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Malaria epidemics detection and associated climatic factors in the Hauts Bassins Health Region of Burkina Faso

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ABSTRACT

Background: Malaria is endemic in the Hauts Bassins Health Region, making it necessary to detect epidemics. Though malaria is a climatic sensitive disease, the association between malaria occurrence and climate is not well known in the Hauts Bassins Health Region. The study sought to detect malaria epidemics and assess the correlation of malaria cases with climate.

Methods: A secondary analysis of ecological data from the National Health Information System (NHIS) and the General Directorate of Meteorology of Burkina Faso was conducted. Mean, quartiles and cumulative sum methods were performed to set epidemic thresholds. Correlation between malaria and climatic factors in the health region was assessed using Spearman's test. A Mann-Whitney test determined the association of malaria transmission seasons with climatic variables, at 5%. Kruskal-Wallis test evaluated the relationship between malaria and the years of the occurrence, at a 5% significance level.

Results: From 2013 to 2016, 2,521,789 malaria cases were reported in the region, with a mean incidence of 269 cases per 10,000 people. The annual incidence increased from 2,048 cases per 10,000 people in 2013 to 5,277 cases per 10,000 people in 2016. Regardless of the method used, cases were high in 2016, with few exceptions. There was a weak negative correlation between malaria and minimum (r=-0,292; p-value=0.044) and maximum (r=-0,391; p-value=0.006) temperatures. The relationship between relative humidity and malaria was positive and weak (r=0,304; p-value=0.036). Lowest temperatures and highest relative humidity simultaneously drove malaria within-year variability during the high transmission season.

Conclusion: Malaria incidence increased unexpectedly in 2016. Malaria endemicity hides a within-year and year-to-year variability, partially driven by the temperature, relative humidity and rainfall.
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Keywords: malaria, detection, correlation, climatic, Burkina Faso

INTRODUCTION

Vector-borne diseases like malaria are a public health problem. Worldwide, malaria cases decreased from 251 million cases in 2010 to 228 million in 2018 (World Health Organization, 2019). While the reduction was significant before 2014, it has stabilized since 2014. Further, most of the malaria cases occur in Sub-Saharan Africa, as well as the deaths. In Burkina Faso, malaria is endemic in all the health regions, including the Hauts Bassins region. Malaria is the leading cause of hospitalisation, outpatient consultations, and deaths (Ministère de la santé, 2019).

Given its significant morbidity and mortality, malaria has been considered a priority disease by the technical guide of the integrated disease surveillance and response (IDSR) in the African Region (WHO & CDC, 2010). Under the IDSR, malaria surveillance is done at the national level, following the international framework defined by the International Health Regulations (IHR). Surveillance data is meant to be analysed and interpreted so that potential epidemics can be investigated and confirmed in time (WHO & CDC, 2010).

Detecting outbreaks at the initial stage becomes a big challenge (Teklehaimanot et al., 2004). It enables implementing the appropriate responses early enough to control the epidemic phase and reduce the number of cases (WHO & CDC, 2010). Regarding malaria, the epidemic threshold must be determined at the local level. Only simple tools but reliable could be performed at the lowest level of the health system like the health facilities, the health district or region. The World Health Organization has recommended quartiles to set thresholds in malaria-endemic settings (WHO & CDC, 2010; World Health Organization, 2004).

In addition to quartiles, mean + 2 standard deviations (SD) and cumulative sum are simple techniques used in Ethiopia, Kenya, and Sudan to set malaria epidemic thresholds with different performances (Hay et al., 2002; Hussien, 2019; Teklehaimanot et al., 2004). The three methods could also detect malaria epidemics in the Hauts Bassins Health Region of Burkina Faso, given that the epidemic threshold has not been established in the region yet. Once an epidemic is detected, the factors leading to its emergence should be examined, aside from the response deployment.

