Impact of Climate Variabilty on Water Resources And Population Health in the South Eastern Coastal Area of Côte d'Ivoire

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doi: 10.19044/esj.2016.v12n35p319 URL:http://dx.doi.org/10.19044/esj.2016.v12n35p319

Abstract

The present study evaluates the impact of climate variability on water resources and population health in the coastal area of Cote d'Ivoire between Abidjan and Aboisso. First, hydroclimatic methods (Nicholson index) and statistical tests (Pettitt test, Hubert segmentation) were used for variability characterisation. Then, Thornthwaite Water balance method was used to evaluate water availability for aquifers recharge. Coefficient depletion method was also used to assess the impact of climate variability on surface water resources. The relationship between diseases occurence (AhigbeKoffikro and Samo) and rainfall pattern was evaluated through descriptive method.

The results revealed important fluctuations of water resources levels at that time. The relationship rainfall-runoff showed with synchron trend that rivers flows regime was linked to rainfall. The impact on groundwater resources was explained by deficit of infiltrated water of about 35.49% and 22.61% after 1982 break at Abidjan airport and Bingerville stations respectively.

Concerning health, 63% of malaria cases was observed against 2.85% for diarrhoea and 2.35% for helminthiasis. There was a strong relationship between rainfall and the diseases (malaria and diarrhoea).

Keywords: Climate variability, water resources, malaria, diarrhoea, helminthiasis, coastal area, Côted'Ivoire

Introduction

The climate variability and changes questions have been placed some years ago in focus of scientist's preoccupations and policies decisions in the world due to their immediate and lasting repercussions on the natural middle and man (Kouassi et al., 2010). Present climate change effects have been translated by the climatic rise, i.e. the rainfall weakness (GIEC, 2013). Decline trend of rainfall has been observed in West Africa at the end of 1960's and at the beginning of 1970's until 1990 decade (Mahe & Olivry, 1995; Bricquet et al., 1997; Servat et al., 1999). However, proved consequences of climate variability have made it to be considered today like one of the most serious threats of the lasting development of developing countries like Côte d'Ivoire. In Cote d'Ivoire, several studies showed rainfall deficit during the last decades with marked breaks at the beginning of 1970's years with regards to the rainfall and rivers flows (Paturel et al., 1995). Subsequently, rainfall scarcity and the decrease in rainfall contributions to surface water have negative consequences on the environment (Bigot et al., 2005; Adja, 2009) and on human activities (agriculture, breeding, fishing, energy production, etc.). Additionally, the decline of water resources have been noted by some authors in the north, the center, and the south-west of Côte d'Ivoire (Adja, 2009; Kouakou, 2011; Soro et al., 2011; Kouassi et al., 2013). Although there is a large knowledge of the effect of climate variability on water and other natural resources, there is still a lack of information on its actual impact on human health, especially in the coastal areas of Côte d'Ivoire. It is in this context that this present study was initiated to evaluate the climate variability effect on groundwater resources and the population health of the coastal area in the South-East of Côte d'Ivoire.

Description of the Study Area

Geographical Context

The study area is located in the South-East of Côte d'Ivoire between longitudes 3°00 and 4°15 West and latitudes 5°00 and 5°30 North. It covers Abidjan, Grand-Bassam, Bonoua, Adiaké, and Aboisso regions. Also, it covers a total land of about 7.717 22 km^2. It is surrounded by Alépé department in the North and the North-east, by Songon commune in the West, and by the Altantic Ocean in the South (**Figure 1**).

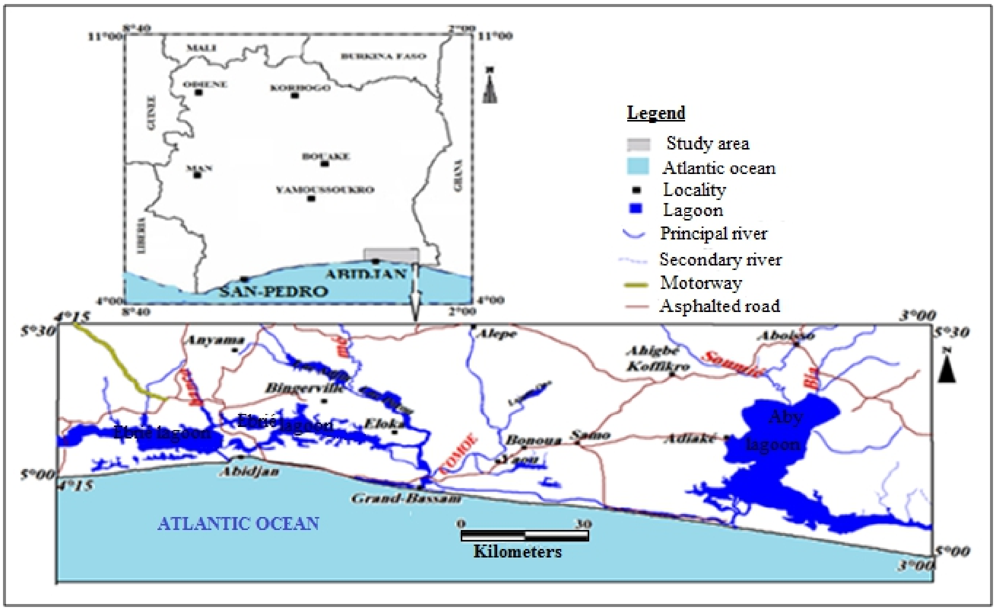

Figure 1. Location of the study area

This area is one of the most populated in Côte d'Ivoire (about 6 millions inhabitants). This is mainly because of the population migration due to 2002 political crisis and the concentration of agricultural labour and industries ((PALMCI or Palm of Côte d'Ivoire, PALMAFRIQUE, AGRIVAR or Agro-Industry Varied).

Therefore, the study area belongs to the equatorial climate of transition which is known as calledattéen with two rainy seasons and two dry seasons.

Geological and Hydrogeological Context

The study area is covered at 90% by sedimentary formations in the south and 10% by bedrock crystalline formations at the north and north-east. Sedimentary formations is made up of sands, clays and ferruginous sandstones of Mio-Pliocene old (Terminal Continental), marine sands, vases, and the washed sands of old Quaternary (Holocene).

Bedrock paleoproterozoic formations consist of biotite granite, metaarenites, biotite metagranodiorite and hornblend, metamonzogranite and biotite metamonzonits, metadiorites and metatonalites, chlorit schistes and amphibols, and biotite smooth gneisses in some places (Papon & Lemarchand, 1973; Soro, 1987; Dibi et al., 2004; Adiaffi, 2008). Therefore, the geological formations are illustrated in **figure 2** below.

