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CONSEQUENCES OF THE EFFECTS OF CLIMATE CHANGE ON WATER RESOURCES IN A HUMIC TROPICAL ZONE OF CENTRAL EASTERN CÔTE D'IVOIRE

CONSEQUENCES DES EFFETS DU CHANGEMENT CLIMATIQUE SUR LES RESSOURCES EN EAU DANS UNE ZONE TROPICALE HUMIQUE DU CENTRE EST DE LA COTE D'IVOIRE

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ABSTRACT

This study aims to show the impacts of global warming on water resources in the department of Bocanda, located in the central-eastern part of Côte d'Ivoire, in a humid tropical environment. What are the periods of climate change in this locality? Thus, the Pettitt test was applied to the climatic series from 1920 to 2009 of the Bocanda station. This test shows a unique break in the rainfall series in 1968. Thus, a wet period of low temperatures can be distinguished, from 1920 to 1968, where the annual rainfall is abundant, with an annual average of 1270.14 mm. There is also a dry period, from 1969 to 2009, with low rainfall, with an annual average value of 1145.4 mm, and almost all high temperatures. These temperatures increased by 0.60°C on annual average during the dry period and the rate of reduction in rainfall is 10.01% on annual average. It is therefore a case of global warming in this humid tropical environment which results in a decrease in rainfall. The water balance method has made it possible to highlight the impacts of this global warming on the region's water resources. The results show that, in wet periods, real evapotranspiration, which was on average 905.46 mm per year according to Coutagne's method, is reduced to 852.74 mm in dry periods, a reduction of 5.82%. Annual average runoff, which was 87.63 mm in the wet period, is reduced to 79 mm in the dry period, a reduction of 9.0%. Finally, the effective infiltration in wet period is 277.04 mm, which is reduced by 22.88% in dry period.

Keywords: Climate change, water resources, Côte d'Ivoire.

RÉSUMÉ

Cette étude vise à montrer les impacts du réchauffement climatique sur les ressources en eau dans le département de Bocanda, situé au centre-est de la Côte d'Ivoire, en milieu tropical humide. Quelles sont donc les périodes du changement climatique dans cette localité ? Ainsi, le test de Pettitt a été appliqué à la série climatique de 1920 à 2009 de la station de Bocanda. Ce test montre une rupture unique en 1968 dans la série pluviométrique. On distingue donc une période humide de basses températures, qui va de 1920 à 1968, où les pluies annuelles sont abondantes, avec une moyenne annuelle de 1270,14 mm. Il y a aussi une période sèche, évoluant de 1969 à 2009, à pluviométries faibles, avec une valeur moyenne annuelle de 1145,4 mm, et à températures presque toutes élevées. Ces températures ont augmenté de 0,60°C en moyenne annuelle en période sèche et le taux de réduction de la pluviométrie est 10,01 % en moyenne annuelle. Il s'agit donc d'un réchauffement climatique dans ce milieu tropical humide qui a pour conséquence, la baisse de la pluviométrie. La méthode du bilan hydrologique a permis de mettre en évidence, les impacts de ce réchauffement climatique sur les ressources en eau de la région. Les résultats montrent qu'en période humide, l'évapotranspiration réelle qui était en moyenne annuelle de 905,46 mm selon la méthode de Coutagne, est réduite à 852,74 mm en période sèche, soit une réduction de 5,82%. Le ruissellement moyen annuel qui était 87,63 mm en période humide, est réduit à 79 mm en période sèche, soit une réduction de 9,0%. Enfin, l'infiltration efficace en période humide est 277,04 mm, celle-ci a subi une réduction de 22,88% en période sèche.

Mots clés : Changement climatique, ressource en eau, Côte d'Ivoire.

INTRODUCTION

The studies on the impact of climate change on water resources have been of interest to the global community following several large-scale climate events. These include the drought that has affected the two tropical bands of our planet, especially the Sahelian countries of west Africa, since the 1970 (Sircoulon, 1976). In addition to this drought, the World Meteorological Organization's (WMO) findings on global warming, above 0.7°C, since the beginning of the last century and the recent El Niño phenomena (Cantat, 1995; Nicholls, 1988). The reality of climatic variability, whose causes are difficult to identify, is manifested in some countries by long periods of drought with negative effects on the hydrological cycle, the environment and socio-economic activities. The drought that has been raging for about thirty years in the Sahelian countries has extended to the humid countries bordering the Gulf of Guinea, with serious consequences: reduced rainfall, lower piezometric levels and lower river flows (Savané and al., 2001; Servat and al., 1998). A downward trend in rainfall was observed in west Africa from the late 1960 and early 1971 (Bricquet and al., 1997; Hubert and al., 1987; Mahé and Olivry, 1995; Servat and al., 1998; Doumounia and al, 2020). The input deficit has been estimated at 16 percent for tropical Africa.

