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Contribution to the Analysis of Rainfall Data from the Boketa Station in DR Congo from 1960 to 2018

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Abstract:- The quality of the statistics of precipitations makes it possible to take into account the fluctuations high frequencies of precipitations of the station of BOKETA. ¶Preliminary studies showed that the rainfall graphs describe clearly that in this station, two great seasons ago with the presence of the peaks in October and April what explains the passage of the sun to the zenith at the time of the equinox following the example decade 2000-2009 when October had to collect 401,4 mm of water.¶This article aims to study the rainfall indices for each decade of 1960 to 2018 to prevent with the risks related to the climatic change and in addition, the evolution of the characteristics of the rain.

Keywords:- *Climate, Rainfall Index, Precipitations, Congo River.*

I. INTRODUCTION

Faced with the many increasingly recurrent environmental problems in the world; climatology plays a leading role in the world of science today. Global warming and climate change are becoming issues of concern. For several decades, the whole world has been haunted by the alarming specter of climate change, and its major impact on our ecosystems and their biodiversity as a whole. Throughout the world, we observe several extreme meteorological phenomena; here and there are cyclones, droughts, floods, etc. At the same time that this scourge causes a rise in ocean levels, it causes an unprecedented scarcity of fresh water on the surface of the earth.

II. METHODOLOGIE

The study of climatic and hydrological phenomena is a rather delicate task because of the seasonal and interannual fluctuations that they can take on. The data processing technique used in this study is based on the frequency analysis method. It is a statistical method of prediction consisting in studying past events, characteristic of a given process (hydrological or other), in order to define the probabilities of its future occurrence. Thus, the mean, the standard deviation and the coefficient of variation were calculated. The coefficient of variation, which is the ratio between the standard deviation and the average, makes it possible to assess the dispersion of rainfall around the average. The method used consisted in the quantitative analysis of the rainfall parameters (average, minimum and maximum) of each decade including their indices determined from the mathematical formula below:

$$I = P_{(i)} - P_{(m)}/\sigma \quad (1)$$

With:
I: Rainfall index
P(i): Unit rainfall of the series
P(m): Average rain
σ: Standard deviation

Data processing for this study required the use of software such as Excel for the calculations and graphs and Hyfran 1.1 (Hydrological Frequency Analysis, EL Adlouni et al., 2008) for the frequency analysis of maximum daily rainfall annuals.

III. DATA

The climatic data used during our study were made available to us by the region of the Boketa station were obtained from INERA in the territories of Gemena, these are daily rainfall data from the station from Boketa, we calculated their monthly and annual averages from 1960 to 2018, divided into 6 decades.

IV. STUDY OF THE ENVIRONMENT

The INERA station is located in the territories of Gemena, province of Sud Ubangi, 12 km from the town of GEMENA on the Gemena-Akula road axis. It is in the forest zone of Ubangi; it was created in 1948 by the National Institute for Agronomic Studies (INEAC) and became an experimental station in 1952 during the reorganization of the Institute into sectors. In 1987, the station was entrusted to the Agro-industrial Development Center (CDAI) under the management of the Presidency of the Republic, and then retroceded to INERA in 2000. The concession of the station covers an area of 543 hectares and its geographical coordinates are: 19°46' East longitude, 3°11' North latitude and 475 m altitude. It benefits from an Equatorial climate and its rainfall is 1597 mm with an average annual temperature of 24°C, with a soil mainly of ferralitic type.

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Fig. 1: Maps of the location of Boteka station in Gemena territory, Sud Ubangi, DR Congo

V. RESULTS AND INTERPRETATIONS

The analysis of the rainfall parameters of these different decades is presented in three stages, in particular the presentation of the rainfall heights, their characteristic values including their evolutions.

A. For the First Decade: 1960-1969

The rainfall graph is shown below:

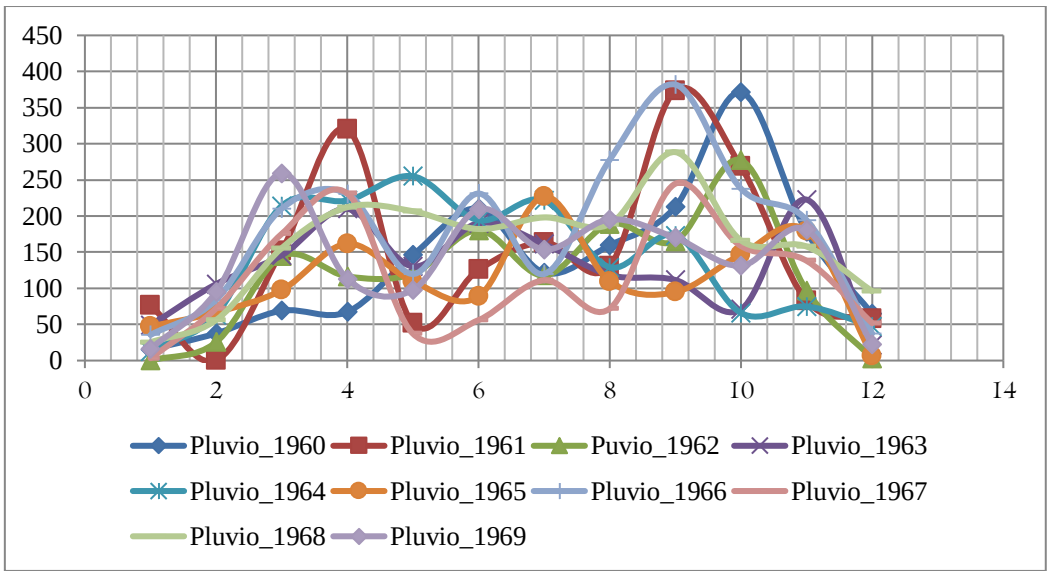

Fig. 2: Graph of rainfall heights from 1960-1969

The analysis of this figure informs us that the maxima was observed during the month of September 1966 and the minima in the month of February 1962 and their characteristic values of the rainfall series are represented in table 1.

Characteristic values	Months											
	Jan.	**Feb.**	**Mar.**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Max	76	105.8	259.3	320	255	231.1	227.1	277.9	381.9	371.1	222.7	96
Min	0	0.2	69	67.3	37.2	56	111.1	71.8	94.7	65.9	74.8	3.2
Mean	28.04	60.6	162.28	188.39	127.35	166.78	159.5	157.03	221.58	189.38	150.61	40.78
Standard Dev.	24	32	56	74	65	57	44	58	100	97	51	29

Table 1: Characteristic values of the rainfall series

Their evolutions are described using figure 3 below:

