



Effects of Climatic Factors on Malaria Prevalence in Calabar Metropolis, Cross River State, Nigeria

by

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Abstract

Climate variability is widely considered a major driver of inter-annual variability of malaria. However, detailed studies of the interaction of climatic parameters in influencing malaria in high-risk areas have not been adequately researched. This study examined the effects of climatic parameters on malaria prevalence in Cross River State, Nigeria. Reported cases of malaria and climatic data were collected from the record unit of the General Hospital and Nigerian Meteorological Agency, Calabar, Cross River State, Nigeria respectively for twenty-nine years (1983-2012). The study used both descriptive and inferential statistics to analyze the collected data. The descriptive statistics used include line and bar graphs, mean, mode, percentage and tables whereas, the inferential statistic mainly Pearson's correlation, Multiple Regression Analysis (MRA), and Principal Component Analysis (PCA) were used to identify prominent factors that influence malaria prevalence in the area. The results obtained from the correlation analysis showed that malaria prevalence had a low positive and insignificant associations with maximum temperature ($r = 0.331, p > 0.05$), minimum temperature ($r = 0.313, p > 0.05$), wind speed ($r = 0.119, p > 0.05$), sunshine ($r = 0.355, p > 0.05$) and evapotranspiration ($r = 0.357, p > 0.05$) on the one hand, and on the other, prevalence showed low negative and insignificant relationship with rainfall amount ($r = -0.216, p > 0.05$) and relativity humidity ($r = -0.285, p > 0.05$). The result revealed generally a low association between malaria prevalence and climatic variables. The PCA identified maximum temperature to be responsible for malaria incidence in the wet season, while in the dry season, malaria prevalence is jointly influenced by rainfall amount and wind speed. The results showed that climatic variables have direct influence on malaria prevalence. Appropriate malaria prevention measures are required to reduce the prevalence of the disease in the area.

Key words: Malaria, Prevalence, Maximum and Minimum Temperature, Dry and Rainy Season

1. Introduction

Malaria is endemic in Nigeria with variations in different parts of the country due to differences in environmental and socioeconomic factors. More than 90 percent of the total population is at risk of malaria and at least 50 percent of the population suffers from at least one episode of malaria each year (World Health Organization, 2003). Transmission of malaria is associated with changes in temperature, rainfall, humidity as well as level of immunity (Bai, 2013; Huang *et al*, 2011). Climate variability is widely considered to be a major driver of inter-annual variability of malaria incidence worldwide. Furthermore, existing studies on the interaction between climate and malaria have focused in recent time on the potential role of climate change in determining increases in malaria transmission in highland areas in Africa where temperature and rainfall rather than other climatic factors have been the parameters of greatest interest.

However, detailed studies of the interaction of climatic parameters and malaria in Nigeria and elsewhere are limited. There are obvious reasons for this deficiency. These include the general weakness of the health information systems leading to paucity of times series of confirmed case data, and difficulties in accessing appropriate climatic data for the specific locations and time periods for which case data are available. More so, several studies have served to highlight the significant methodological difficulties in undertaking such analyses (Parhan and Michael, 2010; Srinivasulu *et al.*, 2013). Hitherto, earlier studies on malaria prevalence focus on environmental/hygiene related factors of malaria. Recent studies on malaria focused on spatial distribution of malaria and its incidence (Ohwofasa, 2010; Omumbo, 1998), and some other scholars categorized malaria occurrence (Wen *et al.*, 2008). While it is generally agreed that scholars have explored the resultant effort of malaria in the tropics, studying the interactive effects of climatic factors on malaria prevalence is scanty. This study focuses on the impact of climatic factors on malaria prevalence in Calabar, Cross River State, Nigeria.

2. Study area

Malaria is endemic in Cross River State. The state is situated in Nigeria's delta region, in the tropical rainfall belt. It lies between latitudes 5⁰32' and 4⁰27' North and longitudes 7⁰50" and 9⁰28' East of the equator. It is bounded in the north by Benue State, in the South-West by Akwa Ibom State, in the West by Ebonyi and Abia States. The State shares an international boundary with the Republic of Cameroon, and an Atlantic coastline in the south. Cross River State occupies the catchments of the Cross River, which originated from the Cameroon Mountains, across the flat lying Cross River Basin into a vast estuary located along the Southern Nigeria/Cameroon border. A variety of water bodies in the area (Fig. 1) provide suitable breeding ground for mosquito vectors, thereby influencing the endemism and distribution of the disease. With an area of 23,074 square kilometers and population of 1.8 million (NPC, 2010) and its divided into 18 Local Government Areas. Its capital is Calabar and other major towns in the state include; Akamkpa, Ikom, Obubra, Odukpani, Ogoja, Okundi, Ugep, Obudu, Obanliku, Akpabuyo among others.