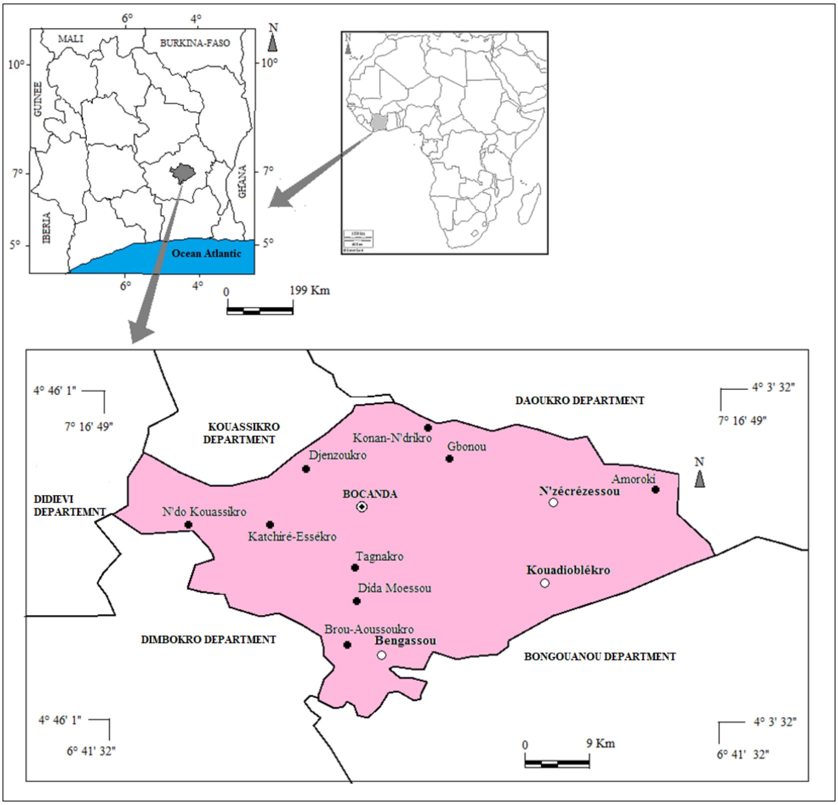

Figure 1: Geographic location of the Department of Bocanda

In Côte d'Ivoire, the studies on global warming have shown that a trend towards drought has manifested itself in the north, center and south from the 1968's onwards (Brou, 1997; Assemian, 2013; Kouao and al, 2020). This phenomenon did not occur homogeneously over time; it first affected the north, then gradually spread towards the center and finally to the coast (Kouassi 2008). The characterization of global warming and its impact on water resources using statistical tests and the water balance are the major objectives of this study in Bocanda department. It is therefore a question of highlighting the periods of breakdowns and assessing their impacts on the components of the water cycle. Bocanda is located in the central-eastern part of Côte d'Ivoire, in the humid and forested tropical zone, precisely between longitudes 4° 03' 32" and 4° 44' 01" west and latitudes 6° 41' 32" and 7° 16' 44' north (figure 1). Its plateau relief, with an average altitude of 320 m, generally rests on crystalline and metamorphic rocks, composed of schists and granite. The aquifer is a basement, with an altered horizon at the top and below, a fissured horizon and healthy rock. The forest vegetation has undergone a deep degradation for the cultivation of cocoa, coffee, rubber, oil palm and food crops. The current total absence of primary forest has had an impact on the local climate. The total surface area of this department is 2594 km^2, with a perimeter of 259.2 Km.