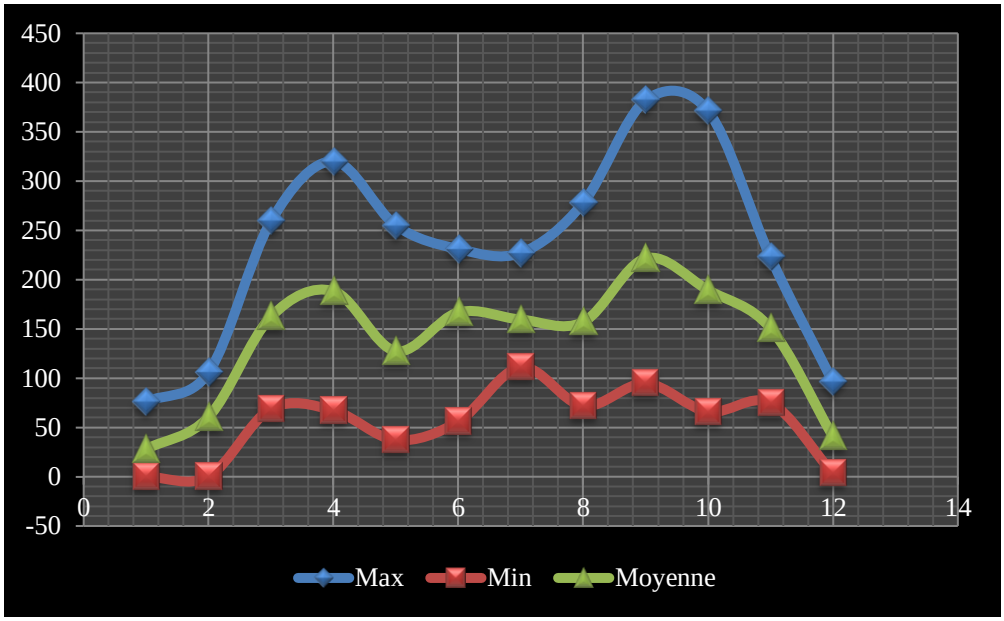

Fig. 3: Evolution of characteristic values from 1960-1969.

Table 1 and Figure 3 above tell us that the main rainy season is from January to April and the main dry season is from October to December. To this, just add the intermediate seasons: short rainy season: from May to June; and small dry season: from July to August.

B. For the second decade: 1970-1979

The graphic presentation of the rainfall heights for this decade is shown in Figure 4 below:

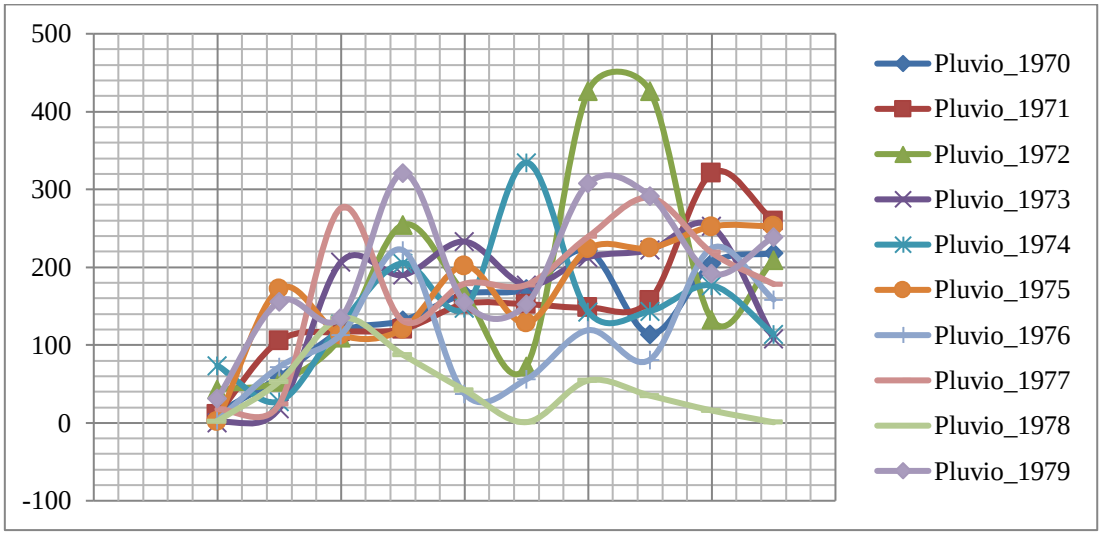

Fig. 4: Graph of rainfall amounts from 1970-1979.

This figure indicates that the maxima is observed in July 1971 and the minima in January 1973.

Characteristic values	Months											
	Jan.	**Feb.**	**Mar.**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Max	73.7	172	276.2	320.8	232.9	334.6	426.5	426.3	320.7	259.7	236.5	154.2
Min	0.1	18.4	109.8	87.7	37.2	1	54.5	35	15.9	0.8	1.7	10
Mean	19.7	74.06	145.04	178.39	147.89	142.44	209.57	198.59	199.07	173.89	122.43	47.76

Table 2: Characteristic values of the rainfall series from 1970 to 1979

The evolution of characteristic values for the year 1970-1979 is described using figure 3 below:

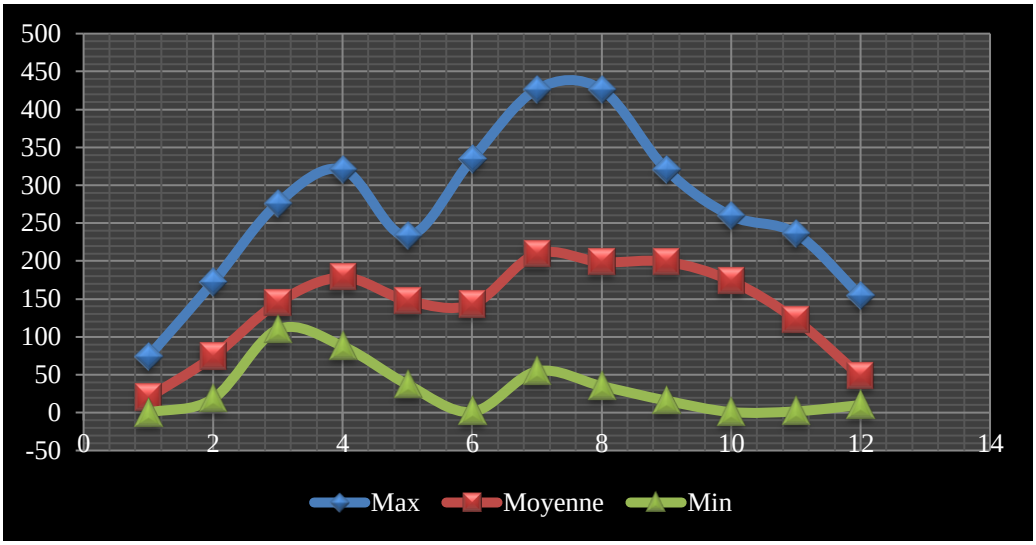

Fig. 5: Evolution of characteristic values for the year 1970-1979.

Compared to the previous decade (1960-1969) where two long seasons were recorded separated by two short seasons, figure 5 indicates values almost lower than 200 mm except for the average for the month of July, which is an exception. It is also necessary to note the anticipated drop in rainfall (August) unlike the previous decade 1980-1989.