The climate within Cross River State is tropical humid with wet and dry seasons, with average temperature ranging between 15⁰c-30⁰c and the annual rainfall between 1300-3000mm. The high plateau of Obudu experience climatic conditions which are markedly different from the generalized dry and wet period in the rest of the Cross River State. Temperature 4⁰c- 10⁰c lower due to high altitude than in the surrounding areas

similarly, the annual rain fall figures are higher than in areas around them, particularly on the windward side. Cross River State, can thus be broadly divided into the following sub-climatic regions; the moderate sub-temperate within the high plateaus of Obudu and the hot wet tropical extending from the southern lowland to the central and northern hinterland part. Precisely, the area is characterized by high temperature, rainfall and humidity. Higher rainfall combined with increasing temperature offset potential evaporation, so that both factors tend to increase surface water available for breeding of vectors. This climatic pattern has serious effects on the abundance and seasonal distribution of malaria vectors. Therefore, this study sets out to examine the effects of climatic factors on malaria prevalence in Cross River State, Nigeria.

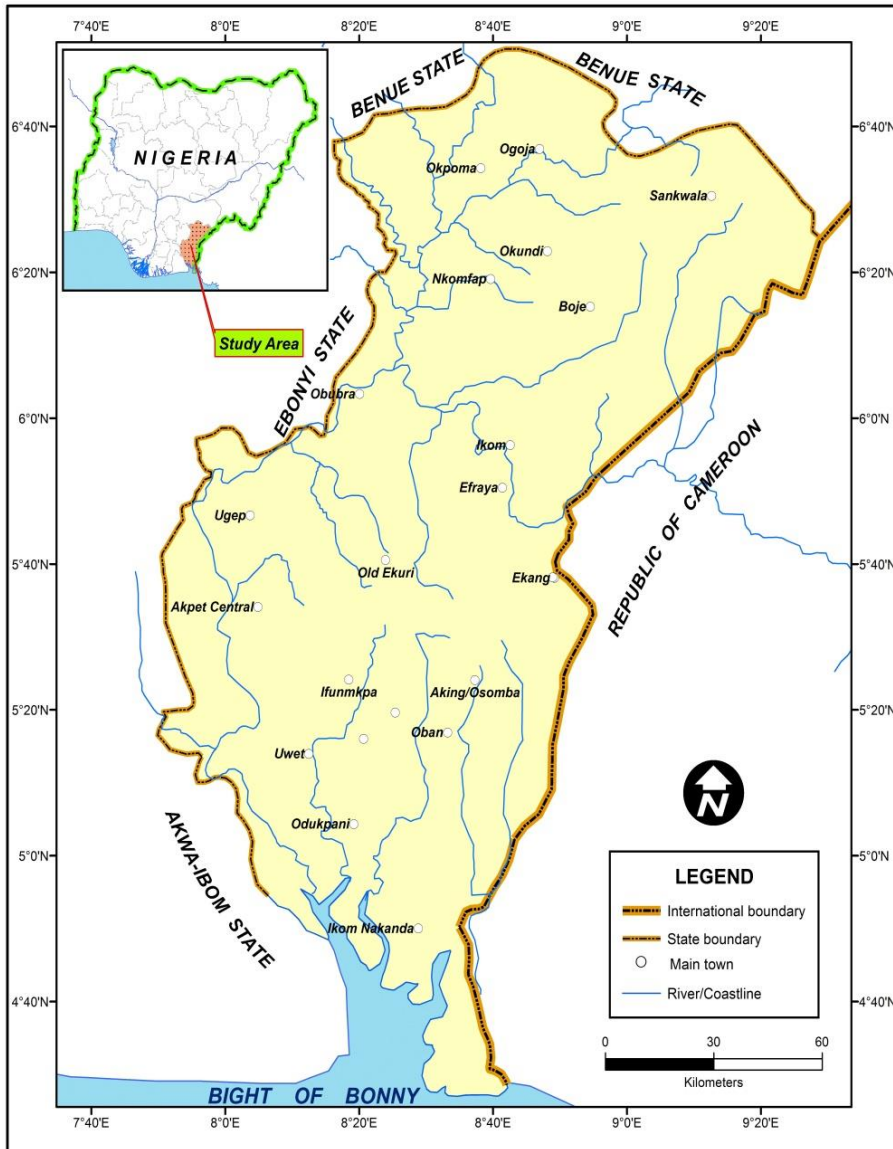


Figure 1: Cross River State showing vector environment
 Source: Cross River State Ministry of Lands and Surveys, 2013

3. Research methodology

The study made use of secondary only. Reported cases of malaria were collected from the record unit of the General Hospital, Calabar. The climatic data were gathered from the Nigerian Meteorological Agency which controls stations in Cross River State, Nigeria for twenty-nine years (1983-2012). The study used both descriptive and inferential statistics to analyze the collected data. The descriptive statistics used include line and bar graphs, mean, mode, percentage and tables whereas the inferential statistic mainly Pearson's correlation, Multiple Regression Analysis (MRA), and Principal Component Analysis (PCA) were used to identify prominent factors that predispose