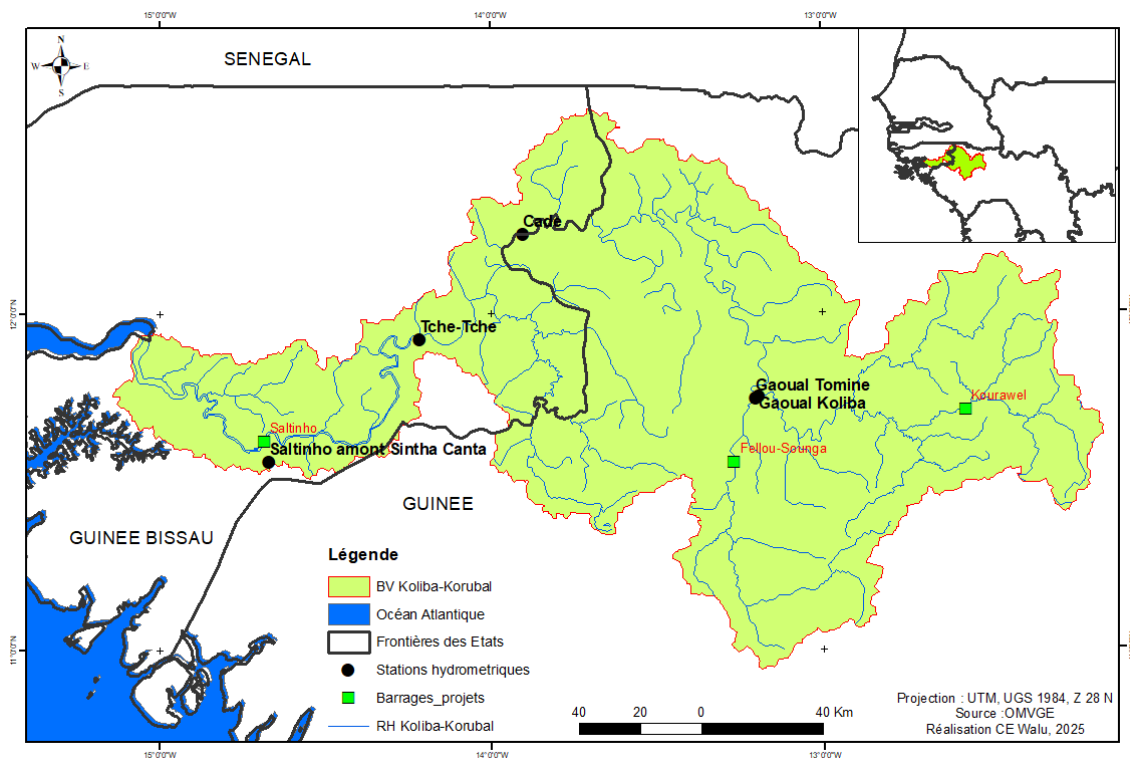


Figure 1: Koliba Corubal Watershed at the Stations of Tché , Cade, Gaoual_Koliba and Gaoual Tomine

The river originates west of Fouta Djallon, in Middle Guinea, in the Labé region. It is formed by the confluence of two rivers: the Tomine, which originates at Sangale, and the Komba, which originates at Madina. Wora. These two rivers join at Gaoual to form the Koliba. After meandering westward for over 200 km, the river marks the border between Guinea and Guinea-Bissau for a few kilometers before entering Guinea-Bissau, where it becomes the Corubal. The river then flows into the Kayanga / Geba near Xime, in a flat, marshy region where tides penetrate deep inland, forming the Geba estuary [1,2]. Although its drainage basin is relatively small, this

river is the main source of fresh water for Guinea-Bissau. The basin's vegetation includes dense forests, degraded montane forests, dry forests frequently affected by bushfires, wooded savannas, forested areas, as well as cultivated land and fallow fields [1,10]. The region has a tropical climate, characterized by a single rainy season, lasting five months in the north and six months in the south, and a dry season (from April to November), during which rainfall remains low (a few millimeters). Rainfall decreases from south to north, following the flow of the West African monsoon. Average monthly maximum temperatures range from 26.0 to 33.4

°C in Labé and from 31.1 to 40.2 °C in Koundara, in August and April, respectively. Average minimum temperatures vary from 10.2 to 18.3 °C in Labé and from 15.0 to 24.2 °C in Koundara between December and May.

3. Materials and Methods

3.1. Data

(Climate data Hazards Infrared Precipitation with Station Data). The CHIRPS system is a precipitation estimation method that combines satellite observations and ground-based data from meteorological stations. This system was developed to provide accurate precipitation estimates, particularly in regions where meteorological station networks are insufficient or nonexistent [5,15,16]. CHIRPS data are widely used in climate, hydrological, agricultural, and disaster management studies due to their ability to provide daily and monthly rainfall information on a global scale. CHIRPS data are generally available with a resolution of 0.05° (approximately 5 km x 5 km) and cover the period from 1981 to the present [16]. They are particularly useful for drought monitoring, climate risk assessment, and precision agriculture. The combination of satellite and terrestrial data makes it possible to compensate for the biases present in satellite observations alone, particularly in areas where weather station networks are limited or nonexistent [5]. The temperature data used in this study are ERA5 data produced by the European Centre for Medium-Range Weather Forecasts (ECMWF), a key resource for

climate and meteorological studies worldwide. They provide detailed information on temperature, atmospheric pressure, precipitation, and other climate variables at a spatial resolution of 31 km [6]. These data are obtained through reanalysis, a method that combines numerical weather prediction models and real-world observations to generate homogeneous time series of past atmospheric conditions [17].

