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Analysis of the Variability of the Characteristics of Water Resources in the Diani Watershed: Case of the Silissou District

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Abstract: This study aims to analyze the spatio-temporal variability of the characteristics of water resources in the Diani watershed, located in the southeast of the Republic of Guinea. The objective is to assess the availability and quantity of water for sustainable management of this essential resource. The results obtained show a slight variability of hydro-climatic parameters. The most remarkable wet periods by their intensity of (1982-1998) and (2005-2012) are moderate and that of 1986-1990 is extremely severe during which they are felt on all the stations of the South of Guinea. In addition, the dry years, the end of 1970 and 1980 to 1987 recognized by the WMO (World Meteorological Organization) as drought years were highlighted in the Diani watershed in the South of the Republic of Guinea.

Key words: Variability, characteristics, resources, water.

1. Introduction

Earth is the only planet in the solar system to have, thanks to its privileged position, liquid water on its surface. Water is essential for life. Habitat of some fauna and flora, source of hydroelectricity production, essential element for agriculture, vital element of food, water becomes a coveted and increasingly rare commodity for the world's population.

The water envelope covers an area of 71% of the planet. It is made up of 68% salt water and 3% fresh water. This fresh water is a major stake of covetousness on a global scale, three quarters of which is stored in the form of ice. Cans (1994) in his book *The Water War*, paints a sometimes alarming picture of the future of this resource. Its quantitative distribution on a global scale is very heterogeneous, and often different from the distribution of populations.

In Guinea, many studies have been conducted by different authors at regional and local scales. All these studies have highlighted the impacts of climate variability on water resources and related ecosystems. This indicates the rainfall deficit observed in recent decades [1].

The watersheds of Guinea and those of the countries of the sub-region form an entity of integrated management of water resources. Thus, many models, allowing to simulate the functioning of the basins and their response to the climate, have been developed. However, the resource simulated by these models depends on the stability of the climate as well as the stationarity of the behavior of the watershed. The objective of this work is to determine the main characteristics in terms of the hydrological balance, to better understand and model the flows and water transfers.

The Diani Watershed and its tributaries remain today under the impact of this observed climatic variability (rise in temperature, drop in rainfall, hydrological deficit, drought, etc.).

The Diani River Watershed extends mainly in Guinea, with a longitudinal continuity from upstream

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to downstream and reaches an area of 5,200 km^2. Its average annual contribution is 4,400 mm^3 of water on an average slope of 1/1,000 (Fig. 1). The Diani River which serves as the boundary between the prefecture of Macenta and that of N' Zérékoré takes its source in the classified forest which runs along the Milo River, to the east between Kassiadou and Balladou 4 km from Vasséridou center (Prefecture of Macenta). It is the most important river in the forested Guinea and the only one to have a reliable gauging station which is located at the Diani bridge at which the hydrological observations were made, 6 km from Koulé (Prefecture of N' Zérékoré) on the national road linking Macenta to N' Zérékoré. The Diani delimits Guinea from Liberia over a course of 50 km before passing into Liberian territory near Banié, prefecture of Yomou where it takes the name of Saint Paul River.

2. Tools and Methods

2.1 Summary Presentation of the Study Area

2.1.1 Watershed Characteristics

- The Diani watershed is located in Forest Guinea, in the Macenta prefecture. It is the largest watershed in this natural region.
- It covers an area of 640 km^2 and is subject to a strong disturbance of its hydrological regime.
- The Diani watershed is one of the 23 river basins of Guinea, 14 of which are transboundary.

2.1.2 Hydrographic Network

- The basin's hydrographic network is dense, with numerous watercourses having their source in the Fouta-Djallon massif.
- The Diani hydrometric station allows monitoring the flow of the eponymous river.

2.1.3 Hydrological Regime

- The Diani watershed has a very irregular hydrological regime, with high flows in the rainy season and severe low water levels in the dry season.
- This variability is linked to rainfall hazards. A study of the hydrological balance was carried out to assess water availability.