C. For the third decade 1980-1989

The rainfall presentation for this decade is represented in this way:

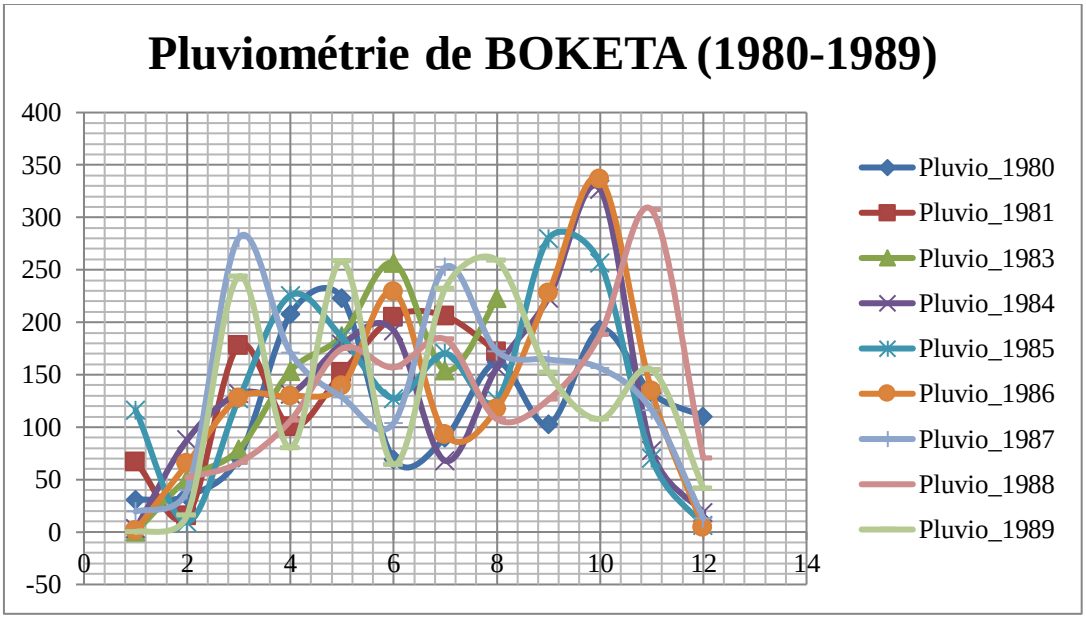

Fig. 6: Graph of rainfall amounts for 1980-1989

Table 3 shows us the characteristic values of rainfall levels from 1980-1989.

Characteristic values	Months											
	Jan.	**Feb.**	**Mar.**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Max	116.2	87.9	280.5	225.6	258.1	256.6	252.6	294.7	279.9	336.8	307.1	110.3
Min	0	9.4	65.8	80.3	128.5	64.5	67.9	107.6	102.7	107.7	64.4	4.3
Mean	27.01	43.93	145.87	143.44	176.71	150.21	154.56	179.11	178.3375	211.8875	132.1875	35.9875

Table 3: Characteristic values of rainfall levels (1980-1989)

ISSN No:-2456-2165

Their evolutions are described using the figure below:

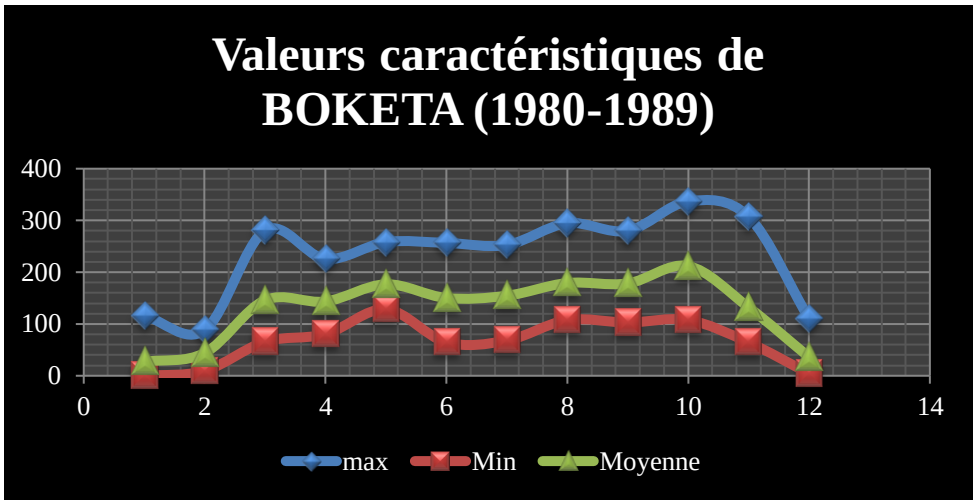

Fig. 7: Evolution of characteristic values for the year 1980-1989.

Figure 7 shows that the rainfall curve is more or less stable from March to November, but we observed a small decrease in January, February and December.

D. For the fourth decade 1990-1999

The graphic presentation of the rainfall heights during this decade is described by the figure below:

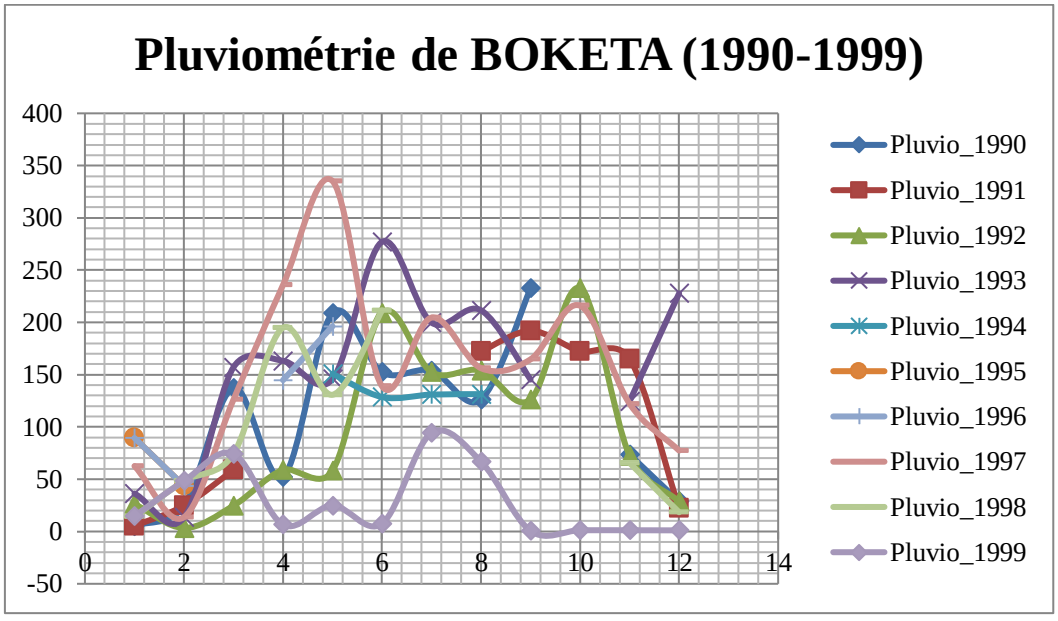

Fig. 8: Graph of rainfall amounts from 1990-1999.

The characteristic values related to these rainfall heights are shown in Table 4.

Characteristic values	Months											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Max	89.5	48.3	157.1	235.8	335.2	277.1	204.6	211.6	232.6	232.6	165.1	127.8
Min	5.3	3.4	24.7	6.6	24.9	7.5	94.3	66.9	0.6	1.2	1.2	1.1
Mean	38.2	29.3	93.3	122.4	156.4	160.7	156.0	145.5	143.6	155.6	89.3	57.8

Table 4: Characteristic values of rainfall heights (1990-1999).