3.2. Daily Variability of Rainfall in the Basins

Regarding the potential impacts of climate change on extreme events at the watershed scale, the eleven extreme precipitation indices (I), a subset of 27 extreme indices, are recommended by the World Meteorological Organization's Commission on Climatology (WMO-ICC). The Expert Team on Climate Change Detection and Indices (ETCCDI) of the World Climate Research Programme (WRCP)/ Climate Variability and Predictability (CLIVAR) was selected based on available data describing the climatic behavior of the climate in the Gambia basin upstream of Gouloumbou. Furthermore, they can also provide indicators to identify the risks of frequent extreme events such as floods and droughts in terms of intensity, frequency, and severity. The selected indices were calculated from daily rainfall data using the Climact software (I). Climact was used to check data quality and the homogeneity of historical data before calculating the extreme indices.

Hint	Index name	Definition
R99p	Days of extreme rain	Total annual precipitation in days > at the 99th percentile
Rx3days	Maximum amount of rainfall over 3 days	Maximum annual rainfall over 3 consecutive days
Rx5days	Maximum amount of rainfall over 5 days	Maximum annual rainfall over 5 consecutive days
SDII	Daily rainfall intensity index	Rapport des précipitations totales annuelles au nombre de jours humides (≥ 1 mm)
CWD	Consecutive rainy days	Nombre maximum de jours consécutifs où précipitations ≥ 1 mm
R20	Number of days with very heavy rainfall	Nombre annuel de jours lorsque précipitations ≥ 20 mm

Table 1: Definitions of Selected Extreme Precipitation Indices

Since precipitation data from meteorological stations in the areas of interest were not available, we used the mean value of the MERRA-2 data in the Casamance and Kayanga-Géva basins (1981-2024). A set of extreme precipitation indices that are used in many studies (Dos Santos Bodian, Xu & Dione and Faye, 2025) were calculated from these data [12,14,18,19]. These include, among others, the annual total precipitation in days > 99th percentile (R99p), the annual maximum consecutive precipitation over 3 days (Rx3day), the annual maximum consecutive precipitation over 5 days (Rx5day), the Daily Rainfall Intensity Index (SDII), the maximum number of consecutive days with precipitation ≥ 1

mm (CWD) and the annual number of days with precipitation ≥ 20 mm (R20).

3.3. Daily Variability of Temperature in the Basins

On a daily scale, 4 indices were selected and examined to characterize temperatures in the Koliba-Corubal basin (I): TN90p (Annual percentage of days where TN > 90th percentile); TNx (Annual maximum value of daily minimum temperatures); TX90p (Annual percentage of days where TX > 90th percentile); TXx (Annual maximum value of daily maximum temperatures).

Hint	Index name	Definition
TN90p	Hot nights	Annual percentage of days where TN > 90th percentile
TNx	Max of Tmin	Maximum annual value of daily minimum temperatures
TX90p	Hot days	Annual percentage of days where TX > 90th percentile
TXx	Max of Tmax	Maximum annual value of daily maximum temperatures

Table 2 : Definitions of Selected Extreme Temperature Indices

When changes in climate indices at selected stations are examined in warm and cold periods, the change in the warm period is observed to be more pronounced than the change in the cold period [12,14,18,19].

3.4. Standardized Precipitation Indices (SPI)

The SPI is a probability index derived solely from rainfall statistics for a specific location and period (months or years). This index converts the cumulative probability into a standard normal random variable [20]. The median rainfall value and the SPI quantify the probability of observing a given amount of rainfall within a specific time frame [9]. According to Sadja, negative and positive SPI values reflect drought and humidity, respectively [21]. These values increase negatively or positively, respectively, as drought or humidity increases. According to Dione this study used three-month (SPI 3) (January-March), six-month (SPI 6) (January-June), and twelve-month (SPI 12) (January-December) SPIs to describe, respectively, seasonal variations in precipitation, variations related to agricultural drought, annual variations, and longer-term trends related to hydrological drought [22]. The evolution of the dataset resulted in the addition of a new SPI value each month, derived from the calculated values of previous months. Historical records were used to calculate the probability of any observed precipitation data point. To calculate the deviation of precipitation from a normally distributed probability density function with a mean of zero and a standard deviation of one, this probability was used in conjunction with an inverse normal estimate. According to Javanmard this figure represented the SPI for the precipitation data point [23].

For $0 < H(x) \leq 0.5$,

$$SPI = -\left(t - \frac{c_0 + c_1 + c_2 + t^2}{1 + d_1 t + d_2 t + d_3 t}\right), \quad t = \sqrt{\ln \frac{1}{(H(x))^2}} \quad (1)$$

For $0.5 < H(x) \leq 1$,

$$SPI = +\left(t - \frac{c_0 + c_1 + c_2 + t^2}{1 + d_1 t + d_2 t + d_3 t}\right), \quad t = \sqrt{\ln \frac{1}{(1.0 - H(x))^2}} \quad (2)$$

Or $c_0 = 2.515517$, $c_1 = 0.802853$, $c_2 = 0.010328$, $d_1 = 1.432788$, $d_2 = 0.189269$ and $d_3 = 0.001308$ [23].

