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# Impact of Meteorological Drought on Streamflows in the Lobo River Catchment at Nibéhibé, Côte d'Ivoire

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## Abstract

The management of water resources in watersheds has become increasingly difficult in recent years due to the frequency and intensity of drought sequences. The Lobo River catchment, like most tropical regions, has experienced alternating wet and dry periods. These drought periods have a significant impact on the availability of water resources in the basin. The objective of this study is to analyse the impact of meteorological drought on flows in the Lobo River catchment. Therefore, using the Normalized Precipitation and Evapotranspiration Index (SPEI) and the Drought Flow Index (SDI), the characteristics of droughts were studied. The results of this study show that meteorological droughts were more frequent than hydrological droughts in the Lobo River watershed. However, the hydrological drought was longer and more intense than the meteorological drought. The greater relationship between meteorological and hydrological drought was observed at the Daloa and Vavoua station ($0.43 < r < 0.50$) compared to the Zuenoula station ($r < 0.5$). In addition, there was a resumption of precipitation and runoff between 2007 and 2013 in the basin. The study of these climatic trends would be very useful in the choice of management and adaptation policies for water resources management.

## Keywords

Rainfall, Normalized Index, Meteorological Drought, Hydrological Drought, Lobo River

## 1. Introduction

The availability of water resources in reservoirs has been increasingly threatened in recent years due to the frequency and intensity of meteorological and hydrological droughts. Drought events are characterized by water scarcity due to reduced precipitation, high evapotranspiration and overexploitation of water resources [1] [2]. These are natural phenomena that influence the balance of ecosystems around the world. Both developing and industrialized countries are [3]. In Côte d'Ivoire, the climatic ruptures experienced by several African countries south of the Sahara since the 1970s have had impacts on water resources [4] [5] [6]. This led to hydrological droughts for several decades. The catchment area of the Lobo River, the source of drinking water supply for the third largest city in Côte d'Ivoire, is not on the fringes of this significant decrease in rainfall and runoff.

For the past decade, the city of Daloa has been facing a crucial problem of water accessibility in terms of availability and quality. Surface water, treated by Water Distribution Company of Côte d'Ivoire, does not serve all the populations, especially those living in rural areas. The rate of access to drinking water for populations is 73% in urban areas and 50% in rural areas [7]. In addition to the decrease in rainfall, the water reservoir built to supply water to the city is invaded by macrophytes, resulting in a degradation of water quality [8]. On the other hand, the massive destruction of forest cover for agriculture and the decline in rainfall after the break-up of the 1970s have had an impact on the availability of water resources, creating water shortages in recent years in the Lobo River catchment area.

Predicting the onset of drought sequences would then be very valuable for water resource managers. Indeed, the complexity of the physical factors involved in their onset is evidence of the difficulties in recognizing and planning for them [9]. According to [10], the current accepted management approach is based on statistical indices. Of all the drought indices, the Standardised Precipitation Index (SPI) and Standardised Drought Index (SDI) are the most widely used to characterise them [11] [12]. They are applied to characterize the intensity, duration, frequency and impacts of meteorological drought on runoff. The SPI index [13] is powerful and simple to calculate. It can be applied on a variety of time scales, and allows for early detection of drought situations. However, the main limitation is that it considers only one parameter during drought index calculations. In response to this limitation of SPIs, [14] has developed a new index (SPI) that takes temperature into account in the calculations. The Standardized Precipitation and Evapotranspiration Index (SPEI) is virtually similar to the SPI, however it only takes into account temperature data for the calculation of potential evapotranspiration [15]. According to [16], the SPEI is the ideal approach to assess meteorological drought.

Thus, in a climatic context marked by a possible increase in temperature and the impact of droughts in the coming years [17], it is essential to analyse drought sequences. It is within this framework that the present study was initiated to analyse the impact of meteorological drought on the availability of surface water in the Lobo catchment area using the SPEI and SDI indices.

## 2. Materials and Methods

### 2.1. Study Area

The watershed of the Lobo River in Nibéhibé is located between the Longitude 6˚2' and 6˚8' West and between the latitudes 6˚8' and 7˚9' North, with an area of 7280 km$^2$ in Nibéhibé (**Figure 1**). This river is the main tributary of the left bank of the Sassandra River [18]. The Lobo River is a very important resource, especially as a source of drinking water for the city of Daloa, the third largest city in Côte d'Ivoire. Anthropogenic activities in the basin are very diverse. However, agriculture remains the main activity of the people.

The climate of the Lobo watershed is of a transitional equatorial type with a rainy season from March to October and a dry season from November to February (**Figure 2**).