Their evolutions are represented using Figure 9.

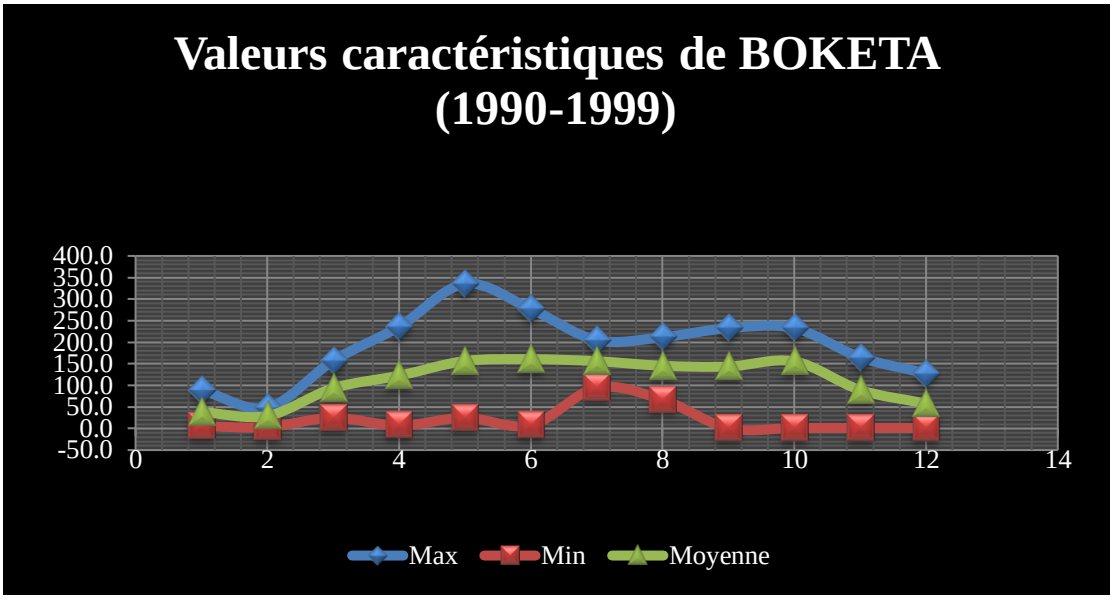

Fig. 9: Evolution of characteristic values for the year 1990-1999.

Figure 9 provides information on the following elements:
- The dry season: beginning of October until the end of January;
- The rainy season: from February to October;
- However, from July to August, there is a drop in rainfall.

E. For the fifth decade 2000-2009

Graphic presentation of the rainfall levels of BOKETA (2000-2009).

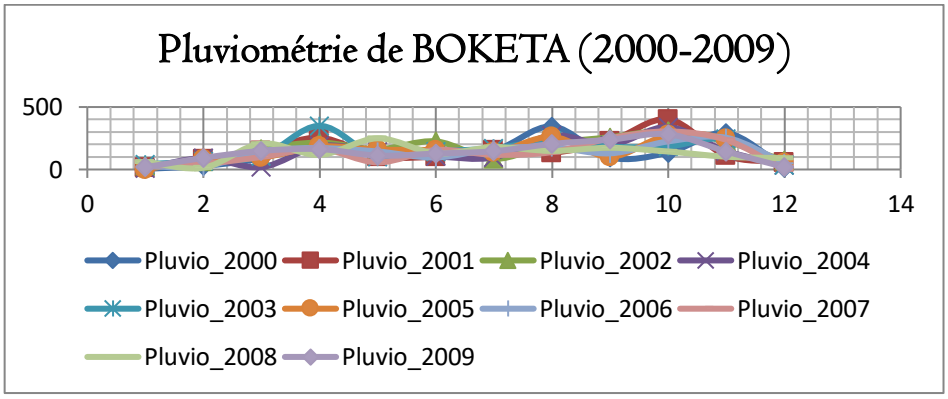

Fig. 10: Graph of rainfall heights from 2000-2009

Table 5 presents the characteristic values of rainfall levels from 2000 to 2009.

Characteristic values	Months											
	Jan.	**Feb.**	**Mar.**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Max	59,7	93	207,3	349,7	249,4	224,9	177,6	344,2	258,2	401,4	291,7	90,4
Min	0	14,4	19,1	116,8	56,8	96,5	84,6	134,1	96,3	134,1	102,2	0,3
Mean	23,95	59,2	122,78	204,19	135,66	140,25	140,31	211,88	185,48	259,92	200,08	43,38

Table 5: Evolution of the characteristic values of Boketa (2000-2009)

ISSN No:-2456-2165

Evolution of the characteristic values of Boketa (2000-2009):

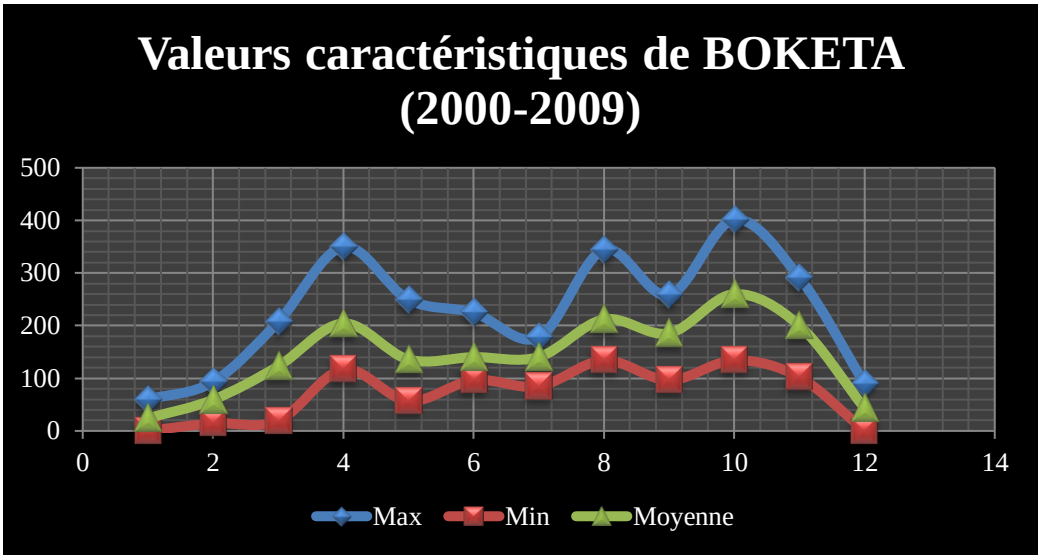

Fig. 11: Evolution of characteristic values for the year 2000-2009.

The analysis of table 6 with figure 11, shows us that the average rainfall during the decade (2000-2009) behaved as follows:
- From January to February and from November to December there is a decrease in rainfall;
- From March to October: fairly stable rainfall;
- Presence of two peaks: April: 349.7 mm and October: 401.4 mm.

Table 6 shows Boketa's raw data from 2010 to 2018.