malaria incidence in the area. For instance, Pearson's correlation was employed to understand the pattern of association or interrelationships between malaria incidence and climatic variables for dry and wet seasons. MRA was used in two instances, first, for the climatic parameters, MRA was performed using the stepwise multiple regression analysis approach to build predictive models in predicting malaria prevalence using climatic variables precisely maximum temperature, minimum temperature, rainfall, humidity, sunshine and wind speed. Whereas, PCA is a technique for simplifying a data set by reducing multidimensional data sets to lower dimensions in the data. Thus, PCA was employed to understand or extract the most significant and prominent climatic variable responsible for the temporal pattern in malaria incidence for the 29 years period. The PCA procedure was performed using variable maximization (varimax rotation) as well as the Kaiser rule of extracting components with eigenvalues >1 (Gaur and Gaur, 2006). The above mentioned statistical analyses were carried out using Statistical Package for Social Sciences (Version 17) for Windows and the results are discussed below.

4. Results

4.1. Trends in malaria incidence

Table 4.1 shows the trends in malaria incidence from 1983 to 2012. In 1983, 74 cases of malaria were reported. The number of reported cases of malaria increased substantially to 106 in 1986 and then dropped drastically to 61 cases in 2003, which perhaps represents the lowest reported cases of malaria in Calabar. It increased steadily thereafter. As depicted in the Table., malaria increased to 189 cases in 2009 and 302 malaria cases in 2012. The trend in malaria incidence from 1983 to 2012 revealed 75.5% increase. As could be seen, the figure shows an upward trend in the cases of malaria for the period under review. This increasing trend may be attributed among numerous factors to poor access to mosquito treated net, and increasing rainfall amount (Table 4. 2). The Table also reveals that the maximum cases of malaria of 302 were in 2012, while the minimum cases of 61 were recorded in 2003.

