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Seasonal implications of malaria and their correlations with meteorological parameters in the districts of indoor residual spray extension in north Benin, West Africa

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Abstract

Benin has chosen to continue the implementation of indoor residual spraying as a complementary strategy for the prevention of malaria and to continue its extension to other eligible communes from 2017 onwards. The aim of this study was to compare the results of the evolution of the monthly incidence of malaria obtained before and after the implementation of the Indoor Residual Spray (IRS) and their correlation with climatic parameters.

Clinical and meteorological data collection was carried out respectively in the study's joint synoptic stations and health facilities in the Alibori and Donga departments where the houses were treated with pyrimiphosmethyl.

Also the incidence is higher between the period from July to August (31% before the IRS and 27% after the IRS) followed by the period from November to October (30% before the IRS and 25% after the IRS). Evaporation and humidity contribute to the increase in malaria incidence while temperature and wind are metrological parameters that contribute to the decrease in incidence.

The present study has shown, once again, the effectiveness of pyrimiphosmethyl on resistant anopheles populations especially the variation and the interaction between climatic factors determine the increase of malaria especially during the rainy season in the implementation of the IRS. Only a better understanding of these interactions between climate and health will lead to better strategies, policies and effective measures to deal with this environmental pathology.

Keywords: malaria, IRS, *Anopheles gambiae*, climate, man

1. Introduction

Malaria is endemic in most countries of sub-Saharan Africa and regularly affects populations (Grover-Kopec, 2006) [6]. The distribution of seasonal malaria is closely related to the characteristics of the climate. Malaria in Africa is met wherever climatic conditions are favorable for transmission between the mosquito genus Anopheles (vector) and the human (host). Climate changes significantly influence the geographical distribution and epidemiology of malaria (Lindsay; 1996) [11].

The effects of climate are felt on the distribution and abundance of anopheles vectors; the possibility and success of the sporogonic development of the parasite inside the vector and the modulation of the human-vector contact (Trape; 1999) [19]. Distribution and abundance of anopheles vectors; (ii) the possibility and success of sporogonic development of the parasite within the vector; (iii) the modulation of the human-vector contact. Many components of the climate are involved in these processes. Indeed, the temperature influences the duration of the sporogonic development of the parasite, the duration of the pre-imaginal development of the vector, and the survival of the adult Anopheles: The larval life is variable according to the species and the temperature conditions. In tropical zones, the aquatic phase of Anopheles lasts from 1 to 3 weeks. In temperate areas, the larval stage can last several weeks, or months, as some species can hibernate in the larval stage as An. Claviger (Kasap, 1986; Simsek, 2006) [9, 18]. In contrast, it has been found in Egypt, larvae of *An. pharoensis* in rice paddies where the temperature was 40 °C. Summer temperatures on *An. Merus* produce small larvae at the origin of adults with relatively short wings (Sharp, 1989) [17].

Above 35 °C and below 18 °C, the sporogonic development of P. falciparum is stopped; at temperatures of 20, 24 and 30 °C it is respectively 20, 11 and 9 days. The species P. vivax withstands more moderate temperatures, up to 15 °C and, at temperatures of 20, 24 and 30 °C, the sporogonic development is respectively 16, 9 and 7 days.

The pre-imaginal development of Anopheles is aquatic. It lasts about ten days for *An. Gambiae* and twenty for *An. Funestus* at 25 °C. This phase lengthens when the temperature decreases (up to three weeks for *An. Gambiae*) and shortens when it increases (five days at 30 °C for *An. Gambiae*).

In all regions of the world where there is a long dry season, anopheles are very scarce throughout this season. In these areas, the rate and amount of precipitation are the key factors that determine the existing anopheline species and their abundance and the duration of their seasonal presence. In the Sahelian zone, drought reduced the duration of impoundment of breeding sites and the intensity of malaria transmission, so that a "malaria retreat" was observed (Lindsay, 1996) [11].

Furthermore, climatic factors influence the incidence of vector-borne diseases such as malaria. They modify the abundance of mosquito populations, the duration of the extrinsic parasite cycle in the mosquito, the dynamics of malaria and the appearance of epidemics in areas of low endemicity.

Contrary to the trend towards reducing malaria morbidity and mortality in some areas, the burden of malaria has increased in many other regions due to deteriorating health systems, increasing resistance to drugs and insecticides, failure of water management and climatic, socio-economic, sociodemographic and land-use factors. (WHO, 2010; Nájera) [24, 12].