As a climate-sensitive disease, malaria epidemics could be partially explained by climatic conditions and meteorological cycles(Najera et al., 1998). Temperature, humidity, and rainfall are the most critical climatic elements influencing malaria occurrence (McMichael, 2003). Association of climatic factors with malaria cases or incidence have been widely assessed at the Sahelo-Sudanese zone of Burkina Faso, but not in the Sudanese climatic area, including the Hauts Bassins health region (Ouedraogo et al., 2018; Rouamba et al., 2019).

In this study, we focus on detecting malaria epidemics (the unusual increase in malaria cases beyond the expected) in 2016 in the Hauts Bassins Health Region, using three simple statistical methods, and assessing the association between malaria cases and temperature, relative humidity and rainfall.

MATERIALS AND METHODS

The cases definitions for malaria

Malaria cases were diagnosed as defined by the technical guidelines for Integrated Disease Surveillance and Response (IDSR) in the WHO African Region (WHO & CDC, 2010):
-uncomplicated malaria – any person, living in the health region with a history of fever within 24 hours, without signs of severe disease (vital organ dysfunction) was diagnosed clinically;
-confirmed uncomplicated malaria – any person with fever or history of fever within 24 hours, with laboratory confirmation of diagnosis by malaria blood film or another diagnostic test for malaria parasites;
-unconfirmed severe malaria – any patient living in the health region, hospitalized with an acute fever accompanying vital organ dysfunction diagnosed clinically;
-confirmed severe malaria – any patient hospitalized with malaria as confirmed by laboratory test with accompanying symptoms and signs of severe disease (vital organ dysfunction) diagnosed through a laboratory.

Study setting

The Hauts Bassins Health Region is one of the 13 health regions in Burkina Faso. It covers an area of 25,434 square kilometers, with an estimated population of 1,836,838 inhabitants in 2013 and 2,025,511 inhabitants in 2016 (Ministère de la santé, 2014, 2017). The number of public health facilities of different levels increased from 199 distributed across seven health districts in 2013 to 274 facilities in 8 health districts in 2016 (Ministère de la santé, 2014, 2017). From 2013 to 2016, private health facilities increased from 69 to 74.

Burkina Faso has a semi-arid tropical climate divided into three climatic zones: Sahelian in the North, Sahelo-Sudanese in the middle, Sudanese in

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the South (Abdoulaye et al., 2017). The Hauts Bassins region is located in the Sudanese climatic zone, the least hot and the wettest area. Given the climatic data, between 2013 and 2016, the mean minimum and maximum temperatures were 22.5°C ± 2.1°C and 33.8°C ± 2.6°C, respectively. The median rainfall during the period was 60.7 mm (0.6; 172.7). The median humidity was 57.5 (31.8; 75.3). Mean (minimum and maximum) temperatures were higher during the low transmission season (January to June) than the high transmission period (July to December). In contrast, median humidity and rainfall were higher in the high transmission each year from 2013 to 2016.

Data collection and sources

Epidemiological data were available from 2013 because a different database hosted it before that. Malaria monthly reports from 2013 to 2016 were obtained from Endos-BF, under the National Health Information System (NHIS), following a request for data to the Regional Health Directorate of the Hauts Bassins. Monthly data on the minimum and maximum temperatures, rainfall and relative humidity from 2013 to 2016 were sought from the General Directorate of Meteorology.

Epidemiological data came from the monthly reports of health facilities (public and private), hospital care and specialised units. At the district level, data are entered into the Health Data Warehouse (Endos-BF) from the Centres for Health Information and Epidemiological Surveillance (CISSE) and from the Hospital Planning and Information Services (SPIH) or Medical Information Services (SIM) at the hospital level. Reports are meant to be transmitted by the 5th of the month following the covered month. The district or hospital level has until the 20th of the month following the covered month to check the data on Endos-BF, the regional level until the 25th and the national level 15 more days (Ministère de la santé, 2014).