3.5. Standardized Precipitation and Evapotranspiration Indices (SPEI)

The SPEI is an advanced drought index used to assess the impact of climate change on drought conditions [8]. It is distinguished by its ability to integrate the effects of high

temperatures and evapotranspiration, making it particularly relevant for analyzing drought in the context of climate change. The calculation of the SPEI in this study follows the method defined by Vicente-Serrano, which is based on a climate water balance [7]. This balance is established by taking the difference between precipitation (P) and potential evapotranspiration (PET) for a given month. The basic formula used for the calculation is:

$$D_i = P_i - ETP_i(3)$$

D_i It offers a simple indication of excess or deficiency of water for the month studied. PET is determined using the Thornthwaite equation [24].

The D_i calculations are grouped at different time levels, using the same method as that applied for the SPI. The variation, $D_{i,j}^k$ for a given month j and year i , varies according to the chosen time scale, k . For example, the monthly variation for a year over a 12-month period is calculated using this formula:

$$X_{i,j}^k = \sum_{l=13-k+j}^{12} D_{i-l,j} + \sum_{l=1}^j D_{i,l,j}, \quad si \ j < k, et(4)$$

$$X_{i,j}^k = \sum_{l=j-k+j}^j D_{i,l,j}, \quad si \ j \geq k(5)$$

Where $D_{i,j}$ is the difference in P-ETP of the l th month of year i , in mm.

Next, we choose the log-logistic distribution to standardize the D series in order to calculate the SPEI. The log-logistic distribution is defined by its probability density function.

$$f(x) = \frac{\beta}{\alpha} \left(\frac{x-\gamma}{\alpha}\right)^{\beta-1} \left[1 + \left(\frac{x-\gamma}{\alpha}\right)^{\beta}\right]^{-2} \quad (6)$$

Where α , β and γ are respectively the scale, shape and origin parameters for D values within the range ($\gamma > D < \infty$).

Thus, the probability distribution function of series D is given by:

$$F(x) = \left[1 + \left(\frac{\alpha}{x-\gamma}\right)^{\beta}\right]^{-1} \quad (7)$$

With $F(x)$, the SPEI can easily be obtained as normalized values of $F(x)$. For example, after the classical approximation of Abramowitz and Stegun [25]:

$$SPEI = W - \frac{c_0 + c_1 W + c_2 W^2}{1 + d_1 W + d_2 W^2 + d_3 W^3} = (8)$$

When p is less than or equal to 0.5, we have $W = \sqrt{-2 \ln(p)}$, where p represents the probability of exceeding a certain value D , with p equal to 1 minus the cumulative distribution function $F(x)$. If p is greater than 0.5, then p will be substituted by $1 - p$ and the sign of the resulting SPEI will be reversed. The fixed values are: $C0 = 2.515517$, $C1 = 0.802853$, $C2 =$

0.010328 , $d1 = 1.432788$, $d2 = 0.189269$, and $d3 = 0.001308$. A drought event occurs when the SPEI is equal to or less than -1 for a given period. Based on the values of the indices (SPI or SPEI), the states of meteorological drought are defined. Five states are considered, designated by an integer ranging from 0 (no drought) to 4 (extreme drought) and defined through the criteria of Table 3.

SPEI values	Drought sequences	SPEI values	Wet sequences
SPI/SPEI < -2.00	Extremely dry	2.00 < SPI/SPEI	Extremely humid
-2.00 < SPI/SPEI < -1.50	Severely dry	1.50 < SPI/SPEI < 2.00	Severely humid
-1.50 < SPI/SPEI < -1.00	Moderately dry	1.00 < SPI/SPEI < 1.50	Moderately humid
-1.00 < SPI/SPEI < 0.00	Slightly dry	0.00 < SPI/SPEI < 1.00	Slightly damp

Table 3: Categorization of the Degree of Drought/Humidity According to Standardized Precipitation and Evapotranspiration Indices

4. Results

4.1. Characterization of Precipitation and Extreme Temperatures in the Basin

4.1.1. Extreme Precipitation

The analyzed parameters reveal varied trends in climatic conditions (table 4 and). Regarding r_{99ptot} , the amount of extreme precipitation, the average is 4.89 mm, with a maximum of 16.2 mm and a minimum of 0 mm. Kendall's tau is -0.11 , indicating a slight negative trend, although the p -value of 0.3 suggests that this trend is not statistically significant. Thus, although years with little extreme precipitation do exist, no significant change is observed over the years. For rx_{3day} , which measures maximum rainfall over three consecutive days, the average is 102 mm, and the maximum reaches 174 mm, representing significant rainfall events. Kendall's tau of 0.02 shows no clear trend, and the p -value of 0.84 confirms that the observed trend is not significant. Similarly, for rx_{5day} , the maximum rainfall over five consecutive days averages 142 mm, with maximum values reaching 204 mm. Kendall's tau of -0.01 indicates slight stability in extreme events, but again, the p -value of

0.94 suggests that this trend is insignificant.