Some problems remain, endangering the objectives and the durability of spraying in districts of IRS in North-Benin. These problems include the resistance of some households to the spraying of their rooms and the omission of some households during the operation. In fact, in 2015, of the 270,141 structures found, 252,705 structures were sprayed during the campaign, representing a coverage rate of 93.55% for the total number of eligible structures found by the spray operators. Thus, during this campaign, 17,435 eligible structures found by sprayers in 2015 were not sprayed (IRS Benin Report, 2016) [14]. In addition, during the 2017 IRS campaign, 384,761 structures were sprayed out of the 419,785 eligible structures found by sprayers. The spray coverage was 91.7% of the total eligible structures found by the sprayers (IRS Bénin report, 2017) [15].

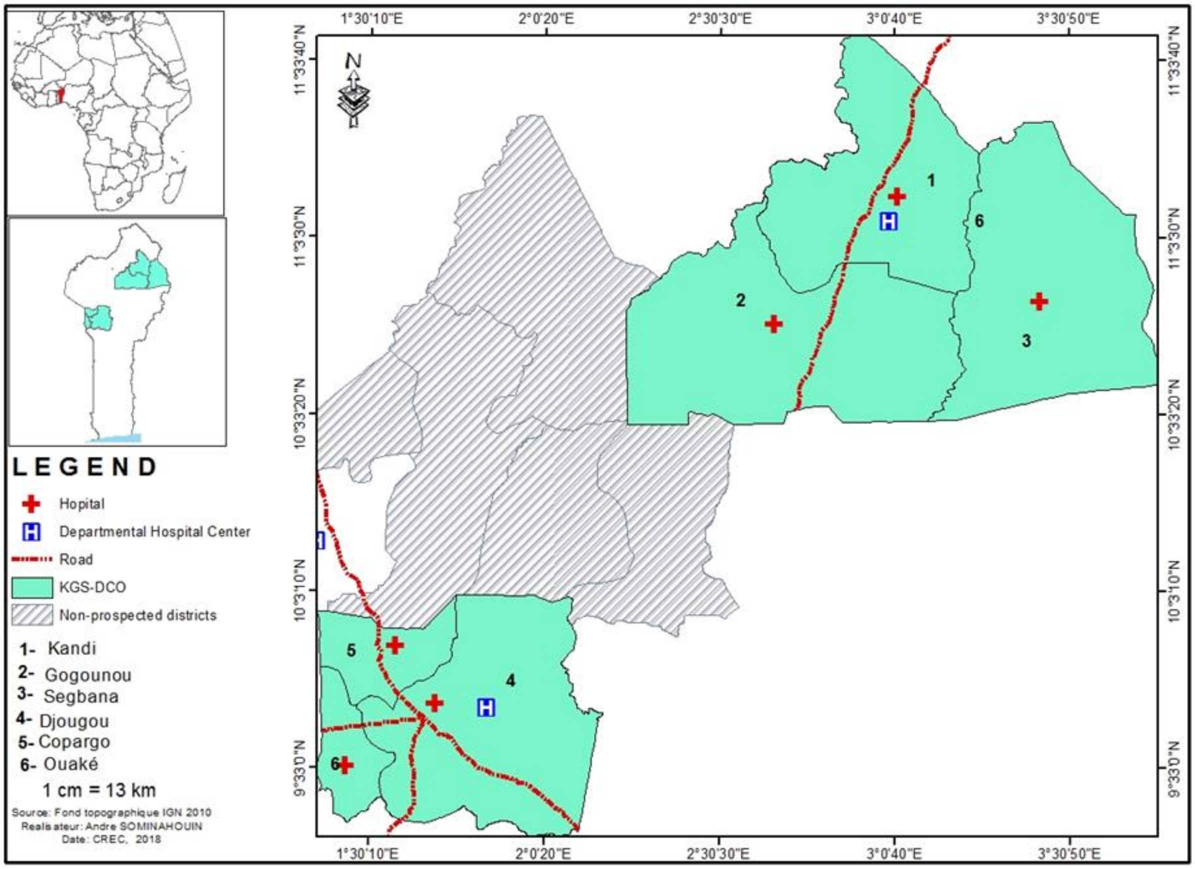
Simple methods for accurate prediction, early warning and rapid case detection in low and high transmission areas are needed to enable more effective control measures (WHO 2003; WHO 2009) [23,21].

The thematic maps represent theoretical models based on real monthly health data that simply allow us to understand the dynamics of data in time and space, compare these data by localities using colors and size to make distinctions. They make it possible to determine what is encroaching, are around and concomitant, find the best locations to satisfy certain criteria in order to understand how to distribute certain resource (Karam) [10].

2. Material and Methods

2.1 Study zone

The study was carried out in the north of Benin and including six communes, three from Alibori District (Kandi, Gogounou, Ségbana) and another three from Donga District (Djougou, Copargo, Ouake). (Fig1).



Source: Fond topographique IGN 2010
Realisateur: Andre SOMINAHOUIN
Date: CREC, 2018

Fig 1: Map showing the study area

2.2 Field data collection

Malaria incidence data

The incidence of a malaria is defined as the number of new cases infected in relation to the total population over a given period of time (Kalala *et al*., 2014; Hellenbrand, 1999) [16, 7].