The General Directorate of Meteorology, in collaboration with the World Meteorological Organization, is responsible for the collection and management of climatological data in Burkina Faso. The rainfall was measured using an association or direct-reading rain gauge. Mercury and alcohol thermometers placed in a weather shelter read the maximum and minimum temperatures. Relative humidity was measured using a hygrometer. An automatic station controlled the rainfall, temperatures, and relative humidity values.

Data analysis

Data was analysed using Microsoft Excel for setting thresholds and Statistical Package for Social Sciences (SPSS) version 20 for the other analyses. The reported number of malaria cases and the season of malaria transmission were the dependent variables. Malaria transmission was divided into two periods following the dry and rainy seasons: low transmission period from January to June; and high transmission period from July to December. The independent variables were minimum and maximum temperatures, rainfall, and relative humidity, as well as the year of occurrence. The different analyses are shown below.

The incidence rate of malaria

Malaria incidence per month was calculated by dividing the number of cases of the targeted month by the population at mid-year for the concerned year. In the Hauts Bassins region, the population at mid-year was estimated at 1836838, 1898361, 1961204 and 2025511 people in 2013, 2014, 2015 and 2016 respectively.

Mean + 2 standard deviation method

This approach, developed by Cullen et al., was applied by calculating the mean and standard deviation of monthly malaria cases from 2013 to 2015 (Cullen et al., 1984). The mean and mean +2SD figures were plotted, representing the malaria epidemic's lower and upper thresholds. In the graph, when the number of monthly malaria cases in 2016 exceeds the upper limit, an outbreak was suspected. The area between the two limits represents the usual trend of malaria cases.

Median and third quartile method

The median is recommended as part of the

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Integrated Disease Surveillance and Response (ISDR) in the African Region (WHO & CDC, 2010). Median and third quartile were calculated with monthly malaria cases from 2013 to 2015 and plotted with the data of 2016. Any time that malaria cases in 2016 exceeded the third quartile (upper limit), an epidemic situation was suspected. When the cases lie between the upper limit and the lower limit (median), an endemic trend is declared, representing the "normal channel". Mean, mean +2SD, median and third quartile, and the 2016 data were plotted together in a graph.

Cumulative sum method at the 3-months moving average

The Centers for Disease Control and Prevention (CDC) has developed the cumulative sum (C-sum) for setting epidemic thresholds suggested by WHO to be used with malaria(World Health Organization, 2004). A 3-year baseline data of malaria -from 2013 to 2015- was used to calculate the C-sum. For the actual month, the C-sum was obtained using malaria cases from 2013 to 2015 of the previous and following months. For example, February C-sum was calculated by summing the cases of January, February, and March 2013 to 2015 and dividing by 9. Then, C-sum and refined C-sum + 2SD were plotted with monthly malaria cases of 2016.

Association analyses

Spearman's test assessed the correlation between monthly malaria cases and minimum and maximum temperatures, rainfall and relative humidity. The closer to zero the coefficient, the weaker was the relationship. It was regarded as strong when the coefficient was closer to 1, independently of the sign, which indicates the association direction. Using the number of malaria cases as a dependent variable, the association with the season of transmission and the reporting year were assessed by Mann-Whitney and Kruskal-Wallis, respectively. The climatic variables distribution by the season of transmission was also tested.

RESULTS

From 2013 to 2016, 2 521 789 malaria cases were reported in the Hauts Bassins Health Region, with the lowest number seen in April 2013 (14554 cases) and the highest in October 2016 (171166 cases). Median cases remained stable between 2013 and 2015 and increased significantly in 2016, compared to previous years.

The median cases of malaria were 30367 (19963, 41658) cases in 2013, 34669 (28554, 51884) cases in 2014, 32584 (26909, 64234) cases in 2015 and 87911 (56489, 113769) cases in 2016.