Based on hydrogeological plan, one can distinguish between Quaternary aquifers, Terminal Continental, and those of Maestrichian in the the sedimentary watershed (Guerin-Villeaubreuil, 1962; Leroux, 1978; Aghui & Biémi, 1984; Oga, 1998), alterites aquifers, and fractured aquifers in the bedrock.

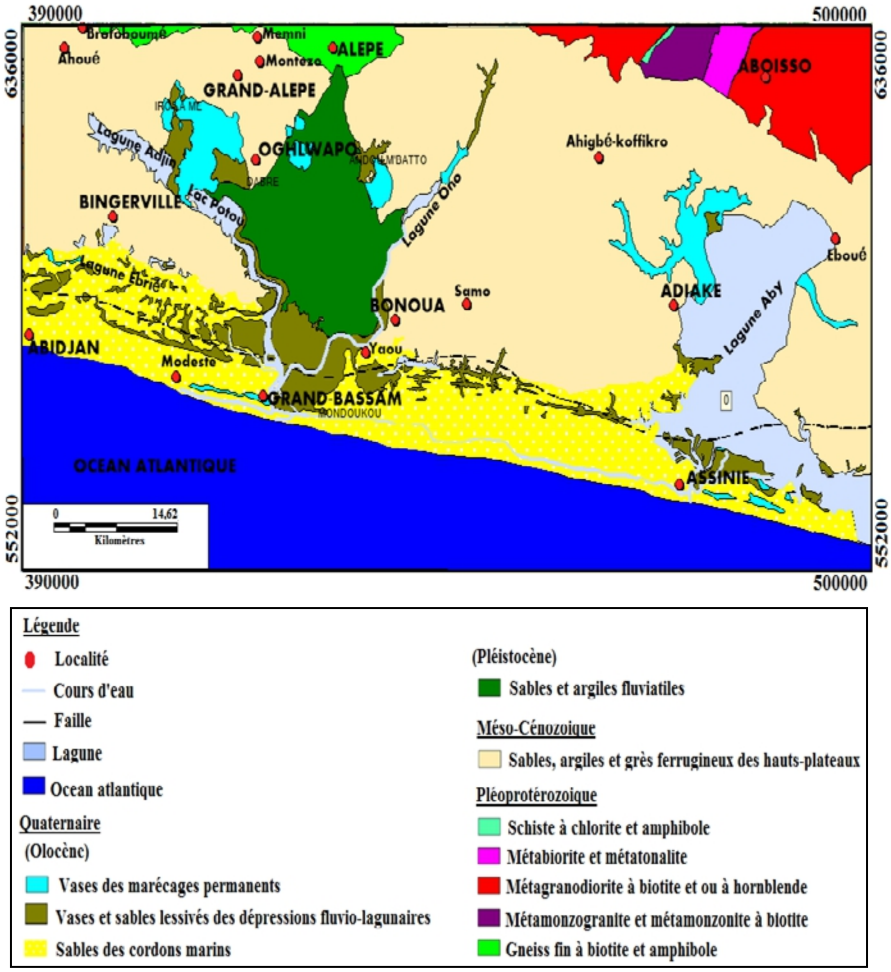

Figure 2. Geological formations of study area

Material and Methods

Material

Cartographic Data

Geological maps of Grand-Bassam and Abidjan at 1/200 000 scale was established respectively. Also, Geological Direction (1992) and the remote sensing and cartography center (CCT, 2012) were used.

Hydroclimatic and Hydrological Data

The climate data (rainfall and mean monthly temperatures) of four weather stations were collected from Society of Development Aeroportuary, Aeronautic and Meteorological (SODEXAM). However, it is the stations of Abidjan-airport (1936-2012), Adiake (1945-2014), Anonkoua Koute (1950-2002), and Bingerville (1960-2012).

Concerning hydrological data, there were daily river flow data from the hydrometric station which were collected from ONEP (National Office of Potable Water) (**Figure 3**).

Health Data

Two villages, Ahigbe Koffikro and Samo, located between Grand-Bassam and Aboisso were selected as reference sites to study population's heath (**Figure 3**). These secondary data were collected from archives (health registers) of health centers of these localities. These health data was recorded between 2012 and 2014, and they are related to malaria, diarrhoea, helminthiasis, yellow fever, and dengue.

Data Processing

The data were processed using MapInfo 8.0 for differents thematic maps realisation and Khronostat 1.01 softwares for heteregenous study (breaks) in the chronological dataset.

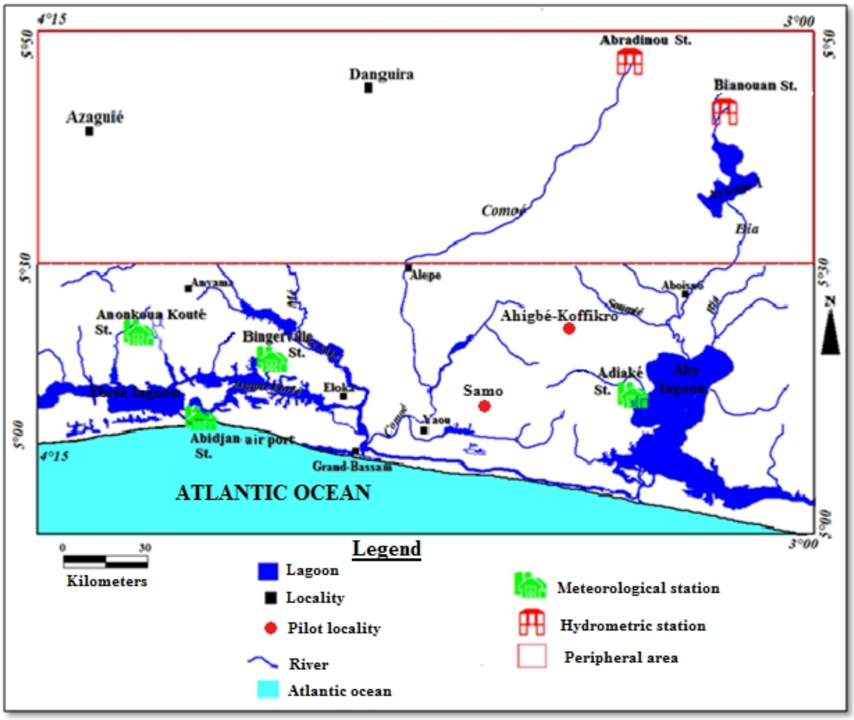

Figure 3. Geographical location of data sites

Methods

Climate Variability Characterization

Method of Rainfall Indexes or Nicholson Index

It is used to determine the number of deficit and surplus year. Thus, it is used to identify wet, normal, and/or dry periods from rainfall dataset. This rainfall index was computed using **equation 1** below (Nicholson, 1993):

$$\mathbf{I}_i = \frac{(\mathbf{Xi}-\bar{\mathbf{X}})}{\boldsymbol{\sigma}} \qquad \textbf{Eq (1)}$$

Where:

- I_i: Rainfall index;
- X_i: Height quantity of rainfall in the year i (mm);
- $\bar{X}$: Mean height quantity of rainfall on the study period;
- σ: Standard deviation of height quantity of rainfall on the study period.