The incidence rate is evaluated as follows:

$$\text{Incidence rate} = (\text{New Case Count}) / (\text{Target population}) \times 100$$

The incidence rate indicates how quickly a disease or infection spreads in a population. The impact makes it possible to evaluate the resources needed for case management.

Malaria health data are from the Health Zone Statistics database and cover the period from May 2016 to May 2018. Only the incidence attributed to malaria was included in this study. Monthly visits to all household in the area were organized between 2016 and 2018. Taking into account the entomological, epidemiological, socio-anthropological data and previous results of implementation of the IRS, these health zones since June 2017 were the geographical areas benefiting from IRS in the country.

To study the correlation between the two types of variables, Pearson's linear correlation coefficient (r) was calculated, showing the intensity and direction of the relationship:

$$\mathrm{r} = \frac{\frac{1}{N}\sum_{k=0}^{n}(xi-\bar{x})(yi-\bar{y})}{\sigma(\mathrm{x})\sigma(\mathrm{y})}$$

Where N is the total number of individuals; xi and yi, the values of the series; $\bar{x}$ and $\bar{y}$ are the averages of the variables; σ (x) and σ (y) represent their standard deviations

Meteorological data

The meteorological data used concern four parameters corresponding to the period of the recorded incidences: rainfall, evapotranspiration, temperature and sunshine, wind speed. During the study period, they are collected on a monthly scale and are recorded from the synoptic stations of Météo-Benin of Kandi, Parakou and Natitingou and those closer to the study area.

2.3 Data Analysis

The geographic coordinates of the sites surveyed in the sanitary zones of Kandi-Gogounou-Ségbana (KGS) and Djougou-Copargo-Ouaké (DCO) were recorded thanks to a computer equipped with card processing software (Arc-Gis 10.3). In order to establish the correlation between the variables and the regression analysis, a numerical classification was carried out with the software SPSS 21., Minitab 15 and Excel. The explanatory power of the model (R-two adjusted) makes it possible to compare models where the number of explanatory variables differs. It takes into account the number of degrees of freedom of the model.

3. Results

3.1 Dynamics of monthly incidences before and after spraying in the Kandi-Gogounou-Ségbana health zone

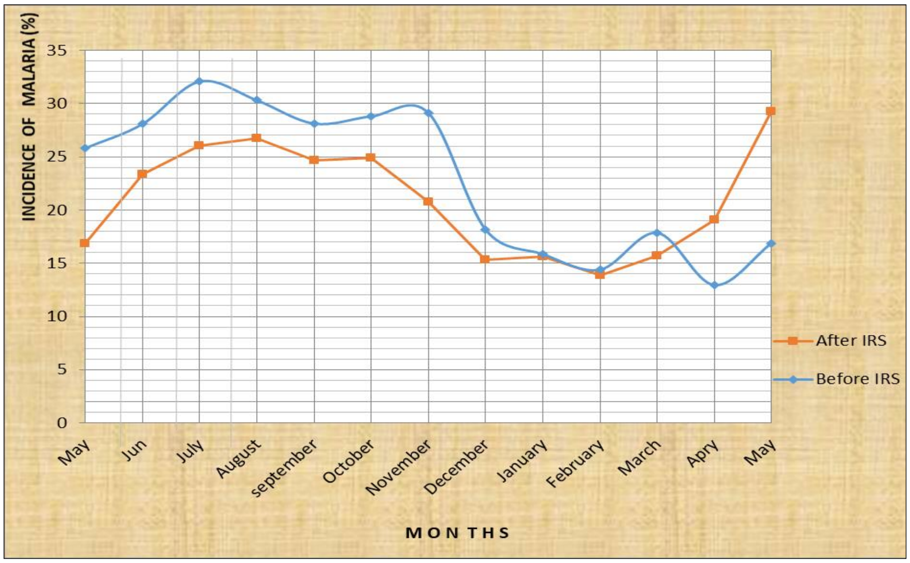


Fig 2: Monthly incidence of malaria in the KGS health zone before and after the intervention of the IRS

Crossing the incidence of malaria before and after the implementation of the IRS, we find that those recorded before the IRS remain less in the zone from June to mid-July, October in December and February to April than those observed after the implementation of the IRS, implementation of the IRS contrary to what was observed during the other months.

From fig2, we note that the incidence of malaria in health facilities is influenced by the implementation of indoor residual spraying. It is noted that the incidence is higher in the months following the implementation of the IRS in the KGS health zone. The peak seasons were from mid-June to mid-July and from September to November while the peak months were July and October.