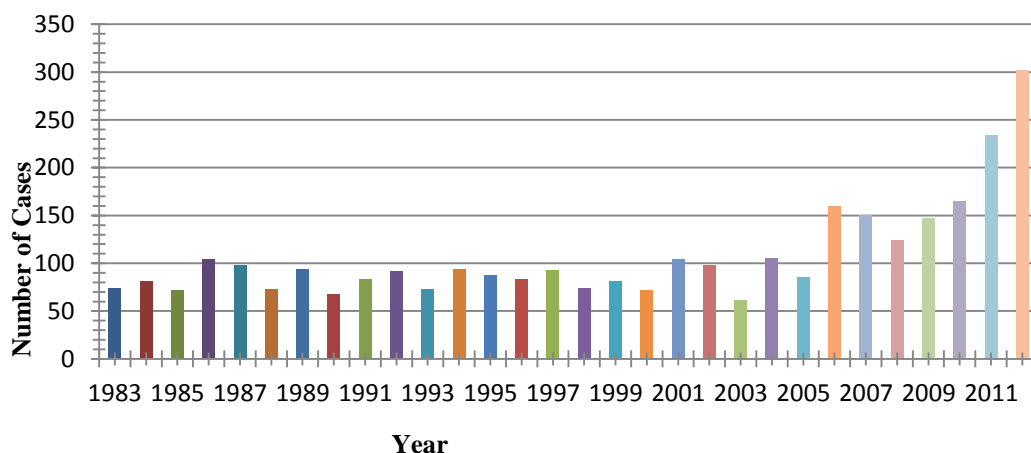


Figure 2: Total Number of Reported Cases of Malaria

4.2 Inter correlation between Malaria cases and climatic variables

The information in Table 4.2 shows that for the last three decade (1983–2012), a total of 3,142 cases of malaria were recorded in the period under review, with minimum and maximum cases of 61 and 302 respectively; and a mean malaria case of 104.73. For rainfall, a total amount of 7,061.2mm with a mean value of 243.5mm was reported with minimum and maximum amounts of 318.8mm and 7,061.2mm respectively. Information on reported cases of malaria for the time period reveals that 1,720 were males, while 1,485 were females. This simply implies that males are more infected by malaria than their female counterparts. For temperature, mean maximum and minimum temperature values for the period under review were 30.8 °C and 23.1 °C respectively. It further shows that the mean humidity and wind speed recorded the 30 years was 84.7% and 3.8 respectively.

Table 4.2: Descriptive statistics of malaria incidence & climatic variables

Variables	Minimum	Maximum	Sum	Mean	Std. Deviation
Malaria cases	61	302	3142	104.73	53.231
Max Temperature	30.1	31.5	891.9	30.755	.3785
Min Temperature	22.1	23.8	668.8	23.062	.4917
Rainfall amount	195.58	318.79	7061.24	243.4910	32.64522
Wind speed	3.0	5.3	125.0	4.310	.6026
Humidity	82.42	87.75	2456.00	84.6897	1.16867
Sunshine	2.4	4.8	109.1	3.762	.5722
Male inpatient	29	166	1720	57.33	30.981
Female inpatient	29	136	1485	49.50	28.120

Source: Fieldwork, 2014

The information in Table 4.3 shows the associations or interrelationships between malaria incidence and climatic variables. The association between the variables was determined using a parametric statistical technique. The Pearson’s correlation result in Table 4.3 shows that reported malaria cases had low positive and insignificant

associations with minimum temperature ($r = 0.120, p > 0.05$), rainfall ($r = 0.199, p > 0.05$), humidity ($r = 0.366, p > 0.05$) and sunshine ($r = 0.224, p > 0.05$). This pattern of association means that an increase in the aforementioned climatic variables would result in a parallel rise in the cases of malaria. This positive association implied that the set of climatic variables exert some amount of effects on malaria incidence, but the effect caused is insignificant. Similar pattern of associations was reported by Srinivasulu et al., (2013) and Tay et al., (2012).

The result further showed that maximum temperature had low negative and insignificant association with malaria ($r = -0.319, p > 0.05$), while wind speed had a low negative and significant relationship with malaria cases ($r = -0.451, p < 0.05$). The negative signs mean that an increase in any of the climatic variable would bring about a corresponding decrease in malaria incidence. From the obtained pattern of association, only wind speed has an indirect but significant association with malaria. Hence, the higher the wind speed, the lower the bite rate and incidence and vice versa. On the other hand, the negative association recorded for maximum temperature is unexpected; as one would have expected a positive association. This is because it is commonly believed that mosquitoes thrive better in warmer condition. Low and negative association between maximum temperature and reported malaria cases has also been reported elsewhere.

However, among the climatic variables, only sunshine and humidity showed moderate positive and significant association ($r = 0.526, p < 0.05$); this means that an increase in one would also result in the increase of the other and vice versa. While, humidity ($r = -0.487, p < 0.05$) and sunshine ($r = -0.449, p < 0.05$) showed a low negative and significant associations with wind speed; which meant that wind speed was reduced when these two climatic variables increased. Thus, the positive associations between the variables implied that they are probably influenced by similar environmental and site factors, while the negative associations mean that the various variables are not influenced by similar environmental factors. In all, the analysis implied that climatic variables have direct and indirect influence on malaria incidence and these variables can predict malaria incidence and maybe suitable for predicting the malaria occurrence in areas with similar ecological.