Statistical Methods for Breaks Detection

Pettitt Test

Pettitt test determines the most significant break into chronological hydroclimatic dataset. The test input work supposes that for all inst and t comprised between 1 and N, chronological dataset (X_i) for i=1 to t and t+1 to N belong to the same population. This test is based on the $U_{(t,N)}$ variable calculation defined by equation 2:

$$U_{t,N} = \sum_{i=1}^{t} \sum_{j=t+1}^{N} Dij \qquad \textbf{Eq (2)}$$

with Dij = sgn(Xi-Yi) ;

like (Z) = 1 si Z$>$ 0 ; 0 si Z = 0 et -1 si Z$<$ 0

Hubert Segmentation Procedure

Hubert segmentation procedure divided dataset chronological in "m" segments. Also, the mean calculated on all segment is significantly different from the mean of (or the) segment (s) neighbour (s). The Standard quadratic Dm between the segmentation which was considered is given by equation 3:

$$\boldsymbol{D_m = \sum_{k=1}^{m} d_k} \textbf{Eq (3)}$$

ou:

$$d_k = \sum_{i=i_{k-1}+1}^{i=i_k} (x_i - \bar{x}_k)^2$$

Study of Climate Variability Impact on Surface Waters

The impact of climate variability on surface water was assessed using coefficients of depletion by mean of dichotomic method and water volumes quantification mobilised by the aquifers (Fadika et al., 2008; Kanohin et al., 2009).

Coefficient of Depletion Calculation

The coefficient of depletion (k) was determined by Maillet method which was approved by dichotomical resolution proposed by Savane et al. (2001). Thus, the mathematical expression of depletion is given by equation 4:

$$\mathbf{Q_t = Q_0 e^{-kt}} \quad \textbf{(Eq. 4)}$$

Where:
Q_t = flow at given time;
Q_0= initia flow (flow at beginning of depletion);
t = time expresed in days;
k = Maillet coefficient of depletion.

Therefore, this can be obtained by resolution as shown in the equation 5 below:

$$\mathbf{\frac{e^{-kt}}{k} + \frac{V}{Q_0} - \frac{1}{k} = 0} \quad \textbf{(Eq. 5)}$$

Where:
V = water volume flow at each time (m^3).

Water Volume Mobilised Calculation

The water volume mobilised by all the aquifers was computed from the integration of equation 6 formula on the interval 0 to +∞:

$$\boldsymbol{V_{mobilized} = \int_0^t Q_0 e^{-kt} dt = \frac{86400 * Q_0}{k}} \quad \textbf{(Eq.6)}$$

Where:
Q_0= Initial flow (flow at the beginning of depletion), expressed by m^3/s;
k = Maillet coefficient of depletion, expressed in j^{-1}.

Study of Climate Variability Impact on Groundwater

The estimation method of aquifers recharge by water balance was used to evaluate climate variability impact on groundwater resources. The water balance establishment passes through the determination of some parameters as potential evapotranspiration (ETP), real evapotranspiration (ETR), runoff (R), and infiltration (I) which strongly influenced climate factors.

In this study, the infiltration was the parameter used to evaluate aquifers recharge. It was based on its pluri-decades fluctuations link to those of rainfall that climate variability impact on groundwater resources has been highlight. Many methods have been used for water balance calculation (Thornthwaite, Penmam, Turc, Courtagne, etc.). Thornthwaite method was used in this study because as an input, only rainfall and temperature data were fully available at Abidjan and Bingerville weather.

Study of Climate Varability Impact on the Population's Health

An epidemiological study was also conducted in two tests villages (Ahigbé-Koffikro and Samo). According to WHO, the epidemiology is the study of the distribution and determinants of health-related states or events (including disease), and the application of this study to the control of diseases and other health problems (OMS, 2015)

Differents methods have been used to conduct epidemilogical study. Monitoring and descriptive studies have been used to study the distribution, while analytical studies have been used to identify decisives (causes, risk factors).

In the present study, a descriptive study was done to describe diseases schemes appearance according to time, place, and people. This study is an ecological study which allows the establishment of a correlation between a particular climate event (temperature and rainfall variation) and some diseases (malaria, diarrhoea, helminthiasis, yellow fever, and dengue) for Ahigbé-Koffikro and Samo populations over a three years period (2012, 2013, and 2014). Therefore, the purpose was to assess the possible relationship between monthly rainfall and the number of monthly cases of malaria, diarrhoea, helminthiasis, yellow fever, and dengue. Malaria, yellow fever, and dengue are some diseases that occur when vectors (the mosquitoes) reproduce and develop themselves in water, while the diarrhoea and the helminthiasis are directly related to poor water quality. Therefore, these waterborne and vectorborne diseases are related to temperature and climate variation. Adiaké station was chosen because of its proximity to pilot villages (Ahigbé-Koffikro and Samo).

Results

Characterization of Climate Variability

Cutting of Rainfall Dataset into Climate Periods

Analysis of rainfall data using Nicholson rainfall indexes is presented in **Figure 4**. This figure highlights wet years (i.e. with positive values of Nicholson index) and dry years (i.e. with negative values index) that occured in the south-east area of coastal.

At Anonkoua-Kouté station, wet period stretched from 1950 to 1970, while dry period covered the period from 1970 to 2002 (**Figure 4a).** By comparing the rainfall amount of both dry and wet periods and mean annual rainfall (estimated to 1579.92 mm), there was an excess of 229.51 mm for wet years and a deficit of 149.22 mm for dry years.

At Abidjan-airport station, three climate periods was identified: one normal period from 1936 to 1948, one humid period from 1948 to 1982, and one dry period from 1983 to 2012. The normal period (1936-1948) showed a mean rainfall of 1859.77 mm, slightly equal to mean interannual rainfall

(1873.40 mm) of all chronic (1936-2012). The humid period, with length of 34 years (1948-1982), recorded a mean annual rainfall of 2097.42 mm with an excess of 224.02 mm. The dry period (1983-2012) showed a mean rainfall of about 1584.89 mm, resulting in a deficit of 288.51 mm (**Figure 4b**).