3.2 Dynamics of monthly incidences before and after spraying in the Djougou-Copargo-Ouaké health zone

The monthly incidence of malaria before IRS and after IRS varied by time of year. The highest incidence was observed between the period from July to August (31% before IRS and 27% after IRS) followed by the period from November to October (30% before IRS and 25% after IRS). This period of high malaria incidence coincides with that of the great rainy season from May to October.

The incidence is low over the period from mid-October to May (drought period) and around 15% before the IRS.

With regard to monthly variations in the incidence of malaria cases, the peak incidence in 2016 was observed in July (Fig3).

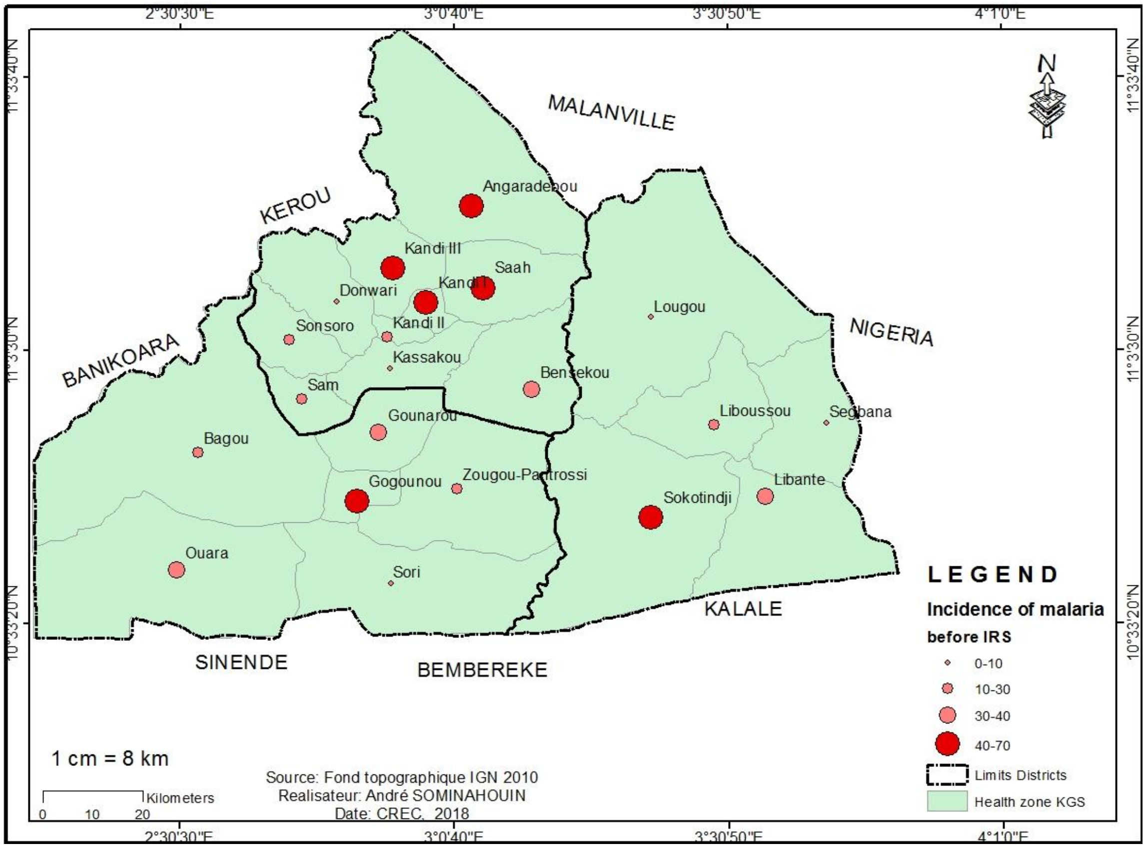
Fig 3: Monthly incidence of malaria in the COD health zone before and after the intervention of IRS

3.3 Spatial distribution of the season of high monthly incidence before and after the indoor spraying (IRS) in the Kandi-Gogounou-Ségbana sanitary zone

The boundaries of malaria endemic areas in the Health zone KGS are not static. The spatial distribution of malaria incidence prior to the intervention is characterized by a trend towards concentration in the northern and southern parts of the study area.

