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Effects Of Climatic Variability On The Hydrological Regime Of Niandan (Guinea Republic)

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Abstract: From the beginning of the twentieth century to the present day, the water resources of the Niger river Basin have undergone major changes, in relation to the significant climatic variations recorded in West Africa. This situation has resulted in a decrease in the water quality of the watercourses in the basin. The present study proposes to study the effects of the variation of the rainfall regime of the Niandan basin on the flow of the Niandan river, which is a tributary of Niger. In this work, the method of the trace analysis was used to highlight, during the period from 1961 to 2009, the decay of the average rainfall of upstream (1968 mm) downstream (1467 mm) of the Niandan. Regarding the determination of the effects of climate variability on the water resources of the Niandan basin, this work has proved that the flow is highly sensitive to downstream rainfall variations, with a trend in rainfall and flow. on the decline. In the south, it has been shown that although Niandan water supply comes mainly from rainwater, the rainfall is not sufficient to satisfactorily explain all the changes in Niandan flow regime.

Key words: Anthropogenic activities, Climate change, Rainfall variability, Flow.

1. INTRODUCTION

For decades, issues of climate change and variability have been of concern to scientific communities and policy makers because of their damaging effects on ecosystems and human activities. This risk is amplified by the climatic disturbances experienced by the planet as a whole (Paul et al., 2012 and Janicot et al., 2001). Over the last 15 years, the Intergovernmental Panel on Climate Change (IPCC) and the Climate Convention (Rio, 1992) have recognized the existence of Climate Change due to the emission of Greenhouse effect and the need to address it (Kyoto Protocol, 1997). The questions about the possible influence of human activities on the planet's climate appeared in the 1970s, in connection with the observations on the increase of the concentration of carbon dioxide CO2, whose current level is around 370 ppm, against 260 in the pre-industrial era (Gérard et al., 2006). The implications of these climatic variations on water resources are particularly strong and affect many sectors of human and environmental activities, such as agriculture and livestock farming (Sandra A-B.,2004 and Kouassi E. A., et al., 2013). The regulation of different needs for water uses in these areas depends on normal or average trends in the hydrological cycle. These trends are the result of stationary conditions that have developed as a result of a balance of different environmental factors. Disturbance in these balances also causes disruption in normal patterns of the hydrological cycle, which has implications for the distribution and management of available water resources [6]. In West Central Africa, the synoptic situation occurs through phenomena such as recurring droughts, disturbances of rainfall patterns and rainfall deficits of the order of 20% to 30% (Servat et al., 1999; Noufé et al., 2011; Bricquet et al., 1997 and Noufe et al., 2016). The consequences of these devastating droughts in the sub-region have been the subject of several studies since 1951(Bamba et al., 1996; and Yaya B., 1997; Olivry et al., 1988 and Gil M., 2006). The Republic of Guinea, although sufficiently watered and located in the tropical climate zone with abundant rainfall, was no exception to this decrease in rainfall and runoff. Data from meteorological stations between 1961 and 2009 show that the average rainfall height has been regressed and the temperature has experienced a linear trend of elevation. The northern part of the country, more arid and warmer during the dry season, is the area most affected by the scarcity of water, by the premature drying up of water points. This northern region of the country covers more than 80% of the Niandan Basin, which is the subject of this study (Rapport, 2002 and Sangaré et al., 2006). The Niandan basin belongs to the Niger watershed. Like the latter, its populations are faced with enormous difficulties of water supply, both in quantity and quality. To reverse this trend, it is important to research the root causes of this shortage, and the factors and relationships that determine these causes. Hence the interest of this research.

2. STUDY ZONE

Niandan is a river from West Africa that has its source in Kissidougou, it flows from south to north and crosses Guinea (mainly located in Upper Guinea). It is a tributary of Niger on the right bank. It is 190 km long, its watershed has an area of 12770km2, the average flow in Baro is 251 m3 / s, it has a tropical rain regime. It is between 9 ° and 10 ° 40 'north latitude and 9 ° 20' and 10 ° 30 'west longitude. The relief of the basin, is generally not very rough. The southern part covers the Kissidougou prefecture, which is a post-forest area between Upper Guinea and Forest Guinea. This part belongs to the Guinean Ridge. To the north, the basin is relatively low and monotonous. The climate is mainly of the Sudanese type, characterized by two very contrasting seasons: a dry season, receiving only 2% of the annual precipitation and a wet season. The Niandan bed has a variation of altitude between 400 and 600 m, which favors the need for the construction of the Fomi hydroelectric dam on this river, with nearly 90 MW (Republic of Guinea, 2006). Figure 1 shows the Niandan watershed.

