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PRECIPITATION TRENDS IN THE GAMBIA RIVER BASIN (SENEGAL) FOR THE PERIOD 1971-2010

Abstract: Since the 1970s, West African streams experienced profound modifications connected to pluviometric deficit, which have influenced on a strong decrease of water resources. The objective of this study is to analyze trends of precipitation at the six selected stations in the Senegalese part of Gambia River basin, using graphical and statistical approach. Methodology is consisted of an analysis of monthly, seasonal and annual variability of precipitation for the 1971-2010 period, through Non-parametric tests. Study revealed a strong variability and often a contrasting evolution between various stations (Kédougou, Simenti, Tambacounda, Kounghel, Nioro and Goudiry). Between the periods 1971-1990 and 1991-2010, the value U of Mann-Whitney, had changed from 60 to 40 at Tambacounda, 64 to 59 at Kédougou and 63 to 51 at Simenti station, which showed non-significant trends in annual total precipitation for the studied period. Sen's estimator revealed significant descending trends on Kédougou station (9.812 mm/year for the period 1971-1990 and 0.309 mm/year for the period 1991-2010), and Simenti station too. On the other hand (in the whole article), on the stations of Tambacounda, Goudiry and Koungheul, the reduction is noticed for the period 1971-1990 (3.658 mm/year on Tambacounda), and an increase is noticed in the period 1991-2010 (13.21 mm/year on Tambacounda). For the station Nioro, on other hand, increase is noted in both periods (3.801 mm/year and 8.841 mm/year). The assumption is that these significant trends of precipitation during the last four decades could be attributed to the climate changes.

Key words: rainfall, trend, non-parametric tests, Gambia River, Senegal

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Introduction

Climate changes, connected to rising surface temperatures, are often manifested by long periods of drought, with negative effects on the hydrological cycle, environment and socio-economic activities (agricultural, industrial and commercial). Decreasing trends in rainfall were observed in West Africa from the late 1960s and early 1970s to the early 1990s. This decreasing trend was noted in many works (Dione, 1996; Sighomnou, 2004; Goula et al., 2005; Sow, 2007; Faye, 2013; Faye et al., 2015b). One of the major issues, in the researches of a complex phenomenon like climate variability, is to quantify its impact on the river flow, which may be different from one region to another. In addition, the appearance of some humid years in the end, after the year 2000, raises questions about the end of the dry period that has been going on, since the beginning of the 1970s, the climatic scale being thirty years old. Some authors have attempted to provide answers to these uncertainties (related to the characterization of this period as dry or wet) by relating the 2000 decade to the previous dry decades (Ali et al., 2008; Niang, 2008; Ali & Lebel, 2009; Ozer et al., 2009; Ouoba, 2013).

These studies, although managed in the Sahelian region, have not identified much of the hydro-climatic dynamics of the Gambia River basin. In addition, they do not confirm or refute with certainty the idea of return to more humid weather conditions, like the very humid situation in the 1950s and 1960s. In this context, this study was initiated in Senegal, in the Gambia River basin, on the recent spatiotemporal variations of rainfall parameters, of hydrological and agronomic interest. In order to study climate changes and improve climate impact research, trend detection is of great interest for both hydrology and climatology. In addition, this trend detection of precipitation series is crucial for regional water resources planning and management. Unlike the other sub-Saharan basins, the spatio-temporal variability of rainfall in the Gambia River basin has been poorly studied so far, while its impact on water resources is very important. The objective of this study is to analyze precipitation trends at six selected stations in the Senegalese part of the Gambia River basin. The methodology is consisted of the analysis of the monthly, seasonal and annual variability rainfall in the Senegalese part of the Gambia River basin, for the period 1971-2010, through non parametric tests.