Analysis of s_{dii} , the daily rainfall index, shows an average of 11 mm. Although daily rainfall shows a slight positive trend (Kendall's tau = 0.22), this trend is statistically significant with a p -value of 0.04, meaning that rainy days with moderate amounts have increased slightly over the years.

Regarding c_{wd} , which measures the duration of dry periods, the average is 48.2 days, with maximums reaching 100 days. Sen's slope is positive (0.07), suggesting a slight trend toward longer dry periods, but the p -value of 0.75 indicates that this trend is not significant. Finally, for r_{20mm} , which measures days with rainfall exceeding 20 mm, the average is 22.8 days. Kendall's tau of 0.16 indicates a weak positive trend, but the p -value of 0.14 suggests that this trend is not significant enough to be considered reliable. In summary, the analyses show some moderate trends, including a slight increase in moderate rainy days and an extension of dry periods, but most of the trends observed are not statistically significant, implying some climatic stability in this region over the period studied.

Settings	r_{99ptot}	rx_{3day}	rx_{5day}	s_{dii}	c_{wd}	r_{20mm}
Average	4.89	102	142	11	48.2	22.8
Maximum	16.2	174	204	12.6	100	36
Minimum	0	68.8	103	9.14	23	11
Number of years with positive indices	21	19	18	22	18	20
Number of years with negative indices	22	24	25	21	25	23
Variable	r_{99ptot}	rx_{3day}	rx_{5day}	s_{dii}	c_{wd}	r_{20mm}
Tau of Kendall	-0.11	0.02	-0.01	0.22	0.03	0.16
Sen slope	-0.03	0.04	-0.03	0.02	0.07	0.08
P-value	0.3	0.84	0.94	0.04	0.75	0.14

Table 4: Values of Selected Extreme Precipitation Indices in the Koliba -Corubal Basin (1981-2024)

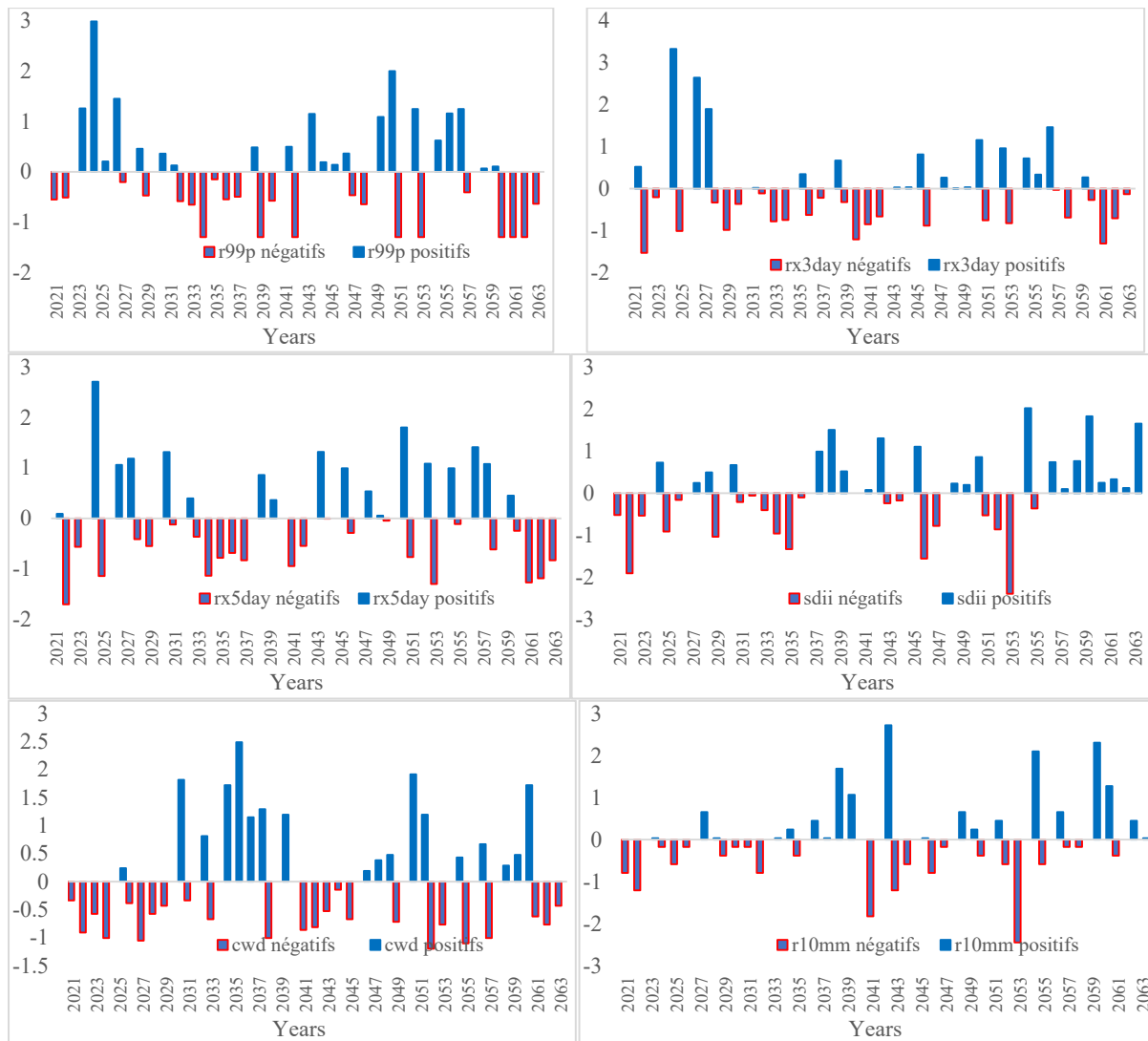


Figure 2: Evolution of Standardized Anomalies of Extreme Temperature Indices in the Koliba -Corubal Basin (1981-2024)

