International Journal of Advanced Engineering Research and Science (IJAERS)
Peer-Reviewed Journal
ISSN: 2349-6495(P) | 2456-1908(O)
Vol-10, Issue-6; Jun, 2023
Journal Home Page Available: https://ijaers.com/
Article DOI:https://dx.doi.org/10.22161/ijaers.106.3

Climatic Rhythms and Prevalence of Malaria in the Municipality of Sinende in Northern Benin

Jean Sodji[1,2], Donatien Azian[1,3], Victorin Vidjannagni Gbenou[4]

[1]Laboratory of Rural Geography and Agricultural Expertise /University of Abomey Calavi (LAGREA/UAC)
[2]Living Environment Institute (ICaV)
[3]Department of Geography and Regional Planning (DGAT)
[4]Département de Sociologie Anthropologie (DSA)

Received: 29 Apr 2023,

Receive in revised form: 30 May 2023,

Accepted: 06 Jun 2023,

Available online: 14 Jun 2023

***Keywords*— limate rhythm, prevalence, malaria, Municipality of Sinende**

***Mots clés*— Rythme climatique, prévalence, paludisme, Commune de Sinendé**

Abstract*— *Malaria is endemic and the overall population in Benin is vulnerable to contracting this disease. Malaria is the leading cause of mortality in children under five and of illness for adults. It accounts for 40% of outpatient consultations and 25% of all hospital admissions. The aim of this study is to analyze the impact of climatic rhythms on the prevalence of malaria in the municipality of Sinende in northern Benin. To achieve this goal, a statistical analysis of monthly averages of climatic data, mainly rainfall, temperature and relative humidity on the one hand, and monthly and annual malaria prevalence on the other, were collected respectively at the Benin meteorological station and at the documentation centre of Sinende Bembereкè regional hospital. The data were collected over the period 2003 to 2021. The results show that the transmission of malaria is seasonal. The prevalence rate is lower in the dry season than in the rainy season. Likewise, there is a positively strong correlation (R=54%) and a coefficient of determination of (R2 = 72%) between the monthly prevalence of malaria and the monthly average rainfall. This same correlation exists between relative humidity and average monthly precipitation (R=98%). With regard to temperature, the hottest months record the highest and lowest rates of malaria cases, while the months with lower temperatures are the most malarial. The significant drop in temperature is responsible for the high prevalence of malaria cases. These results are relevant because a good control strategy should take into account the climatic conditions and the rhythm of malaria morbidity in order to combat this endemic effectively.

Résumé*— *Le paludisme est endémique au Bénin, et l'ensemble de la population béninoise présente le risque de contracter la maladie. Le paludisme est la principale cause de mortalité chez les enfants de moins de cinq ans et de morbidité chez les adultes. Il représente 40 % des consultations externes et 25 % de toutes les admissions à l'hôpital. L'objectif de la présente recherche est d'analyser l'impact des rythmes climatiques sur la prévalence du paludisme dans la commune de Sinendé au nord Bénin. Afin d'atteindre cet objectif, l'analyse statistique des moyennes mensuelles des données climatiques notamment les précipitations, les températures et l'humidité relative d'une part, et les prévalences mensuelles et annuelles du paludisme d'autre part ont été

collecté respectivement à météo Bénin et dans le centre de documentation de l'hôpital de zone Sinendé Bemberekè. Les données ont été collectées sur la période 2003 à 2021. De l'analyse des résultats, il ressort que la transmission de paludisme est saisonnière. Le taux de prévalence est plus faible en saison sèche qu'en saison pluvieuse. De même, Il existe une corrélation positivement forte (R=54 %) et un coefficient de détermination de (R2 = 72 %) entre les prévalences mensuelles du paludisme et les moyennes mensuelles de précipitations. Cette même corrélation existe entre d'humidité relative et les moyennes mensuelles de précipitations (R=98%). En ce concerne la température, les mois les plus chauds enregistrent les plus fortes les plus faibles taux de cas de paludisme, tandis que les mois à faible température, sont les plus paludéens. La baisse sensible de la température est responsable de la forte prévalence des cas paludisme. Ces résultats sont très important car une bonne stratégie lutte devrait prendre en compte les conditions climatiques et la saisonnalité de la morbidité palustre en vue d'une lutte efficace contre cette endémie.