YEARS	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	42.4	0.3	11.4	42.3	10.9	57.2	0	64.5	52.2
February	130.4	86.9	166.5	12.1	83.9	41	49.2	49.7	111.8
March	142.8	125.2	157.7	142.1	121.1	201.7	135.1	52.6	173.6
April	174.6	147.1	82.2	183.1	275.8	111.7	191.8	323.9	85.4
May	136.8	135.3	105.7	85.8	143.5	275.8	321.2	121.6	287.4
June	111.4	120.4	100.7	172	115.5	72.3	22.2	91.2	194.7
July	134.1	54.4	91.8	128.2	83.8	143.7	122.4	242.9	182.4
August	358.9	244.4	194.4	353.2	153.1	179.4	256.7	134.8	-
September	252.2	302.9	306.6	111.3	199.4	142	105.8	142.4	-
October	160.2	302.8	324.7	130.6	190.5	196.5	132.8	224.6	-
November	67.8	121.8	113.1	193.8	181.1	136.6	70.9	151.9	-
December	32.7	0	13.9	23.1	67.1	130.6	123	20	-

Table 6: Raw rainfall data in mm from Boketa 2010-2018.

ISSN No:-2456-2165

a) Graphic presentation of the rainfall levels of BOKETA (2010-2018).

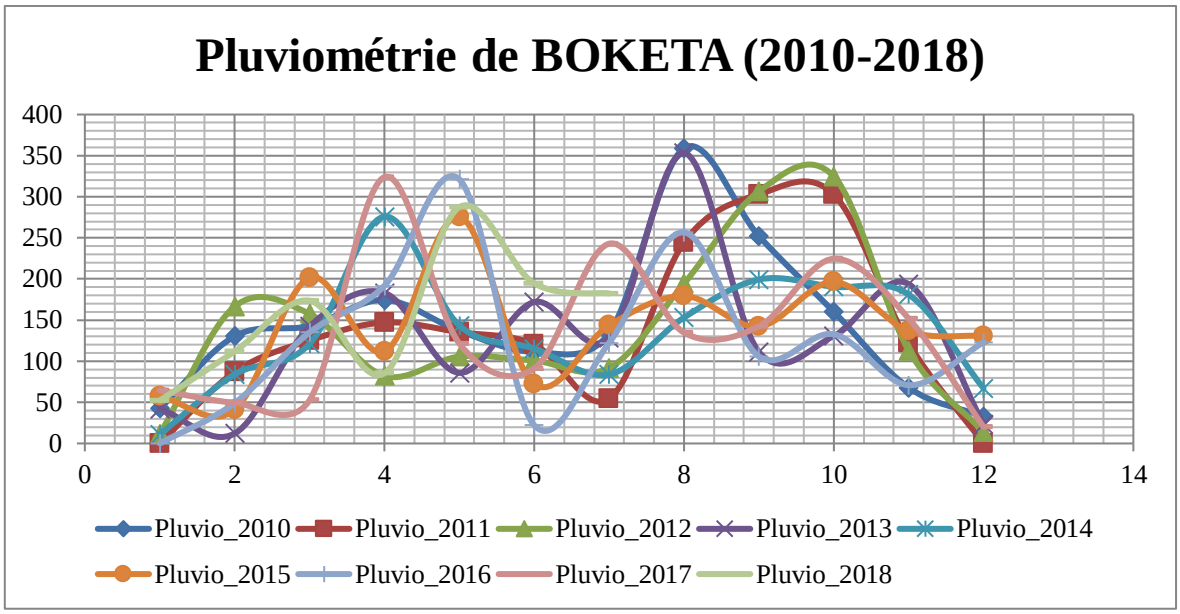

Fig. 12: Graph of rainfall amounts from 2010-2018

Characteristic values	Months											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Max	64.5	166.5	201.7	323.9	321.2	194.7	242.9	358.9	306.6	324.7	193.8	130.6
Min	0	12.1	52.6	82.2	85.8	22.2	54.4	134.8	105.8	130.6	67.8	0
Mean	31.24	81.27	139.1	175.0	179.2	111.1	131.52	234.3	195.32	207.84	129.625	51.3

Table 7: Characteristic values of rainfall levels (2010-2018).

b) Graph of characteristic values of Boketa (2010-2018)

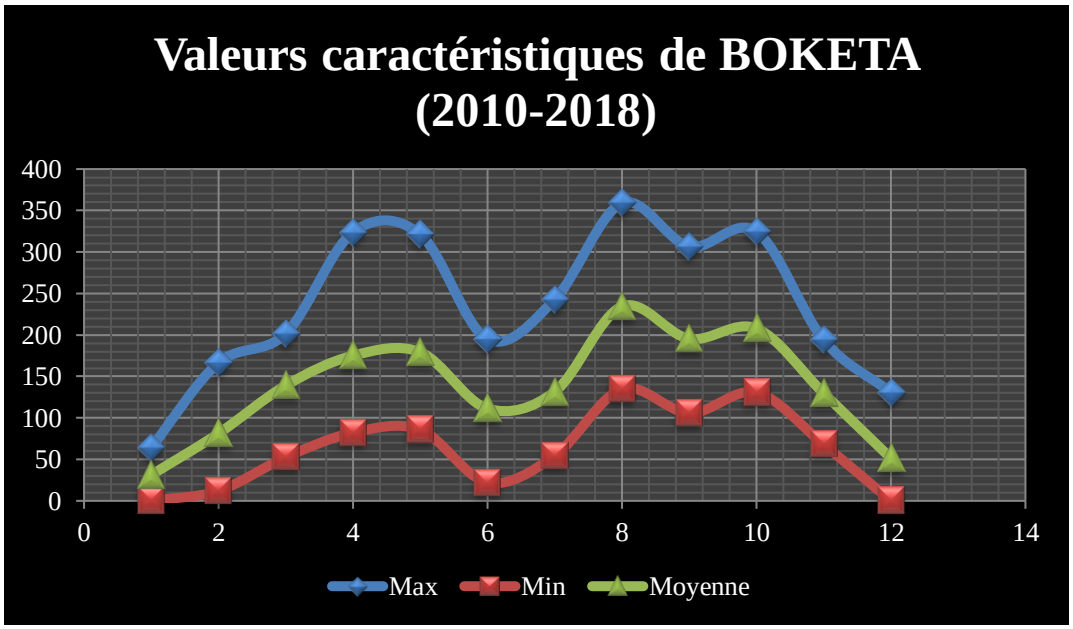

Fig. 13: Evolution of characteristic values for the year 2010-2018.

After analysis we find that the average curve of the series (2010-2018) of Boketa followed the pace below:

- From March to October: long rainy season whose peak in August culminates at 358.9 mm
- The months of December, January and February: short dry season.

F. Analysis of minimum rainfall data

a) Boketa's minimum rainfall data series from 1960 to 2018 is shown in Table 9 below.

Series	1st Decade	2nd Decade	3rd Decade	4th Decade	5thDecade	6thDecade
January	0	0.1	0	5.3	0	0
February	0.2	18.4	9.4	3.4	14.4	12.1
March	69	109.8	65.8	24.7	19.1	52.6
April	67.3	87.7	80.3	6.6	116.8	82.2
May	37.2	37.2	128.5	24.9	56.8	85.8
June	56	1	64.5	7.5	96.5	22.2
July	111.1	54.5	67.9	94.3	84.6	54.4
August	71.8	35	107.6	66.9	134.1	134.8
September	94.7	15.9	102.7	0.6	96.3	105.8
October	65.9	0.8	107.7	1.2	134.1	130.6
November	74.8	1.7	64.4	1.2	102.2	67.8
December	3.2	10	4.3	1.1	0.3	0

Table 8: Boketa minimum rainfall data series (1960-2018)

b) Graph of Boketa minimum data (1960-2018).

