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RESEARCH ARTICLE

ANALYSIS OF CLIMATE VARIABILITY AND ITS INFLUENCES ON SEASONAL RAINFALL PATTERNS ON THE BATÉKÉ PLATEAUS IN THE REPUBLIC OF CONGO-BRAZZAVILLE.

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Abstract

Climate variability, in Africa in general and in the Republic of Congo-Brazzaville in particular, has been widely documented over the past 20 years. However, variables related to rainfall, such as the nine-month rainy seasons, have been very little studied in the Batéké Plateaux zone, which play a major role in regional hydrology. The objective of this study is to investigate the influence of climatic events on seasonal rainfall patterns on the Plateaux Batéké. On the one hand, it involves monitoring the evolution of climatic parameters through the analysis of temperature, relative humidity and rainfall variation. On the other hand, it was a question of comparing the monthly rainfall normals over the period 1987-2016 in order to determine the behaviour of seasonal rainfall patterns in the context of climate variability. The principal component analysis, based on nine (09) variables, highlighted the impact of climate variability on seasonal rainfall patterns. The first principal component (F_1) is associated with the factors defining the climatic conditions of the Plateau Batéké. The second main component (F2) does not express clear correlations. Generally speaking, the temperature and relative humidity of the air are factors in the temporal variability of seasonal rainfall regimes on the Plateaux Batéké.

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Introduction:-

As the water cycle is one of the major components of climate, the implications of its changes on rainfall patterns are important (Kouassiet *al.,* 2011; Faty, 2017). Precipitation is the most important climate factor for both populations and ecosystems. It is the climatic factor that is the most easily accessible along with temperature. For these reasons, most studies and analyses focus on precipitation much more than on other climate parameters. Characterising the impact of climate variability on seasonal rainfall patterns then becomes essential in order to propose solutions adapted to development projects. The variability of climatic conditions in West and Central Africa in general, and in the Republic of Congo in particular, is no longer in doubt (Mpounza*et al,* 2003; Paturel*et al,* 1997; Servat et al, 1997; Servat*et al,* 1998; Servat et *al,* 1999; Ardoin et al, 2003, Ardoin, 2004; Kouassi et *al,* 2008, 2010, 2011; Laraque, 2001). Most of the climate studies carried out in Congo-Brazzaville have been limited to the analysis of annual or monthly rainfall data over the entire territory and in the southern part of the country. On the Batéké Plateaux (Fig.1), the lack of meteorological stations does not facilitate access to data. This could be justified by the difficulty in acquiring daily measurement data that is reliable and has few gaps. Thus, in the course of this study, we

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will attempt, on the basis of two (02) stations, to analyse climatic parameters such as temperature or relative air humidity and study their impact on the variability of the precipitation regime.

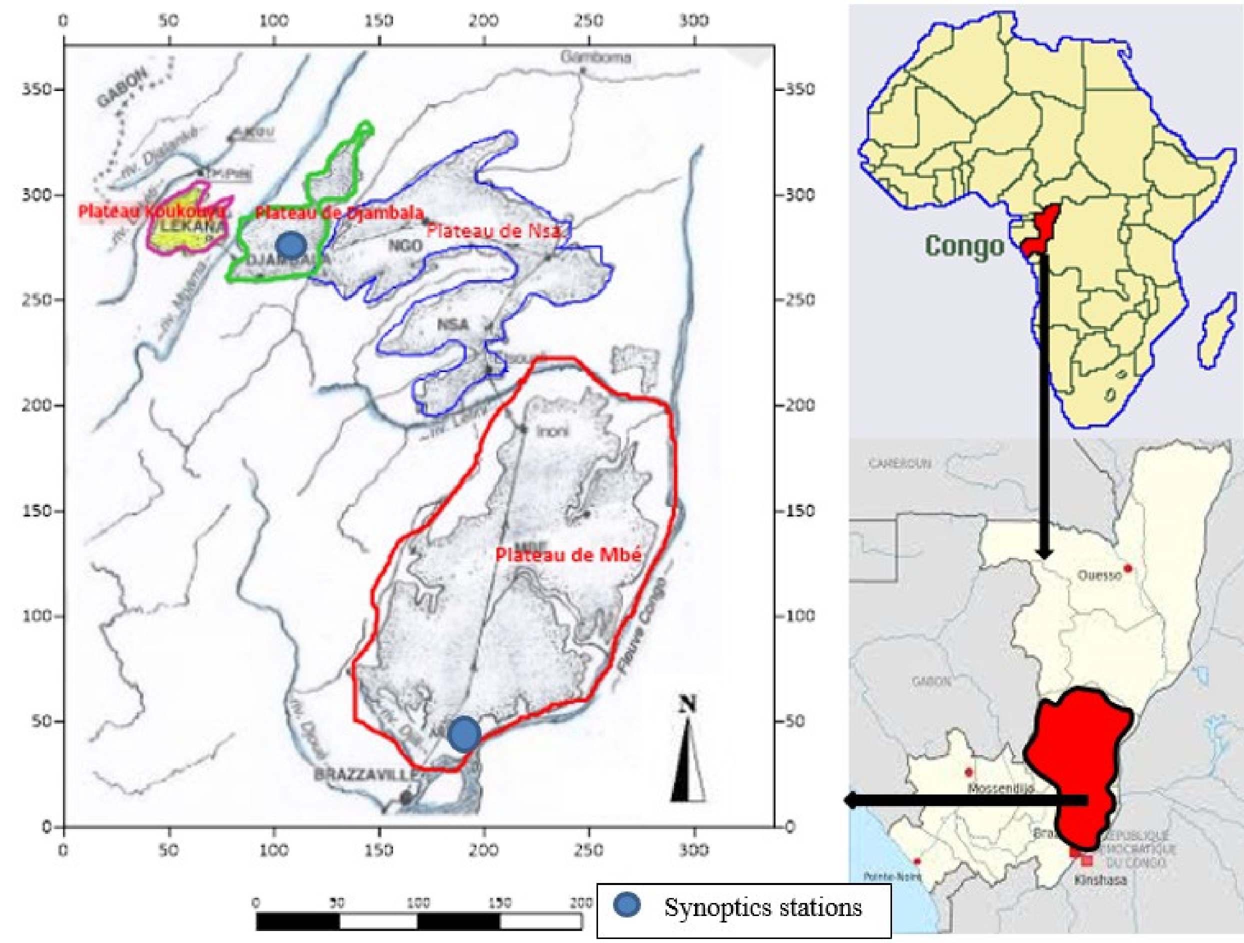


Figure 1:- Geographical context of the study area.