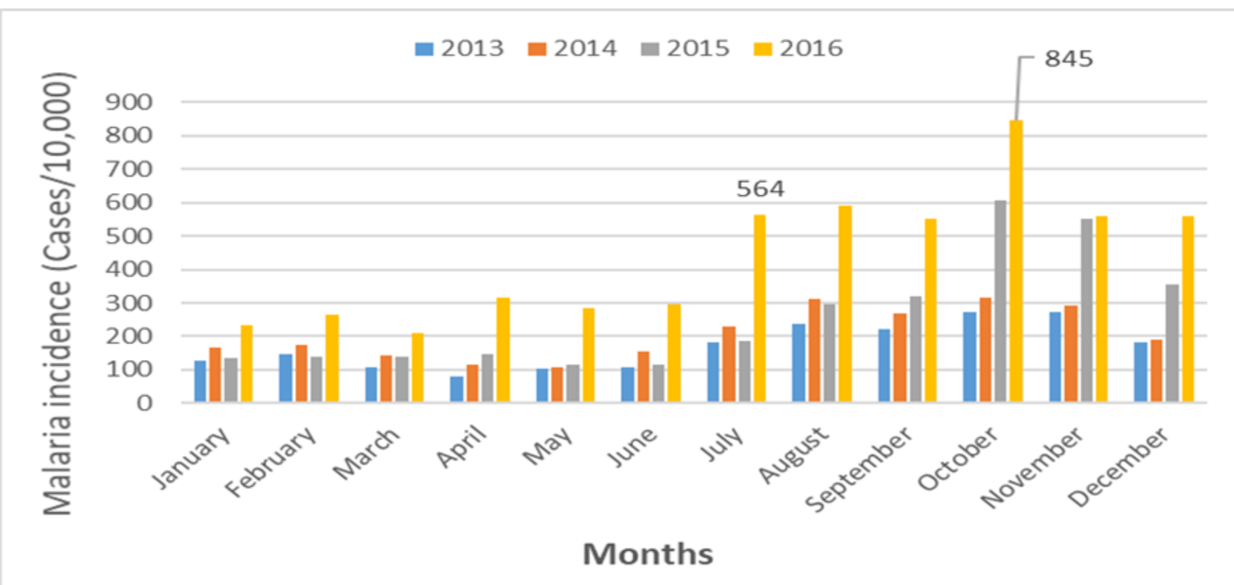

Figure 1: Incidence of malaria in the Hauts Bassins Health Region, from 2013 to 2016

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Incidence of malaria in the Hauts Bassins region from 2013 to 2016

The annual incidence of malaria increased from 2048 cases per 10,000 people in 2013 to 5277 cases per 10,000 people in 2016. Over the study period, the mean incidence was 269 cases per 10,000 people in the Hauts Bassins health region. Over the period, malaria was endemic, and cases were reported every month. Globally, Figure 1 showed two main periods of malaria transmission: low transmission from January to June, and high transmission from July to December, with a peak in October. The year 2016 showed an unexpected increase in malaria cases significantly compared to the previous years. Malaria incidence was higher in 2016 than that of every month from 2013 to 2015. During the low transmission period in 2016, malaria incidence was 300 cases per 10,000 people, while it ranged from 600 to 900 cases per 10,000 people during the high transmission season. Malaria incidence was also significantly higher from October to December 2015 than that of the previous years.

Epidemic detection of malaria in 2016 using median and mean methods

There was generally an unexpected increase in malaria cases during the whole of 2016, above the 3rd quartile level (Figure 2). Malaria cases increased abnormally in 2016, except for November when the cases were lower than the mean + 2 SD threshold (135,024 cases).

Epidemic detection of malaria in 2016 using the cumulative sum (C-SUM)

Malaria cases increased unexpectedly in 2016, regarding the refined C-sum (C-sum+1.96), except in January, where the 47,432 cases were below the month upper limit (61,481 cases), and November with 113,557 cases lower than the limit (123,082 cases) (Figure 3).

Correlations between malaria and climatic factors

Considering the Spearman's correlation, malaria was negatively correlated with minimum and maximum temperatures (Table 1). This correlation was weak and statistically significant (p-values =0.044 and 0.006, respectively). Thus, any unit increase in minimum temperature (+1°C) results in a 29% decrease in malaria cases, while the rise in maximum temperature was associated with about 39% reduced cases.