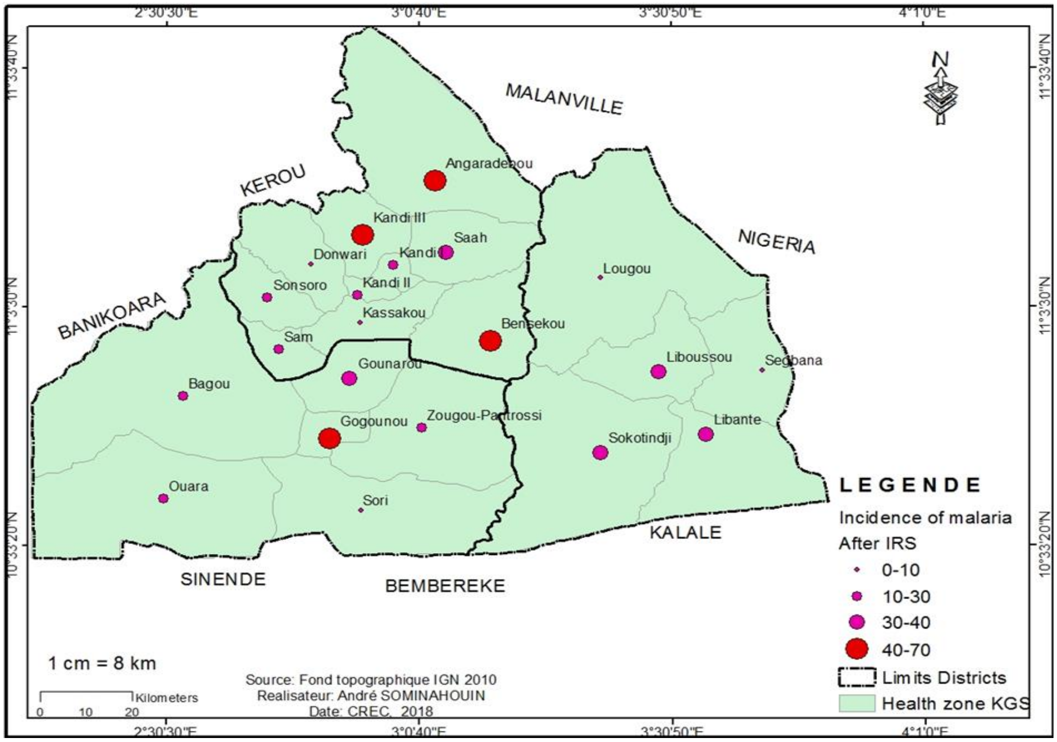
During the high incidence before the intervention, the endemic areas were those of Kandi I, Kandi II, Saah, Angaradebou, Gogounou and Sokotindji. (Fig4).

During the high incidence after the intervention, the spatial distribution of malaria incidence is characterized by concentration by a tendency towards concentration in the northern parts. In fact, the endemic areas were those of Kandi I, Kandi III, and Angaradebou. (Fig 5).



Source: Fond topographique IGN 2010
Realisateur: André SOMINAHOUIN
Date: CREC, 2018

Fig 4: Spatial distribution of the July 2016 incidence of malaria in the KGS health zone before the intervention of the IRS



Source: Fond topographique IGN 2010
Realisateur: André SOMINAHOUIN
Date: CREC, 2018

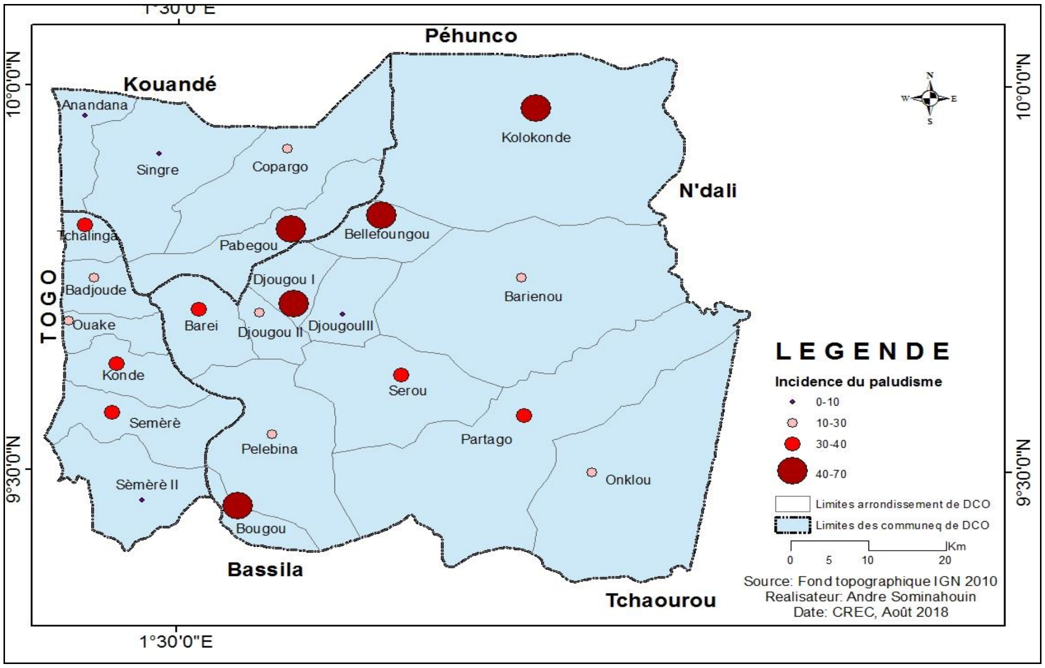
Fig 5: Spatial distribution of the incidence in July 16 of malaria in the KGS health zone after the intervention of the IRS