I. INTRODUCTION

Changes in climate parameters present significant risks to people's health and well-being, with the effects of extreme weather events, natural hazards, air quality, stratospheric ozone depletion and diseases transmitted by water, food, vectors and rodents (Seguin, 2008; Costello et al. 2009; WHO, 2012). While humans are closely linked to nature in physiological terms, in pathological terms, changes in nature have a major influence on disease, and the World Health Organization considers climate change to be the greatest health challenge of the 21st century (Howard, 2019). According to the impact assessment carried out in a number of European countries, as well as research funded by the EU and WHO-EURO, climate change is influencing the epidemiology of many diseases and health conditions. This assessment is also underpinned by WHO and IPCC reports describing the negative impact of climate change on human health (Barnett, 2007; IPCC, 2007a; Solomonetal., 2007; WHO, 2009).

The climate acts either directly or indirectly by affecting pre-existing pathological conditions or by encouraging the development of parasites or microbes, thereby maintaining the endemicity of certain diseases (WHO, 1972). Likewise, to maintain its temperature at 37°C, the human body has to fight against the external environment which is governed by the pressures of the climate variables.

Climate and water also have an indirect influence on health by generating favorable conditions for the growth of pathogens and the proliferation of their host vectors. It therefore seems possible to establish the existence of a dependent link between meteorological phenomena and the widespread of certain diseases. The aim of this study is therefore to establish the possible existence of a relationship between hydro-climatic elements and the occurrence of malaria among the population of the municipality of Sinendé.

1- Survey area

The municipality of Sinendé is located in the north-west of the department of Borgou, and is the geographical focus of this study. It lies between latitude 10° 20.41 North and longitude 2°22.45 East, and covers an area of 2,289 km2, which is 8.85% of the area of the department of Borgou. It is bordered to the north by the municipality of Gogounou in Alibori department, to the south by that of N'Dali, to the east by Bembereke and to the west by the municipalitys of Ouassa-Péhunco and Djougou (Figure 1).