Study area

The Gambia River basin covers an area of nearly 77,100 square kilometers, shared by three states (Lamagat, 1989): Guinea (where the river Gambia originates); Senegal (from which it drains almost the entire Tambacounda region and part of Upper Casamance and South Sine-Saloum); Gambia (it is the backbone). It extends, in latitude, from 11° 22' N (in the Fouta-Djalon) to 14° 40' N (in the Far-Eastern Ferlo) and, in longitude, from 11° 13' W (Fouta-Djallon) to the 16° 42' W (Banjul, confluence). The Gambia River originates at the altitude of about 1,150 m in Fouta Djallon, near Labé (Guinea) and the total length of the main course is 1,180 km. A river flow is consisted of two diversion bays: a continental reach and a marine reach (Dione, 1996; Sow, 2007). In the continental reach there are a numerous tributaries on the left side (Duagueri, Niokolo-Koba, Niéri-Ko, Sandougou, etc.) and on the right side (Thiokoye, Diarha, Koulountou, etc.) (Fig. 1).

Data and methods

Data

The data, used in this study, include precipitation data from six selected stations in the Senegalese part of the Gambia River basin (Kedougou, Tambacounda, Simenti, Goudiry, Koungueul and Nioro) for the period of 40 years (from 1971 to 2010), obtained from of the Water Resources Management and Planning Department. This choice is explained by the absence of stations and/or data available in the part of the river basin, which is used in this study. Thus, only these six selected stations have long series of non-gap data. This period is considered as rather long for a valid average statistical study (Kahya & Kalayci, 2004), especially as Burn & Elnur (2002) specify that a length of minimum 25 recorded years, ensures the statistical validity of results, when it is connected to trends and climate changes.

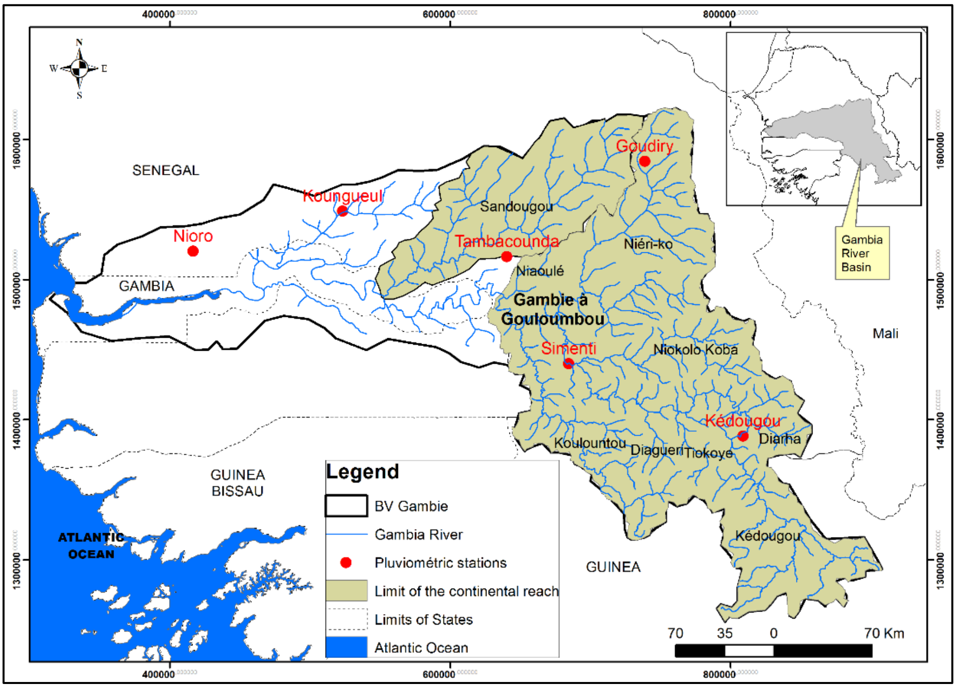

Fig. 1. Location of studied stations in the Gambia River Basin (Source: DGPRE)

Methods

Statistical tools commonly used to detect significant trends in climate and hydrological data series are generally non-parametric tests such as: the Mann-Whitney U-test, the Wilcoxon-V test, the Mann-Kendall test, or the correlation test, type of Spearman and parametric tests such as Student's test (Ifeka & Akinbobola, 2015).