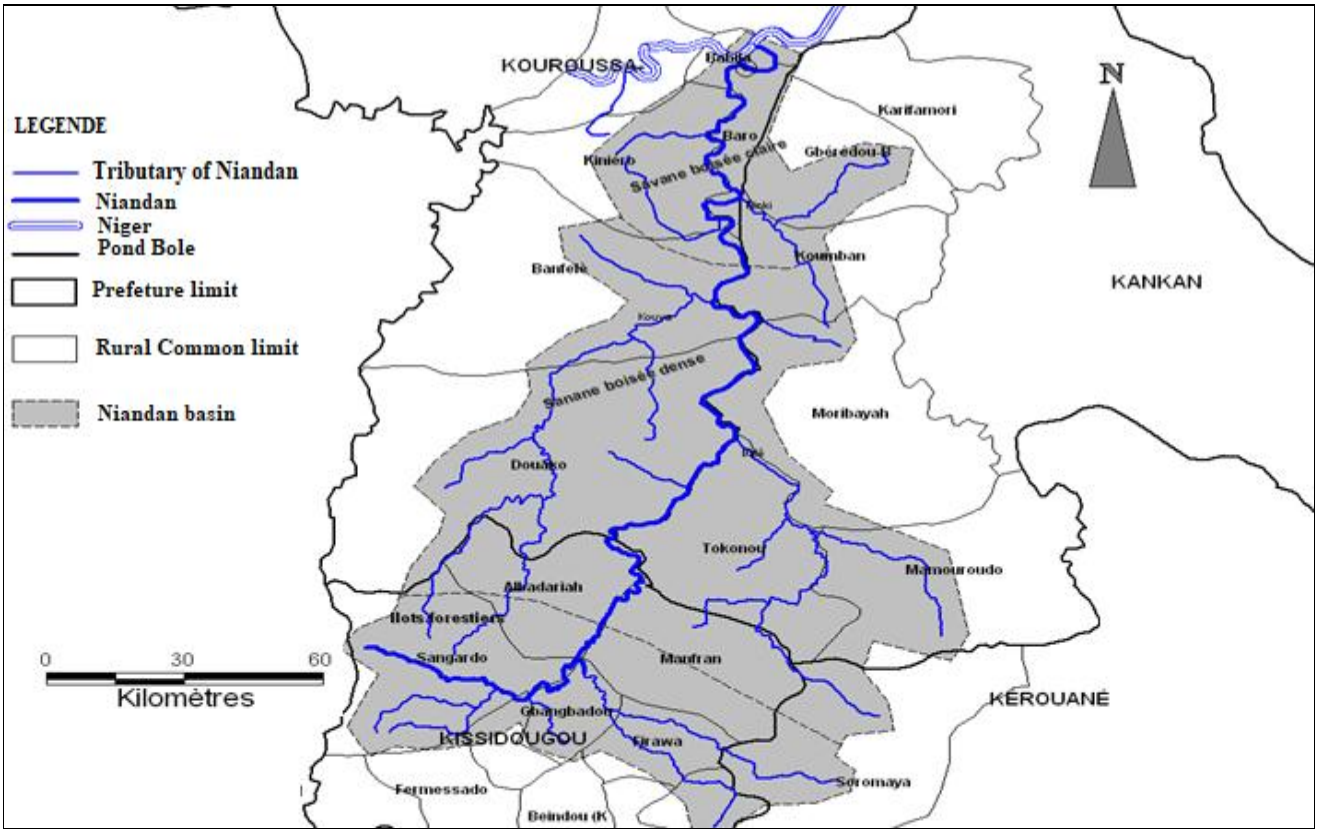

Figure 1. *Study zone*

3. METHODOLOGY

To evaluate the effects of rainfall variability on water resources in the Niandan Basin, we proceeded by the method of trace analysis, which applies to statistical registers produced by governmental authorities or by other organizations. Its particularity is that it makes it possible to look at the data of various origins to analyze, cross and interpret them (Giroux, (1998).

3.1 Methodological approach

The methodological approach used is essentially focused on three stages (Sutcliffe V.J. et Piper B.S., 1986 and Le B L. et al., 1993).