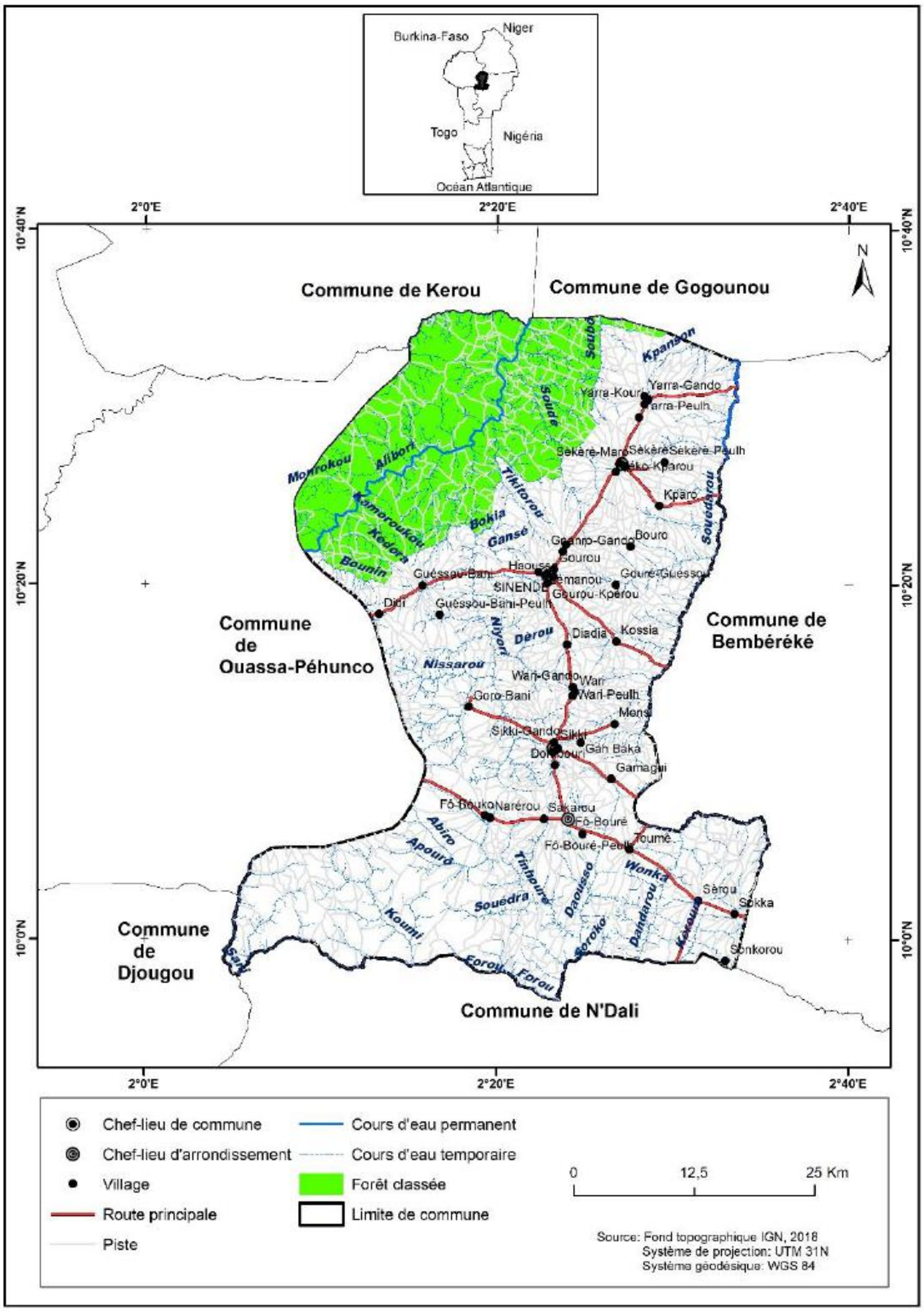

Fig.1: Location of the Municipality of Sinendé

The Municipality of Sinendé belongs to the climatic zone influenced by the Sudano-Guinean climate (Adam and Boko, 1993). It is characterized by an alternating rainy season from mid-April to mid-October, with average rainfall of between 800 and 1100 mm/year, peaking between July and September, and a single dry season from mid-October to mid-April. The unimodal rainfall pattern divides the year into two seasons. A rainy season from May to October and a dry season from November to April. Specifically, rainfall is less than 50mm during the dry season from December to April, with almost no rainfall in December, January and February.

During this season, the harmattan blows continuously from December to February. Its appearance results in a sudden drop in minimum temperatures. It also causes accelerated drying and evaporation; and is characterized by dry, light winds (2.30m/s), frequent haze, high insolation and low atmospheric moisture levels (30-60%).

The rainy season from May to October is characterized by two types of weather. The time preceding the heavy rains and the time of the main rainy season. The weather leading up to the rains is characterized by constant hot weather, increasing humidity and cloud cover and a corresponding decrease in sunshine. This type of weather is conducive to thermoconvection, which generates sudden thunderstorms (placid C. OKE, 1993).

II. DATA AND METHODS

During the period 2003 to 2021, the climatic data (rainfall, temperature and atmospheric humidity) were collected from the national agency Meteo Benin.

The malaria data consisted of reported cases of all forms of malaria collected by the statistics department of Bembereke-Sinende zonal hospital of the Ministry of Public Health. These data were used to quantify the number of malaria sufferers in the Municipality and their progression over time.

2.1- Arithmetic mean

This is used to study rainfall and temperature patterns and trends in malaria cases. The average $\overline{X}$ can be used to characterize the average climatological state and draw up a number of dispersion indices.