Precipitation Concentration Index (ICP): The PCI index (Oliver, 1980; Murugan et al., 2008) is proposed as an indicator of rainfall concentration and the erosive power of rainfall (Iskander et al., 2014). It is expressed mathematically as follows:

$$PCI = \frac{\sum_{i=1}^{12} P_i^2}{(P_t)^2} \times 100 \quad (1)$$

where Pi represents the monthly precipitation in the year i and Pt the total of the annual precipitation.

This index represents a hydrological overage or deficit for the considered month or year. According to Oliver (1980), a value of PCI<10 reflects relatively uniform rainfall over the year, a value between 11 and 15 a moderate concentration, a value between 16 and 20, a mean concentration and a value of PCI>20 high concentration.

The Mann-Kendall test: It detects the presence of a linear trend (increasing or decreasing) within a time series. This trend test was first studied by Mann (1945) and then taken up by Kendall (1975) and its robustness is validated by several comparison tests carried out by Yue and Wang (2004). The Mann-Kendall statistic is defined as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sign}\,(x_i - x_j) \quad (2)$$

where xi and xj are the sequential values of the data and n is the size of the sample.

The Mann-Whitney U test: This test is used to evaluate if there is a significant difference between the average in a series before and after break.

$$U_x = n_x n_y + \left((n_x(n_x + 1)\right)/2 - R_x \quad (3)$$

$$U_x = n_x n_y + \left((n_y(n_y + 1)\right)/2 - R_y \quad (4)$$

where n_x is the number of observations in the first group, n_y the number of observations in the second group, Rx the sum of the ranks assigned to the first group and Ry the sum of the ranks assigned to the second group. In other words, the two equations (U) can be understood as the number of observation times in a previous sample or observation in the next sample.

The Wilcoxon rank test: It is expressed mathematically as follows:

$$z_T = \frac{T - \mu_T}{\sigma_T} \quad (5)$$

where

$$\mu_T = \frac{N(n+1)}{4} \quad (6)$$

$$\sigma_T = \sqrt{\frac{N(n+1)(2n+1)}{24}} \quad (7)$$

with n represents the sample size, T - the sum of ranks for a smaller sample size (n_1), n_1 - the smallest sample size, n_2 - the largest sample size, n_1 ≥ 10 and n_2 n ≥ 10.

Student's z-average test: The z-statistic uses the sample mean, m-estimator. It follows the normal reduced centered law and is established as follows:

$$z = \frac{\overline{x} - m}{\sigma/\sqrt{n}} \quad (8)$$

where $\overline{x}$ is the observed mean, m is the reference mean, σ is the reference standard deviation, and n is the sample size.

The slope (S) of the trend: The slope (S) of the trend present on the series was determined using the estimator of Sen and the set of slopes

$$S = \frac{R_{A\_} - R_B}{N_A - N_B} \quad (9)$$

with R_A the rank of group A, R_B the rank of group B, N_A the number of samples in group A and N_B the number of samples in group B.

$$\text{Tan } \alpha + \beta + \varphi = \frac{\text{Tan } \alpha + \frac{\text{Tan } \beta + \text{Tan } \varphi}{1 - \text{Tan } \beta \times \text{Tan } \varphi}}{1 - \text{Tan } \alpha + \frac{\text{Tan } \beta + \text{Tan } \varphi}{1 - \text{Tan } \beta \times \text{Tan } \varphi}} \quad (10)$$

where Tan α is the slope of group A, Tan β the slope of group B, Tan φ the slope of group C, α is the angle of group A, β the angle of group B and φ the angle of group C.