- The analysis of interannual variability of precipitation (for each station, a climatic normal was calculated and compared to the average rainfall of the study period). It was also used to calculate standardized anomalies (by standard deviation) of annual rainfall averages.
- The analysis of the inter-annual variability of flow rates (a climatic normal for flows was calculated and used similarly).
- Analysis of the effects of rainfall variability on flows, this analysis was based on the comparison of the evolution of standardized anomalies (by standard deviation), precipitation and average annual flows upstream and downstream. downstream, for the period 1961-2009.

3.2 Data collection

Data collection involved two trace-tracking parameters: basin rainfall and flow upstream and downstream. Rainfall is the culmination of the combined action of important climate parameters. Flow rates show the flow regime of the watercourse. The climate (rainfall) and hydrological (flow) data series were collected at the regional meteorological station, at the Kankan regional hydropower station, and at the National Meteorological and Hydrological Directions. Observations cover the period 1961-2009 and were made upstream and downstream of the Niandan River at Kissidougou and Baro.

3.3 Data processing

The raw data collected on the quantitative rainfall and flow data were presented in the form of histograms and annual average curves over the 1961-2009 period, using the EXCEL spreadsheet. These curves and the trends associated with them have facilitated the analysis of flow sensitivity to rainfall disturbances in the study area. Finally, to analyze the interannual variability of the baseline variables over the 1961-1990 reference period, standardized anomalies were calculated using formula 1 (Nicholson, S. E., 1980 and Expédit V., 2007).

$$A_j = \frac{x_y - \bar{x}}{\sigma_x}$$

Where: x is the variable considered; there is the year; x_y is the average of the variable in the year considered; A_j is the anomaly of the year j; is the average of the calculated variable over the study period; is the interannual standard deviation of the variable x calculated over the study period.

4. RESULTS and DISCUSSIONS

4.1 Results

The results obtained during this research concern the interannual variability of rainfall in the Niandan watershed, the interannual variability of Niandan flows and the effects of rainfall variability on Niandan flows during the 1961 study period 1961-2009. These results are represented by graphs of Figures 2, 3, 4, 5, 6, 7 and 8, to facilitate their interpretation and discussions.

4.1.1 Interannual variability of precipitation

Figures 2, 3 and 4 show, respectively, the evolution of the standardized anomalies compared to the climatic normal (1961-1990), annual average rainfall in Kissidougou, Kankan and in the Niandan basin. The climatic normal calculated for the Kissidougou and Kankan stations are respectively 1915 mm and 1470 mm.