With the relative humidity, malaria showed

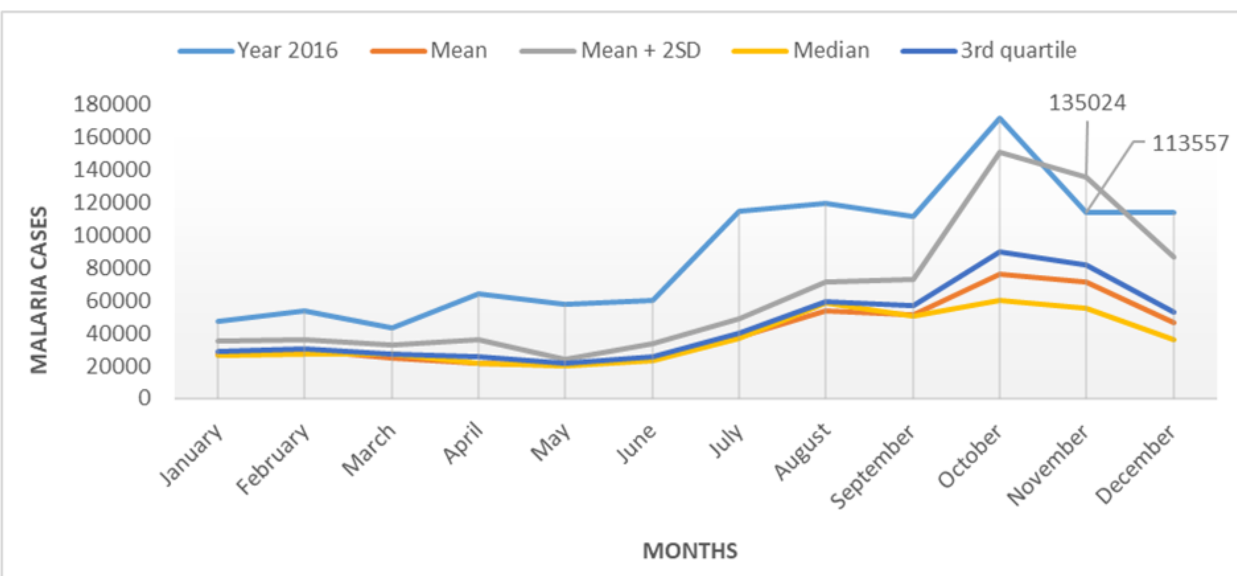

Figure 2: Malaria epidemic threshold in the Hauts Bassins Health in 2016 using the median and mean methods