4.1.2. Extreme Temperatures

Analysis of the parameters relating to minimum and maximum temperatures reveals diverse and significant trends (Table 5 and). For tn_{90p} (minimum temperature above the 90th percentile), the mean is 10.5°C, with a

maximum of 29.7°C and a minimum of 2.17°C. Kendall's tau of 0.3 indicates a moderate positive trend, and the p-value of 0.01 suggests that this trend is statistically significant. Sen's slope of 0.22 confirms a slight increase in minimum temperatures over time.

Settings	tn 90p	tnx	tx 90p	txx
Average	10.5	25.5	10.4	39
Maximum	29.7	26.6	35.8	40.4
Minimum	2.17	24.7	1.82	37.7
Number of years with positive indices	14	21	13	20
Number of years with negative indices	29	22	30	23
Variable	tn 90p	tnx	tx 90p	txx
Kendall's Tau	0.3	0.13	0.3	-0.25
Sen slope	0.22	0.01	0.21	-0.02
P-value	0.01	0.21	0	0.02

Table 5: Values of Selected Extreme Temperature Indices in the Koliba -Corubal Basin (1981-2024)

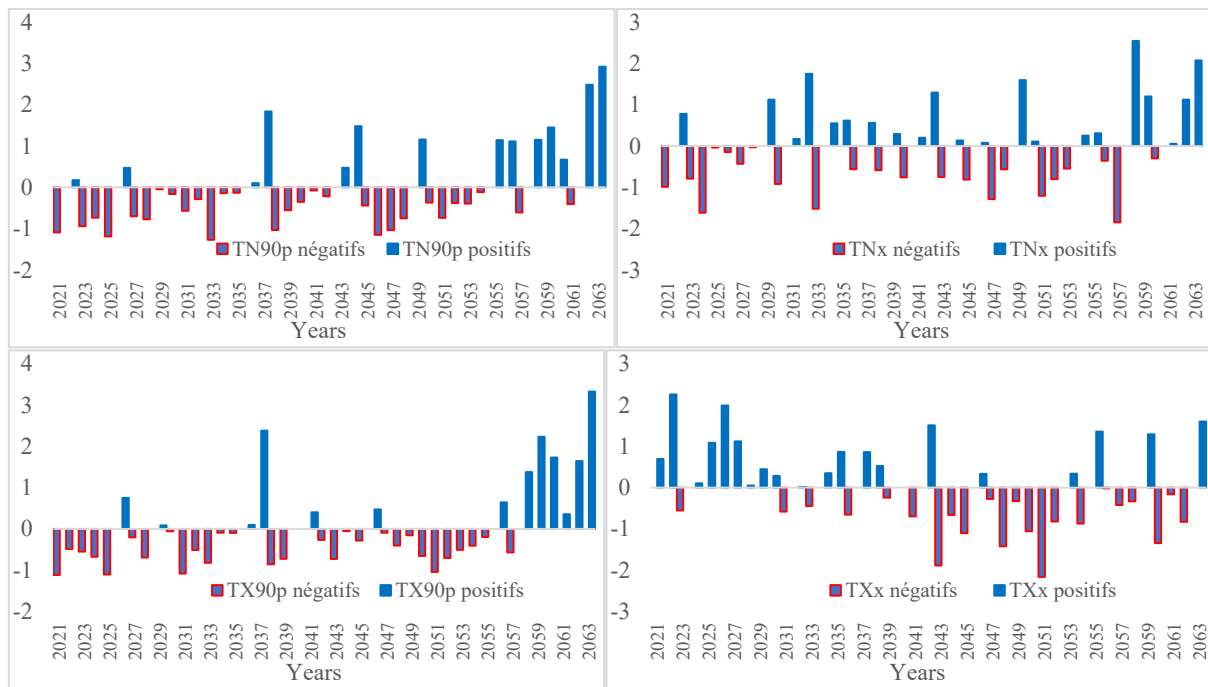


Figure 3: Evolution of Standardized Anomalies of Extreme Temperature Indices in the Koliba -Corubal Basin (1981-2024)

Regarding tnx (average daily maximum temperature), the average is 25.5°C , with a maximum of 26.6°C and a minimum of 24.7°C . Kendall's tau of 0.13 shows a positive trend, but the p-value of 0.21 indicates that this trend is not statistically significant. Sen's slope of 0.01 suggests negligible variation in maximum temperatures over the years. For $tx90p$ (maximum temperature above the 90th percentile), the average is 10.4°C , with a maximum of 35.8°C and a minimum of 1.82°C . Kendall's tau of 0.3 indicates a notable positive trend, and the p-value of 0 shows that this trend is statistically significant. Sen's slope of 0.21 confirms a gradual increase in extreme maximum temperatures over the study period. Regarding txx (the highest annual maximum temperature), the average is 39°C , with a maximum of 40.4°C and a minimum of 37.7°C . Kendall's tau of -0.25 suggests a negative trend, indicating a slight decrease in extreme maximum temperatures. However, the p-value of 0.02 shows that this trend is statistically significant, although Sen's slope of -0.02 indicates a small decrease in maximum temperatures. In summary, the parameters $tn90p$ and $tx90p$ show significant upward trends in extreme minimum and maximum temperatures, while tnx remains stable and txx exhibits a slight downward trend. The results suggest that extreme minimum and maximum temperatures tend to increase, but annual maximum variations are more stable or slightly decreasing.