Materials and Methods:-

Equipment:

The material is composed by:

Data available:

The data, at monthly time step, were obtained from the climate-data.org site and from the National Civil Aviation Agency (ANAC) in Brazzaville. They cover the periods 1982 - 2012 and 1987-2016 respectively, i.e. two (02) periods of 30 years, which corresponds to the duration recommended by the World Meteorological Organization for climate analyses (WMO, 2011) on two (02) stations. Synoptic: Brazzaville and Djambala stations. Data quality control consisted of looking for outliers (too high or too low or even negative) using the XLSTAT Pro software (Addinsoft, 2016). But, no aberrant data has been identified. Some missing data has been completed with said software. This control result makes it possible to say that the data series used are homogeneous and of good quality for the analyses envisaged. The rainfall (Pt in mm) is measured using the rain gauge, the temperature (° C) is measured using a thermometer while the relative humidity of the air (RH in %) is measured at using the psychrometer and many other parameters such as wind speed on the ground. On the basis of monthly data, the study of the relative homogeneity of the series was carried out with the non-parametric test known as the Mann-Kendall trend test; this test makes it possible to detect the trend and the years of breakage of the series (Sneyers, 1975 and Vandiepenbeeck, 1995). The temperature (° C) is measured using a thermometer while the relative humidity of the air (RH in %) is measured using the psychrometer and many other parameters such as wind speed on the ground. On the basis of monthly data, the study of the relative homogeneity of the series was carried out with the non-parametric test known as the Mann-Kendall trend test; this test makes it possible to detect the trend and the years of breakage of the series (Sneyers, 1975 and Vandiepenbeeck, 1995). The temperature (° C) is measured using a thermometer while the relative humidity of the air (RH in %) is measured using the psychrometer and many other parameters such as wind speed on the ground. On the basis of monthly data, the study of the relative homogeneity of the series was carried out with the non-parametric test known as the Mann-Kendall trend test; this test makes it possible to detect the trend and the years of breakage of the series (Sneyers, 1975 and Vandiepenbeeck, 1995).

Table 1:- Coordinates of synoptic stations.

Stations	Coordinates (m)		Altitude (m)
	X	Y	
Brazzaville	- 4.23	15.25	313
Djambala	- 2.56	14.766	789

Methods:-

The methodological approach is based on acquisition techniques and data processing:

Data acquisition:-

Climatic factors (Rain, T °, humidity,) synoptic stations of Brazzaville and Djambala are provided by the National Agency of Civil Aviation (ANAC) of Brazzaville. The Brazzaville station is located to the south and Djambala to the northwest of the study area. The climate-data.org site, made it possible to obtain the climatic factors (precipitation, temperatures) of the various localities in the area, and covers the period 1982 - 2012.

Data processing:

a) Climatic parameters:

We calculated the monthly averages on the two (02) stations and on different localities of the study area.

b) Statistical study in Principal Component Analysis (PCA):

A statistical study (Max and min temperature; Max and min relative humidity; Evaporation; Insolation; Wind speed and Flow) using Principal Component Analysis would allow us to observe the impact of precipitation on flows at the Brazzaville station. On the other hand, at the Djambala station, it would make it possible to observe the correlation that exists between climatic factors.

Results and Discussion:-

Evolution of climatic parameters:

a) Variation of average and annual precipitation levels:

The variation curve of the monthly means of precipitation (Figure 2) period 1982-2012 of the four (04) localities, shows that the month of October is the rainiest on the whole, with an average of 251 mm of precipitation while the driest month is July, with 22 mm of precipitation. Individually, the locality of Lékana stands out from the others, with April 286 mm and November 277 mm the wettest. However, July remains the driest month.

For the period 1987-2016 (Fig. 2), the two stations present the same appearance as the localities studied. With 284.2 mm the month of November and the month of July 14.1mm, representing the rainiest and driest month respectively.

It can be noted that on the Djambala and Lékana stations the highest rainfall is recorded. These results confirm the proximity of the locality and the synoptic station.