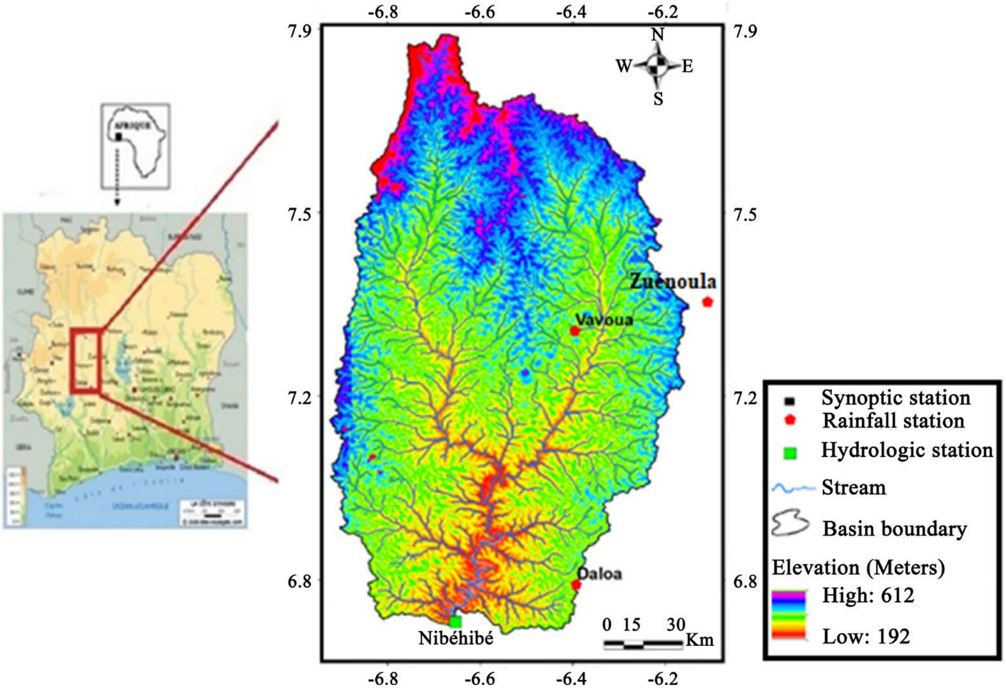

**Figure 1.** Location of the Lobo catchment area at Nibéhibé.

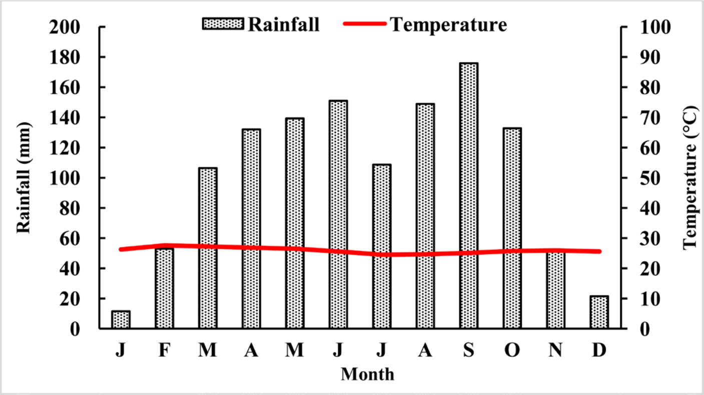

**Figure 2.** Ombrothermal diagram of the Daloa synoptic station over the period 1971-2016.

## 2.2. Available Data

The meteorological data (rainfall, maximum and minimum temperature, solar radiation) used were provided by the Airport, Aeronautical and Meteorological Operating and Development Company (SODEXAM). The hydrometric data were taken from the database of the Hydrology Direction (DH). These data cover the period 1971-2016 at monthly time step.

## 2.3. Methodology

### 2.3.1. Calculation of the Evapotranspiration ($ET_0$) and SPEI

SPEI is a meteorological drought index that consists of the precipitation data (mm) and the evapotranspiration data (mm/day). The $ET_0$ was calculated using the Hargreaves method [19]:

$$ET_0 = 0.0023 R_a \left(T + 17.8\right)\left(T_{\max} - T_{\min}\right)^{0.5} \tag{1}$$

where, $ET_0$ HG = reference evapotranspiration (mm/day); $T$, $T_{\max}$ and $T_{\min}$ = mean, maximum and minimum temperature (˚C) respectively. For computing SPEI, we used method of [14]. This index is accumulated at different time scales. The SPEI is based on a monthly climatic water balance (precipitation minus $ET_0$), which is adjusted using a three-parameter log-logistic distribution. SPEI was calculated using a script on R.3.6.1 software (https://cran.r-project.org/bin/windows/base/).