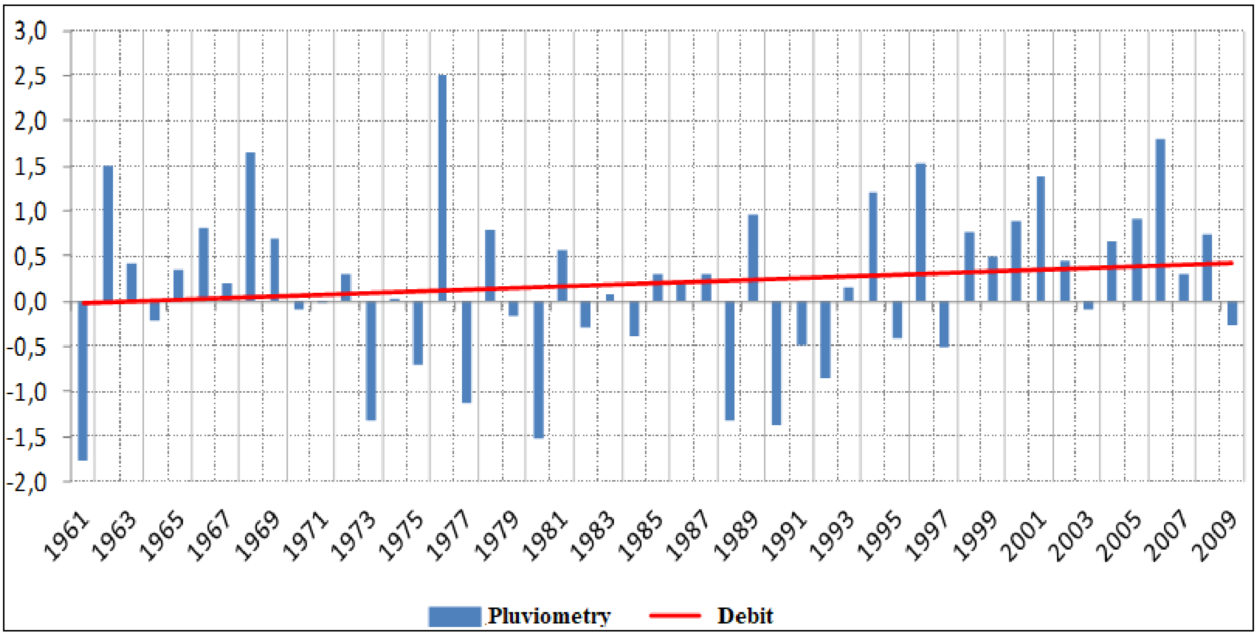

***Figure 2**. Standardized anomalies (by standard deviation), from the 1961-1990 normal, of the mean annual precipitation for the period 1961-2009 in Kissidougou*

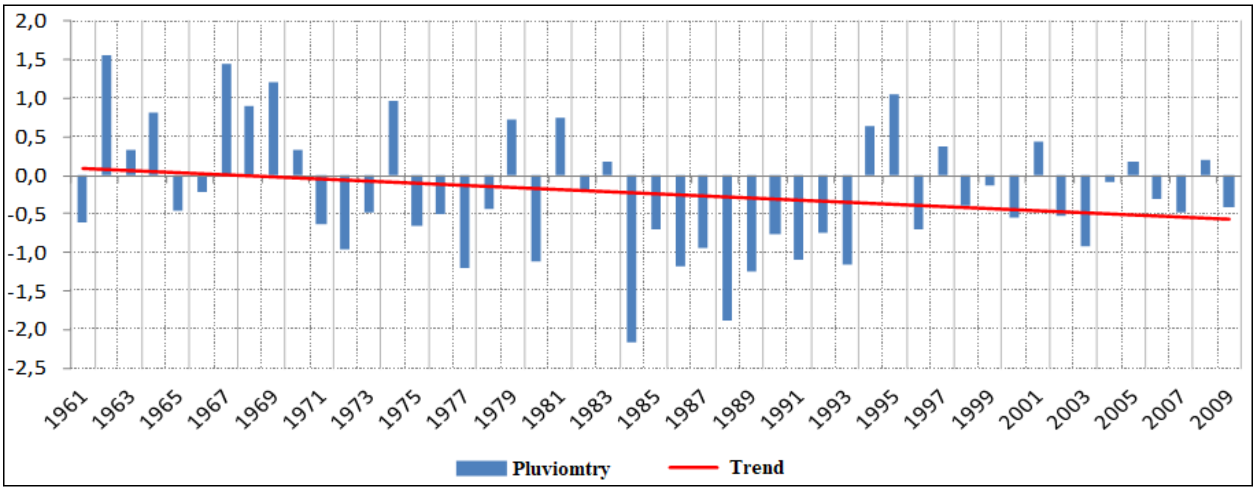

***Figure 3.** Standardized anomalies (by standard deviation), relative to the 1961-1990 normal, of the mean annual precipitation for the 1961-2009 period in Kankan*