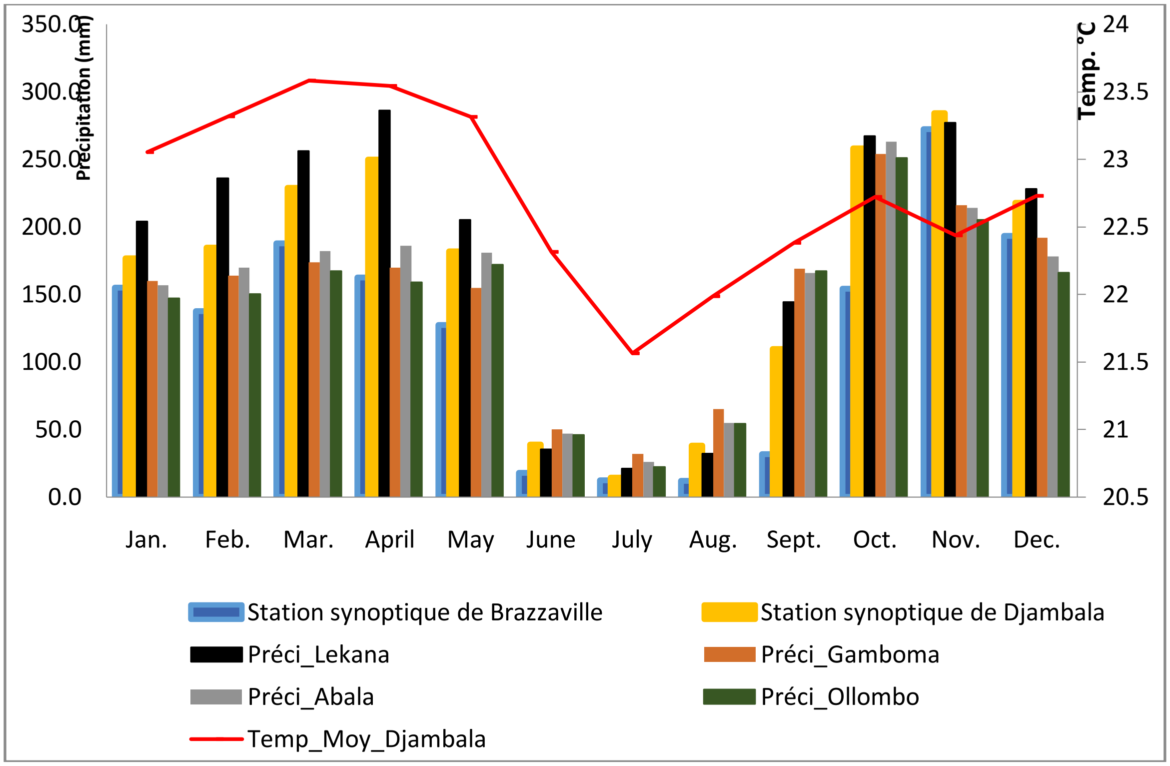


Figure 2:- Evolution of precipitation and monthly average temperature (1982-2012) and (1987-2016).

The analysis of the interannual variation curves of precipitation (Fig. 3) on the synoptic station of Djambala, for a period of 30 years (1987-2016), shows that the year 1988 is the wettest year with precipitation of 3863.6 mm and the year 1991 is the driest with 1615.7 mm. The interannual mean value is 2048 mm and a standard deviation of 402 mm. On the other hand on the synoptic station of Brazzaville (Fig. 3), the year 1990 was the wettest with precipitation of 2001 mm and the year 2015 was the driest with 839.6 mm andaninterannual mean value of 1447 mm and a standard deviation of 260 mm. These results confirm those of certain authors who have shown that the Batéké trays are one of the regions of Congo-Brazzaville where the interannual variability of precipitation is the most pronounced (Laraqueeand al., 2001; Nicholson and Grist, 2001; Samba and Nganga, 2011;Okoolaand, Ambenje, 2003; Samba et al., 1999, 2005, 2008, H. Obami-Ondon and al, 2019).

The two (02) stations (fig. 2), show that the last 30 years (1987-2016), allow to distinguish 2 scenarios:
a first scenario in 2016 which opposes the two stations. Djambala remains the wettest with 2545 mm and Brazzaville with 1100 mm. Characterized by a rainfall deficit;

a second scenario is repeated seventeen years more (2013). But this time Djambala has a rainfall deficit and Brazzaville maintains its variation without any considerable change.

It can be noted that the analysis of the pluviometric heights of the two (02) stations for the period from 1987-2016, shows a decreasing trend on the two stations.

This allows us to say that we are therefore witnessing a significant rainfall deficit which leads us to speak in terms of continuous drought (Bouka and al.Mpounza, 2009).

Inter-annual variability appears to be lower at the Djambala station than at the Brazzaville station, especially since 2000.

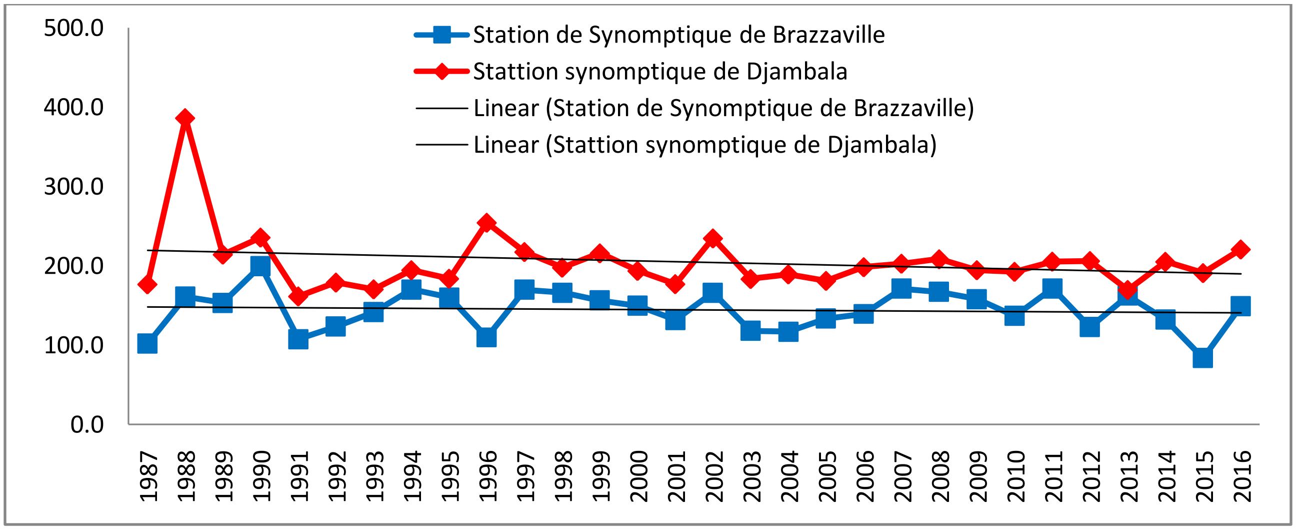


Figure 3:- Evolution of interannual average precipitation on the stations of Brazzaville and Djambala for the period (1987-2016); (source: ANAC de B / ville).

b) Change in monthly, annual and inter-annual temperature averages:
On the 2 stations, the interannual average temperature for the period 1987-2016 (the stations) is 22 ° C. However, that of the localities (climate-data.org) observed are higher with an average of 25.5 ° C. This difference could be explained by the altitude of Djambala which is around 800 m.