4.2. Characterization of Dry and Wet Conditions in the Basin Using SPI and SPEI Indices

To characterize the SPI and SPEI indices, the values of the wet and dry period categories in the Koliba - Corubal basin (1981-2024) are shown in Table 6 and Figures 4 and REF_Ref205023603 \h * MERGEFORMAT 8.

4.2.1. For SPI indices

- **3-Month SPI:** Over the 3-month period, the data show a dominance of slightly wet periods (37.50%), followed by moderately wet (8.33%) and extremely wet (2.08%) conditions. These results suggest that, over short periods, wet conditions are predominant in the basin. However, moderately dry (6.82%) and extremely dry (3.03%) periods also occur, although they remain limited. This indicates that, while the overall trend is wet, transient drought events can occur. The low percentage of severely dry periods (4.36%) indicates that extreme droughts are rare in the short term.

- **6-Month SPI:** The 6-month analysis shows a high proportion of slightly wet (39.20%) and moderately wet (7.95%) conditions. The proportion of moderately dry periods (5.87%) remains modest, but extremely dry (3.22%) and severely dry (4.92%) periods increase compared to the 3-month timescale. This indicates that as the observation period lengthens, the basin begins to experience more drought. Severely wet conditions (3.98%) are less frequent on this timescale, suggesting that excess moisture is less pronounced than on the 3-month timescale.

- **12-Month SPI:** On the 12-month scale, slightly dry (42.61%) and moderately dry (2.84%) periods predominate. Notably, moderately wet periods (11.74%) still occur, but are much less frequent than at 6 months. The rates of severely dry (7.39%) and extremely dry (3.22%) periods are higher, indicating a greater predisposition to prolonged dry conditions. Severely wet (2.84%) and extremely wet (2.27%) periods are almost nonexistent, reflecting a more pronounced imbalance in favor of drought over the course of a year.

- **24-Month SPI:** On the 24-month scale, slightly wet

conditions (31.44%) remain the predominant category, but the proportion of slightly dry conditions (32.20%) becomes more significant. Moderately dry periods (9.85%) increase compared to other scales, and severely dry periods (6.25%) are more frequent. This scale shows a strong trend

toward drought, with a total of 13.64% moderately dry conditions and an increase in severely dry and extremely dry conditions (5.49%). Wet conditions (only 32.95%) decrease significantly, illustrating a predisposition of the basin to experience prolonged droughts.

Sequences	SPI 3	SPI 6	SPI 12	SPI 24	SPEI 3	SPEI 6	SPEI 12	SPEI 24
Extremely humid	11	15	12	14	9	11	11	12
Severely humid	26	21	15	10	29	22	23	18
Moderately humid	44	42	62	35	44	54	53	63
Slightly damp	174	169	143	189	183	172	155	169
Slightly dry	198	207	225	166	170	182	202	143
Moderately dry	36	31	15	52	59	46	32	72
Severely dry	23	26	39	33	22	27	30	23
Extremely dry	16	17	17	29	12	14	22	28
Total	528	528	528	528	528	528	528	528
Extremely humid	2.08	2.84	2.27	2.65	1.70	2.08	2.08	2.27
Severely humid	4.92	3.98	2.84	1.89	5.49	4.17	4.36	3.41
Moderately humid	8.33	7.95	11.74	6.63	8.33	10.23	10.04	11.93
Slightly damp	32.95	32.01	27.08	35.80	34.66	32.58	29.36	32.01
Slightly dry	37.50	39.20	42.61	31.44	32.20	34.47	38.26	27.08
Moderately dry	6.82	5.87	2.84	9.85	11.17	8.71	6.06	13.64
Severely dry	4.36	4.92	7.39	6.25	4.17	5.11	5.68	4.36
Extremely dry	3.03	3.22	3.22	5.49	2.27	2.65	4.17	5.30
Total	100	100	100	100	100	100	100	100

Table 6: Categories of Wet And Dry Periods in the Koliba -Corubal Basin (1981-2024)