The Diani watershed, despite its importance, faces disturbances in its hydrological regime which pose challenges in terms of sustainable management of water resources. Further studies would be necessary to better understand its functioning.

2.2 Data

The climate data used in this study are rainfall, flow rate and air temperature at monthly time steps. These data come from the National Directorates of Meteorology and Hydraulics. They were collected from the Nzérékoré Weather Station from 1982-2012.

2.3 Methodology for Analyzing Climate Variability

To assess climate variability, statistical methods have been used because of their performance and robustness. A break is defined as a change in the probability law of random variables whose successive realizations define the time series studied.

Flow measurements and water samples were taken at 8 hydrometric stations in the watershed between 1982-2012.

2.4 Analysis of Meteorological Parameters

The meteorological parameters of the watershed were determined using statistical methods and the use of Excel software. The analysis made it possible to understand the seasonal and interannual variation of temperature in the Konkouré watershed. This parameter influences precipitation in a given region [9]. With regard to rainfall, we focused on the rainfall index which is the ratio of the deviation from the interannual average to the standard deviation of annual rainfall heights. This allowed us to observe interannual variability and periods of rainfall deficits and surpluses.

The rainfall index method is applied to assess the rainfall variation during a given observation period. This method has the advantage of highlighting surplus

Fig. 1 Location of the Diani watershed [12].

and deficit periods. Thus, for each of the rainfall stations selected, an interannual rainfall index was determined and is defined as a reduced centered variable expressed by the equation below [4]:

$$I_i = \frac{P_i - P}{\sigma} \quad (1)$$

where I_i—rainfall index (Nicholson index); P_i—value of the average annual rainfall of year i; P—Interannual mean value of rainfall over the period studied; σ—interannual value of the standard deviation of rainfall over the period studied.

The representation of interannual rainfall indices, calculated by decade over the period 1982-2012, reflects the evolution in space of the reduced centered variable studied while highlighting the areas that are sometimes deficient or surplus. This method makes it possible to monitor fluctuations in rainfall and hydrological regimes. According to the NICHOLSON index, aridities can be classified into six categories according to Table 1 below.

Table 1 Classification of rainfall indices.

Rain index class	Degree of aridity
Ip > 2	Extreme humidity
1< Ip < 2	High humidity
0 < Ip < 1	Moderate humidity
-1< Ip < 0	Moderate aridity
-2 < Ip < -1	High aridity
Ip < -2	Extreme aridity

2.5 Water Blades Flowed

After the reconstitution of the modules at the outlet of the watersheds, the annual flow rates will be calculated by the relation:

$$L_e = \frac{31.536Q}{S} \quad (2)$$

where L_e—the annual flow rate (m); Q—flow rate module (m^3/s); S—watershed area (km^2); the constant 31.536 is relative to the time in seconds in the year. The flow rate (Le) is related to the flow coefficient (K_e). The flow coefficient on watersheds is determined by the following relation [6]:

$$K_e = \frac{L_e}{P} \quad (3)$$

where P is precipitation in mm.

2.6 Calculation of PET (Potential Evapotranspiration)

PET, which is defined as the total water losses by evaporation and transpiration from a surface of a watershed of uniform height, completely covering the land, in full growth period and abundantly supplied with water. PET can be evaluated using many formulas (Thornthwaite, Turc, Penman, etc.) that we will not detail here, as evapotranspiration is the most delicate term to evaluate.

3. Results and Discussion

The data of meteorological and hydrological parameters were used to study climate variability. The variation in precipitation represents the most important factor in the climate for both inhabitants and ecosystems. This explains the exceptional resonance that the anomalies that affect this parameter take.

3.1 Average Annual Rainfall

The analysis of the hydroclimatic regime of the Diani Basin makes it possible to assess the impact of climate change on water resources using the regional vector method by constituting homogeneous climatic units, on several nested spatial scales (micro, meso and macro), in order to establish the representativeness and regional persistence of climatic signals.