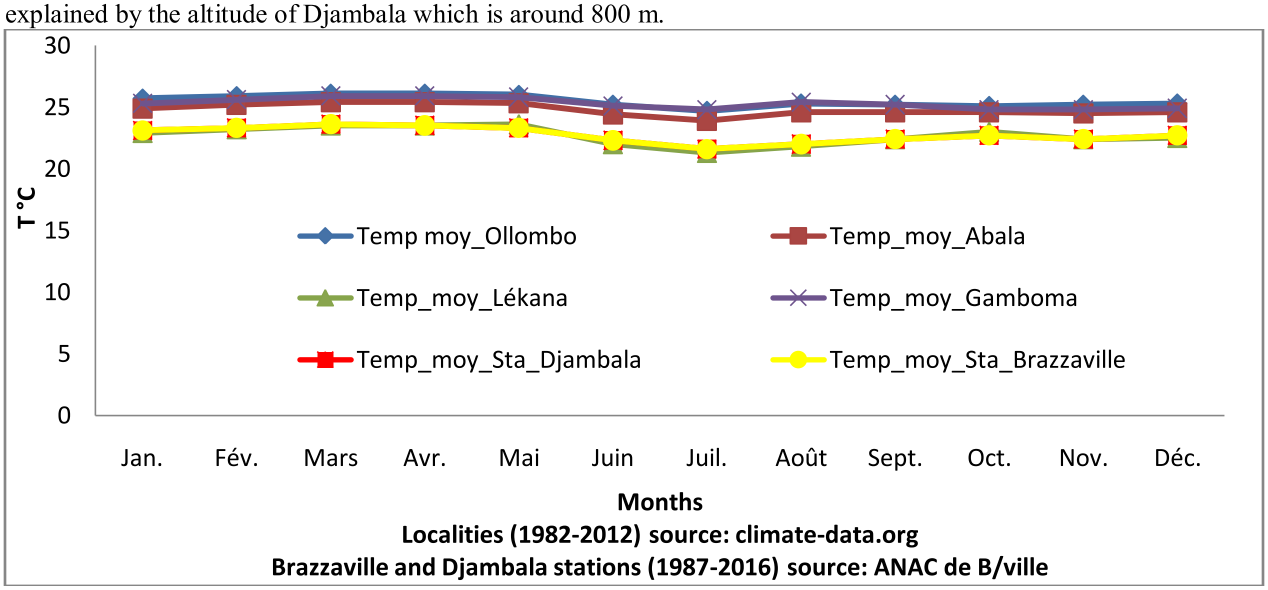


Figure 4:- Variation of monthly average temperatures.

Temperature is a parameter very important in the evaluation of the flow deficit, which enters into the estimation of the water balance. The climate of the study area results in a long rainy season (September-May) and a dry season (June-August) as shown in Figure 2.There are growing trendlines in the period from 1987-2016 as well (Fig. 4). The slopes are in the orders of magnitude (0.52 - 0.65°C) found at the level of the evolution of the temperature of the globe: 0.7 ° C [0.56 - 0.92] (IPCC, 2007). This warming is more felt in urban cities with high population density, thus creating urban heat islands (Bouka and Mpoundza, 2009). The dry season (JJA) during which it was relatively cool, appears increasingly hot in the city of Brazzaville, where the majority of the Congolese population lives (Bouka and Mpoundza, 2009; Laraque, 2001).