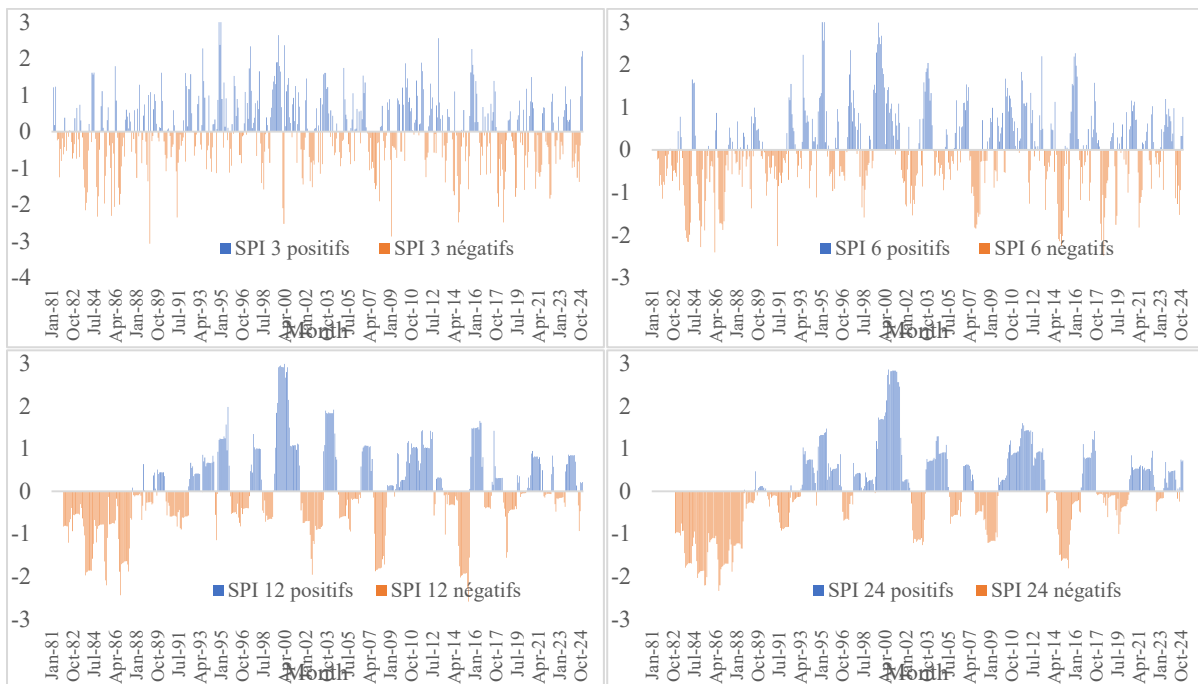


Figure 4 : Comparison of 3, 6, 12 and 24 Month SPI Indices in the Koliba -Corubal Basin (1981-2024)

4.2.2. For SPEI Indices

• **3-Month SPEI:** Analyzing the 3-month SPEI, we observe that slightly humid conditions (34.66%) remain dominant. However, the proportion of moderately dry (11.17%) and severely dry (4.17%) conditions is higher than that of humid conditions. Drought thus becomes more significant in the short term compared to the SPI, although moderately humid periods (5.49%) are relatively balanced. The total number of dry conditions reaches 19.72%, illustrating a vulnerability to more frequent and intense dry periods over these short timeframes.

• **SPEI 6 Months:** On the 6-month scale, slightly wet conditions (32.58%) remain dominant, but the proportion of moderately dry (8.71%) and extremely dry (2.65%) conditions shows an increasing trend towards longer dry periods. Severely wet (4.17%) and severely dry (5.11%) conditions are less frequent, but prolonged dry conditions are more prevalent than at 3 months, indicating an amplification of droughts over longer periods. Drought periods become increasingly pronounced as the analysis scale lengthens.

• **SPEI 12-Month:** On the 12-month scale, slightly dry (38.26%) and moderately dry (6.06%) conditions are the dominant categories. Severely dry (5.68%) and extremely dry (4.17%) conditions indicate a trend toward more severe and prolonged droughts. Wet periods (32.58% slightly wet, 10.23% moderately wet) are less frequent, with a large majority of dry conditions. This analysis highlights that prolonged droughts are becoming a major concern, with longer periods of low humidity.

• **SPEI 24-Month:** The 24-month scale reveals a dominance of slightly dry periods (27.08%), while moderately dry (13.64%) and severely dry (5.30%) periods occur at a significantly higher frequency. Wet conditions decrease significantly, with only 32.01% of periods classified as slightly wet. This illustrates a more pronounced trend towards drought over time, with longer periods of insufficient moisture, particularly marked by the moderate and severe nature of dry conditions on the 24-month scale.