Table 4.3: Zero order correlation matrix

Variables	Malaria	Max tempt	Min tempt	Rainfall	Wind speed	Humidity	Sunshine
Malaria cases	1						
Max tempt	-0.319	1					
Min tempt	0.120	0.006	1				
Rainfall	0.199	0.016	-0.353	1			
Wind speed	-0.451*	-0.118	-0.257	0.020	1		
Humidity	0.366	-0.115	0.218	0.281	-0.487*	1	
Sunshine	0.224	-0.069	-0.007	0.288	-0.449*	0.526**	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed)

Source: *Fieldwork, 2014*

4.3. Predicting malaria incidence using climatic variables

Thus, stepwise multiple regression analysis was employed to build predictive models in predicting malaria prevalence using climatic variables precisely maximum temperature, minimum temperature, rainfall, and humidity, sunshine and wind speed. Stepwise multiple regression analysis makes it possible for only significant variables that contribute to the variation in the dependent variables to be upheld in the model. The stepwise multiple regression approach is used in generating equation with a small number of predictor variables, but with a high multiple R². Malaria incidence in Calabar for the 29 years period was best explained by wind speed and maximum temperature. These extracted and retained predictor variables explained 34.4 per cent of the observed variation in malaria incidence (Table 4.3). The analysis of variance result for the regression yielded an F-ratio of 6.806 which was statistically significant at 0.01 confidence level. The result indicated that a unit increase in wind speed would result in 49.5 per cent reduction in malaria incidence, while a unit increase in maximum temperature would also bring about 37.7 per cent decrease in malaria incidence. The regression analysis generated a regression model mathematically defined as:

$$Y = 1421.505 - 0.495 (WS) - 0.377 (MT) \dots \dots \dots \text{eqn 4.1}$$

Where:

- Y = the predicted malaria incidence
- WS = Wind speed ()
- MT = Maximum temperature (°C)

In addition, a look at Table 4.4 and considering the standardized regression coefficients reveals that wind speed exerts the principal influence on malaria incidence, as it helps to reduce the prevalence of malaria. This is closely followed maximum temperature. The results imply that wind speed and maximum temperature negatively affect malaria prevalence in Calabar.

Table 4.4: Summary of stepwise regression result of malaria cases with climatic variables

Predictor variables	Coefficients		
	B	β	t-value
Wind speed	-31.815	-.495	-3.097*
Max temperature	-38.577	-.377	-2.359 ⁺
Test results			
F- value	6.806*		
R	0.344		
R ²	0.586		
Constant	1421.505		2.786 ⁺

*Significant at 0.01 significance level

⁺ Significant at 0.05 significance level

Source: Researcher’s fieldwork, 2014

4.4 Temporal association between variables in the rainy season

As usual, the Pearson’s correlation analytical tool was used to find out the nature of association between malaria incidence and climatic variables in the rainy season. The result obtained is presented in Table 4.5. From the table, malaria incidence is shown to have low positive and insignificant associations with maximum temperature ($r = 0.331$, $p>0.05$), minimum temperature ($r = 0.313$, $p>0.05$), wind speed ($r = 0.119$, $p>0.05$), sunshine ($r = 0.355$, $p>0.05$) and evapotranspiration ($r = 0.357$, $p>0.05$) on the one hand, and on the other, it had low negative and insignificant relationship with rainfall amount ($r = -0.216$, $p>0.05$) and relativity humidity ($r = -0.285$, $p>0.05$). The result in the table reveals generally a low association between malaria incidence and the selected climatic variables. As noted earlier, low associations between malaria incidence and climatic variables has been reported elsewhere. Nevertheless, high positive, negative and significant associations were observed between the climatic variables. It could be deduced from the negative associations mostly between malaria incidence and rainfall, that during the rains, mosquitoes breeding sites are usually destroyed as many pools of water are filled leading to movement. The constant rains may affect the productivity of breeding sites.