Consequently, Bingerville and Adiaké stations had two main periods (**Figures 4c and 4d**):

-Wet period that stretched respectively from 1960 to 1982 and from 1945 to 1982 with a mean rainfall equal to 2059.82 mm at Bingerville station and 2119.27 mm at Adiaké station. The observed rainfall excess was equal to 213.56 mm at Bingerville and 221.39 mm at Adiaké.

- Dry period occured from 1983 to 2012 at Bingerville station and from 1970 to 2014 at Adiake station with a rainfall deficit of 179.71 mm at Bingerville and 158.39 at Adiake .

III.1.2. Detection of Breaks in the Rainfall Dataset

III.1.2.1 Pettitt Test

The results of Pettit test are presented in the **table** 1. Three of the four weather stations showed a break in the year 1982. At Anonkoua-Kouté, this break occurred in 1969.

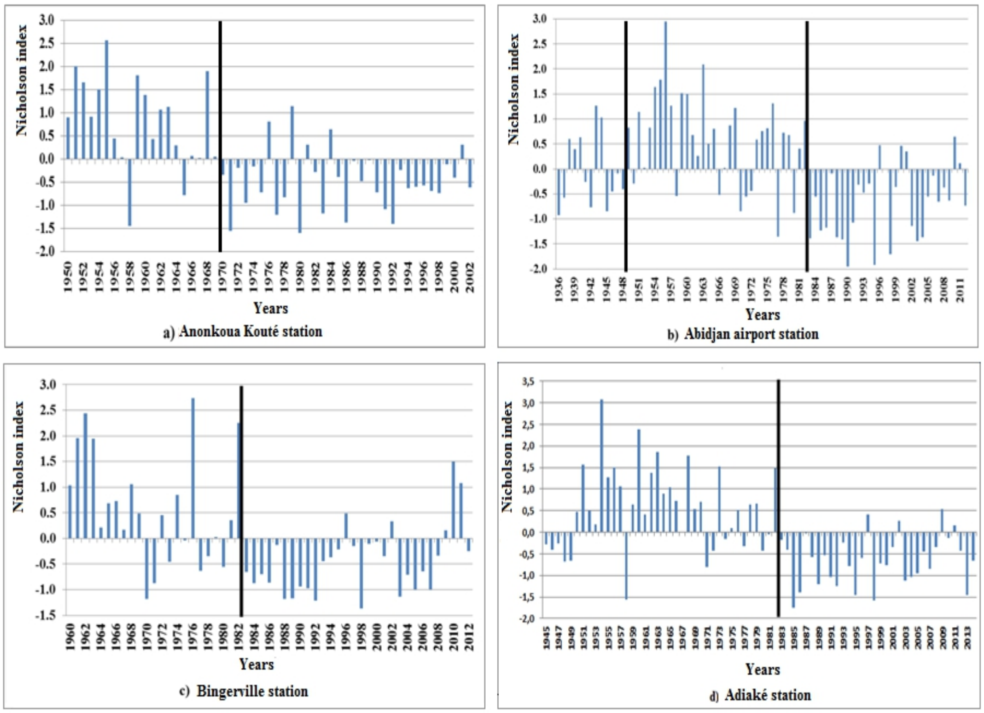

Figure 4. Variation of Nicholson rainfall index in the south-east of ivorian coastal

Table 1. Rainfall dataset break of study area

Station	Observation periods	Break date
Anonkoua Kouté	1950-2002	1969
Abidjan-airport	1936-2012	1982
Bingerville	1960-2012	1982
Adiaké	1945-2014	1982

Fluctuation of Pettitt U variable calculated for each year at Abidjan-airport and coupled with rainfall pattern is presented in **Figure 5**.

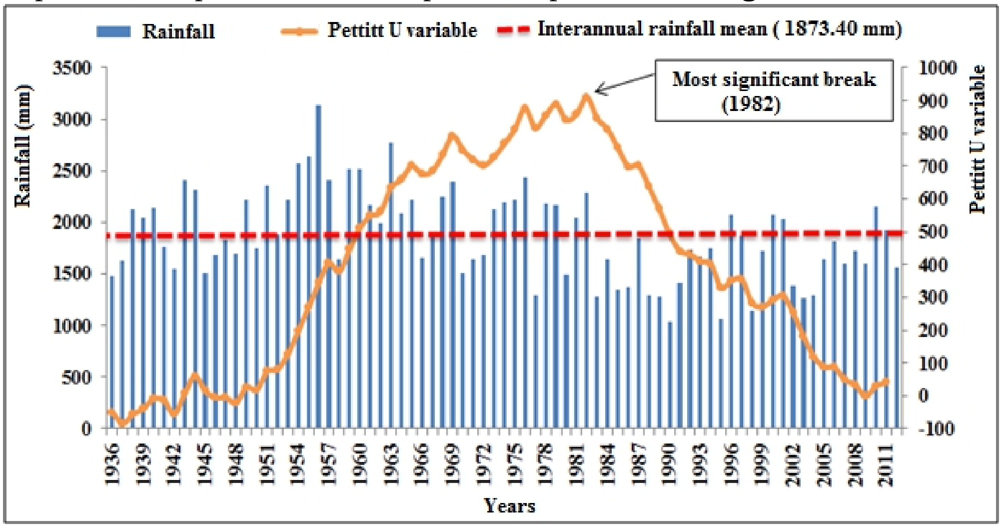

Figure 5. Variation of Pettitt U variable and rainfall from 1936 to 2012 at Abidjan-airport.

The break revealed by Pettitt test was most significant because it show the rupture between two trends in the rainfall evolution. At the Abidjan-airport station, before 1982 which is a year of significant break detected by this test, rainfall increased from 1481 mm in 1936 to 2283 mm in 1982. This period was characterised by a mean rainfall of about 2057.56 mm. Compared to the mean interannual rainfall estimated at 1873.4 mm, this period showed excessive rainfall of 184.16 mm. From 1983 to 2012, with interannual rainfall mean of 1584.89 mm, the deficit in rainfall was equal to 288.51 mm.

Result of Hubert Segmentation Break

The results of Hubert segmentation applied to time series data is presented in **table 2**. The stations of the coastal area of Ivorian south-east were characterised by two to three breaks. At Anonkoua–Kouté, two breaks were observed in 1955 and 1970. At Abidjan-airport, breaks were observed in 1953, 1957, and 1982. At Bingerville station, there were two breaks in 1963 and 1982. At Adiaké station, two breaks years were recorded.