It is described as follows:

$$\overline{X} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

2.2- Centred reduced abnormalities

Rainfall, temperature and humidity abnormalities are identified by a reduced centred index based on variables such as monthly rainfall, monthly temperature and monthly relative humidity. This index enables the sequential evolution of these different parameters to be monitored.

$$X'_i = \frac{X_i - \overline{X}}{\sigma(x)}$$

With :

X'_i = reduced centred anomaly for year i

X_i = the variable value,

$\overline{X}$ = the series average.

$\sigma(x)$ = standard deviation of the series

2.3- The khi2 correlation test

To assess the link between climatic parameters and malaria, the khi 2-square statistical test is used to determine correlation coefficients (r). The variables used for this correlation are the centred reduced indices of monthly rainfall and the number of monthly malaria cases.

$$\chi^2 = \sum_{i,j} \frac{(n_{ij} - n^*_{ij})^2}{n^*_{ij}}$$

2.4- Data processing methods

Several steps were followed in processing the data. The climatic data and the years with more than 20% missing data were discarded after a consistency check. Years with less than 20% missing data were filled in using the linear regression method. The homogeneity of the rainfall data was checked using the double accumulation test. Climatic and pathological data were processed using Excel to overlay the curves showing the annual evolution of malaria diseases on those showing climatic variables.

III. RESULTS AND DISCUSSIONS

3.1- Pathology related to hydro-climatic factors

Climate is a key component of our living environment. The dynamics of some of its parameters determine the prevalence of some infectious diseases, mainly malaria. The link between water-borne diseases and climatic parameters is complex, and the mechanisms involved are not yet fully understood. Variations in climatic parameters will increase the risk of transmission of water-borne diseases in regions where they have traditionally been controlled, as well as in new regions that were previously spared. For instance, temperature rise, precipitation and humidity can lead to the proliferation of malaria-carrying mosquitoes in high-altitude regions, increasing transmission in regions that were not previously exposed (D.J. Rogers, 1996 and R.W. Sutherst, 1998).

3.2- Monthly trends in rainfall and malaria cases

In low-lying areas that are already affected, higher temperatures will accelerate the development cycle of the parasite in the mosquito, favoring transmission and thus increasing the disease burden (S.D. Fernando et al.; 2012). The links between malaria and rainfall are shown by the curves in Figure 2.

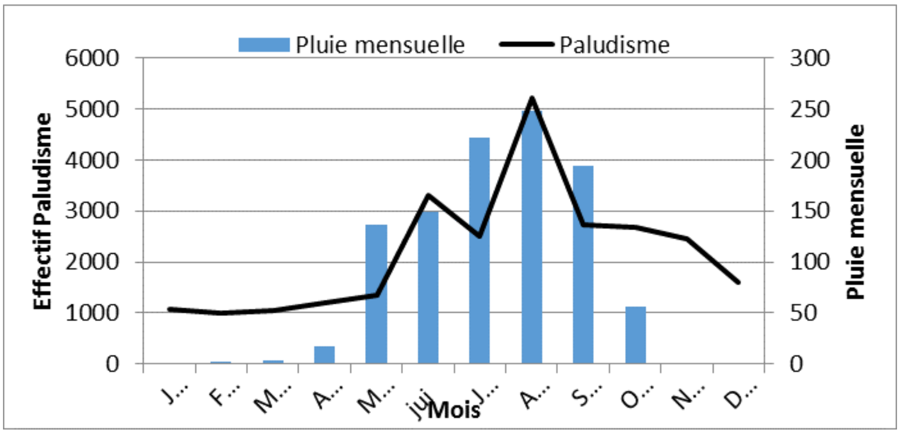

Fig.2 : Interannual trends in malaria and rainfall from 2003 to 2012

Inter-monthly trends in malaria prevalence and rainfall patterns show a similarity between the two parameters. The months of highest rainfall correlate with the highest malaria prevalence rates. There is therefore a strong positive correlation (R= 54%) between monthly malaria prevalence and average monthly rainfall. The calculated coefficient of determination between rainfall pattern and average monthly malaria prevalence is 72%. This means that 72% of monthly malaria cases are caused by the monthly dynamics of rainfall in the Municipality. In fact, rainfall leads to the proliferation of stagnant water, which is in fact the egg-laying substrate for malaria vector species.