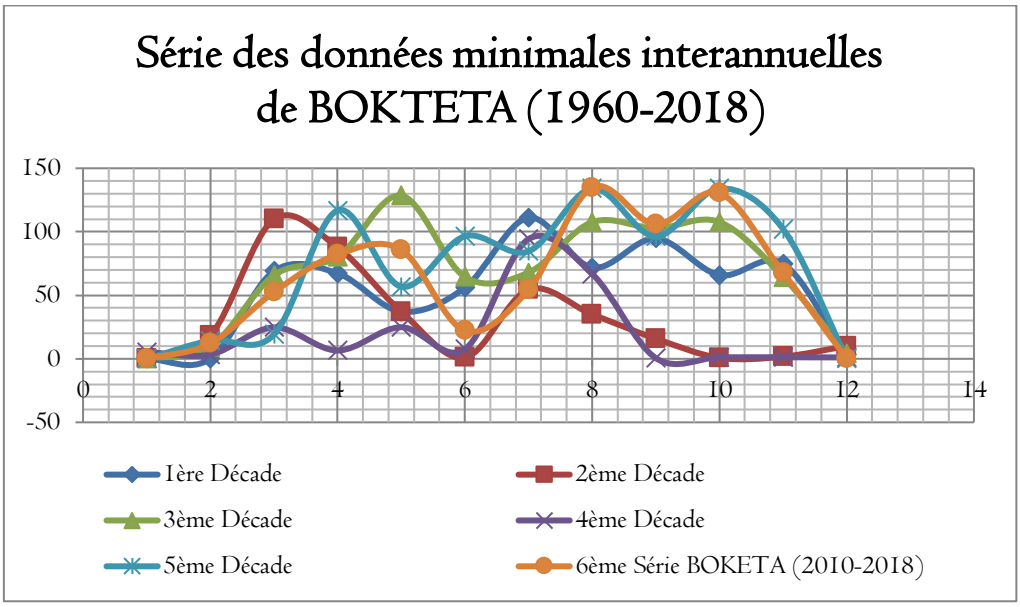

Fig. 14: BOKETA minimum data graph (1960-2018).

G. Descriptive analysis of decadal series

The determination of the extent of the rainfall phenomenon is best explained through the graphical representation of the data, to understand the evolution of the rainfall of INERA Boketa, we will proceed to the determination of the rainfall index (I). We have determined this index is obtained by applying mathematical formula (1). Table 10 below shows us the mean and standard deviation parameters useful for calculations to determine the rainfall index (I).

Parameters	1st Decade	2nd Decade	3rd Decade	4th Decade	5th Decade	6th Decade
Mean	54.2666667	31.0083333	66.925	19.8083333	71.2666667	62.3583333
Standarddev.	36.7872837	36.2868987	42.9499947	30.20185	51.032117	47.5193637

Table 9: position parameters (mean and standard deviation)

The rainfall indices for each decade are as follows:

Starting from the minimum rainfall heights of Boketa (1960-2018), we calculate the inter-monthly rainfall index for the decade.

a) First Decade: 1960-1969

a. Interannual rainfall index of Boketa (1960-1969).

N°	Interannual Minima (1960-1969)	rainfall index (I)
January	0	-1.47514742
February	0.2	-1.46971076
March	69	0.40050071
April	67.3	0.35428909
May	37.2	-0.46392843
June	56	0.04711773
July	111.1	1.54491791
August	71.8	0.47661397
September	94.7	1.09911168
October	65.9	0.31623246
November	74.8	0.55816389
December	3.2	-1.38816084

Table 10: Interannual rainfall index of Boketa (1960-1969).

b. Minimum rainfall evolution of Boketa (1960-1969).

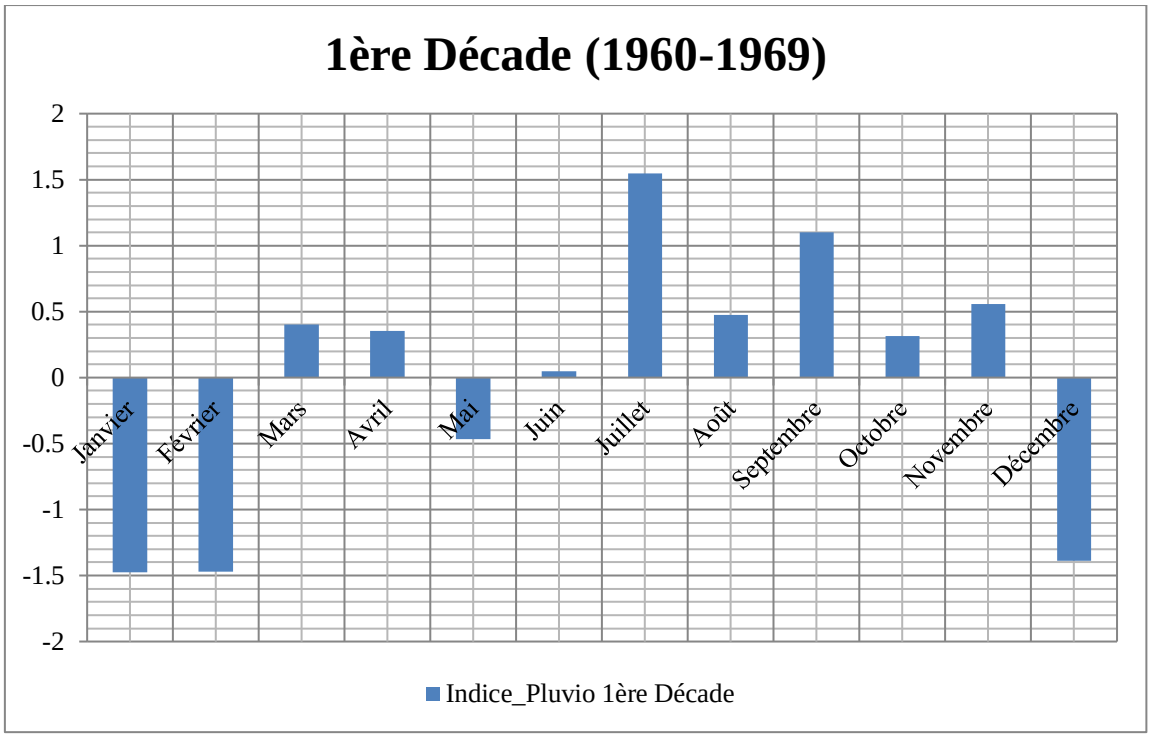

Fig. 15: Minimum rainfall evolution of Boketa (1960-1969)

Considering the hydrograph above, the following emerges:

- 04 months recorded deficit rainfall values (January - February - May and December)
- 08 months presented an above-average excess rainfall (March – April – June- July – August- September – October and November).