The Sen slope estimator test: The magnitude of the trend is predicted by the Sen estimator. Here, the slope (T_i) of all the even data is calculated as follows (Sen, 1968):

$$T_i = \frac{x_j - x_k}{j - k} \qquad \text{for } i = 1, 2, \ldots..N \quad (11)$$

Where x_j and x_k are considered data values at the moment j and k (j> k) corresponding. The median of the N values of $T_i$represented as the slope estimator of Sen is given by the following formula:

$$Q_i = \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) - \text{ N is odd} \quad (12)$$

$$Q_i = \frac{1}{2}\left(T_{\frac{N+1}{2}}\right) - \text{ N is even} \quad (13)$$

The slope estimator of Sen is calculated as: $Q_i = \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right)$ appears odd, and it is considered $Q_i = \frac{1}{2}\left(T_{\frac{N+1}{2}}\right)$ if N appears even. At the end, Q_i is calculated by a two-sided test with a confidence interval of 100 (1- α) %, then a real slope can be obtained by the non-parametric test. The positive value of Q_i indicates an upward trend and a negative value of Q_i indicates a downward trend in the time series.

Models for total annual precipitation were developed from trend analysis using statistical and logical techniques.

Results and discussion

For the results of this study, the precipitation trends (annual and monthly) are discussed.

Trends in annual precipitation

The analysis of the annual precipitation sequences is mainly based on the Tambacounda, Kédougou and Simenti stations. The other stations used in this study (Koungheul, Goudiry and Nioro) illustrate the analysis of observed trends (Tab. 1 and Fig. 2).

Tab. 1. Statistics of the tests on the annual evolution of the precipitations (Source : ANACIM)

Stations	Years	Average	Man-Whitney U	Wilcoxon V	Student Z	Spearman Correl. Matrix	Kendall Tau	Sen Slope
Tambacounda	1971-80	742.8	60	36	1.014	-0.263	-0.094	-3.658
	1981-90	674						
	1991-00	700.1	40	23	-0.695	-0.036	0.273	13.21
	2001-10	759.4						
Kédougou	1971-80	1,181	64	38	1.344	0.117	-0.263	-9.812
	1981-90	1,075						
	1991-00	1,245	59	29	0.362	0.133	-0.010	-0.309
	2001-10	1,205						
Simenti	1971-80	884.7	63	38	1.252	0.016	-0.252	-8.466
	1981-90	795.1						
	1991-00	927.6	51	23	0.217	-0.222	-0.073	-3.349
	2001-10	902.5						
Goudiry	1971-80	627.5	67	37	1.129	0.171	-0.231	-4.631
	1981-90	570.1						
	1991-00	649.6	34	16	1.286	-0.291	0.021	1.293
	2001-10	524.6						
Koungheul	1971-80	715.5	63	40	1.140	0.163	-0.021	-0.321
	1981-90	632.2						
	1991-00	697.3	28	6	-0.488	0.533	**0.357**	**16.24**
	2001-10	753.2						
Nioro	1971-80	687.3	46	25	0.084	0.438	0.147	3.801
	1981-90	680.9						
	1991-00	721.3	53	29	0.204	-0.071	0.115	8.841
	2001-10	702.6						

The analysis of the annual rainfall trend in the Gambia River Basin, based on the mean values, revealed a high variability and often an opposite evolution between the different stations of the study. The results show a heterogeneous distribution of mean rainfall across the basin, related to latitude and longitude. The comparison of the annual rainfall data's for the period 1971-1990 and those for the period 1991-2010 shows an increase in rainfall at the Tambacounda (708 mm to 730 mm), Kédougou (1,128 mm to 1,225 mm), Simenti (840 mm to 915 mm), Koungheul (674 mm to 725 mm) and Nioro (684 mm to 712 mm) stations. Only the Goudiry station has a slight decrease between the two periods, with an average changing from 599 mm to 587 mm. These average values seem to show an increasing trend of precipitation (Ali et al., 2008; Niang 2008; Ozer et al., 2009; Ouoba, 2013). However, the stations are distinguished by several differences: the 1990s period is drier than the following years (decade 2000) at the Tambacounda and Koungheul, which is not the case at the Kedougou, Simenti, Goudiry and Nioro stations where a decreasing of precipitation has been observed. This decrease in rainfall is in contradiction with the rainfall recovery from the 2000s noted by some authors in the Sudano-Sahelian zone (Ali and Lebel, 2009, Panthou et al., 2014).