In west regions of the Basin coast, rainfall will be correlated with the North Atlantic Oscillation, especially for the heart of the rainy season. The decline in rainfall is widespread and highlighted by a break in the time series between 1990 and 2020.

The flow rates of the majority of the tributaries of the Diani River have been decreasing since the beginning of the 2000s: the break dates for the flow rates and the monthly runoff coefficients are consistent with those of the rainfall, over the period up to 2002.

In Fig. 2 we observe normalized maxima of rainfall in 1990 (15.13 mm), 1995 (18.87 mm), 1998 (19.73 mm). From 1999 to 2007 a series of decreases with a minimum value in 2003 (1.67 mm). Thus from the period 2008 to 2020, we observe an average upward trend with a maximum in 2016 (16.6 mm).

3.2 Rainfall Index

The analysis of Fig. 3 shows an alternation of deficit and surplus periods in three (3) phases. Recent studies show that in Guinea the last decade is characterized by a maintenance of conditions tending towards moderate drought in the North-Eastern part and a return to more rainy conditions in the South-West part. The calculated indices show a greater frequency of opposition of the sign of the indices between very deep deficit periods from 1999 to 2007 with an extreme in 1992 and surplus periods from 2008 to 2019 with a peak in 1998.

3.3 Annual Variation in Flow Rate

Fig. 4 shows the maximum average flow recorded in 2001 for a value of 1,116 m^3/s with a minimum of 113 m^3/s in 2007.

3.4 Limnometric Height

Fig. 5 represents the variability of the limnimetric height along the Diani River watershed, it emerges from the analyses that maxima are observed in 2014 (6.61 m) and in 1990 (5.74 m); the minima observed in 2020 and 2018 (0.47 m), 2006 (0.31 m) and 2008 (0.21 m).