We can preliminarily conclude that the decade (1960-1969) is declared wet.

b) Second Decade: 1970-1979

a. Interannual rainfall index of Boketa (1970-1979).
As is the case for the past decade, the second is as follows:

N°	Interannual Minima (1970-1979)	rainfall index (I)
January	0.1	-0.85177666
February	18.4	-0.34746241
March	109.8	2.17135301
April	87.7	1.56231777
May	37.2	0.17063091
June	1	-0.82697432
July	54.5	0.64738701
August	35	0.11000297
September	15.9	-0.4163578
October	0.8	-0.83248595
November	1.7	-0.80768361
December	10	-0.57895092

Table 11: Interannual rainfall index of Boketa (1970-1979)

b. Rainfall evolution of Boketa (1970-1979).

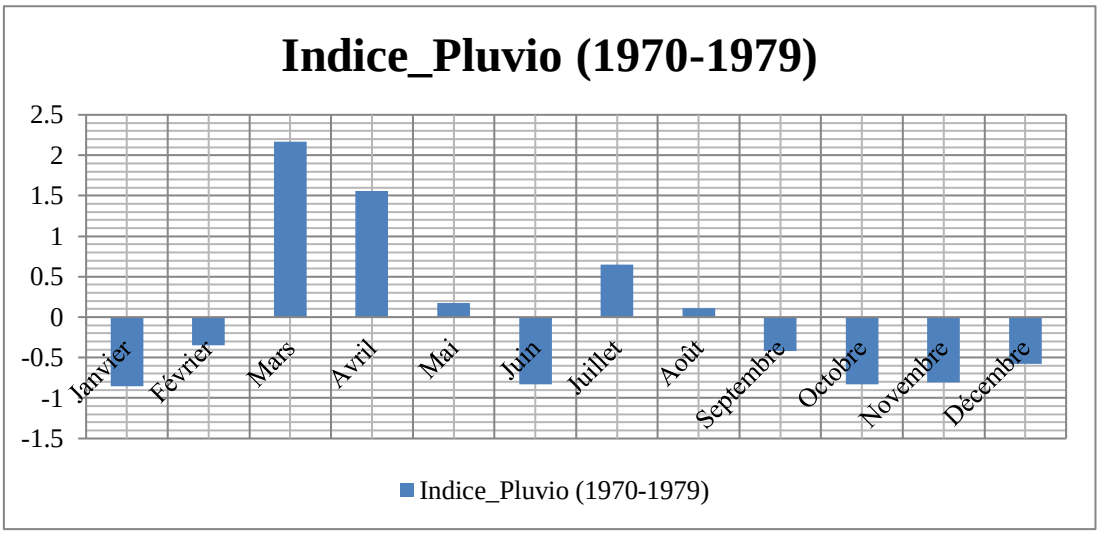

Fig. 16: Minimum rainfall evolution of Boketa (1970-1979).

c) Third Decade: 1980-1989

a. Interannual rainfall index of Boketa (1980-1989).

N°	Interannual Minima (1980-1989)	rainfall index (I)
January	0	-1.55820741
February	9.4	-1.33934824
March	65.8	-0.02619325
April	80.3	0.31140865
May	128.5	1.43364395
June	64.5	-0.05646101
July	67.9	0.02270082
August	107.6	0.94703155
September	102.7	0.83294539
October	107.7	0.94935984
November	64.4	-0.0587893
December	4.3	-1.45809098

Table 12: Interannual rainfall index of Boketa (1980-1989).

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b. Minimum rainfall evolution of Boketa (1980-1989)

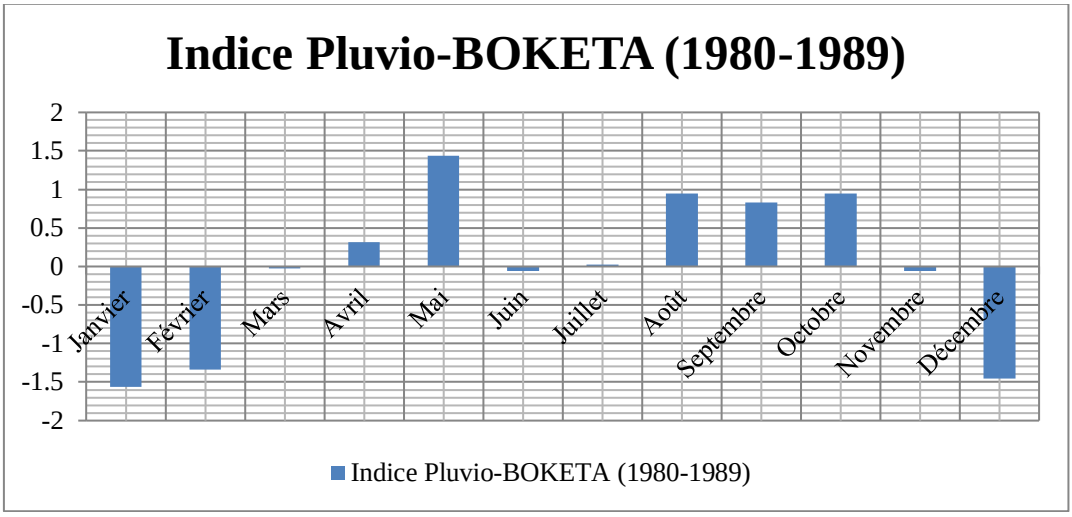

Fig. 17: Minimum rainfall evolution of Boketa (1980-1989).

d) Fourth Decade: 1990-1999

a. Interannual rainfall index of Boketa (1990-1999).

N°	Interannual Minima (1990-1999)	rainfall index (I)
January	5.3	-0.48037896
February	3.4	-0.54328902
March	24.7	0.1619658
April	6.6	-0.43733524
May	24.9	0.16858791
June	7.5	-0.40753574
July	94.3	2.46646039
August	66.9	1.5592312
September	0.6	-0.63599857
October	1.2	-0.61613224
November	1.2	-0.61613224
December	1.1	-0.61944329

Table 13: Interannual rainfall index of Boketa (1990-1999).

b. Minimum rainfall evolution of BOKETA (1990-1999)

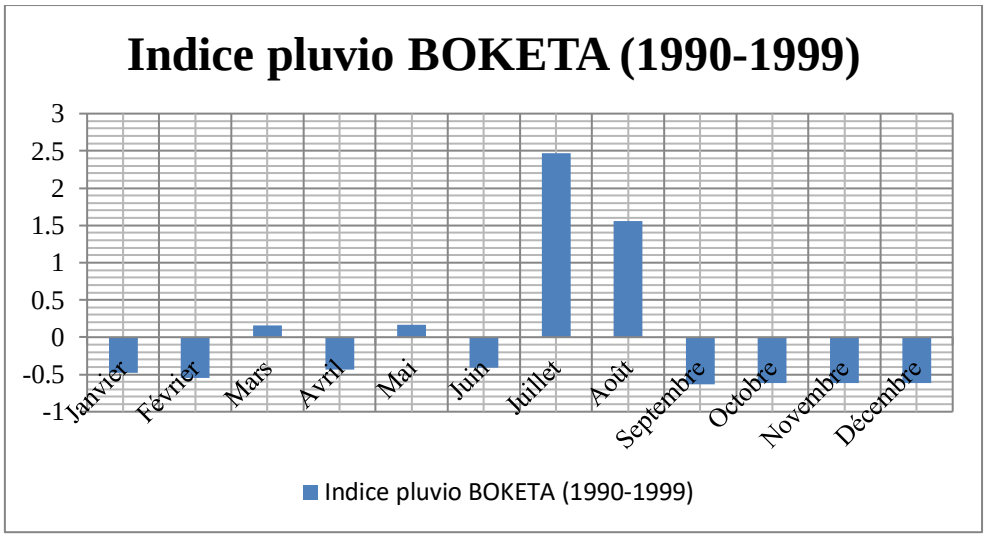

Fig. 18: Minimum rainfall evolution of Boketa (1990-1999).

e) Fifth Decade: 2000-2009

a. Interannual rainfall index of Boketa (2000-2009).