The deficit or surplus accumulation of a climate water balance ($D$) at different time scales is determined by the difference between the precipitation ($P$) and $ET_0$ for the day $i$ (Equation (2)):

$$D_i = P_i - ET_{0i} \tag{2}$$

The probability density function of a three-parameter log-logistic distributed variable is expressed as Equation (3):

$$f\left(x\right) = \frac{\beta}{\alpha}\left(\frac{x-y}{\alpha}\right)^{\beta-1} * \left[1 + \left(\frac{x-y}{\alpha}\right)^{\beta}\right]^{-2} \tag{3}$$

where $\alpha, \beta$ and $\gamma$ are scale, shape and origin parameters for the values of $D$, in the rang ( $\gamma > D < \infty$ ). The parameters of the Pearson III distribution can be obtained by Equations (4)-(6):

$$\beta = \frac{2w_1 - w_0}{6w_1 - w_0 - 6w_2} \tag{4}$$

$$\alpha = \frac{\left(w_0 - 2w_1\right)\beta}{\Gamma\left(1 + 1/\beta\right)\Gamma\left(1 - 1/\beta\right)} \tag{5}$$

$$\gamma = w_0 - \alpha\Gamma\left(\frac{1+1}{\beta}\right)\Gamma\left(\frac{1-1}{\beta}\right) \tag{6}$$

where $\Gamma\left(\beta\right)$ is the gamma function of $\beta$. The probability distribution function of the $D$ series is presented by Equation (7):

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

In the last step, with the value of $F(x)$, the SPEI can be estimated as the standardized values of $F(x)$. The SPEI equation is calculated by Equation (8):

$$\text{SPEI}=W-\frac{C_0+C_1W+C_2W^2}{1+d_1W+d_2W^2+d_3W^3} \tag{8}$$

where $W=\sqrt{-2\ln(P)}$ for $P\le 0.5$, where $P$ is the probability of exceeding a given $D$ value, $P=1-F(x)$. If $P>0.5$, $P$ is replaced by 1-$P$ and the sign of the resulting SPEI is reversed. The constants are $C_0$ = 2.515517, $C_1$ = 0.802853, $C_2$ = 0.010328, $d_1$ = 1.432788, $d_2$ = 0.189269 and $d_3$ = 0.001308.

The mean value of the SPEI is 0, and the standard deviation is 1. The SPEI is a normalized variable, so it can be compared with other SPEI values over time and space. An SPEI of 0 indicates a value corresponding to 50% of the cumulative probability of $D$, according to a log-logistic distribution.

The classification of drought severity based on SPEI values is presented in Table 1. Negative value of SPEI is an indication of dry condition while the positive value signifies wet condition.

### 2.3.2. Streamflow Drought Index (SDI)

The Drought Flow Index (SDI) is used to determine the hydrological response of the Lobo River to flow deficits [20]. A monthly volume of flow flowing in a basin over a given period of time $Q_{i,j}$. With $Q_{i,j}$, $i$ indicating the hydrological year and $j$ the rank of the month in the hydrological year in which it occurred (Equation (10))

$$V_{i,k}=\sum_{j=1}^{ak}Q_{i,j},\quad i=1,2,\cdots;\ j=1,2,\cdots,12;\ k=1,2,3,4 \tag{9}$$

where $V_{i,k}$ is the cumulative elapsed volume of the hydrological year of the reference period. Based on the cumulative elapsed volume $V_{i,k}$, the hydrological drought index SDI is defined for each reference period $k$ of the $i$th water year of the following series by the Equation (11):

Table 1. Standardized Precipitation Evapotranspiration Index classification [21].

| SPEI value | Drought category |
|---|---|
| >2 | Extremely wet |
| 1.50 to 1.99 | Very wet |
| 1.0 to 1.49 | Moderately wet |
| −0.99 to 0.99 | Near normal |
| −1.0 to −1.49 | Moderately dry |
| −1.50 to −1.99 | Severely dry |
| −2 and less | Extremely dry |

$$\mathrm{SDI}_{i,k} = \frac{V_{i,k} - \overline{V_k}}{s_k},\ i = 1,2,\cdots;\ k = 1,2,4 \tag{10}$$

where $\overline{V_k}$ and $s_k$ are respectively the mean and the standard deviation of the cumulative volume passed during the reference period *k*. This type of index had already been used [22] but it was impossible to solve the problem of non-stationarity of the series because it worked on an annual time scale. The two-parameter log-normal distribution was used. Thus, the SDI index was calculated using Drinc 1.5 software (https://drinc.software.informer.com/1.2/) according to Equation (11).

$$\mathrm{SDI}_{i,k} = \frac{y_{i;k} - \overline{y_k}}{s_{y,k}},\ i = 1,2,\cdots;\ k = 1,2,3,4 \tag{11}$$

With

$$y_{i,k} = \ln\left(v_{i,k}\right),\ i = 1,2,\cdots;\ k = 1,2,3,4 \tag{12}$$

The logarithm of the flows cumulated with $\overline{y_k}$ the mean and $\overline{S_{y,k}}$ the standard deviation estimated over a long period of time.

Five (5) states are considered starting from 0 (no drought) to 4 (extreme drought) and are defined through **Table 2**.

### 2.3.3. Maximum Duration of Meteorological and Hydrological Drought

Duration is one of the important characteristics of drought. Indeed, if a drought starts quickly under certain climatic regimes, it usually takes at least two to three months before it moves to other regions. It can then persist for months or even years. The duration is calculated as follows:

- analyzing a series of data over a long period of time to determine the driest period;
- subtract the year of the end of the drought from the year of the initial; the result obtained is added by one (Equation (13)).

$$T = \left(A_{\text{end}} - A_{\text{initial}}\right) + 1 \tag{13}$$

With: $A_{\text{end}}$ : Year of end of dry period.