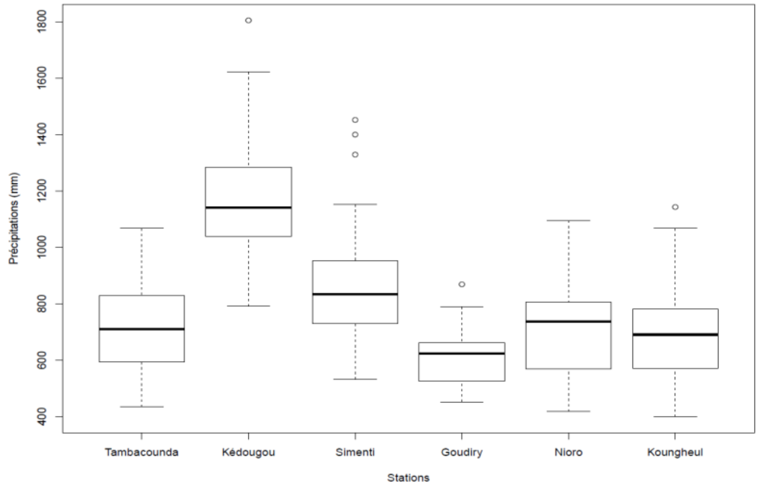

Fig. 2. Box-Whisker plot of total annual precipitation from 1971 to 2010 (Source: ANACIM)

These noted trends in annual rainfall patterns in the Gambia River basin can be attributed to climate changes in the area, as temperature rises and rainfall decreases during the 1970s, 1980s, and 1990's. However, the variation between decades is very small, as evidenced by the statistically insignificant trends in Mann-Whitney statistics calculated between decades. Between 1971-1990 and 1991-2010, the Mann-Whitney U-value, from 60 to 40 in Tambacounda, 64 to 59 in Kedougou and 63 to 51 in Simenti, show slight increasing trends in total annual precipitation over the studied period (the sums of the ranks of the totals between decades are approximately identical), the values of the p-value being greater than the level of significance 0.05. The observation remains the same for the z statistic of Student's test but also the R of Spearman which is interpreted in terms of explained variance and calculated from the ranks. Correlation values, both positive and negative, show non-linear rainfall relationships between decades.

The analysis of the Kendall Tau and the Sen Slope also reveals an opposite evolution between the periods 1971-1990 and 1991-2010 of the analyzed stations. The Sen estimator revealed decreasing trends, which were not significant at all, at the Kedougou station (-9.812 mm/year for the period 1971-1990 and -0.309 mm/year for the period 1991-2010) and Simenti station (-8.466 mm/year for the period 1971-1990 and -3.349 mm/year for the period 1991-2010). On the other hand, the 1971-1990 decade is considerably drier than the period 1991-2010 on these two stations. At the Tambacounda station, if the decline is noted for the period 1971-1990 (-3.658 mm/year), an increase is noted for the period 1991-2010 (13.21 mm/year). The same is true for the Goudiry (-4.631 mm/year for the period 1971-1990 and 1.293 mm/year for the period 1991-2010) and Koungheul (-0.321 mm/year for the period 1971-1990 and 16.24 mm/year for the period 1991-2010) stations. In the case of the Nioro station, on the other hand, the increase is noted over the two periods (3.801 mm/year for the period 1971-1990 and 8.841 mm/year for the period 1991-2010), with a larger increase over the last period. However, this trend of increasing rainfall over the last decade is not statistically significant at the 95% confidence level (only the Koungheul station has a statistically significant increasing trend). Overall, the period 1971-1990 is characterized by its deficit nature compared to

1991-2010, which knows overages and seems to announce the return of precipitation. The values of the Kendall Tau, negative for the period 1971-1990 and positive for the period 1991-2010, reflect this increase in rainfall over the current period, despite the low magnitude. Nevertheless, such trends could be attributed to climate change.