N°	Interannual Minima (2000-2009)	rainfall index (I)
January	0	-1.39650618
February	14.4	-1.11433093
March	19.1	-1.02223207
April	116.8	0.89224857
May	56.8	-0.28348161
June	96.5	0.49445986
July	84.6	0.26127337
August	134.1	1.23125077
September	96.3	0.49054076
October	134.1	1.23125077
November	102.2	0.60615422
December	0.3	-1.39062753

Table 14: Interannual rainfall index of Boketa (2000-2009).

b. Minimum rainfall evolution of BOKETA (2000-2009)

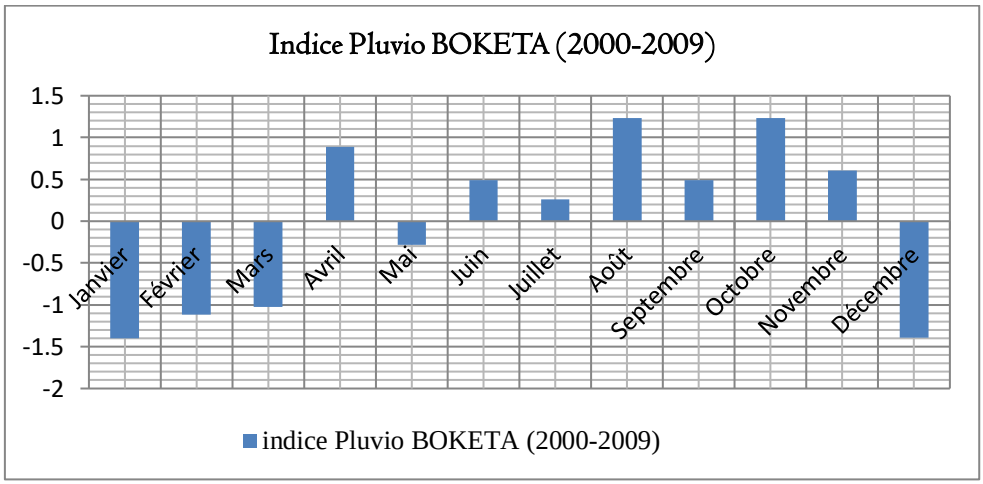

Fig. 19: Minimum rainfall evolution of Boketa (2009-2009).

f) Sixth decade: 2010-2018

a. Interannual rainfall index of Boketa (2010-2018)

N°	Interannual Minima (2010-2018)	rainfall index (I)
January	0	-1.31227206
February	12.1	-1.05763902
March	52.6	-0.20535488
April	82.2	0.41754908
May	85.8	0.49330767
June	22.2	-0.84509409
July	54.4	-0.16747559
August	134.8	1.52446626
September	105.8	0.91418873
October	130.6	1.43608124
November	67.8	0.11451472
December	0	-1.31227206

Table 15: Interannual rainfall index of Boketa (2010-2018)

b. Minimum rainfall evolution of BOKETA (2010-2018)

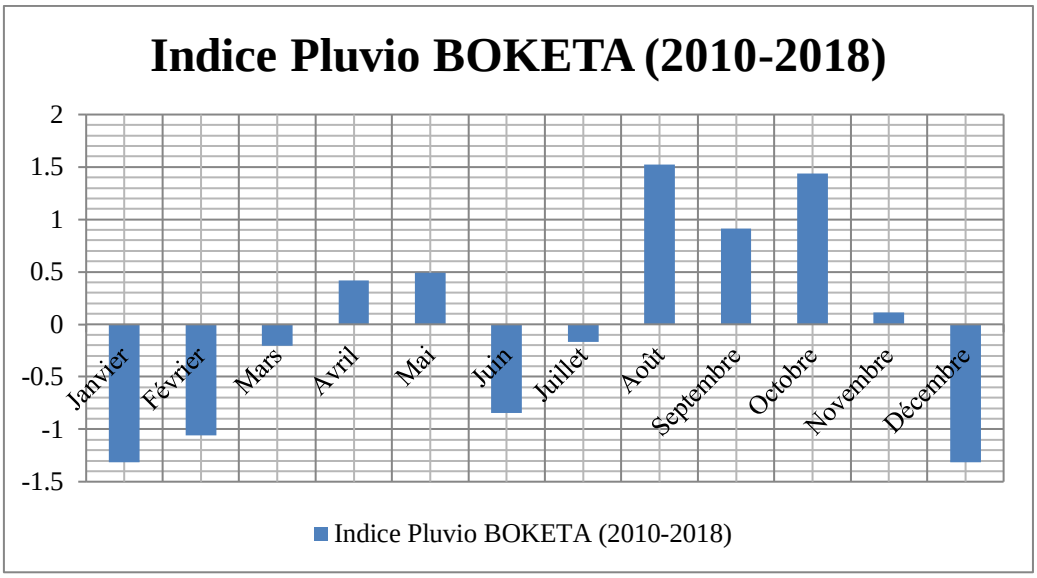

Fig. 20: Minimum rainfall evolution of Boketa (2010-2018)

VI. CONCLUSION

Water is a vital resource, economically and strategically essential to the life of humanity as well as to the stability of States, it occupies 71% of the earth's surface. Of this amount 97.2% is salty and only 2.8% sweet. It is spread over the four largest hydrographic basins in the world, including those of the Amazon and the Congo. The rainfall curves clearly describe that in the Boketa station, there are two main seasons including:

- The rainy season: from March to November.
- The dry season: from December to February.

We noticed the presence of the peaks in the months of April and October which explains the passage of the sun at the zenith during the equinox like the decade 2000-2009 when the month of October had collected 401.4 mm of rainwater.The evolution of the quantity of water falling in the Boketa station releases a form of cycle that is renewable over time. As a precaution we have the obligation to fear the unpleasant surprises linked to nature because it is elusive, especially because of the news linked to global warming. The amount of water drained by the Congo River depends on the rainfall in the equatorial zone where the Boketa station is located. Therefore, we cannot allow the diversion of water from the bed of our majestic river at the risk of suffering a catastrophic decrease in water in the first beneficiary country that we are, because the climatic cycle of our earth's atmosphere is unpredictable. The technological development of the modern world has led to an excessive explosion of the resources of nature to the point of causing harmful consequences in the planets earth.

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