MATERIALS AND METHODS

Climatic data were provided by the « Société d'Exploitation et de Développement Aéroportuaire, Aéronautique et Météorologique » (SODEXAM). It is data from the station of Bocanda in which we have the rainfall series, temperatures, relative humidity, wind speeds, abacuses and corrective factors of the region from the period 1920 to 2009. The topographic maps (scale: 1/50000) were provided by CCT/BNETD. The software used for the processing is: Khronostat provided by IRD and Excel for statistical studies and graphical representations. Finally, the MapInfo 11 software was used to produce the maps. The statistical test applied to highlight the climate changes in the Bocanda region is the pettitt test (Pettitt, 1979). In fact, a break is defined as a change in the probability law of the random variables whose successive realizations define the time series under study (Servat and al, 1998). It makes it possible to highlight the different climatic variations in the series. Pettitt's test consists in decomposing the main series of N elements into two sub-series at each instant t between 1 and N-1. The main series presents a break at time t, if the two sub-series have different distributions. The Pettitt's variables (U) are defined by the following equation (1):

$$U = \sum_{\substack{0 \le i \le m \\ 0 \le j \le m}} D(i, j) \tag{1}$$

where D(i,j) = sg n (xi – xj)

s g n (x) = 1 if x > 0

s g n (x) = 0 if x = 0

s g n (x) = -1 if x < 0

The probability (Prob) of exceeding a k value is defined and makes it possible to assess the importance of the break.

Prob (kn > k) ≈ 2 exp / Prob (kn > k) ≈ 2 exp (-6 k2/n3+n2)

The null hypothesis is that there is no break in the N size series. If the null hypothesis is not rejected, an estimate of the date of the break is given at this moment, defining the maximum in absolute value of the variable U.

The annual water balance method (P = ETR + R + Ie) has been applied to estimate the components of water resources (Kouassi, 2008; Adja, 2009; Assemian, 2013). Here, P is the annual rainfall (mm), ETR is the real evapotranspiration (mm), R is the surface runoff (mm) and Ie is the effective infiltration (mm). For the calculation of ETR, we applied

Coutagne's method. According to Coutagne, (Alassane, 2004), (Lekrine, 2015) and (Belhadj, 2017), ETR can be estimated by the following equation 2:

$$ETR = P - XP^2 \qquad (2)$$

with:

$$X = \frac{1}{0.8 + 0.14t}$$

Where:

P: average annual precipitation (m);

t: mean annual temperature (°C);

ETR: real evapotranspiration (m).

However, Coutagne's formula is applicable only if the following condition is satisfied:

$$1/(8.X) < P < 1/(2.X).$$

Once the ETR has been calculated, the total annual runoff (R) must now be determined. Generally speaking, on a given watershed or in a given localitie, the runoff coefficient (C) is the ratio of the volume of runoff water R by the volume of precipitated water P (Youan Ta, 2008; WEB1, 2018). We then have the following equation (3):

$$R = C.P \qquad (3)$$

The commonly accepted values for the runoff coefficient C are: Woodlands as the study area: C = 0.05 to 0.1 (Youan Ta, 2008; WEB2, 2018). This coefficient is evaluated at 6.79%, so 0.0679 according to M. Youan Ta, 2008), in the N'zi basin of which the study area is part. Finally, for the calculation of the annual effective infiltration (Ie), Ie=P-(ETR+R) is deducted. Once the components of water resources have been calculated, graphical representations and statistical analyses are made according to the periods of breaks in order to understand their evolution.

RESULTS AND DISCUSSION

Results

Highlighting climate change

The annual rainfall series from 1920 to 2009 of the Bocanda station, which has been analyzed, shows a unique break in 1968. For this Pettitt test, the break is identified at the 99% confidence level, with a probability of exceeding the critical value of the test equal to 7.75 $.10^{-3}$ (Figure 2). Indeed, the curve of the variable U of the Pettitt test shows an increasing phase from 1920 to 1968 and a decreasing phase from 1968 to 2009 (figure 3).

These phases are separated by a peak of amplitude in 1968. The increasing and decreasing parts express the spread over two different climatic periods. Two periods can thus be distinguished. A wet or humid period from 1920 to 1968 where the average rainfall and temperatures are respectively 1272.14 mm and 25.62°C and a dry period from 1969 to 2009 where the average rainfall and temperatures are 1145.4 mm and 26.22°C (Table 1).