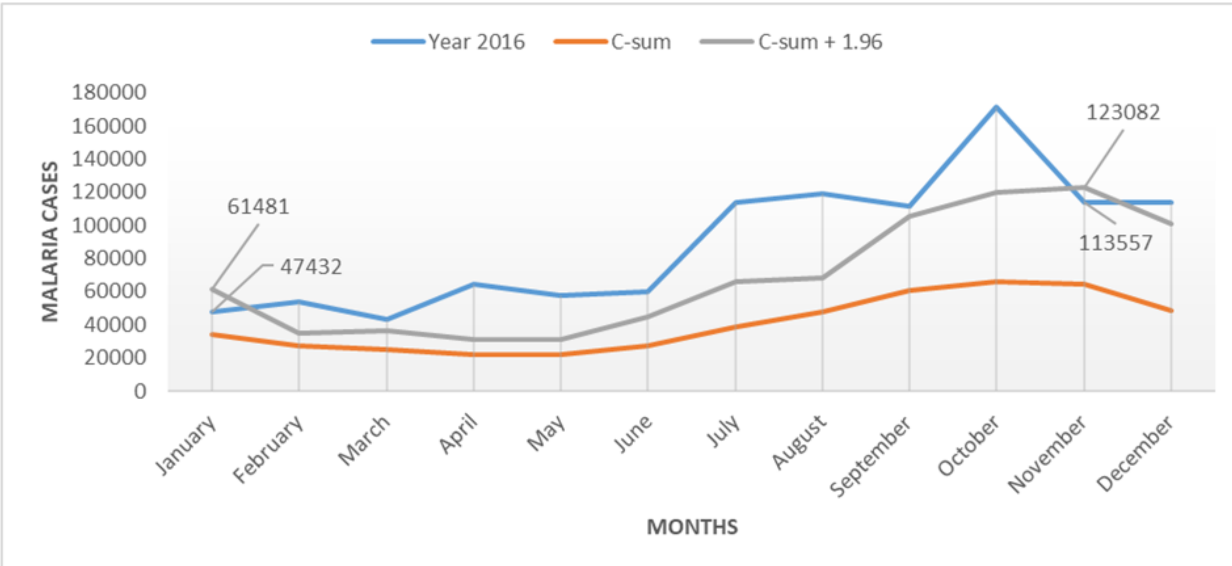

Figure 3: Malaria epidemic threshold in the Hauts Bassins Health Region in 2016 using the C-sums

statistical significance (r=0.304; p-value=0.036) and a weak positive association between malaria cases. Any unit increase in humidity (+1%) provokes about 4% more cases of malaria. There was no significant correlation between malaria and rainfall (r=0.170; p-value=0.248). However, the rainfall was associated with temperature and humidity. Any unit increase in rainfall results in about a 50% decrease in maximum temperature (p-value<0.001). The rise in rainfall origins about a 91% increase in relative humidity (p-value<0.001).

Climatic conditions favourable for malaria within year transmission

We found median minimum and maximum temperatures (22.1 °C versus 23.9 °C; 31.6 °C versus 35.7 °C respectively) systematically lower during the high transmission period compared to the low transmission period. In contrast, relative humidity (75% versus 41%) and rainfall (110 mm versus 31 mm) were higher for the same period (Table 2).

Using the Mann-Whitney test, minimum and maximum temperatures depended significantly on the level of malaria transmission (p-value=0.003 and <0.001, respectively). Similarly, relative humidity (p=0.001) differed statistically between low and high transmission seasons of malaria.

Table 1: Spearman's correlation matrix for malaria and climatic factors in the Hauts Bassins Health Region, from 2013 to 2016, Burkina Faso

Variable	Tmin	Tmax	Rainfall	Humidity	Malaria
Tmin	1				
Tmax	0.636 (<0.001)	1			
Rainfall	0.194 -0.186	-0.518 (<0.001)	1		
Humidity	0.139 -0.345	-0.619 (<0.001)	0.909 (<0.001)	1	
Malaria	-0.292 -0.044	-0.391 -0.006	0.17 -0.248	0.304 -0.036	1

T-max: Maximum temperature (°C); Tmin: Minimum temperature (°C); Humidity: relative humidity (%); Rainfall in mm.

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Table 2: Distribution of climatic elements depending on the malaria season of transmission

	Season of transmission		
Variables	Low (n=24)	High (n=24)	P-value
Minimum temperature (°C)			U=145, 0.003
Median (IQR)	23.9 (21.8; 25)	22.1 (21.6; 22.6)	
Maximum temperature (°C)			
Median (IQR)	35.7 (33.2; 37.1)	31.6 (30.6; 33.7)	U=83.5, <0.0001
Rainfall (mm)			
Median (IQR)	31 (0; 83)	110 (5; 229)	U=380, 0.057
Humidity			
Median (IQR)	41 (27; 63)	75 (47; 80)	U=453.5, <0.0001

U: value for Mann-Whitney Statistic, IQR: InterQuartile Range

Within a year and year-to-year variability of malaria cases

Malaria median cases differed significantly between the low and high transmission periods (Mann-Whitney U=61, n1=n2=24, p-value < 0.001). With 27,150 and 58,881 median cases during the low and high transmission times, respectively, malaria transmission varies within a year (Table 3).