$A_{\text{initial}}$ : Year of the beginning of the dry period.

### 2.3.4. Meteorological and Hydrological Drought Intensity

Drought intensity can be defined as the magnitude and severity of the impact of

**Table 2.** Definition of states of hydrological drought with the aid of SDI [20].

| Description | Criterion |
|---|---|
| Non-drought | $\mathrm{SDI} \geq 0.0$ |
| Mild drought | $-1.0 \leq \mathrm{SDI} < 0.0$ |
| Moderately dry | $-1.5 \leq \mathrm{SDI} < -1.0$ |
| Severely dry | $-2.0 \leq \mathrm{SDI} < -1.5$ |
| Extremely dry | $\mathrm{SDI} < -2.0$ |

the rainfall deficit on runoff. It can be assessed using SPEI and SDI values. The extreme values of the SPEI and SDI are considered as reference values of drought intensity (**Figure 3**).

#### 2.3.5. Frequency of Meteorological and Hydrological Droughts

The cumulative frequency ($F$) of drought gives an idea of the occurrence of dry sequences over a period of time. It is obtained by reporting the cumulative number of dry sequences by the total number of rainfall and flow data.

$$F = \frac{\int n}{N} * 100 \tag{13}$$

With: $\int n$ : Cumulative dry sequence size; $N$: total size of data.

#### 2.3.6. Analyse Correlation

In order to analyze the relationship between meteorological and hydrological droughts in the Lobo river watershed, the Pearson correlation coefficient between the SPEI and SDI indices was calculated at the stations of Daloa, Vavoua and Zuénoula. According to [23] [24], the Pearson correlation coefficient is a very effective method for the analysis of potential relationships between two independent variables. This coefficient was calculated using software R.

## 3. Results

### 3.1. Meteorological and Hydrological Drought in the Lobo Watershed at Nibehibe

The SPEI index used for the evaluation of rainfall deficit over the period 1971-2013 at the Daloa, Vavoua and Zuenoula stations shows a significant fluctuation of dry and wet sequences with a strong tendency to drought (**Figure 4**). At Daloa station, two major drought periods were observed from August 1981 to September 1985 and from January 1990 to October 1995. We note a recovery of rainfall between February 2008 and October 2013 with incursions of dry periods in 2011 followed by a decrease in 2016. Concerning the station of Vavoua, a long wet

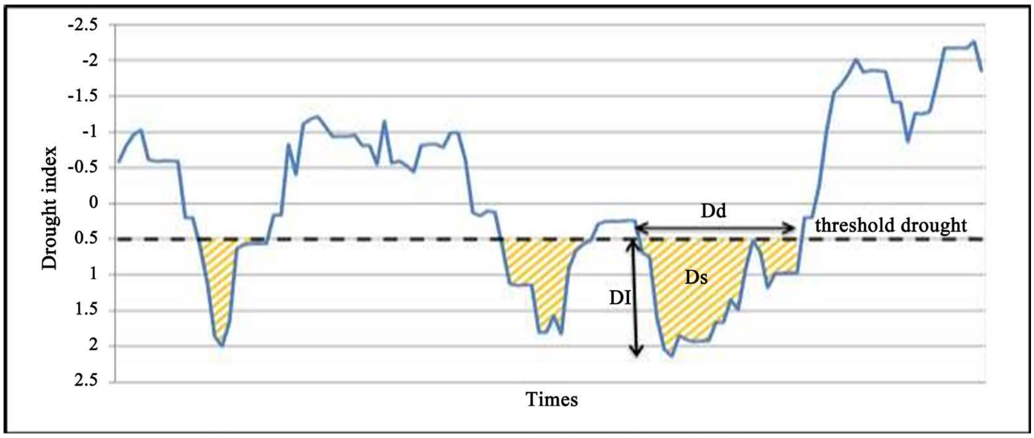

**Figure 3.** Three components of a drought: DS = Severity of drought events; ID = Intensity; Dd = Duration [25].

period is observed from January 1971 to December 1975 with a short dry period in 1973. Four (4) and nine (9) successive dry years from 1981 to 1984 and from 1998 to 2006 with a recovery of rainfall from 2007 to 2013 followed by a decrease in rainfall from 2015 to 2016 were observed. The Zuénoula series begins with a long dry period starting from March 1972 to October 1979 and from January 1981 to December 1984 followed by an alternation of dry and wet periods with climatic episodes described as normal (−0.99 to 0.99). From 2006, a long wet period remains dominant until 2012 with a decrease in rainfall from 2013 to 2016.

## 3.2. Hydrological Drought in the Catchment Area of the Lobo River at Nibéhibé

The analysis of hydrological drought shows an alternation of dry and wet periods. There was a long dry period between 1971 and 1977 with a 12-month incursion of a wet year in 1974. From October 1977 to November 1980, a resumption of flows in the Lobo river basin followed by a more marked hydrological deficit between December 1980 to September 1994 with SDI-12 sometimes between −1.5 and −3.09, synonymous with severe to extreme drought (**Figure 5**).