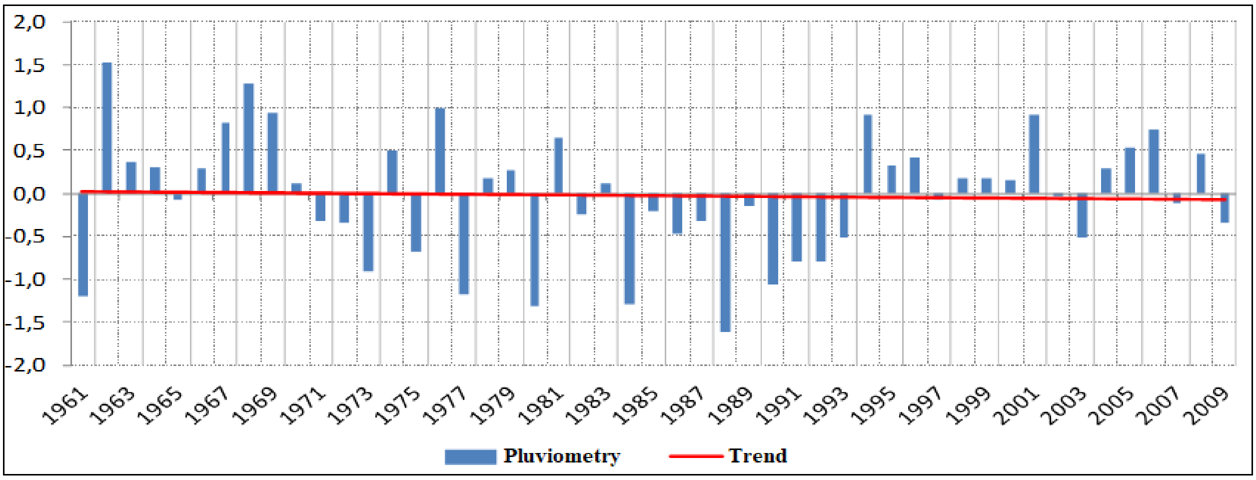

Figure 4. *Standardized (standard deviation) anomalies, relative to the 1961-1990 normal, of the mean annual precipitation for the 1961-2009 period in the Niandan Basin*

4.1.2 Interannual Variability of Flows

Figures 5 and 6 respectively show the evolution of standardized anomalies (by the standard deviation), compared to the climatic norm (1961-1990), annual average flows in Kissidougou and Baro. The climatic normal calculated for the Kissidougou and Baro stations are respectively 38 m^3/s and 215 m^3/s.

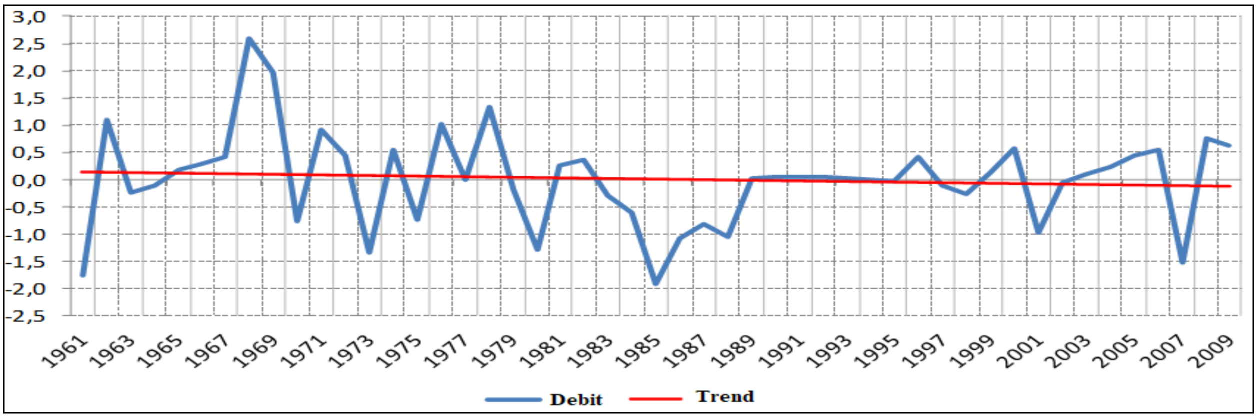

Figure 5. *Evolution of standardized anomalies (by standard deviation), compared to normal (1961-1990), of the average annual flow of Niandan to Kissidougou, for the period 1961-2009.*