3.3- Relationship between annual rainfall variation and annual malaria prevalence

Figure 3 shows the inter-annual variation in rainfall and annual prevalence in the Municipality of Sinende.

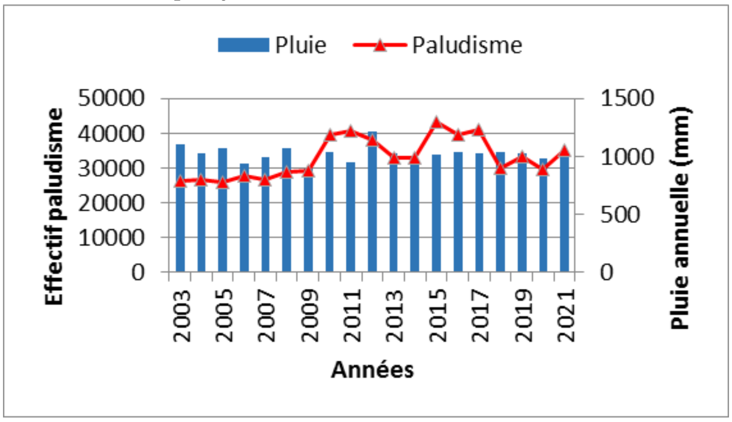

Fig.3: Interannual variation in rainfall and cases of annual prevalence+

The analysis of trends in annual rainfall and malaria prevalence shows that there is no perfect similarity between the two variables. The correlation coefficient (r = 0.13) between rainfall shows that changes in the annual prevalence of malaria cases are weakly correlated with changes in annual rainfall. Thus, changes in annual rainfall have a slight influence on changes in the annual prevalence of malaria in the Municipality of Sinendé. Nevertheless, it should be noted that years with low cumulative rainfall record high malaria prevalence rates.

The results also showed that rainfall has evolved in a jagged pattern, with the greatest precipitation in 2003, while a downward trend in malaria cases was observed over the entire period. The decline observed during this period could be explained by the introduction of specific interventions such as anti-malaria policies such as insecticide-treated mosquito nets, and the treatment of patients aged 0-5 years in hospital units.

3.4- Malaria and temperature

Temperature influences the duration of sporogonic development of the parasite, the duration of pre-imaginal development of the vector and the survival of the adult

Anopheles (O. Ndiaye et al., 2001, p. 25). Figure 4 shows the relationship between malaria and temperature

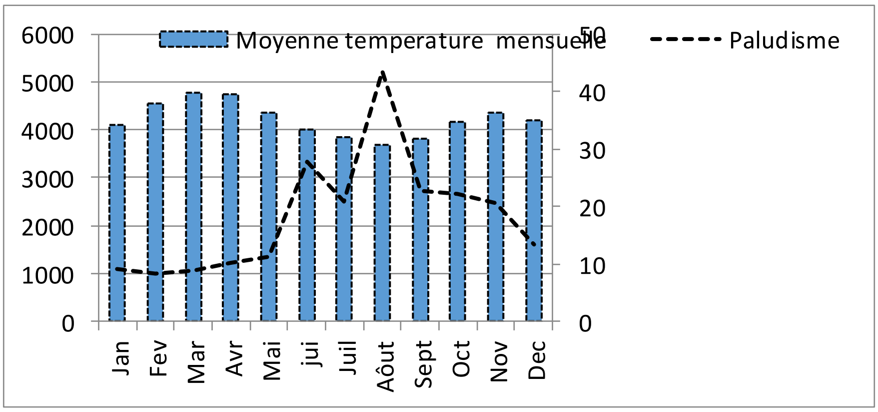

Fig.4: Inter-monthly trends in malaria and temperature from 2003 to 2021

Source : HZ Bembereke-Sinende

The hottest months record the lowest rates of malaria cases, while the months with the lowest temperatures are the most malaria-prone. The significant drop in temperature is the cause of the high prevalence of malaria cases. Maximum temperatures in the Municipality only exceed the 40°C threshold in March and April; minimum temperatures are below 28°C. According to Moussa F. (2011), the optimum temperature for the larval development of Anopheles is 28.87°C, which means that thermal conditions are favourable, both in the dry and rainy seasons for the development of larvae, the hatching of adults and the spread of malaria.