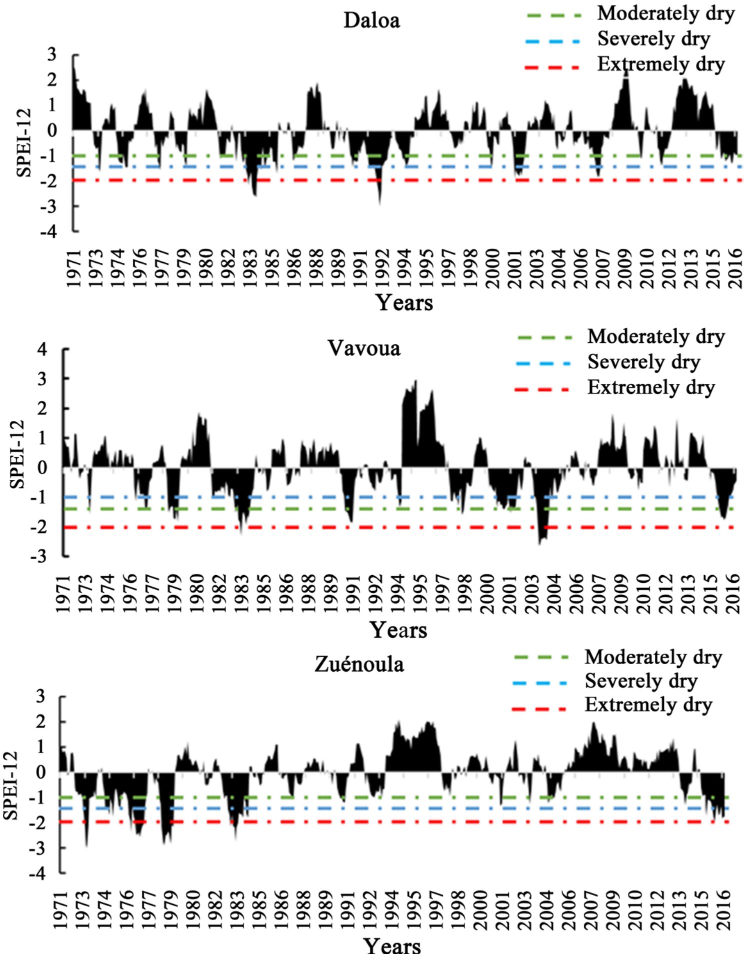

**Figure 4.** Evolution of meteorological drought at the Vavoua, Daloa and Zuénoula stations on the Lobo catchment area at Nibéhibé.

The year 1983 remains the most severe in terms of hydrological drought intensity, with an SDI equal to −3.44. However, this period is still marked by slight outbreaks of wet periods. From 2006 to 2016, there is a long wet period marked by a resumption of the most important flows in the Lobo catchment area.

### 3.3. Intensity and Maximum Duration of Meteorological and Hydrological Drought Sequences in the Catchment Area

The results of estimating the extent of the drought over the 45 years of studies show that the Lobo River watershed has been affected by a severe drought. To this effect, the episodes of August 1992; September 2003; August 1973 observed at the Daloa, Vavoua and Zuénoula stations are characterized by a severe drought with respective indices of −2.99; −2.64 and −2.93. Estimation of the extent of drought using the SDI index generally shows that the 1983 episode observed at the Nibéhibé station is qualified as extreme drought with SDI indices of −3.44.

Analysis of the duration of meteorological drought episodes shows that it varies from one station to another (Table 3). The different results show that the station of Daloa experienced the longest period of drought with thirty-eight (38) months of drought sequences, followed by the station of Zuénoula with thirty-seven (37) months of drought sequences and finally the station of Vavoua with thirty-six (36) months of drought sequences. The longest hydrological