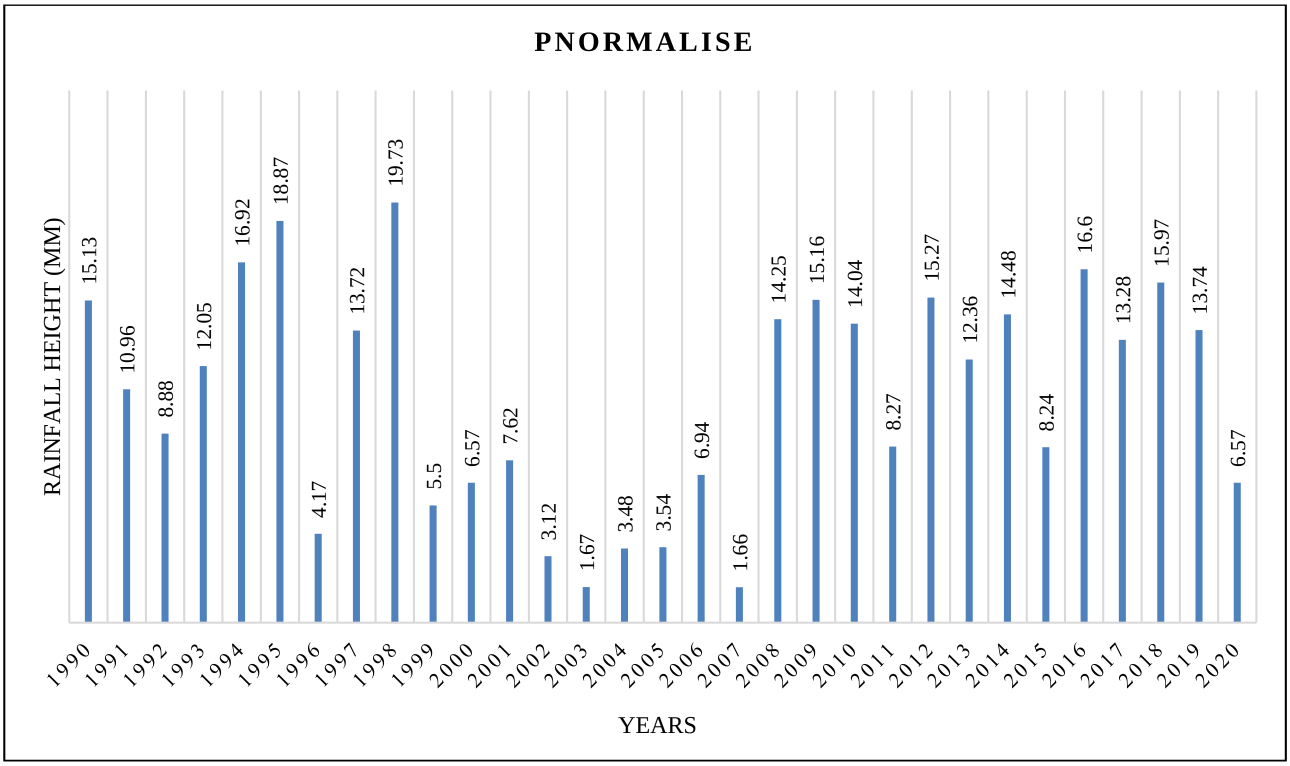

Fig. 2 Average annual rainfall.