Table 2. Breaks in rainfall data for different weather stations according Hubert

Stations	Observation period	Break date
Anonkoua kouté	1950-2002	1955 ; 1970
Abidjan-airport	1936-2012	1953 ; 1957 ; 1982
Bingerville	1960-2012	1963 : 1982
Adiaké	1945-2000	1949 ; 1970

On all the breaks detection tests, some breaks were identified around 1950s (1945, 1953, 1955), 1960s (1957, 1963), 1970s (1968, 1969, 1970), and 1980s (1982).

Climate Variabilty Impact on Surface Water Resources

Analysis of Rainfall-runoff Relationship

The mean interannual fluctuations of runofff and precipitations from 1983 to 2004 at Bianouan and Abadinou stations are presented respectively in **Figure 6 and 7**. At Bianouan station, the increase in rainfall was associated with an increase in runoff over the period. In addition, the analysis generally shows a successive excess and deficit in precipitation amount (**Figure 6**).

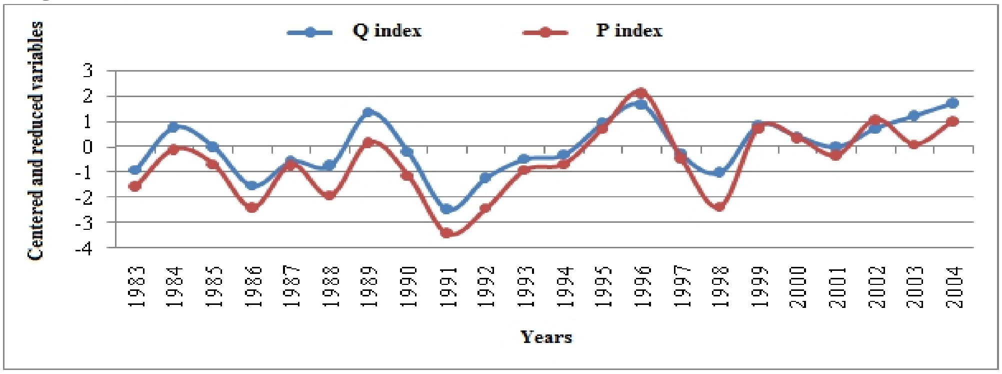

Figure 6. Detailed analysis of rainfall-runoff relation at Bianouan station (1983-2004)

At Abradinou station, the synchrone trend between rainfall and runoff was also observed with some disruption periods (**Figure 7**). The periods of disruption were from 1988-1991, 1994, and 2003. During these periods, decrease in rainfal amount was associated with an increase in runoff and vice versa.

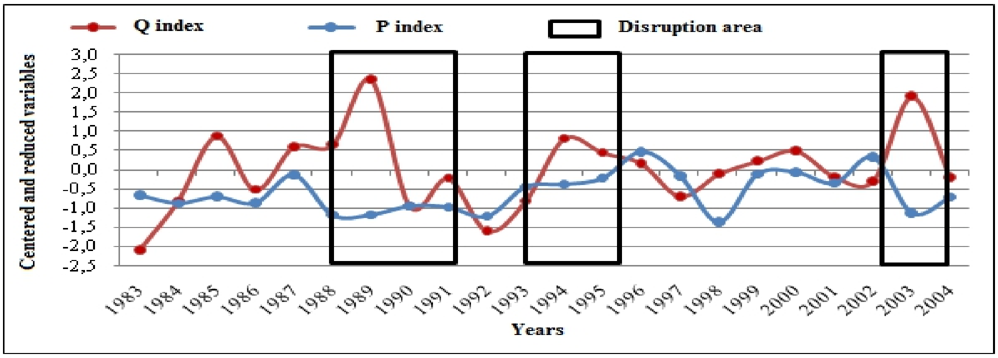

Figure 7. Detailed analysis of rainfall-runofff relation evolution at abradinou station (1983-2004)

Coefficient of Depletion and Water Volume Mobilised by the Aquifers

The coefficients of depletion that was calculated and the water volumes mobilised at Abradinou and Bianouan stations are described below.

At Abradinou station on the Comoé, coefficients of depletion k ranged between1.17.$10^{-2}j^{-1}$ and 2.03.$10^{-2}j^{-1}$ with mean value of 1.62. 10^{-2} j^{-1}. Volume of mobilised water varied between 0.65 and 7.27 km³ with mean of 3.72 km³. A decrease of the coefficient of depletion was observed at Abradinou**,** leading to an increase volumes of mobilised water since 1992 (**Figure 8**).

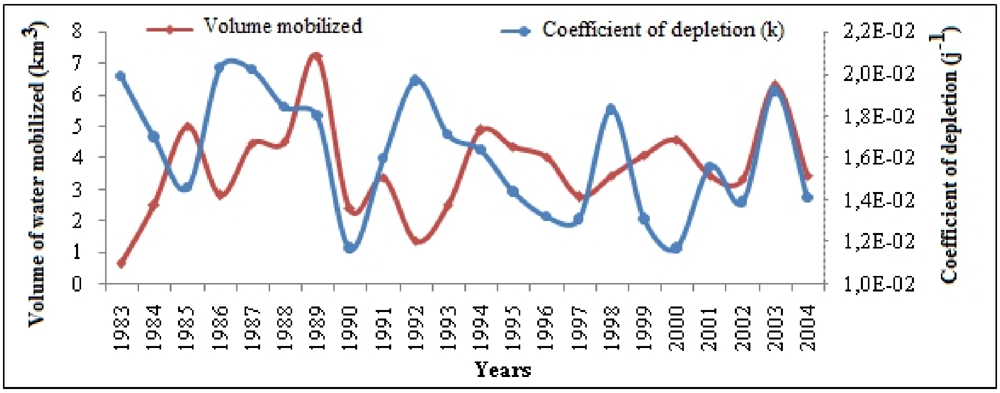

Figure 8. Variation of depression coefficient and annual volume of water mobilised at Abradinou station

At Bianouan station, coefficients of depletion (k) vary between 9.9. 10^{-3} j^{-1} and 4.83. 10^{-2} j^{-1} with a mean of 2.02. 10^{-2} j^{-1}. Volumes of mobilised water vary between 3.86. 10^{-2} km^3 and 1.13 km^3 with a mean of 0.65 km^3. Also, an increasing volume of mobilised water was observed (**Figure 9**).