Monthly precipitation trends

Tab. 2 shows the statistics of the monthly precipitation trends (average, median, maximum and minimum) at the Tambacounda, Kédougou and Simenti stations. It reveals that the rainy season is between May and November, with the months of June, July, August, September and October as the rainiest months. The month of August has the highest magnitude of monthly precipitation trends with 211 mm in Tambacounda, 316 mm in Kedougou and 275 mm in Simenti, followed by September and July. These months corresponds with the maximum of the flow in the basin.

Tab. 2. Statistics of Monthly precipitation trends from 1971 to 2010 (Source: ANACIM)

Tambacounda	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**An**
Average	0.02	0.28	0.31	0.52	16.7	89.4	179	211	165	53.9	2.84	0.67	719
Maximum	0.40	8.60	3.60	16.7	106	198	336	450	326	143	58.0	8.20	1067
Minimum	0	0	0	0	0	20.6	56.8	67.9	55.0	7.40	0	0	434
Median	0	0	0	0	6.05	84	182	204	151	54.0	0	0	710
Ecart type	0.08	1.38	0.84	2.65	23.2	43.7	67.7	83.9	71.1	32.3	10.1	1.91	169
Coef. of var.	3.95	4.89	2.72	5.12	1.39	0.49	0.38	0.40	0.43	0.60	3.57	2.84	0.24
Kédougou	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**An**
Average	0.32	0.07	1.24	3.38	51.6	158	262	316	283	96.0	5.00	0.42	1177
Maximum	9.70	1.60	36.7	34.1	217	284	412	606	458	384	49.6	7.90	1805
Minimum	0	0	0	0	0.80	77.7	141	179	128	23.2	0	0	791
Median	0	0	0	0	43.4	150	269	282	294	83.2	0	0	1141
Ecart type	1.55	0.27	5.86	7.19	46.0	58.5	67.3	103	85.1	67.6	11.2	1.46	214
Coef. of var.	4.87	3.98	4.72	2.13	0.89	0.37	0.26	0.33	0.30	0.70	2.24	3.45	0.18
Simenti	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**An**
Average	0.11	0.25	0	1.46	23.6	111	195	275	218	64.8	3.66	0.39	861
Maximum	1.80	10.0	0.00	12.0	92.5	207	395	459	436	216	46.9	6.70	1452
Minimum	0	0	0	0	0	0	0	68	5	0	0	0	227
Median	0	0	0	0	16.6	109	192	286	218	57.9	0.00	0.00	831
Ecart type	0.38	1.58	0	3.38	25.9	47.5	77.3	90.4	96.2	51.7	9.60	1.43	228
Coef. of var.	3.52	6.32	0	2.33	1.10	0.43	0.40	0.33	0.44	0.80	2.63	3.68	0.27

The analysis of the obtained results shows the surpluses of the monthly rains. The average monthly rains, observed during the 1970s and 1980s at the analyzed stations, are lower than those for the period 2001-2010 (Fig. 2). This increase may explain the strong variability in storminess (Ifeka & Akinbobola, 2015). For almost all months, precipitation increased between the two periods, with a particularly obvious increase over the humid season. The basin is characterized by a monthly decrease in rainfall during the 1970s and 1980s droughts and an increasing trend over the 2000s. The monthly precipitation trends survey clearly showed the slight increase in monthly precipitations during the current period. The entire basin has been affected by a temporal rainfall irregularity over the entire month during these last decades. The assumption is that these significant trends of precipitation during the last four decades could be attributed to the climate change.