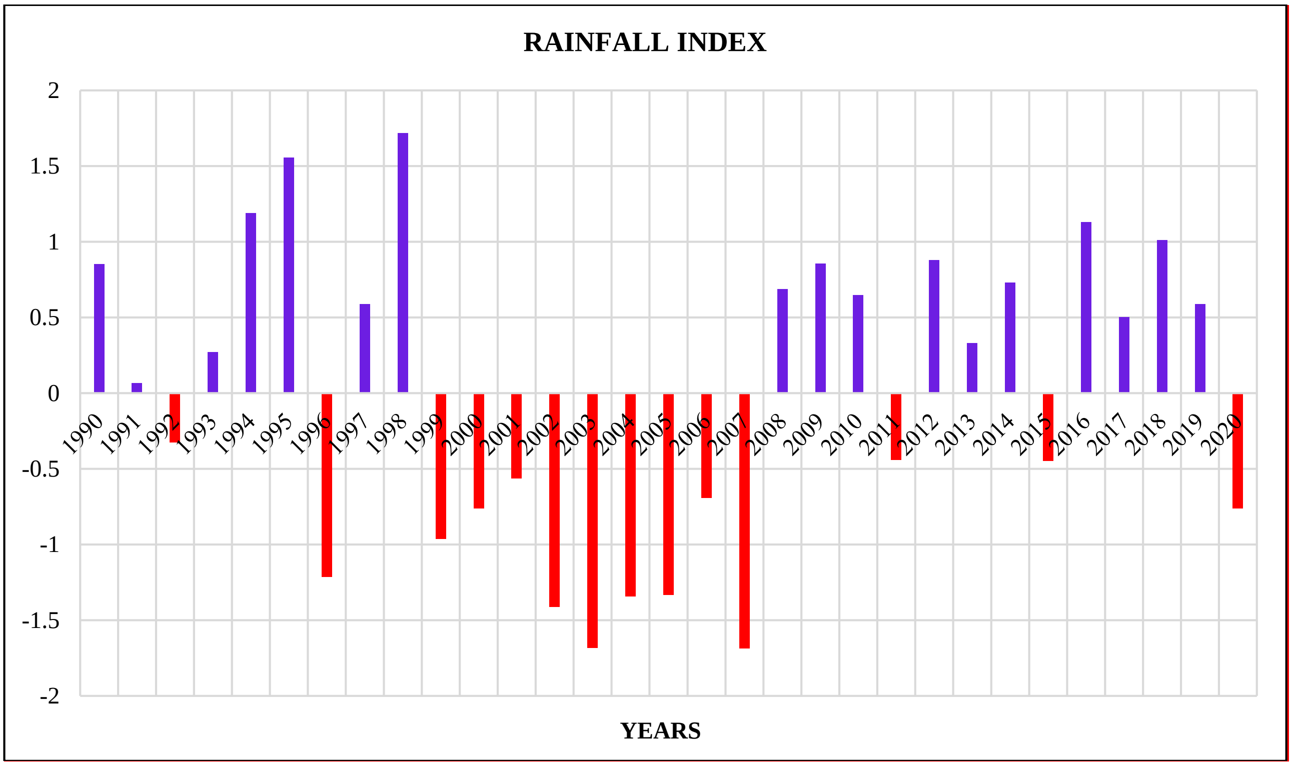

Fig. 3 Variation of the annual rainfall index.

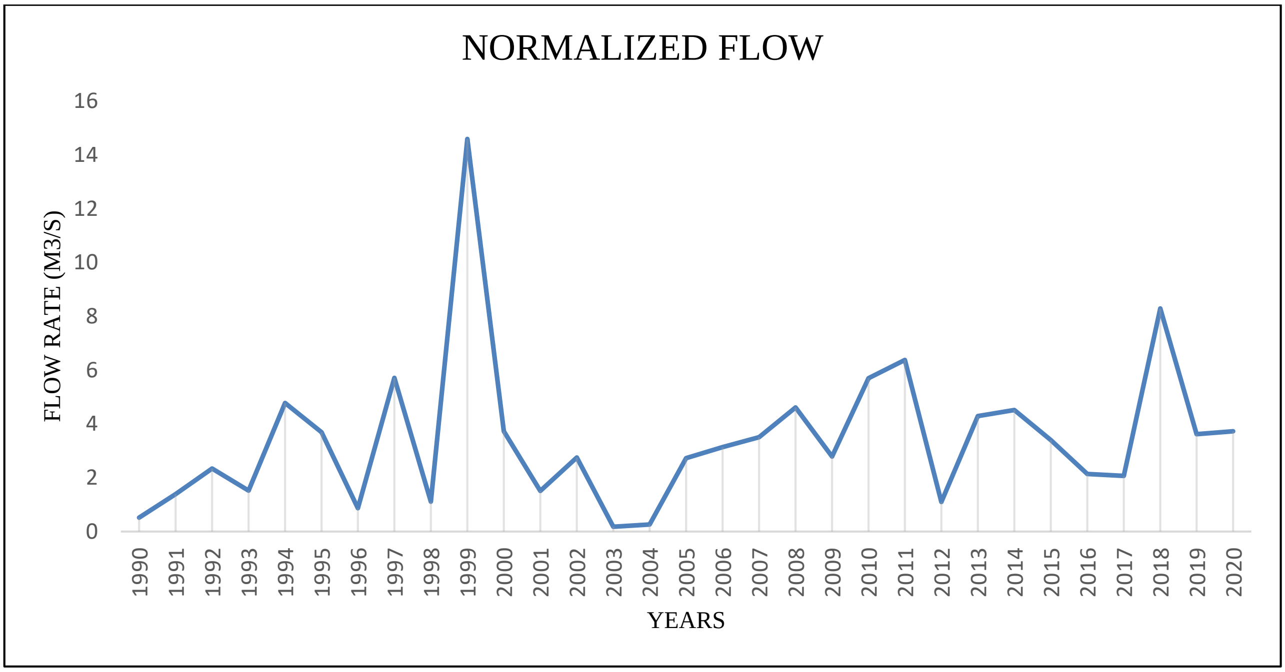

Fig. 4 Average annual flow.