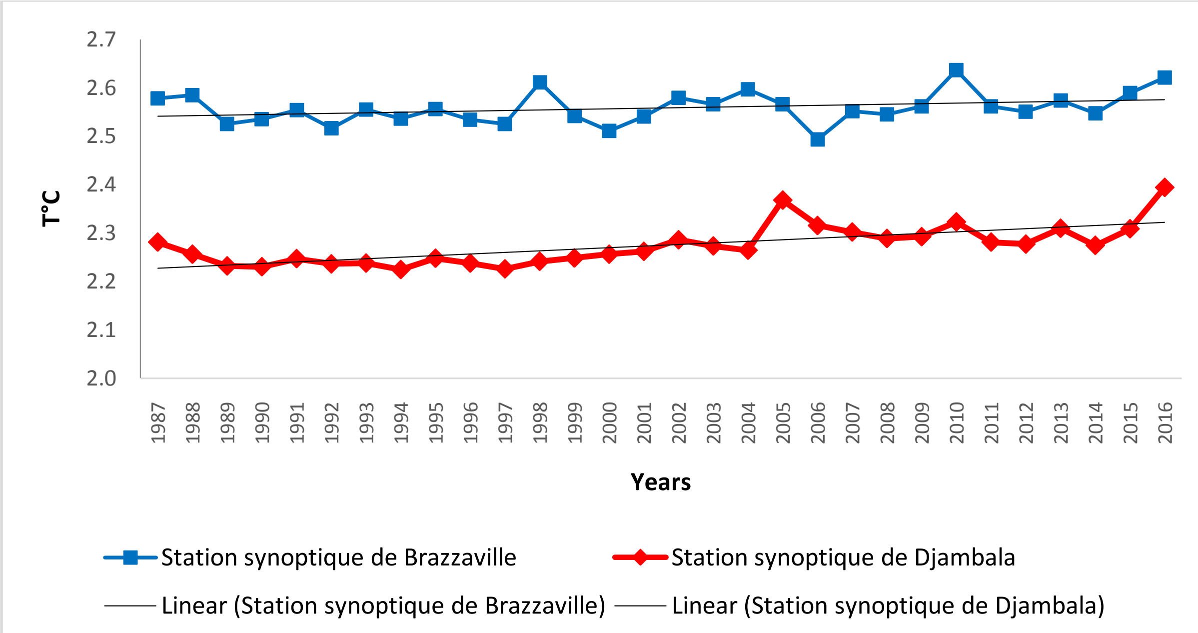
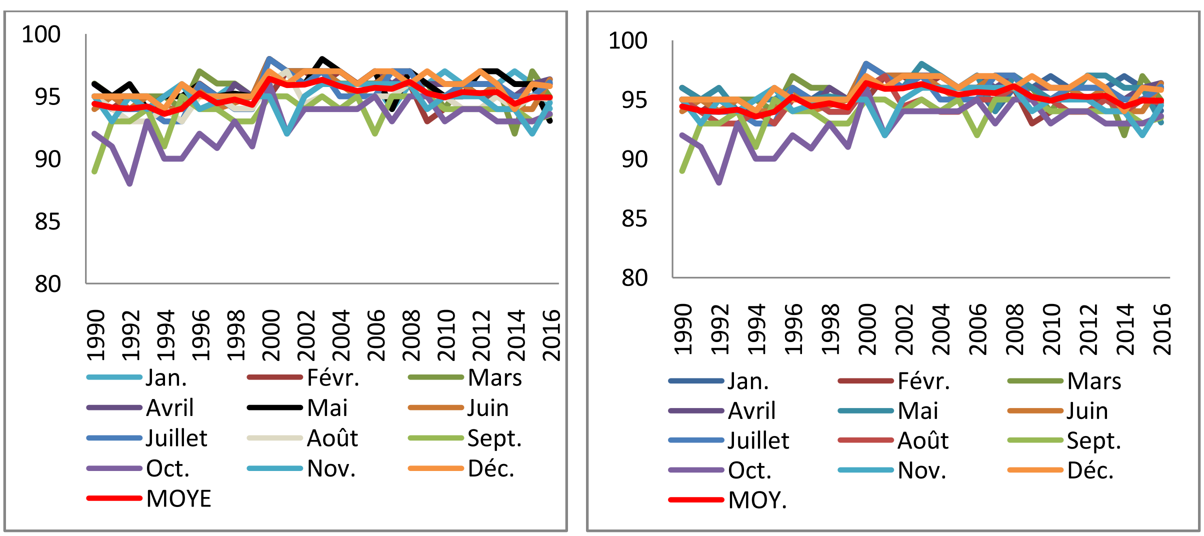


Figure 5:-Change in monthly interannual temperature averages (1987-2016)

c) Relative humidity variations (RH%) monthly interannual mean:
Relative humidity is expressed as a percentage and is defined as the ratio of the amount of water actually contained in the air and the absorption capacity at a given temperature.

Relative air humidity for the period 1990-2016 is high everywhere (Fig. 5); as an annual monthly average, it is equal to 95% on the two stations and presents an increasing curve on the two (02) stations, particularly in September and October (beginning of the wet season).



1- Synoptic station ofDjambala **2- Synoptic station ofBrazzaville**

Figure 6:-Interannual mean relative humidity (RH %) variations at the stations of Brazzaville and Djambala between 1990 and 2016; (source: ANAC de B / ville).

d) Changes in mean monthly interannual evaporation:
The interannual monthly average of evaporation measured under shelter (Fig. 6) on the synoptic station of Djambala (1990-2015), varies between 83.4 mm in 1992 and 29.8 mm in 1994. It is noted that during the months of June, July and August the evaporation undergoes a slight decrease, but it is always high whatever the month. We can see that the monthly variability has decreased since 1990. This is particularly visible for the month of October which shows a continuous decrease (around 15% over the period).

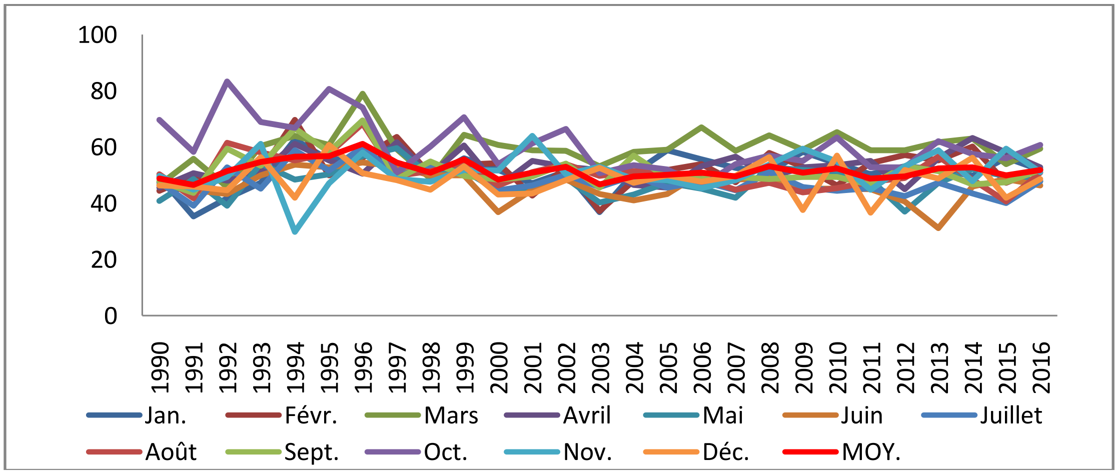


Figure 7:- Variations in interannual monthly average evaporation, source: ANAC de B / ville (1990-2016).