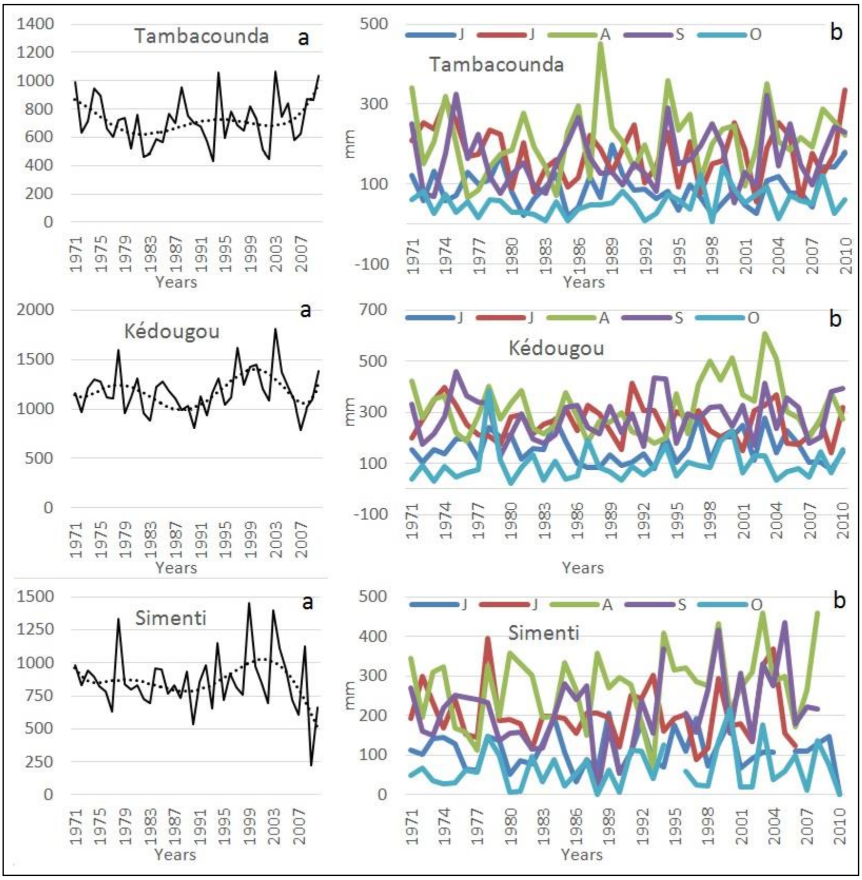

Fig. 3. Evolution of total (a) and monthly (b) precipitation sequences (June, July, August, September and October) from 1971 to 2010 (Source: ANACIM)

For the characterization of the monthly precipitation distribution in the basin, the frequencies of the calculated precipitation concentration index are given in Tab. 3. These values of the PCI show the predominance of the highly irregular distribution of precipitation in the basin. This distribution is generally homogeneous for the six analyzed stations. It is also more pronounced at the Koungheul and Nioro stations (frequencies reaching 100%) and between 90 and 97% at the other stations. An irregular distribution is also noted with low frequencies (3 to 10%).

The mean values of the ICP show the highly irregular and variable rainfall distribution at the different analyzed stations, the mean values being greater than 20 (Tab. 3). On average, the highly irregular rainfall distribution is more pronounced in Nioro (29.21) and Goudiry (28.13), than in Tambacounda (24.71) and Kédougou stations (22.34).

Tab. 3. Frequency and averages of PKI values at different stations (19710-2010) (Source: ANACIM)

Frequencies	Tambacounda	Kédougou	Simenti	Goudiry	Koungheul	Nioro
Uniform distribution	0	0	0	0	0	0
Moderate distribution	0	0	0	0	0	0
Irregular distribution	5	10	10	3	0	0
Highly irreg. distribution	95	90	90	97	100	100
Average	Tambacounda	Kédougou	Simenti	Goudiry	Koungheul	Nioro
Average index	24.71	22.34	26.9	28.13	26.58	29.21

The impact of the variability over the period 1971-2010 is translated by a modification of the pluviometric regime in the analyzed stations. If the decades 1970 and 1980s present all negative anomalies of the pluviometry, corresponding to periods of drought in tropical Africa, the period 1995-2010 marked by return rather sensitive to better pluviometric conditions, in agreement with the works of Ali and Lebel (2009) and Ouoba (2013), register surpluses of the pluviometry in the Gambia River Basin. This upward pluviometry trend augurs of an improvement of the pluviometric regime in this space, by comparison to the drought period. However, the persistence and sustainability of the rise have yet to be proven.