3.6- Relative humidity and malaria

Relative humidity or water vapour in the air has an impact on the prevalence of malaria and also varies with temperature. It is a climatic factor which has a decisive effect on the survival and activity of mosquitoes. Figure 5 shows changes in relative moisture and malaria cases in the Municipality of Sinende.

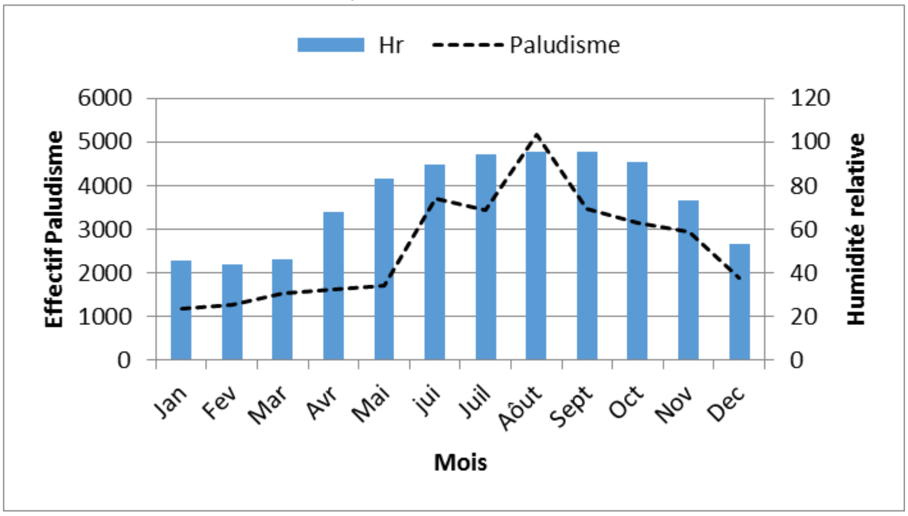

Fig.5: Inter-monthly assessment of relative moisture and malaria from 2003 to 2012

Source : HZ Bembereke-Sinende

The relative moisture content in the Municipality of Sinende varies from 44% to 95.3%. January, February and March have the lowest humidity levels, while July, August and September have the highest. There is a strong correlation between moisture and malaria prevalence (R=98%). Therefore, humidity in the Municipality is conducive to oviposition, larval hatching, proliferation of adult Anopheles and infection of healthy humans. Likewise, the strong correlation between the two parameters could mean that:

- Either the malaria gene finds there additional ecological conditions for its propensity.

- Or, populations are more vulnerable when relative humidity is high.

By combining the three components of climate, we can safely conclude that rainfall, relative humidity and temperature each play their part in influencing malaria. It is therefore easy to conclude that no time of year has a zero rate of malaria sufferers. This shows that climatic factors alone are not enough to explain the spread and development of malaria in our study area.

IV. DISCUSSIONS

The correlation between rainfall patterns and malaria prevalence has shown that months with abundant rainfall correspond with high prevalence rates of malaria cases. There is therefore a strong positive correlation (R= 54%) between monthly malaria prevalence and average monthly rainfall. The same results were found by KANGA K.H et al; (2018) who proved that the inter-monthly evolution of malaria morbidity and rainfall indices have a similar pattern. There are two peaks (in June and November) for the malaria morbidity index and two peaks in April and September for the rainfall index. However, there is a time lag of one to two months between the rainfall maxima and the malaria morbidity peaks.