Statistical study in Principal Component Analysis (PCA):
In order to identify the climatic variables associated with the variability of precipitation, the application of the principal component analysis (PCA) method was undertaken on nine (09) annual average variables which are rain, maximum temperature and minimum, evaporation, maximum and minimum relative humidity, insolation, wind speed and flow at the Brazzaville station. The matrix results presented are the correlation matrices and the eigenvalue matrices.

Table 2:- Matrix of correlations calculated between the variables analyzed at the synoptic station of Brazzaville.

Variables	t_max	t_mini	Precipitation	Evapo_piche	Hum_rel_min	Hum_rel_max	Insol	Vit_vent	Debit
t_max	**1**								
t_mini	0.442	**1**							
Precipitation	-0.119	-0.107	**1**						
Evapo_piche	0.294	0.314	-0.386	**1**					
Hum_rel_min	-0.411	-0.118	0.106	0.064	**1**				
Hum_rel_max	-0.323	**-0.605**	0.239	-0.542	0.499	**1**			
Insol	0.472	0.241	0.050	0.179	-0.102	-0.046	**1**		
Vit_vent	0.028	-0.100	-0.260	**0.610**	0.484	0.055	-0.174	**1**	
Debit	0.132	-0.293	-0.045	0.094	0.109	0.176	0.207	0.132	**1**

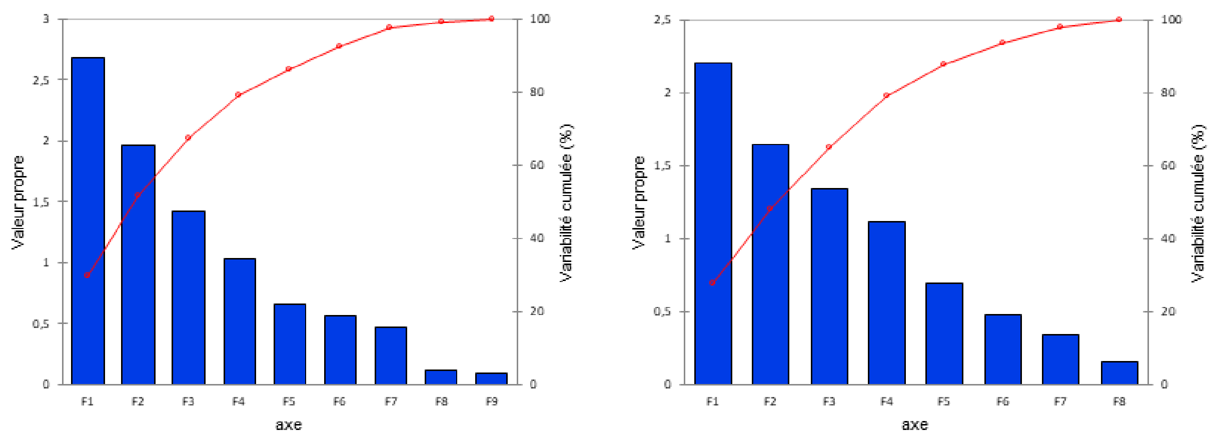
Table 3:- Matrix of correlations calculated between the variables analyzed at the synoptic station of Djambala.

Variables	t_max	t_mini	Precipitation	Evapo_piche	Hum_rel_min	Hum_rel_max	Insol	Vit_vent

t_max	**1**							
t_mini	0.543	**1**						
Precipitation	-0.197	0.040	**1**					
Evapo_piche	-0.356	-0.143	0.005	**1**				
Hum_rel_min	-0.452	-0.248	0.147	-0.147	**1**			
Hum_rel_max	-0.120	0.059	0.143	0.404	-0.381	**1**		
Insol	-0.134	0.044	-0.215	-0.063	0.030	0.149	**1**	
Vit_vent	0.441	0.485	0.288	-0.069	-0.029	-0.047	0.094	**1**

Tables (2 and 3) show that the set of correlation values is relatively weak. Indeed, correlation coefficients are less than 0.70 for the Brazzaville station and less than 0.60 for the Djambala station. It follows that the analyzed variables are not strongly correlated with each other. This significantly reduces the redundancy of information and at the same time justifies the relevance in the choice of these variables to conduct the study.

Figure 8 shows the eigenvalues of each factor at the Brazzaville and Djambala stations respectively. Only the principal components whose eigenvalues are greater than or equal to 1 were considered significant. Only the first four (4) components meet this condition. The results show that the variances expressed by the first four factors are 79.02% in Brazzaville and 79.03% in Djambala. Considering the first three principal components, the expressed variances are 67.57% in Brazzaville and 65.09% in Djambala, ie more than half of the expressed variances. The first three factors therefore contain most of the information relating to the data matrices. But in this case, we are going to work with the first two (02) factors for Brazzaville and Djambala. They express 51.79% and 48.23% respectively.



a) Synoptic station of Brazzaville.
b) Synoptic station of Djambala.

Figure 8:- Eigenvalues of the principal components of the two (02) stations.

The results obtained at the Brazzaville station (Fig. 8a) reveal that temperature, evaporation, precipitation and relative humidity of the air are factors that influence the temporal variability of rainfall variables. In fact, the influence of air temperature in all its components is more evident in the dynamics of atmospheric conditions acting on seasonal rainfall variability due to its very negative correlation with the factor F1. The air temperature is followed by the amplitude of variation of precipitation and relative humidity which, on the other hand, is positively correlated with F1. But the flow does not present a clear situation on these two axes. Finally,

At the Djambala station (Fig. 9b), there is a correlation only around the F1 axis. The variables evaporation and minimum relative humidity are negatively correlated. Temperature and wind are positively correlated.