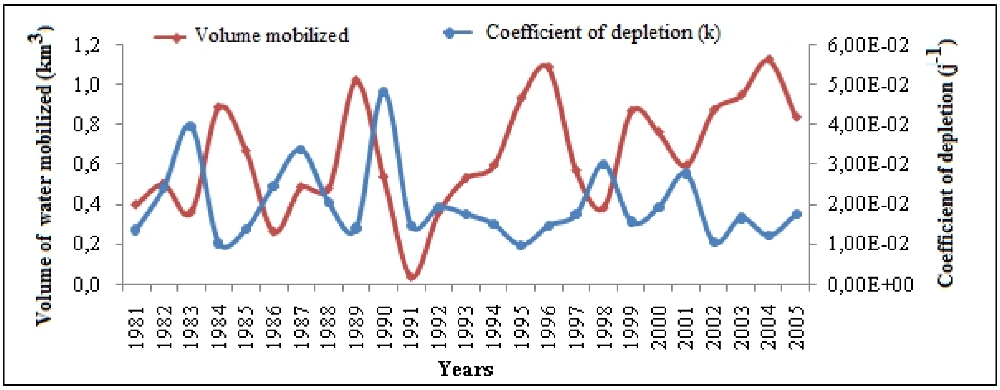

Figure 9. Variation of coefficient depletion and annual volume of water mobilized at Bianouan station

The analysis of rivers regime revealed an important fluctuation of runoff in the Ivorian south-east area. Coefficients of depletion fluctuations and the volume of mobilised water are asynchrone between 1981 and 2005. In this case, the volumes of water mobilized by groundwater storages were important during the rainy season. However, the situation was different during the dry period, where rainfall amount was not sufficient to compensate the loss in groundwater storage.

Climate Variability Impact on Groundwater Resources

Analysis of Aquifers Recharge at Abidjan-airport Station

However, the water balance results is presented in **table 3**.

Table 3. Water balance at Abidjan-airport (1961-2012)

Period	P (mm)	ETR (mm)	R (mm)	I (mm)
1961-2012	1772	1178	270	324
1961-1981	2013	1197	305	511
1983-2012	1596	1156	230	209

For the period from 1961 to 2012, the annual infiltration, contributing to the recharge of aquifers, ranged between 1061.06 mm (1980) and 265.05 mm (1976) with a mean value of 324 mm. The annual infiltrations fluctuations coupled with annual rainfall is illustrated in figure 9. Before rainfall break appeared in 1982, i.e. the 1961-1981 period, a mean annual infiltration enregistered was 511 mm which is an excess of 57.71% on the aquifers recharge. After the rainfall break of 1982, the annual mean infiltration recorded during the period 1983-2012 was equal to 209 mm. This corresponds to a deficit of 35.49% on the recharge compared to the entire chronic.

The **figure 10** also shows a synchrone evolution of rainfall and the water flow pattern. Thus, the more important the rainfall amount, the higher is the water flow pattern.

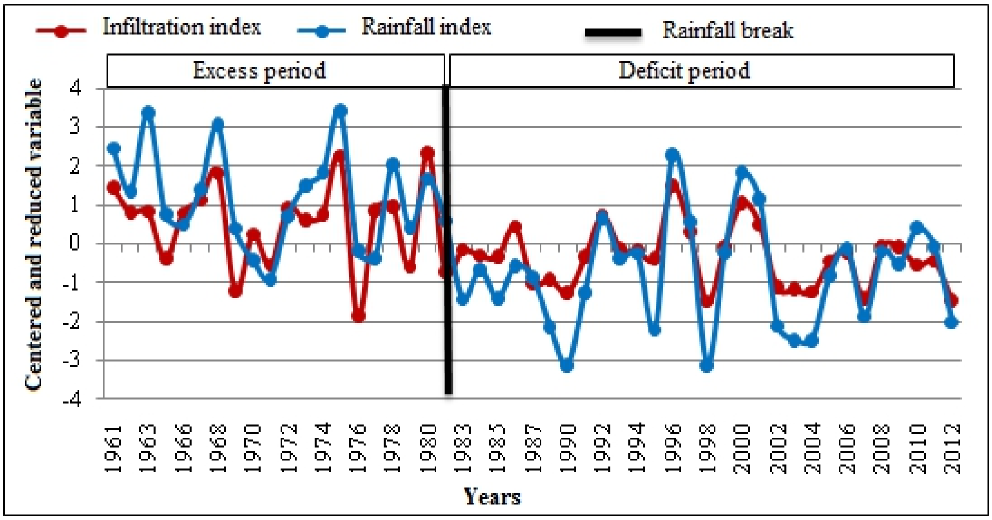

Figure 10. Coupled fluctuations of infiltration and the rainfall at Abidjan-airport station (1961-2012)

Analysis of Groundwater Recharge at the Bingerville Station

The results of water balance at Bingerville station is presented in table 4.

Table 4. Water balance at Bingerville station (1961-2012)

Period	P (mm)	ETR (mm)	R (mm)	I (mm)
1971-2012	1754	1208	263	283
1971-1981	1902	1240	285	376
1983-2012	1667	1198	250	219

At Bingerville station, the annual infiltrations vary between 1385.37 mm (obtained in 1976) and -77.20 mm (obtained in 1988) with a mean value of 283 mm in the entire chronic (1971-2012).

During the period 1971-1981 (before 1982 rainfall break), the mean annual infiltration was equal to 376 mm. This corresponds to an excess of 32.86% on the recharge compared to the entire period.

During the period 1983-2012 (after rainfall break), the annual mean of infiltration was about 219 mm which represents a deficit of 22.61% of recharge. However, the variations of annual infiltrations coupled with annual precipitations is presented in **figure 11**. Also, one can observe a synchronous evolution of rainfall and infiltration over time .