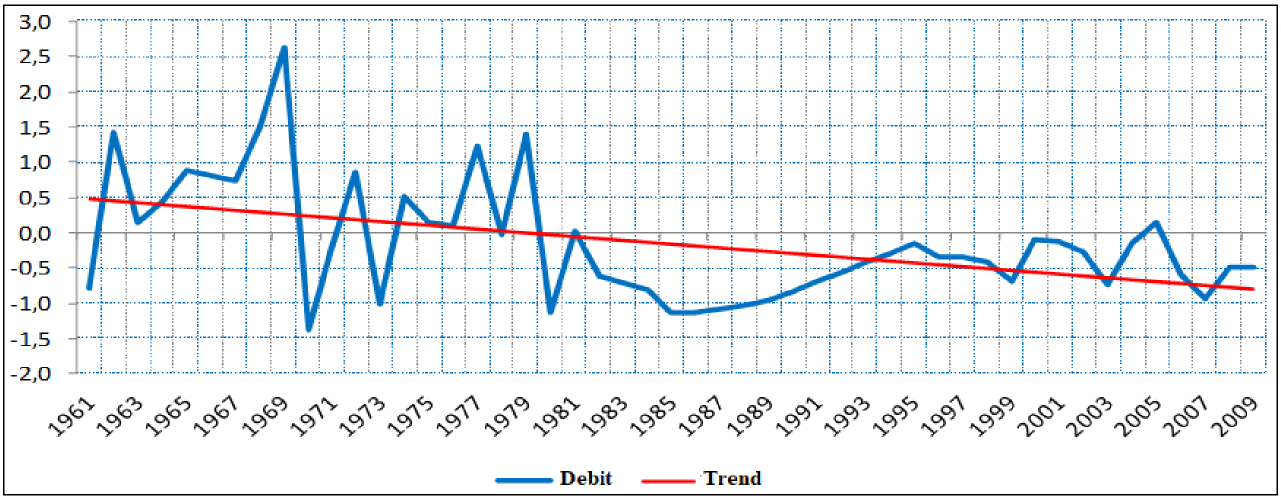

Figure 6. *Evolution of standardized anomalies (by standard deviation), compared to normal (1961-1990), of the average annual flow of Niandan to Baro, for the period 1961-2009.*

4.1.3 Effect of rainfall variability on Niandan flows

Figures 7 and 8 show rainfall heights and mean flows upstream and downstream of Niandan.

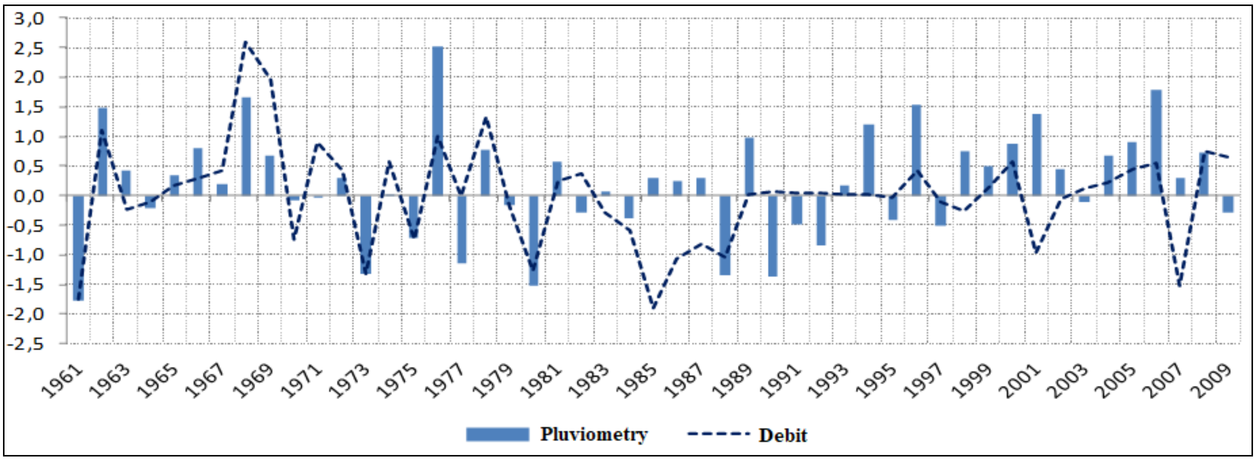

Figure 7. *Evolution of standardized anomalies (by standard deviation), compared to normal (1961-1990), mean annual rainfall and discharge of Niandan at Kissidougou, for the period 1961-2009.*