Table 4.5: Zero order correlation matrix in the rainy season

Variables	Malaria	Max tempt	Min tempt	Rainfall	Humidity	Wind speed	Sunshine	Evapotranspiration
Malaria cases	1							
Max tempt	0.331	1						
Min tempt	0.313	0.979*	1					
Rainfall	-0.216	-0.901 ⁺	-0.946*	1				
Humidity	-0.285	-0.992*	-0.951*	0.858 ⁺	1			
Wind speed	0.119	0.937*	0.966*	-0.981*	-0.913 ⁺	1		
Sunshine	0.355	0.980*	0.930*	-0.804	-0.992*	0.864 ⁺	1	
Evapotranspiration	0.357	0.999*	0.973*	-0.885 ⁺	-0.992*	0.922*	0.984*	1

⁺. Correlation is significant at the 0.05 level (2-tailed).

*. Correlation is significant at the 0.01 level (2-tailed).

Source: Researcher’s fieldwork, 2014

4.5. Temporal association between variables in the dry season

Also, the Pearson’s correlation result for variables in the dry season is presented in Table 4.6. From the table, malaria incidence shows shown high positive and insignificant association with sunshine ($r = 0.781$, $p>0.05$); and a low but insignificant relation with minimum temperature ($r = 0.225$, $p>0.05$) and evapotranspiration ($r = 0.354$, $p>0.05$). In addition, negative but insignificant associations between malaria incidence and climatic variables was observed for minimum temperature ($r = -0.390$, $p>0.05$), rainfall amount ($r = -0.753$, $p>0.05$), relativity humidity ($r = -0.598$, $p>0.05$) and wind speed ($r = -0.350$, $p>0.05$). The result in the table reveals generally a low association between malaria incidence and the selected climatic variables in the dry season, though with an increase in malaria prevalence than what was obtained in the wet season. For instance, there was a high malaria incidence with sunshine, though the increase is

insignificant. Also, the rate of reduction in malaria incidence was higher in the dry season than in the wet season (see association between malaria incidence and rainfall amount as well as relative humidity). This implies that malaria incidence in the dry season decreases with the decrease in the amount of rainfall and relative humidity. This is evident, as the amount of water in the atmosphere reduces during the dry season. On this note, Yang et al., (2010) alleged that the distribution of mosquitoes is dependent on relative humidity; as it determines the extent of malarial spread. In the literature, temperature and rainfall are considered major determinants for malaria transmission. The result of this study does not agree with this assertion. In a related study, Zhou et al., (2010) observed no significant relationship between malaria incidence and relative humidity. The analysis on temporal associations in malaria incidence and meteorological variables shows that meteorological or climatic variable have low association with malaria incidence. This result is affirmed by the result of Wen et al., (2008), when they reported no associations between meteorological factors and malaria incidence. Furthermore, the temporal analysis reveals that although there were variations in monthly cumulative precipitation, monthly mean maximum, monthly mean minimum temperatures, humidity, wind speed, sunshine and evapotranspiration over the 30 years, the changing patterns in climatic parameters were not associated with changes in malaria prevalence, because no significant correlation between malaria prevalence and climatic variables was found.

Table 4.6: Zero order correlation matrix in the dry season

Variables	Malaria	Max tempt	Min tempt	Rainfall	Humidity	Wind speed	Sun shine	Evapo Transpiration
Malaria cases	1							
Max tempt	0.225	1						
Min tempt	-0.390	0.709	1					
Rainfall	-0.753	-0.715	-0.075	1				
Humidity	-0.598	-0.826 ⁺	-0.192	0.902 ⁺	1			
Wind speed	-0.350	0.567	0.616	0.025	-0.365	1		
Sunshine	0.781	0.548	-0.048	-0.941*	-0.751	-0.305	1	
Evapotran spiration	0.354	0.952 [*]	0.498	-0.783	-0.940*	0.595	0.580	1

⁺. Correlation is significant at the 0.05 level (2-tailed).

*. Correlation is significant at the 0.01 level (2-tailed).