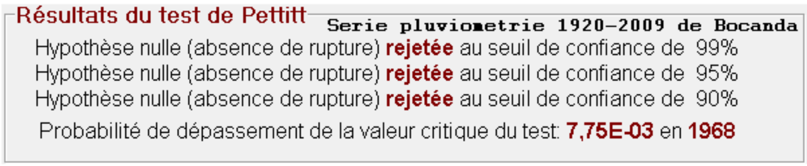

Figure 2: Numerical results of the Pettitt test

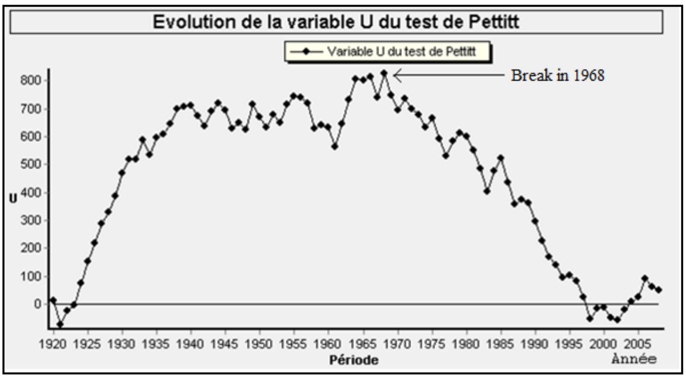

Figure 3: Pettitt's test on the rainfall series 1920-2009

Variability of water resource components

The study of the correlation between real evapotranspiration calculated using Coutagne's method and rainfall shows a strong correlation, with a coeficient $R^2 = 0.9827$ over the two periods (figure 4). This shows that the real evapotranspiration in this locality depends essentially on rainfall. Heavy rainfall systematically leads to high real evapotranspiration.

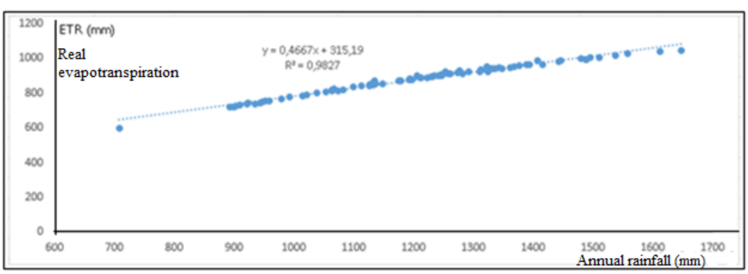

Figure 4: Correlation between annual evapotranspiration and annual rainfall

The average values of the water resource components were calculated during wet and dry periods and recorded in Table 1. The results confirm the evolution of trends over the two periods. Indeed, in the wet or humid period, the average annual ETR is 905.46 mm, in the dry period it is 852.74 mm, a reduction of 5.82%. The average annual runoff in the wet period is 87.63 mm. In the dry period, this value is 79 mm, a reduction of 9.0%. The average annual effective infiltration in wet period is 277.04 mm, while in dry period, its value is reduced to 213.61 mm, a reduction of 22.88%. Global warming in the Bocanda county has resulted in the reduction of water resources since 1968 in the Bocanda county.

Table 1: Average annual values of the components of water resources in the two periods

Water resource and temperature	Wet Période 1920-1968	Dry periode 1969-2009	Reduction percentage (%)
P (mm)	1270.14	1145.39	10.01
ETR (mm)	905.46	852.74	5.82
R (mm)	87.63	79	9.02
Ie (mm)	277.04	213.61	22.88
Température moyenne (°C)	25.62	26.22	Augmentation de 0.60

The graphs showing changes in annual runoff and effective infiltration are shown in Figures 5 and 6. In wet periods, there is an upward trend in runoff values almost exceeding the average value for the period 1920 to 1968. In the dry period, there is a decreasing trend, with almost all values below the average. At the level of effective infiltration, we also have the same trends. In fact, in wet periods, effective infiltration is almost all above average, while in dry periods these values are low. Global warming has led to a significant decrease in surface and ground water resources.