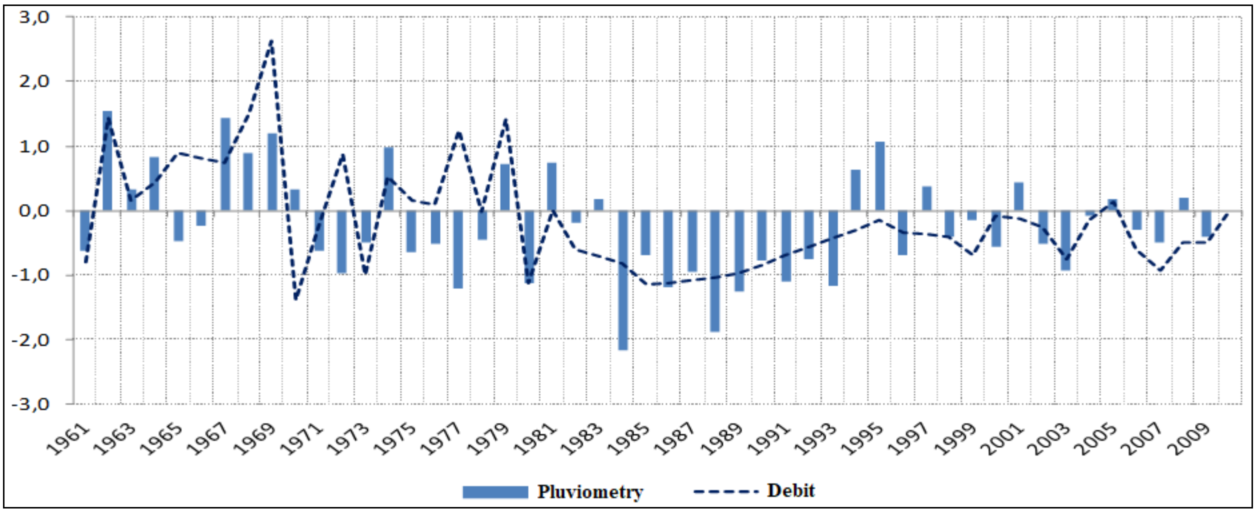

Figure 8. *Evolution of standardized anomalies (by standard deviation), compared to normal (1961-1990), rainfall (mean annual flow) from Niandan to Kankan (Baro), for the period 1961-2009.*

4.2 Discussions

4.2.1 Interannual variability of rainfall

Figure 2 shows that the rainfall anomalies at Kissidougou (upstream of the Niandan Basin) show three periods of rainfall with respective durations (11, 21 and 14 years), namely: **(i)** two (2) wet periods (1961 - 1972) and (1995 - 2009) where rainfall has remained above normal. The exception was recorded in 1961 (1449 mm), where the rainfall is far below the reference mean. This is the lowest height of the entire study period. **(ii)** an intermediate period (1973-1995), relatively less humid than the first two, where the recorded rainfall amounts are distributed on both sides of the climatic norm. This period has the highest height for the duration of the study period at 2572 mm (1976), although it has recorded rainfall levels which remain mostly below normal. Over this period, rainfall amounts varied around an average of 1968 mm (almost reached in 1967), with an increasing rainfall trend. Figure 3 shows that the rainfall anomalies in Kankan (downstream of the Niandan Basin) show three periods of different rainfall characteristics, with respective duration of 10, 22 and 14 years, namely: a wet period from 1961 to 1970, followed by a period of rainfall deficit from 1974 to 1995 and a period of return to normal from 1996. For the entire period of study, the highest rainfall is 1897 mm observed in 1962, the lowest being 1004 During this period, rainfall varied around an average of 1467 mm, which remains very close to normal climatic with an estimated deviation of 3 mm and a trend that is declining. Finally, Figure 4 allows with the same pace as Figure 2, shows that at the basin scale the wet periods are from 1961 to 1970 and from 1994 to 2009. The relatively less humid period is from 1971 to 1993 which coincide to one or two years, to those previously defined upstream of the basin. The mean rainfall height around which the precipitation varied was 1717 mm in 2002, a difference of 21 mm from the climatic normal of 1696 mm (calculated for the whole basin during the period 1961-2009). Throughout the basin, the precipitation trend remained very close to normal climatic with a slight decrease, discernable from the year 1994, beginning of the last wet period 1994 - 2009. The results on the interannual variability of rainfall in the Niandan catchment show that the rainfall regime conditions the main climatic variations. In the West African sub-region, the reference period (1961-

1990) was marked by a variation in annual thermal averages with an upward trend and a great variability in mean annual rainfall (Giroux, (1998). In the southern part, upstream of Niandan, the analysis of the rainfall anomalies over the period 1961 - 2009, the rains are more frequent, the average annual cumulation (1968 mm) calculated for the whole study period exceeds the normal climatic and the national average 1835 mm (Conseil National de l'Environnement, 2007). In the northern part of the basin, downstream from Niandan, the study of interannual variability also presents a predictor of the beginning of a possible process of aridification of the climate of the northern zone of the Niandan Basin (Sylvestre et al., 2017). Despite the return of rainfall to normal during the period 1996-2009 overall, the trend has continued to decline. This result is in line with the conclusions reached by other studies on rainfall behavior in West Africa (Haut Comité National pour l'Environnement, 2001).