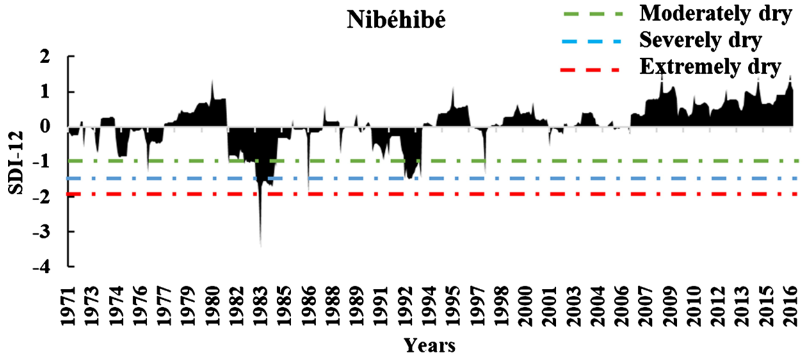

**Figure 5.** Evolution of the hydrological drought at the hydrometric station of Nibéhibé.

**Table 3.** Intensity and maximum duration of meteorological and hydrological drought sequences in the Lobo watershed.

| Parameters | SPEI | | | SDI |
|---|---|---|---|---|
| | Daloa | Vavoua | Zuénoula | Nibéhibé |
| Intensity | −2.63 | −2.69 | −2.93 | −3.09 |
| Date of occurrence | March 1984 | Sep. 2003 | Aug. 1973 | Oct. 83 |
| Duration (months) | 51 | 36 | 37 | 58 |
| Date of occurrence | Aug. 1981-Sep. 1985 | Sep. 1981-Aug. 1984 | Sep. 1974-Sep. 1977 | Dec. 1980-Sep. 1985 |
| Type | Extremely dry | Extremely dry | Extremely dry | Extremely dry |

drought period started in October 1981 and ended in September 1985. This period was characterized by forty-eight (48) months of drought.

### 3.4. Frequency of Meteorological and Hydrological Drought Intensity Classes in the Catchment Area

Analysis of the frequency of drought episodes observed at the Daloa, Vavoua and Zuénoula and Nibéhibé stations shows that these are between 1.6% and 13.3% (**Figure 6**). Periods close to normal (attenuated drought) are higher in the basin. They are between 52.7% and 72.9%. Severe to extreme droughts were rare during the observation period. However, these extreme episodes were most observed at the Zuénoula (5%) and Nibéhibé (3.8%) stations and, compared to the Daloa (1.7) and Vavoua (1.8%) stations.

### 3.5. Relationship between Meteorological (SPEI) and Hydrological (SDI) Drought in the Lobo Watershed at Nibéhibé

The comparison between the SPEI and SDI indices show an acceptable correlation between the meteorological and hydrological drought indices at the station of Daloa ($r = 0.50$) and Vavoua ($r = 0.43$) compared to the stations of Zuenoula (0.40) (**Figure 7**). This correlation is significantly positive at all stations with a probability of $p < 0.0001$ according to a confidence interval between 0.451 and 0.600 at the Daloa station, from 0.356 and 0.513 at the Vavoua station and finally from 0.46 and 0.508 at the station of Zuénoula. However, we observe a bad synchronism between the SPEI and SDI from 1971 to 1977 at the stations of Daloa and Vavoua. From 1978 to 1987 and from 2008 to 2013, we observe a similarity

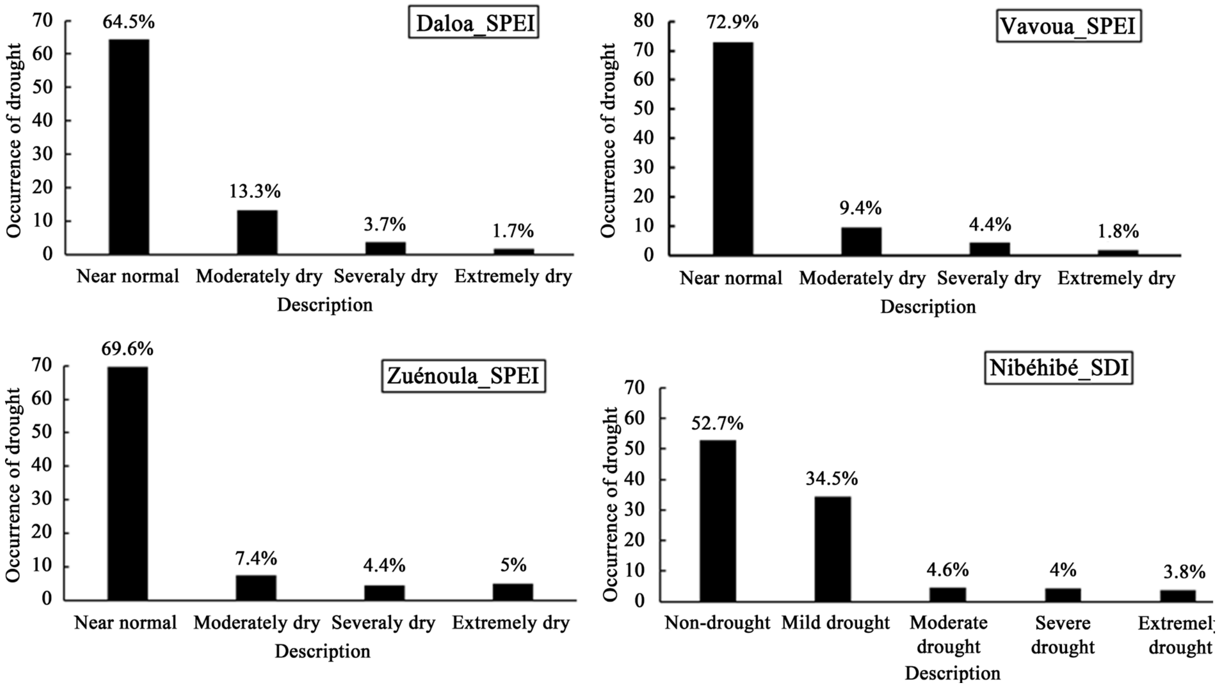

**Figure 6.** Frequency of meteorological and hydrological drought intensity classes at the Daloa, Vavoua, Zuénoula and Nibéhibé stations.