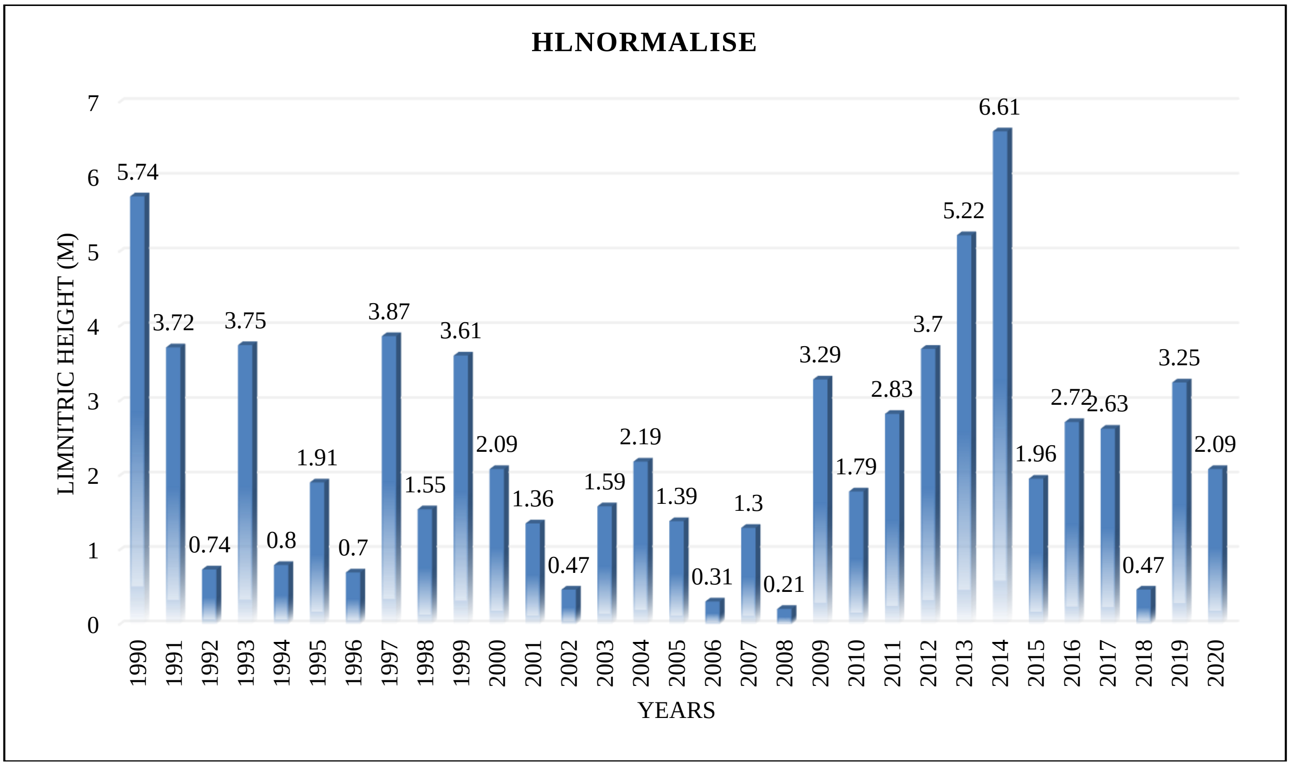

Fig. 5 Variability of limnometric height.

3.5 Water Blade Flowed

Fig. 6 shows the years of moderate aridity from 1982-1991; from 1992-2012 there is high humidity in 1994, 1999, 2011, 2003, 2007, 2011 and 2012; some years of moderate humidity in 1992, 1995, 1996, 2002, 2005 and 2006; high aridity in 1993 and 2000 followed by moderate aridity in 1997, 1998, 2004, 2008, 2009 and 2010.