3.4 Spatial distribution of the season of high monthly incidence before and after the indoor spraying (IRS) in the Djougou-Copargo-Ouaké sanitary zone

The spatial distribution of malaria incidence is characterized by concentration in the central part of the site. The boundaries of malaria endemic areas in the ZS / COD are not fixed. During the high incidence before the intervention, the endemic areas were those of Kolokondé, Bellefoungou, Djougou, and Bougou in the district of Djougou and Pabegou in the district of Copargo. (Fig 6)

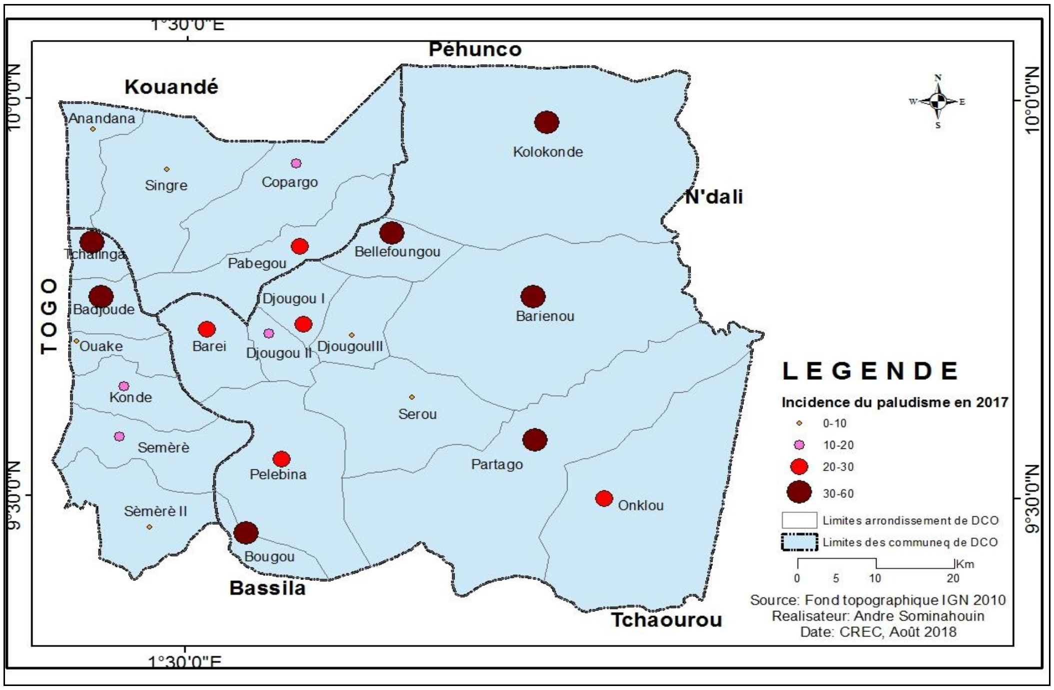
But after the establishment of the IRS in August 2017, the spatial distribution of malaria incidence is characterized by a tendency for frequency concentration in the north-east and west parts of the site.

During the high incidence after the intervention, the endemic areas were those of Bariénou, Kolokondé, Bellefoungou, and Badjoudé. (Fig7)



Source: Fond topographique IGN 2010
Realisateur: Andre Sominahouin
Date: CREC, Août 2018

Fig 6: Spatial distribution of the incidence in July 16 of malaria in the health zone COD before the intervention of the IRS



Source: Fond topographique IGN 2010
Realisateur: Andre Sominahouin
Date: CREC, Août 2018

Fig 7: Spatial distribution of the incidence in July 16 of malaria in the COD health zone after the intervention of the IRS