4.2.2 Interannual Variability of Flow Rates

Figure 5 shows that, for the period 1961 - 2009, the average annual flow of upstream Niandan has fluctuated around the normal flow, the value of which coincides exactly with the average modulus of flow calculated over the entire study period. (38 m^3/s). The observed fluctuations are amortized over time and their shape allows two periods to be observed. During the first period (1961 - 1989), the normal deviations recorded are significant and the average amplitude of the fluctuations calculated over this period is 18 m^3/s. On the other hand, the second period (1989 - 2009), where the deviations from normal are less important, the fluctuations observed on average have an amplitude of 12 m^3/s. Throughout the study period, the trend in flow evolution was slightly downward, with a mean to almost insignificant average deviation. Figure 6 shows that, between 1961 and 2009, the Niandan flow regime has undergone major modifications downstream that distinguish three periods in which the characteristics of flow variability are remarkably different. The period 1961-1969, recorded a recrudescence of the years of strong flows, being regularly maintained above normal value. The highest average flow during this period was reached in 1969. It is 361 m^3/s and exceeds the normal flow of 146 m^3/s. Then followed the period 1970 - 1979, during which the flow made around the normal, a fluctuation of average amplitude 125 m3 / s. Since 1980, it has declined rapidly up to the value of 152 m^3/s recorded in 1985. Although it has grown slowly over the period 1986-1995, it has finally stabilized around the average module of 195 m^3/s (reached in 1997), the flow remained below normal until 2009. Overall, the flow of Niandan experienced a pronounced downward trend variation. These same disturbances were observed on the rivers (Bani to Douna, Sankarani to Sélingué, Tinkisso to Ouaran, Milo to Kankan) (Bamba et al., 1996).

4.2.3 Effect of rainfall variability on Niandan flows

Figures 7 and 8 compare the sensitivity of the flow regime to interannual rainfall variations in the Niandan Basin. Figure 7 shows that the Niandan water flow regime has undergone major changes during the period 1961-2009, with an upsurge of years of high flow during the period from 1961 to 1984, coinciding with the years of heavy rains. During this period, the Niandan flow regime remained particularly sensitive to interannual variations in rainfall. Since 1985, this sensitivity has fallen sharply, giving the appearance of both sizes the impression of evolving independently. In general, during this period, the flow remained close to normal, and its calculated trend over the entire study period, kept the same proximity character, although that of rainfall, during this time has grown rapidly. In addition, Figure 8 is an example of a case of very high sensitivity of the flow to the interannual variations of precipitation. With the exception of the years 1972 and 1977 when the peak of precipitation corresponds to a minimum of the flow, the latter follows the evolution of precipitation in the basin. The trends calculated for both quantities during the study period are all falling. The year 1968 is marked in West Africa by a very strong general rise in flows (Olivry et al., 1988). Finally, the analysis of the straight lines of Figures 2, 3, 5 and 6 shows that downstream of Niandan, there is agreement between precipitation and flow rates. Indeed, as the two straight lines are decreasing, it is easy to understand that the gradual decrease in flow is a consequence of the rainfall deficit observed during the period 1980-2009. On the other hand, upstream, while the tendency of the precipitations evolves on the rise, that of the flow rates, remains attentive to the normal one. Here again, it should be noted that while the increase in rainfall contributes to the maintenance of flow around the normal, it does not explain the lack of agreement between the two trends. Indeed, the flow does not follow the precipitation in its upward trend, but rather is experiencing a downward trend with a very small deviation to normal. Explanation of the causes that hinder this concordance involves other factors such as the lack of Niandan source head maintenance, the destruction of its gallery forests for agricultural or pastoral purposes and the presence of growing populations. many in the basin. These factors exacerbate the negative effects of anthropogenic activities and climate change on the water resources of the basin.

5. CONCLUSION

This descriptive and analytical study, which aims to evaluate the effects of climate variability on the hydrological regime of Niandan, is intended to contribute to research in the context of knowledge on fragile ecosystems of national values such as the Niandan River. whose watershed covers a large part of Upper Guinea. In this region, there is a gradual degradation of water resources as a result of climate change exacerbated by human activities. The Niandan River, like all the other resources of Upper Guinea located at the gates of the Sahel, also undergoes these effects of degradation. The main results obtained in this study are based on trace analysis and concern the evaluation of the effects of rainfall variability on water resources in the Niandan basin. As such, this work has proven that the flow is highly sensitive to rainfall variations downstream of Niandan, with a trend of rainfall and flow rates moving downward. In the south, it has shown that although Niandan water supply comes mainly from rainwater, precipitation does not explain all the changes in the flow regime. The difficult access to climate data and the lack of archiving are the difficulties that, without nullifying the scientific value of the work, have certainly had relatively negative implications for the reliability of the results.

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