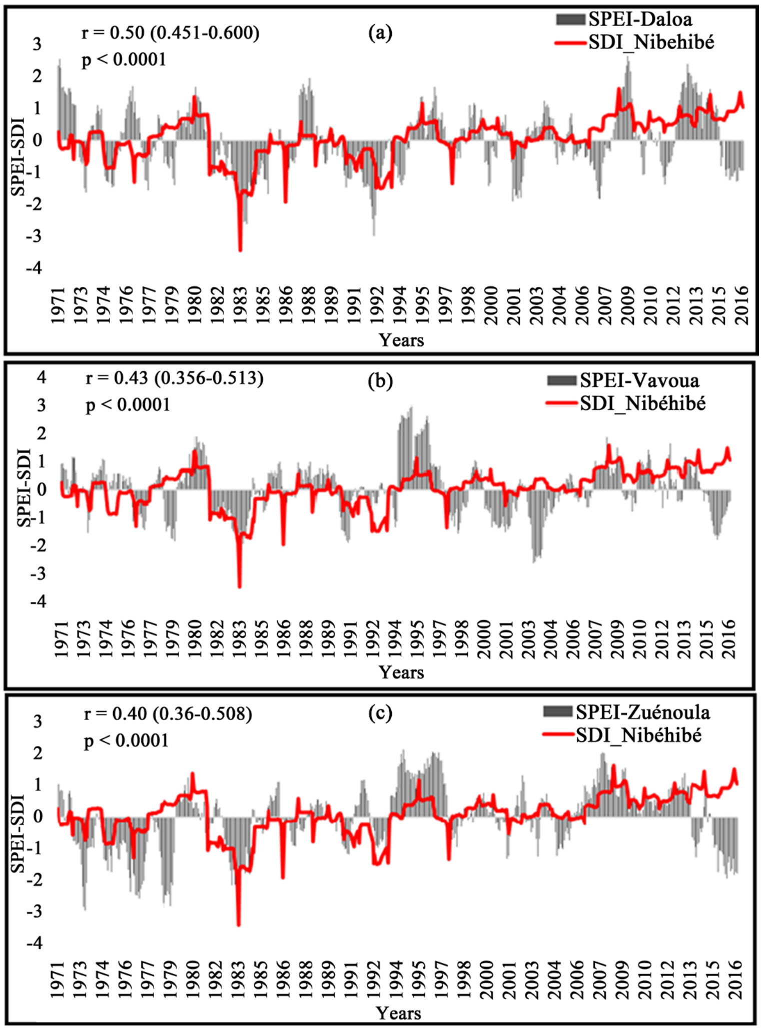

**Figure 7.** Relationship between meteorological and hydrological drought in the Lobo River watershed at the stations of Daloa (a), Vavoua (b) and Zuénoula (c).

between the meteorological drought indices and the hydrological drought indices. Also, the SPEIs showed longer drought incursions than the SDIs between 1990 and 1995 at the Daloa station, unlike the Vavoua and Zuénoula stations. It is also observed between 2007 and 2016 that the SDI showed a longer duration of humidity than the SPEI.

A correlation matrix between the different parameters was carried out in order to estimate the different correlations between the study variables. The results show a positive correlation between the variables. The highest correlation between rainfall indices (SPEI) and flow rates (SDI) was observed at the Daloa station (0.53), then that of Vavoua (0.43) and finally the Zuénoula station (0.40) where a weak correlation was observed (Table 4). The comparison between the rainfall indices shows a strong correlation between the Zuénoula and Vavoua stations. However, there is a weak correlation between the SPEI-Vavoua, SPEI-Zuénoula and Daloa indices. With SPEI between 0.33 and 0.45 ($0.34 < \text{SPEI} < 0.45$).

**Table 4.** Correlation matrix.

| Variables | SDI_Nibéhibé | SPEI_Vavoua | SPEI_Zuénoula | SPEI-Daloa |
|---|---|---|---|---|
| SDI-Nibéhibé | 1 | <0.0001 | <0.0001 | <0.0001 |
| SPEI_Vavoua | 0.435 | 1 | <0.0001 | <0.0001 |
| SPEI_Zuénoula | 0.535 | 0.600 | 1 | <0.0001 |
| SPEI-Daloa | 0.526 | 0.457 | 0.348 | 1 |