Regarding the years, we can note that the years 2005-2016 (Fig. 8b) are positively correlated with axis 1. This could allow us to say on the basis of the analysis of the results of figures 2 and 3 there is a general increase in temperature which has been accompanied by a drop in rainfall levels over the past 30 years. These results are generally consistent with those obtained by several authors (Samba 1999, 2008; Paturel, 1998; Servat, 1997, 1998, 1999; Laraque, 1998, 2001;Nguimalet, 2017)

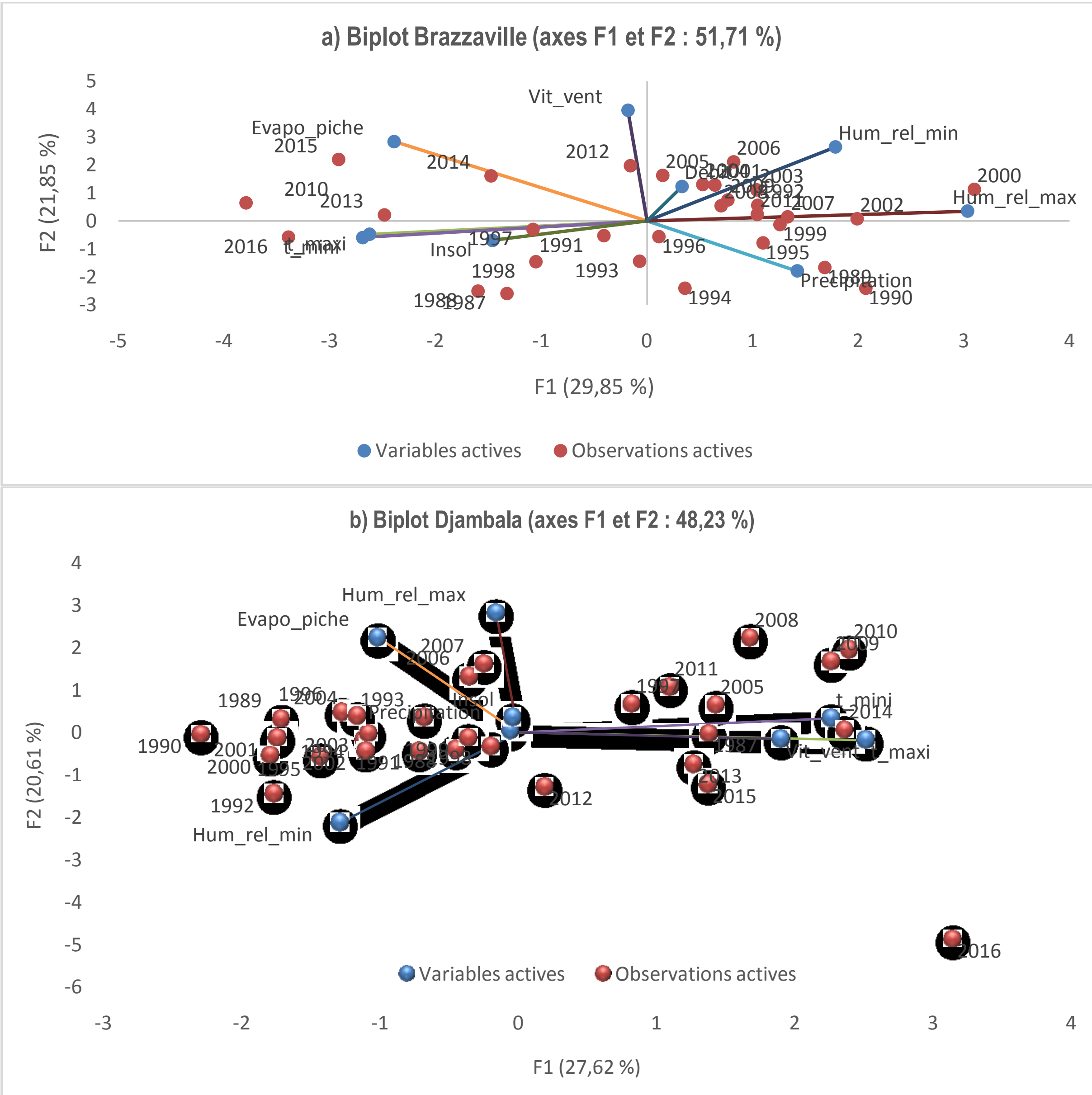


Figure 9:- Spaces of the variables of the factorial designs on the stations of Brazzaville and Djambala.

Conclusion:-

This study made it possible to characterize the main manifestations of climate variability in the Batéké Plateaus for the period from 1982-2012 for the localities and from 1987-2016 for the stations of Djambala and Brazaville in the Republic of Congo. Precipitation varies between 3863.6 mm and 839.6 mm. The analysis highlights a decrease in rainfall levels on the Batéké Plateaux. Interannual relative humidity averages 95%.

The interannual average temperatures vary between 22.6 ° C and 26.4 ° C. The interannual variations of the air temperature show that the air temperature is increasing steadily. Climatic variability is also manifested by a spatiotemporal dynamic of annual rains, a recession in the frequency of rainy days and a reduction in the duration of the rainy seasons. Despite the disturbances of the different seasons of the year, the monthly rainfall regimes have not been modified.