3.6 Correlation between Average Annual Rainfall and Discharge

Fig. 7 shows the correlation curve between rainfall and the flow rate of the Diani River; a close relationship emerges between these two rainfall and hydrological variables. The following observations can be made:

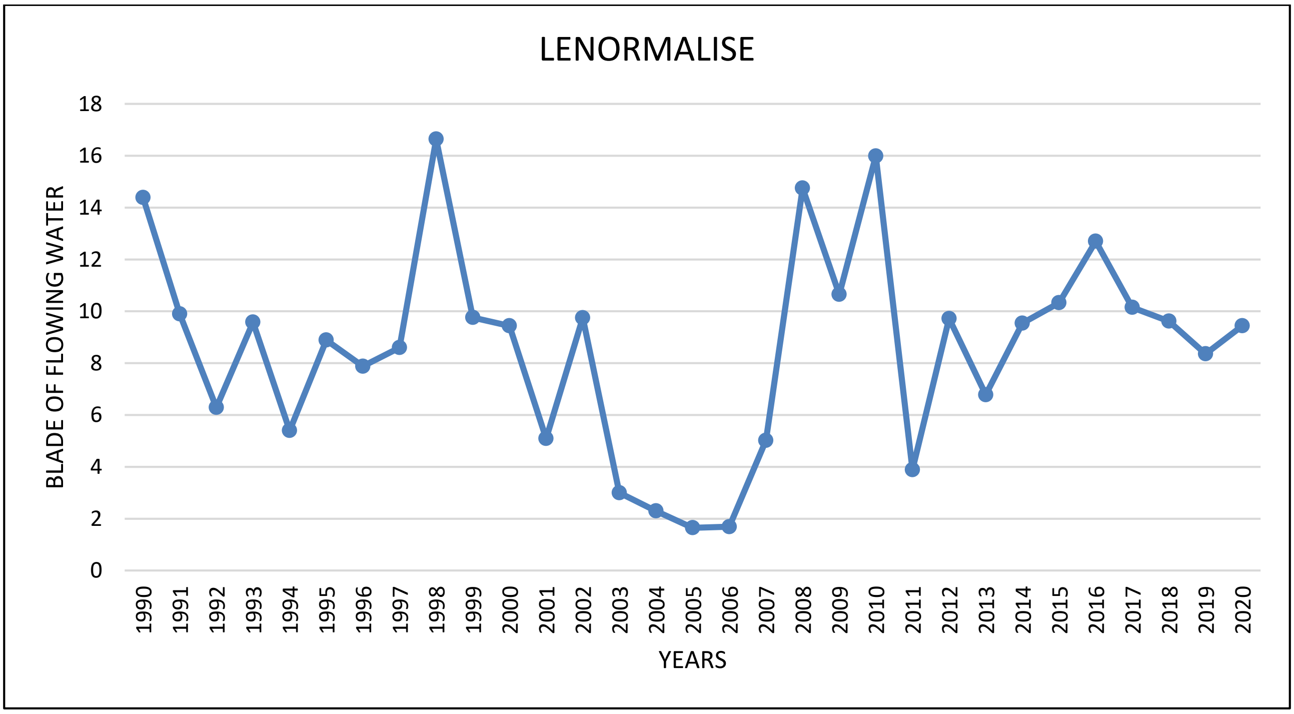

Fig. 6 Variability of the water blade flowing from the Diani.