3.5. Variation of monthly meteorological parameters in DCO and KGS health zones

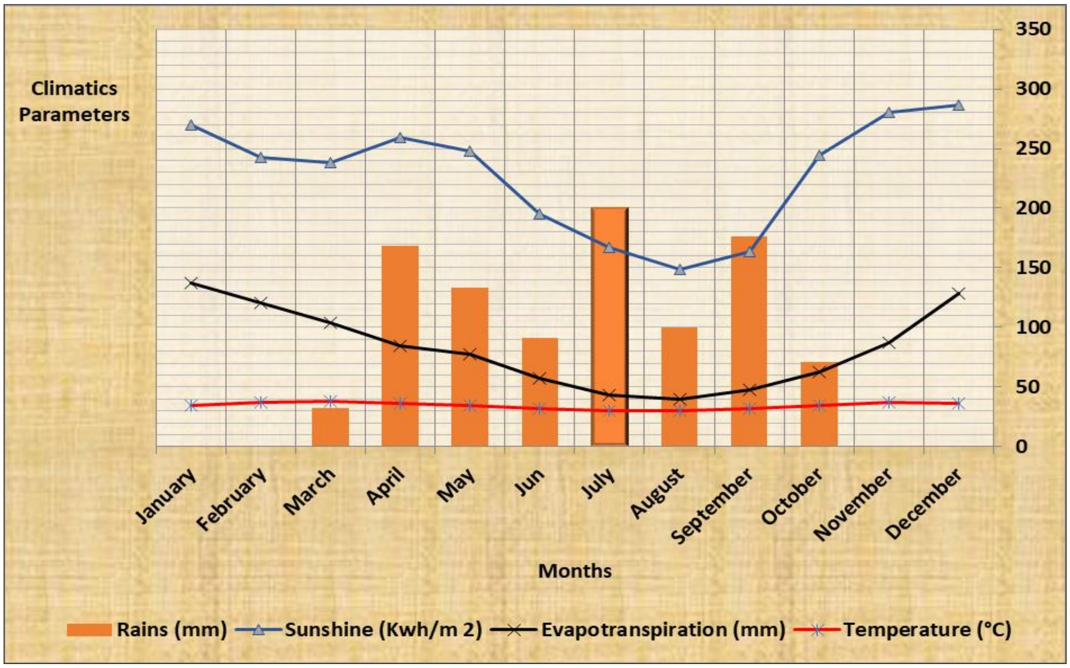


Fig 8: Evolutions of meteorological parameters in 2016 in the DCO area

Temperatures swing between 30 and 38 °C in Benin's Djougou-Copargo-Ouaké health zone. Precipitation is abundant and temperatures are high (30 °C) during the rainy seasons (April to September).

On the other hand, during the dry season, temperatures reach or even exceed 38 °C. In addition, the quantity of water that evaporates or transfers to the atmosphere and the time during which the area is sunny are all high.

The average monthly temperatures vary between 27 °C and 31 °C. The months of November to April are the hottest months (Fig 8). (ASECNA, 2014 et 2015). Research has shown that temperature has an influence on the malaria transmission cycle: by its elevation, it shortens the sporogonic cycle, which is the time it takes for a mosquito to become infective after feeding on the blood of a patient. Infected subject. It is involved in the survival mechanisms of vectors: mosquitoes live and develop better under a temperature between 25 and 30 °C (Assoko, 2005).

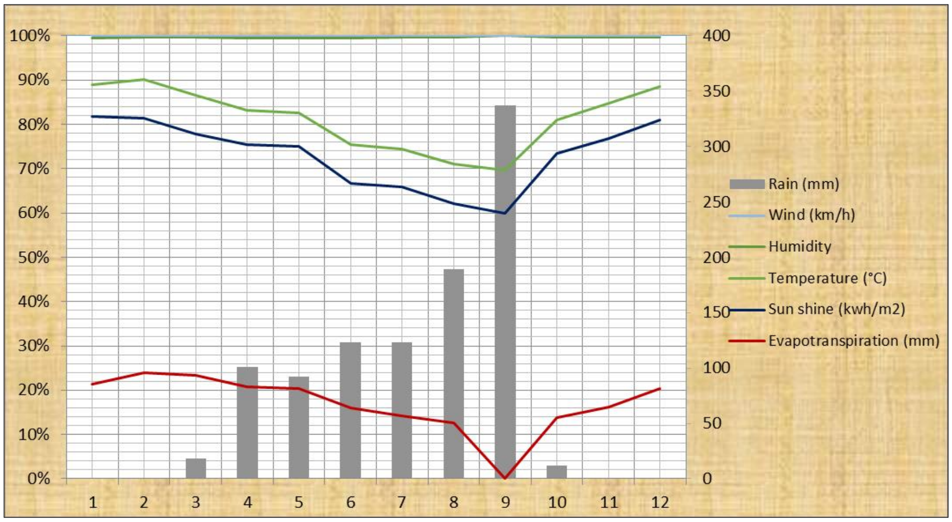


Fig 9: Evolutions of the meteorological parameters in 2016 in the KGS Health zone

3.6 Interpretation of statistical analyzes

3.6.1 Correlation between variables

The first table provided by the Minitab concerns the correlations between the variables studied. We see that there is a very high and significant correlation between malaria incidence and meteorological variables such as ETP, temperature, humidity and wind speed. On the other hand, rain and sunstroke are not correlated.