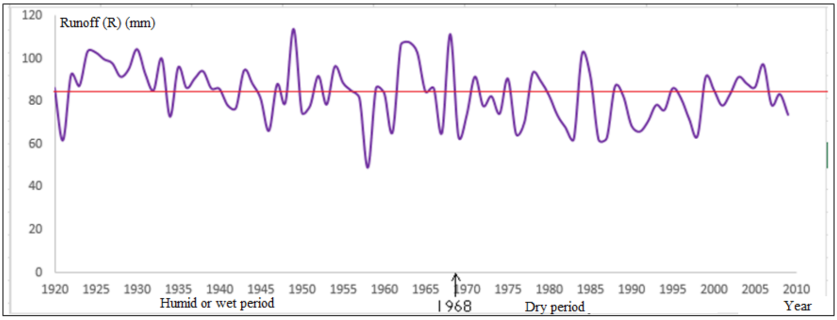

Figure 5: Evolution of average annual runoffs

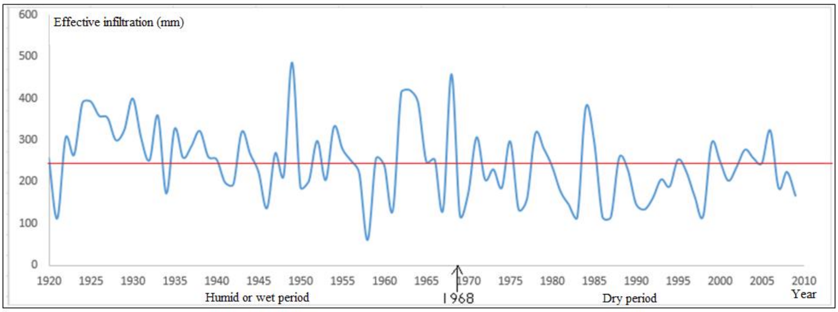

Figure 6: Evolution of annual average effective infiltrations

DISCUSSION

The break date obtained for the rainfall series, according to the Pettitt test is 1968. This break year fits well with the break period of most rainfall stations in west Africa, particularly in Côte d'Ivoire, between 1966 and 1972 (Brou, 1997; Hubert and Carbonnel, 1987; Hubert and al, 1987; Brou, 1997; Lubert-Niel and al, 1998; Servat and al, 1998; Bardion, 2004; Kouame and al, 2014). The average rainfall deficit is 10.01%. It is practically of the same order of magnitude as those obtained by (Moron, 1996), (Servat and al, 1998) and (Meddi and Meddi, 2009) in the Sahelo-Sudanian regions. This similarity in climate variability is said to be global in scale, as it also occurs in some areas of the Pacific (Merle, 1995). Moreover, this decrease in rainfall is accentuated by an increase in air temperature in the Bocanda region; this is in line with a trend of increasing temperatures in the regions between the two hemispheres of the order of 0.08°C .10 $years^{-1}$ (Adiaffi, 2008). This has thus led to a deregulation of the migration mechanism of the intertropical front which determines the seasonal rhythm in west Africa (Adiaffi, 2008). It cannot also be excluded that the increase in temperature and the decrease in rainfall are also locally linked to the regression of evergreen dense forests (effects linked to albedo and less evapotranspiration). The destruction of forest areas for plantations and deforestation has ended up transforming the forest into savannah in the department of Bocanda. CO_2 absorption is reduced. In addition, heavy deforestation in a locality also results in a drop in rainfall.

CONCLUSIONS

Like most countries in the tropical zone, Côte d'Ivoire is not immune to the effects of global warming. This study conducted in its central-eastern part, precisely the department of Bocanda, illustrates this phenomenon and presents its impact on water resources. Indeed, the Pettitt test shows a break in 1968 in the rainfall series from 1920 to 2009. They highlight a wet period and low temperatures, between 1920 and 1968, when the rainfall was abundant, with an annual average of 1270.14 mm. There is also a dry period and high temperatures from 1969 to 2009, with an annual average of 1145.4 mm. This dry period is characterized by a decrease in average annual rainfall of about 10.01%. The components of the water cycle, have undergone a very considerable reduction as a result of this global warming. Real evapotranspiration (ETR) in wet periods is on average 905.46 mm per year, it is reduced to 852.74 mm in dry periods, a decrease of 5.82%. Runoff in wet periods is 87.63 mm, in dry periods, it is 79 mm, a reduction of 9.0%. Finally, effective infiltration in wet periods is 277.04 mm, in dry periods it is reduced to 213.61 mm, a decrease of 22.88%. Such hydroclimatic irregularities can have significant impacts on biodiversity.

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