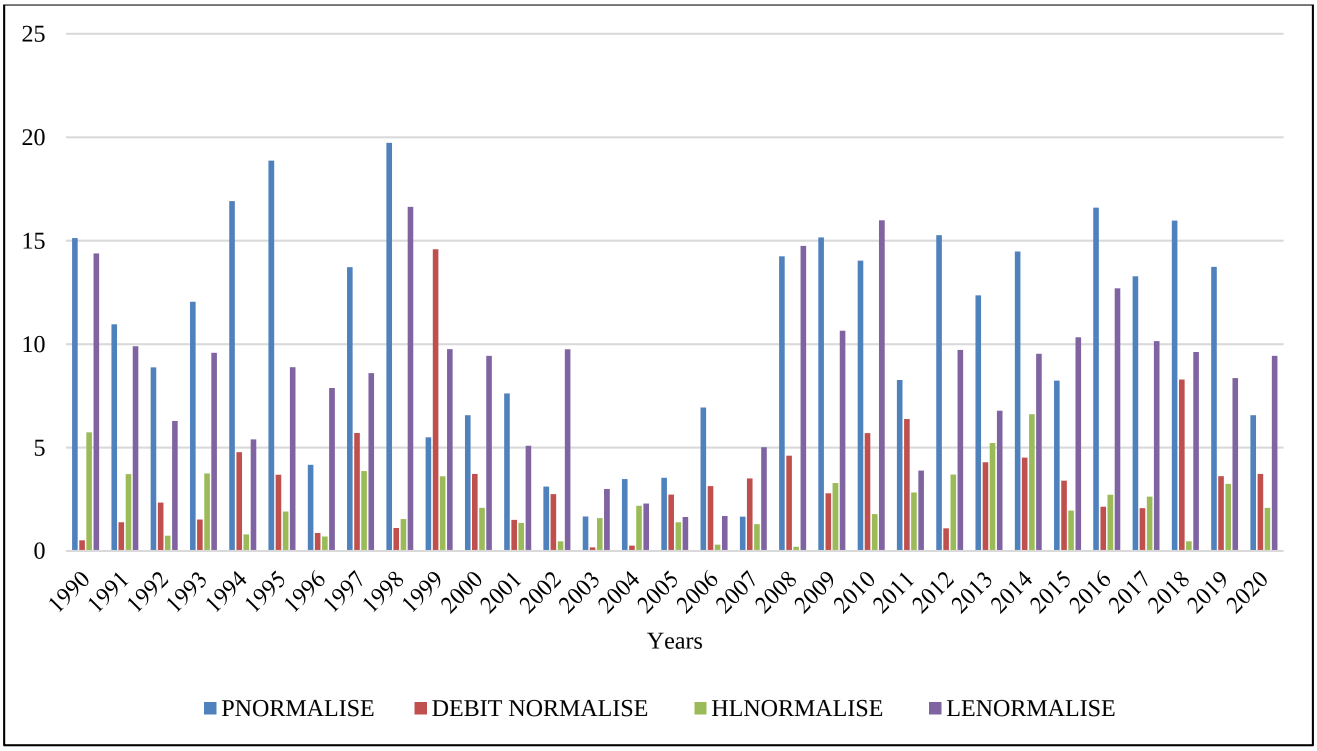

Fig. 7 Correlation between rainfall and flow for the stations.

(1) Strong seasonality: The curve shows a clear seasonality, with flow peaks corresponding to periods of heavy rainfall (rainy season) and severe low water levels in the dry season.

(2) Rapid responsiveness of flow to precipitation: Flow responds very rapidly to rainfall events, with short response times. This indicates a responsive watershed, with little storage in aquifers.

(3) Marked interannual variability: There is strong interannual variability, with very wet years and very dry years. The average annual flow is therefore very irregular from one year to the next.

(4) Close dependence of flow on rainfall: The shape of the curve shows that the flow depends almost linearly on rainfall. Any variation in precipitation has a direct impact on the flow.

This analysis highlights the high vulnerability of the Diani basin hydrological system to rainfall hazards. Sustainable management of this water resource will have to take into account this high natural variability, probably exacerbated by the effects of climate change.

4. Conclusion

This study highlights the fragility of water resources in the Diani watershed, subject to high natural variability and increasing anthropogenic pressures. Integrated and concerted management is essential to ensure sustainable use of this vital resource. Priority actions are proposed: improving knowledge, protecting recharge areas, promoting economical irrigation, and raising user awareness. The participation of all stakeholders is essential to meet this major challenge.

This research corroborates with the feeling generally felt locally of a change in the climate with fluctuations in the rainfall and hydrological regime in the Diani watershed in Guinea in general and in the Nzérékoré region in particular. This feeling is therefore perfectly founded. The historical evolution of climatic elements (temperatures, rainfall, etc.) has made it possible to define more precisely the periods of precipitation deficit corresponding to periods of low flow of the Diani River.

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