Table 1: Correlation of incidence; ETP; Rain; sunstroke; Temperature; Humidity; Wind speed

Malaria incidence						
ETP	-0,885					
Pluviometry	0,344	-0,615				
Sunstroke	-0,485	0,714	-0,749			
Temperature	-0,548	0,765	-0,598	0,687		
Relative Humidity	0,650	-0,753	0,750	-0,622	-0,494	
Wind speed	-0,865	0,733	-0,072	0,355	0,324	-0,340

3.6.2 Evaluation of the quality of the regression model

The ANOVA chart allows us to determine whether we reject the null hypothesis (H0) or not. In our research, we want to know whether climate variables better predict the incidence of malaria in the study area than a model without a predictor. Table 2 shows that the Fisher value obtained for the model is 13.64 at p <0.001, indicating that we have less than 0.1% chance of being wrong in stating that models contribute to better predict the incidence of malaria.

Table 2: Analysis of variance

Source	DF	SS	MS	F	P
Regression	4	419,04	104,76	13,65	0,004
Residual error	6	46,05	7,68		
Total	10	465,09			

The value of the Durbin-Watson test is 2.71617, so the value of the statistic is acceptable. It is agreed that the less there is a problem with the independence of errors. With this value obtained, we can believe that we respect this premise.

3.6.3 Regression Analysis

The Table 3 therefore contains several useful information. This is the value of the regression coefficients, the student statistic, and the significant threshold.

The equation of the model regression is:

Incidence of malaria = 38.3 + 0.015 Evapotranspiration 16 - 0.44 Temperature + 0.122 Humidity - 11.3 Wind speed.

The model shows that without any contribution of climatic parameters, the incidence of malaria in the IRS extension zone in North-Benin is 38.3.

The evapotranspiration increases the incidence by 0.115, so does the humidity by 0.122, so the evapotranspiration and the humidity contribute to the increase in incidence while the temperature and wind are metrological parameters that contribute to the decreased incidence. The explanatory power of the adjusted R-2 model is 83.5%, which means 83.5% of the variations in the incidence of malaria are explained by the variations of the climatic parameters considered.

Table 3: Regression Analysis

Predictor	Coef	T	P
Constant	38,32	1,90	***
ETP	0,0152	0,05	***
Température	-0,439	-0,41	***
Humidité	0,1216	0,84	***
Pluie	0,1018	0,45	***
Vitesse du vent	-11,319	-1,61	***

S = 2, 77045 R-Sq. = 90, 1% R-Sq. (adj) = 83,5%

4. Discussion

The start of the rains coincides with a gradual increase in the number of malaria cases in our study area. These results are consistent with those of Dansou *et al* who showed that the rainy season is the period of strong aggressiveness and infectivity of anopheles, vectors of malaria. In the intertropical field, and in Benin, the inter-annual irregularities of rainfall (Boko, 1988) [3] strongly influence the health calendar and a reduction in performance of health risk management methods

(Vissin *et al.*, 2012) [20]. These consequences are particularly noticeable in the district of Pobè where heavy rains increase the risk of malaria prevalence thus weakening the health of populations.

According to Dansou *et al*, The correlation is negative between malaria and temperature, i.e. $r = 0,40$; this reflects the fact that a rise in temperature leads to a decrease in the number of cases of malaria. High heat then tends to reduce the number of malaria cases. Finally, the explanatory power of the adjusted R-2 model is 83.5%. This shows that the variation of malaria is explained by the variation of the climatic factors including the rain in particular. The high probabilities of significance obtained confirm that the conditions climatic factors are responsible for the temporal evolution of the malaria and that socio-environmental factors also come into play for spread the disease.

The correlation is positive between incidence, rainfall and relative humidity. Unlike other correlations, the correlation coefficient between incidence, sunstroke, temperature, and wind speed is negative. A study in Senegal found the same result (Ousmane, 1997) [13]. The temperature is higher in the northern regions where we carried out our surveys. This result is similar to that of Daouda D on the Impact of Climate Change in West Africa 2007 (Daouda, 2017) [4].

5. Conclusion

The present study has showed the part of the climate in the appearance of the cases of malaria in the district of extension of the IRS. The correlation between these variables, synonymous with causality, is also linked to unhealthy environmental conditions in the northern part of Benin. This creates an ecological environment conducive to the development of malaria germs and vectors that weaken the health of populations in the area.

Abundant rainfall leading to the formation of breeding sites is necessary for the development of mosquito larvae and for abundant vector populations. The high humidity associated with it promotes the survival of adult mosquitoes. A rise in temperature would shorten the parasite's development time in its vector, which would increase the vectorial capacity of the anopheles. Warming could therefore both increase the level of transmission at a given location and allow transmission to areas where it was previously impossible at lower temperatures, depending on the species, at 16 or 18 ° C.

Only a better understanding of the interactions between climate and health will allow the development of effective strategies, policies and measures. Thus, the Beninese Ministry of Health must integrate climate risk management into public health policies and program.

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