Malaria median cases increased from 30,367 in 2013, 34,669 in 2014, and 32,584 in 2015 to 87911 in 2016. Further, malaria median cases differed significantly between years ($\chi 2(3)$ =18.10, n1=n2=n3=n4=12, p-value < 0.001), revealing a year-to-year variability.

From the post hoc test of Kruskal-Wallis in Table 4, the year-to-year variability of malaria cases was especially significant between 2016 and 2013 (p-value < 0.001) and between 2016 and 2014 (p-value=0.017).

DISCUSSION

The study aimed to detect malaria outbreaks in the Hauts Bassins region, using surveillance data from 2013 to 2016, and assess malaria association with climatic elements. Over 2.5 million malaria cases were reported in the health region. Malaria has been endemic as it was reported all year round throughout the study period and is still the primary cause of morbidity and mortality in the Hauts Bassins Health Region (Ministère de la santé, 2014, 2017, 2019). This endemicity hides the fact that the level of transmission and the number of malaria cases are not stable over time, making it essential to monitor and detect unexpected increase under the Integrated Disease Surveillance and Response System in the African Region and guidelines from the World Health Organisation (WHO)(WHO & CDC, 2010; World Health Organization, 2004).

There was a year-to-year variability, with malaria quartiles cases increasing from 30367 (19963, 41658) cases in 2013 to 87911 (56489, 113769) cases in 2016. This variation was statistically significant when comparing the years 2013 or 2014 to 2016. In effect, malaria incidence was higher for each month of 2016, compared to the months from 2013 to 2015. Indeed, the year 2016 showed an unusually high incidence of malaria compared to the base years (2013-2015), regardless of the threshold method used, with a few exceptions. These methods captured an unexpected rise in malaria cases in 2016 in the Hauts Bassins health region, as revealed in Ethiopia and Sudan (Hussien, 2019; Teklehaimanot et al., 2004). However, they performed differently because the mean + 2SD failed to detect unexpected cases in January 2016, while the refined C-sum did not catch it in January and November 2016, respectively.

The mean method is less accurate, missing unexpected increases in cases, as found with Thailand's monthly records (Cullen et al., 1984). It is explained by the fact that both mean and standard deviation are subjected to extreme values. The C-sum + 1.96 SD is also influenced by extreme figures and subject to the standard deviation weaknesses (World Health Organization, 2004).

Table 3: Association between malaria cases, and season of transmission and year in the Hauts Bassins Health Region, from 2013 to 2016

Malaria	Test	Sample size	Median (1st quartile, 3rd quartile)	p-value
Season of transmission	**Mann-Whitney**			< 0.001
Low transmission	U=61	24	27150 (22177, 38029)	
High transmission		24	58881 (43881, 112620)	
Year of occurrence	**Kruskal-Wallis**			< 0.001
2013	$\chi 2(3)=18.10$	12	30367 (19803, 42397)	
2014		12	34669 (28049, 52980)	
2015		12	32584 (26801, 66060)	
2016		12	87911 (55553, 113897)	

Table 4: Dunn's Multiple Comparison Test

Years	2013	2014	2015	2016
2013	1			
2014	0.262	1		
2015	0.112	0.641	1	
2016	< 0.001	0.017	0.070	1

However, the median is insensitive to extreme values and is the best measure for data with significant variability like malaria cases. The quartiles method has then been recommended by WHO in setting malaria epidemic thresholds under the Integrated Disease Surveillance and Response in the African Region (WHO & CDC, 2010). Used in Ethiopia, the percentile was a better threshold, as it detected the epidemics early and prevented a substantial number of malaria cases using weekly data (Teklehaimanot et al., 2004). However, the C-sum is also cited as ideal for seasonal diseases like malaria because it adjusts for it, and it performed the best in Sudan (Hussien, 2019).