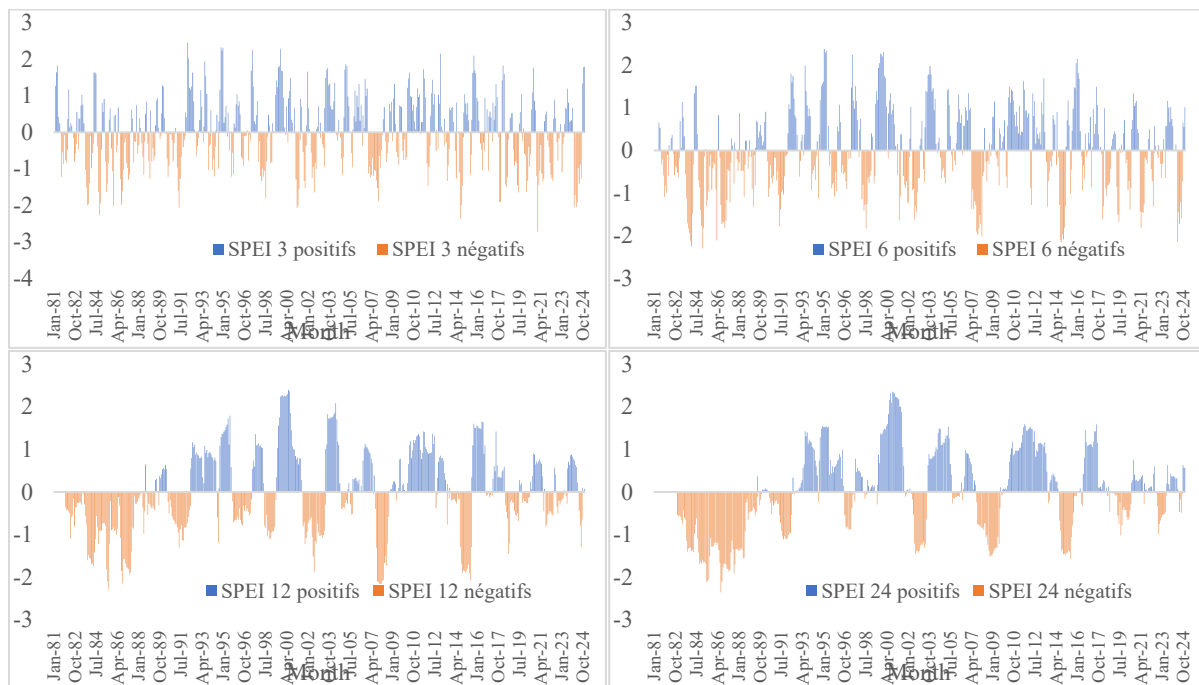


Figure 5: Comparison of SPEI indices for 3, 6, 12 and 24 months in the Koliba -Corubal basin (1981-2024)

5. Discussion

Analysis of climatic conditions in the Koliba /Corubal basin between 1981 and 2024 has revealed several interesting trends regarding extreme rainfall and extreme temperatures, which have direct implications for water resource management and climate change adaptation strategies.

5.1. Extreme Rainfall

The results show that the amount of extreme rainfall, measured by the R99p index, did not show a significant trend over the study period (Kendall's tau = -0.11, p-value = 0.3). This suggests some stability in the frequency of extreme rainfall events, although years with extreme rainfall amounts were observed. However, indices such as the SDII,

which measure the intensity of daily rainfall, show a slight positive trend (Kendall's tau = 0.22), indicating an increase in moderate rainy days over the years, which could suggest a trend toward more frequent but less extreme rainfall events [7]. This is consistent with trends observed in other parts of West Africa, where days of moderate rainfall tend to increase under the effect of climate change [1,14].

5.2. Extreme Temperatures

Extreme temperatures, on the other hand, showed more pronounced trends. The TX90p and TN90p indices, which measure particularly hot days and nights respectively, revealed significant increases in maximum and minimum temperatures (Kendall's Tau = 0.3 and 0.3 respectively, p-value

= 0 for TX90p). These trends suggest a gradual warming of extreme temperatures, with possible implications for water resource management and agriculture, particularly during periods of extreme heat. In contrast, the TXx index (highest annual maximum temperature) showed a slight decrease, which may reflect natural variability or a balance between periods of intense heat and less extreme events.

5.3. Drought and Humidity

Analysis of the SPI and SPEI indices revealed a general trend toward prolonged dry conditions, particularly over periods of 12 to 24 months. On the SPI scale, "slightly dry" periods were predominant (37.50% at 3 months and 42.61% at 12 months), while more severe periods of drought were less frequent. However, periods of moderate and severe drought were more pronounced on the 12- and 24-month scales, suggesting an increased predisposition of the basin to prolonged droughts in the long term [7,8]. This phenomenon is confirmed by the SPEI indices, which also show a trend towards prolonged periods of drought, particularly on the 6 and 12 month scales (SPEI 6 and 12) [12,22]. The results of this study therefore indicate that, although climatic conditions remain relatively stable in terms of extreme rainfall, the Koliba /Corubal basin is experiencing warming temperatures and an increase in prolonged periods of drought. These trends underline the importance of developing adaptation strategies for local communities, including strengthening water management and implementing agricultural practices adapted to these new climatic conditions [11].

6. Conclusion

This study on climate variability in the Koliba /Corubal basin between 1981 and 2024 highlighted several important trends in rainfall and temperature extremes, as well as their impacts on the region's water resources. The results show a general stability in extreme rainfall, with a slight upward trend in moderate rainy days, although extreme rainfall events remain infrequent. However, temperature analysis revealed significant warming in both minimum and maximum temperatures, which could exacerbate drought conditions and negatively affect agriculture and water supply. The study also revealed that the basin is experiencing an increasing trend toward prolonged periods of drought, particularly on a scale of 12 to 24 months. Moderately dry and severely dry periods are becoming more frequent, indicating the basin's increased vulnerability to the long-term impacts of climate change. This predisposition to prolonged drought underscores the need to strengthen adaptation strategies, particularly in the areas of water resource management, sustainable agriculture, and water infrastructure planning. The findings of this research are crucial for formulating climate policies and adaptation strategies that address the specific challenges of the Koliba /Corubal basin. They provide a solid foundation for future actions aimed at improving the resilience of local communities to climate change. Better water resource management, along with increased vigilance regarding extreme temperatures and prolonged droughts, are essential to ensuring a safer and more sustainable future for this region.

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