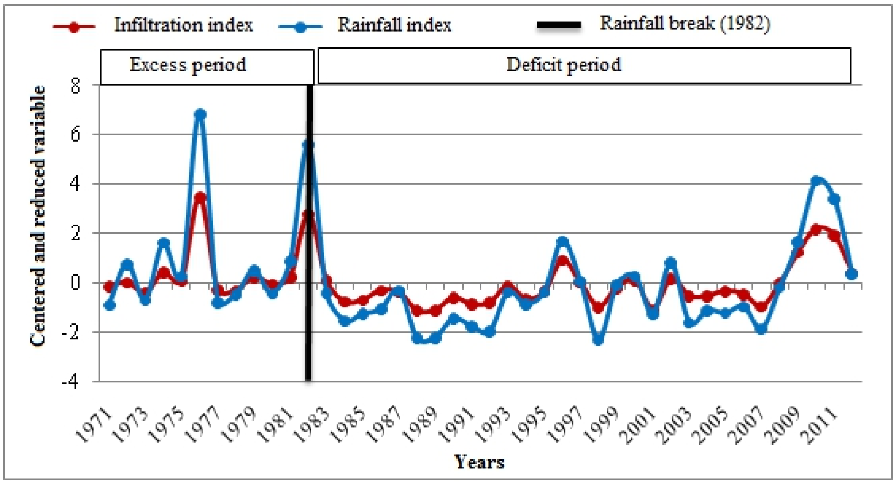

Figure 11. Coupled fluctuations of infiltration and the rainfall at Bingerville station (1971-2012)

Climate Variability Impact on the Population's Health of the Region

From 2012 to 2014, there were no case of degue and yellow fever in Ahigbé-Koffikro and Samo. However, out of 10858 medical visits made by nurses in these villages, 2.85% of them showed diarrhoea cases and 2.35% showed helminthiasis cases. The **figure 12** reveals that a case number of diarrhoea was high during the rainy season (March to July) and it decreases during the dry season (November and December). In this region, there was a relationship between this disease and rainfall pattern. However, there was no relationship between helminthiasis occurence and rainfall. Furthermore, there was steady variation of temperature during a year, which had no effect on diseases occurrence.

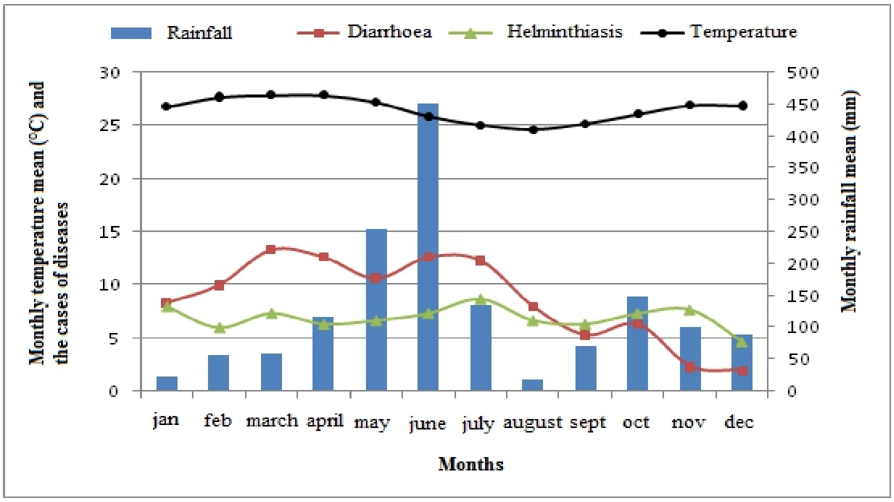

Figure 12. Monthly evolution of diarrhoea and helminthiasis cases versus monthly rainfall and temperature from 2012 to 2014

Malaria was the most frequent disease in the region with more than 63% of medical visits at the local level against 43% at the national level (Fakhi, 2014). This evolution was synchronous with rainfall variations. **Figure 13** shows that the years 2012 (1688 mm), 2013(1292 mm), and 2014 (1594 mm) was associated with 64%, 60%, and 66% of malaria cases respectively.

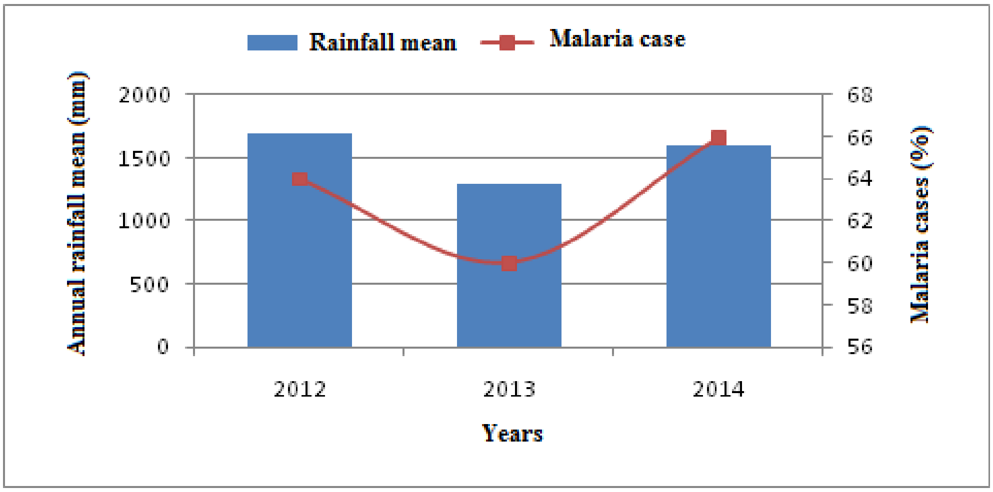

Figure 13. Number of malaria cases versus annual rainfall mean

The highest number of malaria cases in this area was observed in June and July which correspond to the end of the rainy season and the beginning of the short dry season in the region (**Figure 14**). However, this figure showed no relationship between malaria cases and temperature.

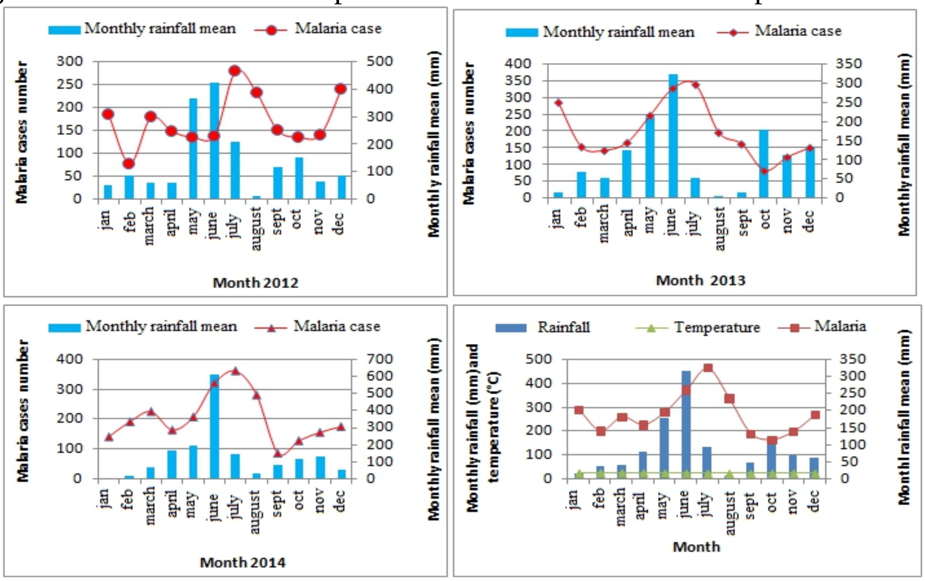

Figure 14. Evolution of malaria case number versus monthly rainfall and temperature mean