## 4. Discussion

The catchment area of the Lobo River in Nibéhibé has experienced climatic variability, materialised by an alternation of wet and dry years after the break observed around the 1970s with regard to the evolution of the SPEI and SDI indices. The decrease in rainfall observed during this study generally occurred after 1970, and is in line with the dry periods defined by previous studies [26] [27] [28] [29] [30]. As reported by [31], the 1970s is a period very representative of the significant drop in rainfall in Côte d'Ivoire. According to these authors, this decline in rainfall had repercussions on the water balance of the regions. The analysis of meteorological drought at the Vavoua, Daloa and Zuénoula stations revealed that the Lobo catchment area was affected by meteorological drought phenomena after 1970. Drought peaks were observed in March 1984; September 2003 and August 1973. These peaks are characterized by extremely severe types of droughts. Results that confirm the research conducted by [31] et [32] in West Africa. In Côte d'Ivoire, the work of [9] [29] [33] [34] showed that the decades 1970-1979; 1980-1989 and 1990-1999 were dry periods. This decline in rainfall intensified during the 1980s and 1990s before rising slightly between 2007 and 2013.

With regard to hydrological drought, the SDI has shown that the Lobo catchment area is characterized by an attenuated type of drought. The dry period observed during 1983 could be due to an accumulated rainfall deficit in the late 1970s [33] [35]. Similarly, below-average rainfall during the 1980s probably resulted in an attenuated to severe drought in the early 1990s, as shown by the SDI with very low values ($\leq -2$), synonymous with severe to extreme drought. This decline in runoff during the 1980s could be due to high water demand pressure or very low water conditions in the basin. However, there is a recovery in runoff from 1995 to 2013, suggesting that the decrease in precipitation has had little effect on the water available in the basin. According to [36], from the decade 2000 onwards, more or less favourable rainfall conditions are at the origin of the increase in runoff in West African catchment areas. This recovery has also been supported by the work of [18] on the Lobo watershed. According to the results of this work, this increase in flows could be due to the strong degradation of surface conditions, through the intensification of agricultural activities. Indeed, like the forest areas of Côte d'Ivoire, the Lobo watershed is undergoing rapid deforestation due to agricultural activities [37]. Indeed, the work of [38] and [39] on the Boubo, Agneby and Davo basins clearly showed that a reduction in vegetation cover contributes to an increase in flows.

In order to assess the impact of meteorological drought on flows, a correlative analysis was carried out between meteorological (SPEI) and hydrological (SDI) drought indices at the Daloa, Vavoua and Zuénoula stations. The results indicate a good correlation between the two drought indices (SPEI-SDI).

This average correlation observed could be due to the presence of water retention in the Lobo River watershed. Indeed, these hydraulic structures (Brakaguhé, Kibouo, Youala and SODECI reservoirs) could modify the temporal distribution of hydrological processes during a hydrological year. They could increase the quantity of water in rivers during the dry season and could decrease the flow of rivers during the flood season, resulting in lower correlation coefficients between climatic and hydrological.

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It is also found that the flow deficit marked by a long drought period (58 months) during the period 1983-1986 is at a faster rate than the rainfall deficit (51; 36; 37 months).

Indeed, according to the work of [26] [29] [35], the rainfall deficit of 1970-1990 led to a deficit twice as large as flows in West Africa. However, during the period 2007-2013, there is a long period of wetness marked by a resumption of rainfall and runoff in the Lobo catchment area. These results are in close correlation with the work of [3]. According to this work, West Africa has been experiencing a return to more humid rainfall conditions since the end of the last millennium. This recovery is marked by the frequency of flooding phenomena. This is the example of the recent floods observed in Côte d'Ivoire on the Cavally to Toulepleu and Marahoué to Bouaflé rivers in 2018 [41]. These events show a resumption of flows in the catchment basins in Côte d'Ivoire. Today, the return of the rains, which is generally very positive, is not always perceived by everyone. Indeed, the vegetation has sometimes been destroyed in favor of agricultural activities, the very encrusted soils. This results in a very large reduction in the water retention capacity of the soil, which could be the cause of a marked increase in floods. Water trickles instead of benefiting soil and vegetation.

## 5. Conclusion

The objective of this study is to assess the impact of meteorological drought on runoff in the Lobo to Nibéhibé catchment area. The methodological approach was based on meteorological (SPEI) and hydrological (SDI) drought indices. These methods enabled us to assess the duration, intensity and frequency of drought sequences in the Lobo to Nibehibe catchment area. The results of this study show that meteorological drought is more frequent than hydrological drought in the basin. However, the hydrological drought has been longer and more intense than the meteorological drought, with consequences on water availability in the catchment area in recent decades. During the period 2007-2013, there is a long period of humidity marked by a resumption of rainfall with a frequency of flooding phenomena. However, incursions of dry periods are observed. This resumption of runoff could be linked to the degradation of soils and vegetation. These results can serve as a basis for the implementation of prevention and water resource management strategies in the Lobo catchment area. Ultimately, it can be noted that adaptation to climate change requires an evolution towards techniques for reforestation of destroyed forests for better management of water resources.

## Author Contributions

B. K. analyzed the data and wrote the manuscript; Z. A. K. assisted in the preparation of the manuscript; A. B. Y. and K. H. K. reviewed the document; M. S. and K. L. K. supervised the study.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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