Beyond setting the thresholds and detecting a virtually unexpected increase in cases, the reasons for the cases rise could be discussed. It is essential to conclude if it is due to an actual outbreak before investigating in the field to confirm it and taking actions. In our study, this increase could result from a free healthcare policy for children under five years and pregnant women -the most vulnerable groups to malaria- that started in Burkina Faso in 2016. It increased the healthcare-seeking behaviour and the availability of rapid diagnostic tests, leading to an increased number of confirmed cases amongst children under five years (Ouédraogo et al., 2020). But, specific climatic conditions could have also explained partially that malaria cases increased significantly in 2016.

There was a negatively weak relationship between malaria cases and the minimum and maximum temperatures, as malaria cases decrease with the increase in temperatures. This trend was also found in Niger, with malaria morbidity significantly and negatively associated with temperature; and especially with maximum temperature in Sudan (Hamidou et al., 2018; Hussien, 2019). This opposite trend of malaria morbidity and the temperature is so because high temperatures (>33° C) can stop the sporogonic cycle of *Plasmodium* and mosquitoes development (Nkurunziza et al., 2010; Pages et al., 2007).

Indeed, 50% of the maximum temperature figures lied between 30.6 and 33.7 °C during the high transmission period in the Hauts Bassins health Region and were lower than those during the low transmission period. The minimum temperature, comprised between 21.6 and 22.6 °C during the high transmission period, was lower than that in the low transmission period. These values are limit to allow the sporogonic cycle of *Plasmodium*, which was reported to be compromised under 23°C or 18°C (Pages et al., 2007). Relative humidity increases during the rainy season, as it was strongly associated with rainfall (r=0.909; p-value<0.001).

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The rise in humidity was associated with an increased number of cases, a trend shown by Spearman's test's positive association. Similar correlations were found in Niger, Sudan and Iran (Hamidou et al., 2018; Hussien, 2019; Mohammadkhani et al., 2019).

These favourable conditions in terms of temperature and relative humidity occur together during the rainy season, with the peak of malaria cases in October, far from heavy rains that could destroy mosquitoes breeding sites. The rainfall was not associated with malaria cases, but it determines the lowest temperatures and highest humidity, as it was negatively associated with temperatures and positively with humidity. Two months after rainfall peak in August, the temperatures were low enough and the relative humidity high enough to favour Plasmodium and mosquitoes development and malaria transmission. This combination of the lowest temperatures and highest humidity during the rainy season, as compared to the dry season, drives malaria cases variability within the year.

It is also crucial to know that malaria cases peak occurred in October, two months after the peak of rainfall and humidity. Malaria being seasonal, populations could be prepared for the highest number of cases in July or August and maybe less cautious when the rainy season is finishing. This is interesting for policymakers and local health staff that could implement actions early during the rainy season to avoid a massive peak, but also and mostly to be ready to face the malaria wave around October each year. The reasons for the rise intervening only two months after that of some climatic elements were not discussed here.

Our study showed the importance of simple methods to detect the malaria epidemic in the Hauts Bassins region and the median method's reliability in line with trials in Ethiopia or Sudan(Hussien, 2019; Teklehaimanot et al., 2004). However, monthly records were used to check the potential utilisation of these methods, while weekly data could be more suitable during an implementation phase on the field.

CONCLUSION

Malaria remains endemic in the Hauts Bassins Health Region. This endemicity hides that cases vary within a year and from one year to the next, modulated partially by climatic elements. Thus, 2016 showed an unprecedented number of cases, as compared to the previous years. Regardless of the method used, the unexpected rise in malaria cases in 2016 was captured. The mean, quartiles, and C-sum would be useful at the peripheric level for field epidemiologists and those responsible for the epidemiological surveillance of diseases.

COMPETING INTEREST

Authors declare that they have no competing interests.

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AUTHORS CONTRIBUTION

JCRPO obtained the data following request to the Regional Health Directorate of the Hauts Bassins and the General Directorate of Meteorology. JCRPO and EMB analysed and interpreted the data. JCRPO wrote the manuscript. EMB reviewed the manuscript and made substantial contributions, read and approved the final version.

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