In contrast, Dansou et al (2015) show that there is a negative correlation between malaria and temperature, i.e. r = - 0.40; in the municipality of Pobe. This shows that the rise in temperature leads to a decrease in the number of cases of malaria. According to them, hot weather tends to reduce the number of cases of malaria. On the other hand, there was a positive but weak correlation between malaria and rainfall (r = 0.71). There is therefore a dependency between malaria and rainfall. All in all, the coefficient of determination R^2 is 50.41%, which shows that the variation in malaria is explained by the variation in climatic factors of which rainfall in particular accounts for 53.5%.

The correlation between temperature and malaria shows that the hottest months record the lowest rates of malaria cases, while the months with the lowest temperatures are the most malarial. The significant decrease in temperature is responsible for the high prevalence of malaria cases. Maximum temperatures in the Municipality only exceed the 40°C threshold in March and April; minimum temperatures are below 28°C. KANGA K.H et al; (2018) have stated that there is a negative association between changes in temperature and changes in malaria morbidity. This negative combination means that the number of cases recorded in the Health District of South Bouake decreases when the temperature rises. Temperature is indeed a factor controlling the development of mosquitoes both in water and on land. Temperature is a key parameter in the production and distribution of malaria vectors.

In terms of air quality, January, February and March have the lowest rates of humidity, while July, August and September have the highest. There is a strong correlation between humidity and malaria prevalence (r=98%). BOMBA Jean Claude et al; (2018) had stated that there is a strong correlation between the two parameters. There is therefore a very strong positive correlation between changes in humidity levels and changes in malaria disease burden. This very strong positive association between changes in humidity levels and changes in malaria disease burden shows that the disease burden recorded in the Health District of South Bouake increases when the relative atmospheric humidity rises.

V. CONCLUSION

This study made it possible to examine changes in rainfall and the prevalence of malaria in the municipality of Sinende. The monthly dynamics of climatic parameters modulate the prevalence of malaria cases in the municipality. This pattern provides a particularly favorable environment for the development of the malaria vector and parasite. The combination of these climatic parameters favors the expansion of malaria-transmitting vector species through the production and proliferation of breeding grounds and the creation of suitable conditions for mosquitoes to thrive.

REFERENCES

[1] HOWARD, C. and HUSTON, P. (2019) Health effects of climate change: Discover the risks and be part of the solution. CCDR, vol. 45, p. 5.

[2] D.J. Rogers, (1996) Changes in disease vector distributions. In: Climate change and southern Africa: an exploration of some potential impacts and implications in the SA DC region », M. Hulme (Ed.), Climate Research Unit, University of East Anglia, Norwich (1996): p.49-55.

[3] R.W. Sutherst, (1998), Implications of global change and climate variability for vector-borne diseases: generic approaches to impact assessments, International Journal for Parasitology 28 (1998): p.935-945.

[4] Wickremasinghe, R., Wickremasinghe, A. R., & Fernando, S. D. (2012). Climate change and malaria: a complex link. UN Chronicle, 47(2), 21-25.

[5] MOUSSA Fane (2011) : The impact of climate on the ecology and transmission of malaria: analysis of malaria risk in northern Mali, PhD thesis, University of Grenoble, 145p

[6] KANGA Kouakou Hermann Michel, KOUASSI Konan, BRISSY Olga Adeline, ASSI-KAUDJHIS Joseph P. (2018) Seasonal variation of malaria and risk of disruption of the agricultural calendar in the health district of bouake sud.

Revue Espace, Territoires, Sociétés et Santé, Vol. 1, No. 2, December 2018, pp. 62- 75

[7] DANSOU, Brice. , ODOULAMI, Leocadie (2015). Climatic parameters and occurrence of malaria in the municipality of Pobè, south-east Benin. In: XXVIIIth Colloquium of the International Climatological Association, Liège. 2015. Pp 129-132.

[8] BOMBA Jean Claude, KEMBE Marcel, ZAGUY GUEREMBO Raoul Ludovic. (2021). Impact of variations in climate parameters on the prevalence of malaria in the city of Bangui (Central African Republic) Revue Espace, Territoires, Sociétés et Santé, 4 (7), 9-24