Discussion

Generally, the dry period resulting from the decrease in rainfall pattern in the years 1970s and 1982 was also observed by Kéhi (2014), Yapi (2014), and Oga et *al. (2016)* within the coastal aera of Côte d'Ivoire. Indeed, several studies identified an important decrease in rainfalls after the year 1970 in Côte d'Ivoire (Paturel *et al.*, 1995) especially in the West, the Center, and the South-west (Goula et al., 2006b; Soro et al., 2004; Kouassi, 2007; Soro et al., 2011). According Goula et *al*. (2006b) and Kouassi (2007), these breaks led to rainfall deficit of about 18 to 25% in the N'zi and N'zo watersheds respectively in the center and west of Côte d'Ivoire.

In terms of the surface water, the analysis of rainfall-runoff relationship showed a high correlation between the the river annual yield and the rainfall pattern. This was also observed by Kouassi (2007) and Kanga and Kaudhis Assi (2016) respectively on the N'zi watershed and Northeast quarter. Analysis of annual coefficients of depletion (k) for the period 1983-2004 at Abradinou and Bianouan stations showed an important variability over time. Therefore, the estimated daily mean values, which was equal to $1.17.10^{-2}$ and $2.03.10^{-}2$ for Abradinou station and 9.9. 10^{-3} and 4.83. 10^{-2} for Bianouan station, were closed to the results from those in Cavally river ($5.7.10^{-2}$ per day) and Drou river (and $3.6.10^{-2}$). Thus, this was presented by Savané et *al.* (2001) in their study. This is an evidence of an important depletion of groundwater resources within the study area. Also, this is related to the climate variability effect through the decrease in rainfall and the increase in evapotranspiration and temperature. This took place since the end of 1960s as observed by Kouassi et *al.* (2013) and also within the N'Zi-Bandama watershed.

This study also revealed a decrease in water volumes mobilized by the aquifers related to the decrease in rainfall pattern at the end of the 1960s. As a result, this has a significant effect on groundwater reserves. This impoverishment of base input flow pattern is linked to the reduction of water volume in the aquifers. Indeed, a considerable decrease in groundwater reserves, which normally ensure the supply of rivers during depletion period, was noticed (Kouakou, 2010; Soro, 2010; Kouassi et al., 2013.) These variations of mobilized water volumes by the aquifers suggest an important regression of groundwater reserves, which could be seen as result of the effect of the recent dry period on water flow patterns. Studies from Savané *et al.* (2001*)*, Saley (2003), and Goula *et al.* (2006b) also underlined a decrease in the volumes of mobilized water by aquifers since the Ivorian rivers in 1970 confims the results of this present study. Moreover, there was also a synchrone trend of rainfall-runoff relationship testifying the dependency of river diet on precipited water flow.

Concerning groundwater resources, the comparison of annual mean infiltrations before and after the rainfall break of 1982, obtained from water balance, gave an idea about the impact of changing rainfall pattern on aquifers recharge. At Abidjan-airport station, aquifers recharge decrease of about 23.60% was recorded since the 1982 rainfall break. Soro et *al*. (2011) also stated a decrease of about 80.5% at Gagnoa station and of 66% at Sassandra station. Furthermore, Soro et *al*. (2004) observed a relative rainfall influence on Abidjan aquifers recharge. A study from Kouassi (2007) indicated deficits in the infiltration of 18.3% for the watersheds of N'Zi at Dimbokro and M'bahiakro and 19.7% for the High N'Zi (Fétêkro) with the 1969 as reference. However, N'guessan et *al.* (2014) observed an infiltration of 6% in Yamoussoukro region.

The present study showed a closed relationship between cases number of diarrhoea and malaria, and climate variability. The highest number of malaria cases was observed in June and July, corresponding respectively to the intense rainy month and the beginning of short dry season in the region. This period is the most available to adult females of anophela which are ovipares and which lay between 50 and 200 eggs. Indeed, these anophelas eggs, like all mosquitoes, pass through four levels in their life cycle (zygota, larvus, pupe, and finally adult). The first three phases take place in wet environment and last from 7 days and 5 weeks according the species.

Subsequently, the adult phase takes place in aerobic environment for one week for male and two months for female (htttp://fr.wikopedia.org/wiki/Anoph%C3%A81e#Cycledevie). The peak observed are the anophelas population increase which bites human to extract the blood inoculation and release the plasmodium (malaria parasite) into the human. Besides, according to OMS (2016) in many places in the world, transmission is seasonal with a peak occuring during or just after the rainy season. These results prove those of OMS (2016) and Fakhi (2014) which indicate that climate conditions have effect on some water diseases or vectors diseases. Moreover, the pathologies related to climate are the most harmful in the world today. Diarrhoeaic diseases malaria and malnutrition energy-proteino were responsible for more than 3 millions death in the world in 2004 with one third in Africa (OMS, 2015). Concerning the relation between the malaria and the temperature, OMS (2016) establishes a relationship between anophelas eggs development and temperature because these eggs develop faster in temperated countries than tropical countries.

Conclusion

In conclusion, this study highlighted the impact of climate variability on groundwater resources in south-east coastal area. In terms of surface waters, the analysis of coefficients of depletion and water volumes mobilised revealed important fluctuations of rivers levels over time. Also, there was a strong relationship between rainfall and runoff. The climate variability impact on groundwater resources was underlined by a deficit of about 35.49% and 22.61% (for Abidja-airport and Bingerville stations, respectively) of water volume infiltrated and made available for aquifers recharge after 1982 break.

Climate variability impact on population health is characterised by a positive correlation between rainfall and diseases like malaria and diarrhoea. These two diseases represent more than 65% of the consultations. However, there was no significant relationship between helminthiasis and climate variability.

Acknowledgements

This study was supported by UEMOA and ADB funds through its Higher Education Project. Several governement agencies (SODEXAM, CNRA, ONEP, Sanitary District of Grand-Bassam) are all gratefully aknowledged for giving us access to required data. The study was hosted by the Laboratory of Sciences and Technical Water and Environment of UFR-STRM.

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