Conclusion

Unlike other sub-Saharan basins, the spatio-temporal variability of rainfall in the Gambia Basin has been poorly studied so far, while its impact on water resources is very important. In order to better characterize this spatio-temporal variability, we used non-parametric statistical tests whose robustness and interest have already been tested in the past. In this basin, we selected six stations whose data are reliable and complete. These data are comprehensively processed to provide a better analysis of the spatio-temporal variability of precipitation. For the six stations considered, the analysis of rainfall data over the period 1971-2010 shows that the chronicles are not stationary and that they have undergone a new break during the 1990s. The surplus of the mean annual precipitation of the period after break from the dry period of the 1970s and 1980s is however weak. On a monthly scale, the stations with the most complete chronicles (Tambacounda, Kédougou and Simenti) show that the average precipitation of the rainiest months over the 2000s is almost always higher than the values of the previous decades. Beyond the slight increase in rainfall on a monthly scale, a very large irregularity was noted.

These results corroborate those of many authors (Dione, 1996, Sighomnou, 2004, Goula et al., 2005, Sow, 2007, Faye, 2013, Faye et al., 2015b) who claim that the long droughts observed in the 1970s , 80 and part of 90, which confirm the return of rain during the last years of the series analyzed (between 2000 and 2010) marked by the predominance of wetter conditions Ali et al., 2008; Niang, 2008; Ali and Lebel, 2009; Ozer et al., 2009; Ouoba, 2013). In parallel with this trend, there is also a clear upsurge of heavy rainfall in almost all stations, as evidenced by an unprecedented increase in flooding in the basin. In addition to temporal variations, spatial variations of precipitation are added. After the precipitation trend has been observed in the basin, as noted in some regions of the Sahel (Lebel & Ali, 2009), it would be interesting to integrate in future research its impact on the flow in the basin.

The information provided by this study can be useful for decision makers in the context of flood and drought monitoring. Therefore, agricultural planning and government policies in this basin should be based on trends in recent rainfall increases. This study should be extended to other areas exposed to drought and floods and to the whole country. Similarly, the impact of climate variability on crop yields in this basin should also be investigated.

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ТРЕНДОВИ ПАДАВИНА У СЛИВУ РЕКЕ ГАМБИЈЕ (СЕНЕГАЛ) У ПЕРИОДУ 1971-2010.

Резиме: Од 1970-их година прошлог века, речне токове на простору Западне Африке, су захватиле дубоке измене повезане са плувиометријским дефицитом, које су утицале на велико смањење водних ресурса. Циљ ове студије је анализа трендова у количини падавина на шест одабраних станица у сенегалском делу слива реке Гамбије, користећи графички и статистички приступ. Методологија се састоји од анализе месечних, сезонских и годишњих варијабилности у количини падавина, у периоду 1971-2010., кроз употребу не-параметарских тестова. Студија је открила снажну варијабилност и често контрастни развој између различитих станица (Кедугу, Сименти, Тамбакунда, Коунгел, Ниоро и Гудири). Између периода 1971-1990. и 1991-2010., вредност U, теста Mann-Whitney, се променила од 60 до 40 на станици Тамбакунда, од 64 до 59 на станици Кедугу и од 63 до 51 на станици Сименти, што је указало на постојање не-сигнификантног тренда промене вредности годишње количини падавина за истраживани период. Коришћењем Сенове процене откривени су значајни опадајући трендови на станици Кедугу (9,812 mm/год. за период 1971-1990. и 0,309 mm/год. за период 1991-2010.), као и на станици Сименти. Са друге стране (у целокупном раду), на станицама Тамбакунда, Гудири и Коунгел, смањење је наглашено у периоду 1971-1990. (3,658 mm/год. - Тамбакунда), док је повећање присутно у периоду 1991-2010. (13,21 mm/год. – Тамбакунда). Код станице Ниоро, са треће стране, повећање је забележено у оба анализирана периода (3,801 mm/год. и 8,841 mm/год.). Претпоставка је да се ове сигнификантне промене трендова у количини падавина, током последње четири деценије, могу приписати климатским променама.