The principal component analysis (PCA) with nine (09) variables made it possible to analyze the factors of temporal variability of seasonal climatic regimes on the Batéké Plateaux. It can be remembered that this statistical study highlights the impact of climate variability on seasonal rainfall patterns. The main factor (F1) is associated with the factors defining the atmospheric conditions. The second factor (F2) does not present any clear situation on the two stations. The factors which influence the variability of seasonal rainfall regimes are the rainfall variables which are influenced by the air temperature as well as the relative humidity of the air. We could say,

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References:-
1. Ardoin B.S., 2004, **Variabilité hydroclimatique et impacts sur les ressources en eau de grands bassins hydrographiques en zone soudano-sahélienne**, Thèse de Doctorat, Université de Montpellier II, France.
2. Ardoin S., Lubès-Niel H., Servat E., Dezetter A., Boyer J.F., 2003, « Analyse de la persistance de la sécheresse en Afrique de l'Ouest : caractérisation de la situation de la décennie 1990 », **IAHS Publication,** vol. 278, 223-228.
3. Faty, A., Kane, A. &Ndiaye, A. L. (2017). Influence de la manifestation climatique sur les régimes pluviométriques saisonniers dans le haut bassin versant du Sénégal. *Revue des sciences de l'eau / Journal of Water Science*, *30* (2), 79–87. https://doi.org/10.7202/1042915ar
4. Kouassi A.M., 2007, **Caractérisation d'une modification éventuelle de la relation pluie-débit et ses impacts sur les ressources en eau en Afrique de l'Ouest : cas du bassin versant du N'zi (Bandama) en Côte d'Ivoire**, Thèse de Doctorat, Université de Cocody-Abidjan, Côte d'Ivoire.
5. Kouassi A.M., Kouamé K.F., Goula B.T.A., Lasm T., Paturel J.E., Biémi J., 2008, « Influence de la variabilité climatique et de la modification de l'occupation du sol sur la relation pluie-débit à partir d'une modélisation globale du bassin versant du N'zi (Bandama) en Côte d'Ivoire », **Revue Ivoirienne des Sciences et Technologie**, vol. 11, 207-229.
6. Laraque A., Mahé G., Orange D., Marieu B., (2001). Spatiotemporal variations in hydrological regimes within Central Africa during the XXth century, J. Hydrol. 245: 104–117.
7. Laraque, A., Maziezoula, B., Orange, D., Olivry, J.C., (1998) « Origine des variations de débits du Congo à Brazzaville durant le XXème siècle. » Variabilité des ressources en eau en Afrique au XXème siècle. Servat, E., Hughes, D., Fritsch, J.M., Hulme, M., Abidjan, Côte d'Ivoire, IAHS. 252: p. 171 – 179.
8. Mpounza M., G. Samba, C. BoukaBiona Et M. Massouangui-Kifouala, 2003 : L'évolution des temperatures dans le Sud du Congo - Brazzaville (1950-1998). *Publication de l'associationInternationale de Climatologie, Vol. 15.*
9. Nguimalet, C. R. (2017). Changements enregistrés sur les extrêmes hydrologiques de l'Oubangui à Bangui (République centrafricaine) : analyse des tendances. *Revue des sciences de l'eau / Journal of Water Science*, *30* (3), 183–196. https://doi.org/10.7202/1044246ar.
10. Nicholson SE., 2001. Climatic and environmental change in Africa during the last two centuries. In: desanker P. (ed.) Africa and global climate change. CR Special 8. Clim. Res., 17, 123-144.
11. O.M.M., 1990, « **Guide des pratiques climatologiques** », vol. 100.
12. Obami-Ondon H., U. GampioMbilou, Raymond Gentil Elenga, Médard NgoualaMabonzo, D. Nkounkou Tomodiatounga, B. Mabiala, 2019. Impact of the Seasonal Variability of the Rains on the Hydrodynamic Operation of the Aquifer Major of the Plateau of Mbe in Pool-Nord in Republic of Congo Brazzaville. *Journal of Scientific and Engineering Research*, 6 (10): 173-184, ISSN : 2394-2630.
13. Okoola RE, Ambenje PG. 2003. Transition from the Southern to the Northern Hemisphere summer of zones of active convection over the Congo Basin. *Meteorology and AtmosphericPhysics*3: 255–265.
14. Paturel J.E., Servat E., Delattre M.O., 1998, « Analyse de séries pluviométriques de longue durée en Afrique de l'Ouest et centrale non sahélienne dans un contexte de variabilité climatique », **Journal des Sciences**

Hydrologiques, **vol.** 43, No.3, 937-945. DOI :10.1080/02626669809492188
15. Paturel J.E., Servat E., Kouamé B., Lubès-Niel H., Ouedraogo M., Masson J.M., 1997, “Climatic variability in humid Africa along the Gulf of Guinea. Part two: an integrated regional approach”, **Journal de l’ Hydrologie, vol.** 191, 16-36.
16. Samba G, MalobaMakanga JD, Mbayi R. 1999. Les saisons des pluies potentiellement utiles (SPPU) sur les plateaux Batéké et sur le plateau des Cataractes en République du Congo. *Publications de*
17. Samba G, Mpounza M. 2005. Application du processus de Markov sur les occurrences des précipitations journalières au Congo-Brazzaville. *CompteRendu Geoscience* 337: 1355–1364.
18. Samba G, Nganga D, Mpounza M. 2008. Rainfall and temperature variations over Congo-Brazzaville between 1950-1998. *Theoretical and Applied Climatolology*91: 85–97.
19. Servat E., Paturel J.E., Kouamé B., Lubès-Niel H., Ouedraogo M., Masson J.M., 1997, “Climatic variability in humid Africa along the Gulf of Guinea. Part I: detailed analysis of the phenomenon in Côte d’Ivoire”, **Journal de l’Hydrologie**, vol. 191, 1-15.
20. Servat E., Paturel J.E., Kouamé B., Travaglio M., Ouédraogo M., Boyer J. F., Lubès-Niel H., Fritsch J.M., Masson J.M., Marieu B., 1998, « Identification, caractérisation et conséquences d’une variabilité hydrologique en Afrique de l’Ouest et centrale », **IAHS Publication**, vol. 252, 323-337.
21. Servat E., Paturel J.E., Lubès-Niel H., Kouamé B., Masson J.M., Travaglio M., Marieu B., 1999, « De différents aspects de la variabilité de la pluviométrie en Afrique de l’ouest et centrale non sahélienne », **Revue des Sciences de l’Eau**, vol. 12, No.2, 363-387. DOI : 10.7202/705356ar.