Source: Researcher's fieldwork, 2014

4.6 Principal component analysis (PCA) of significant climatic variable responsible for the temporal pattern of malaria prevalence

PCA was employed to understand or extract the most significant and prominent climatic variable responsible for the temporal pattern in malaria incidence for the 29 years period. The PCA procedure of using variable maximization (varimax rotation) as well as the Kaiser rule of extracting components with eigenvalues >1(Gaur and Gaur, 2006) yielded only one extracted principal component; which accounted for 94.94% of total variance in the original climatic data set (Table 4.7). The only extracted component contained six sets of climatic variables with correlation coefficients $\pm \geq 0.80$. Hence, based on the concept of CDV, which stipulates the extraction of the variable with the high

component loading (correlation coefficient) as most significant. Hence, looking at the table, maximum temperature is identified as the most prominent climatic variable responsible for malaria incidence in the wet season. The component therefore represents variation in maximum temperature. The result therefore, indicates that maximum temperature constitutes the main climatic variable that significantly influenced malaria incidence.

Table 4.7: PCA result on climatic variables in the wet season

Variables	Principal component
maximum temperature	0.996
Evapotranspiration	0.991
Minimum temperature	0.989
Relative humidity	-0.983
Wind speed	0.965
Sunshine	0.962
Rainfall amount	-0.934
Eigenvalues	6.646
% variance	94.944
Cumulative explanation	94.944

Source: Researcher’s fieldwork, 2014

4.8 PCA Result in the dry season

Using the procedure explained above, two components that accounted for 92.14% in climatic variables in dry season were extracted (Table 4.8). The first extracted component had three sets of climatic variables in the dry season with correlation coefficients $\pm \geq 0.80$. The climatic variables that loaded heavily on the first component were rainfall (-0.995), sunshine (-0.953) and relative humidity (-0.911). Based, on the concept of CDV, this component which was the most important as it explained the largest variance in the vegetation data epitomizes rainfall amount. The second component based on the threshold of $\pm \geq 0.80$ contained two sets of climatic with the high coefficient. The component exemplifies wind speed. The climatic variables on the second component were wind speed (0.932) and minimum temperature (0.859). The above analysis identifies rainfall amount and wind speed as significant climatic variables in the dry season that influence malaria incidence. Therefore, from the PCA result on wet and dry seasons, it is observed that maximum temperature is primarily responsible for malaria incidence in the wet season, while in the dry season, malaria incidence is jointly influenced by rainfall amount and wind speed.

This latter result somehow verified the result of stepwise multiple regression analysis. It therefore shows that maximum temperature, rainfall amount and wind speed are the main climatic variables determining malaria prevalence. The analysis, therefore, identifies these climatic variables to be responsible for the discernible pattern in malaria prevalence in the past 30 years in Calabar. The result of this study supports earlier and related studies that proved that weather variables exert great influences on malaria incidence in different regions of the world, though it still remain a debatable issue. It remains debatable because some authors found correlations between climatic variables and malaria incidence (Kuhn et al., 2003), while others did not detect any significant relationship (Singh & Sharma, 2002). It means, therefore, that meteorological factors that have significant statistical correlations with malaria vary greatly between geographic

areas within the world, which would complicates the decision-making process in choosing weather monitoring targets

Table 4.8: PCA result of climatic variables in the wet season

Variables	Principal components	
	1	2
Rainfall amount	-0.995	-.012
Sunshine	0.953	-.227
Relative humidity	-0.911	-.318
Evapotranspiration	0.781	.610
Maximum temperature	0.709	.688
Wind speed	-0.028	.932
Minimum temperature	0.056	.859
Eigenvalues	3.844	2.605
% variance	54.919	37.218
Cumulative explanation	54.919	92.137

Source: Researcher’s fieldwork, 2014

4.9 Discussion

The interrelationships between malaria incidence and climatic variables showed that reported malaria cases have low positive and insignificant associations with minimum temperature rainfall, humidity and sunshine. This means that an increase in the aforementioned climatic variables would result in a parallel rise in the cases of malaria. The pattern of associations obtained here is in conformity with the works of Srinivasulu et al., (2013) and Tay et al., (2012). The result further showed that maximum temperature have low negative and insignificant association with malaria cases; while wind speed have a low negative but significant relationship with malaria cases. Wind speed influences mosquito mobility, as wind speed affects mosquito’s flying ability. Hence, the higher the wind speed, the lower the bite rate and incidence and vice versa. Parham and Michael (2010) observed that environmental variables such as temperature, humidity, rainfall, and wind speed affect the incidence of malaria, either through changes in the duration of mosquito and parasite life cycles or influences parasite breeding behaviour. The negative association recorded for maximum temperature is surprising; as one would have expected a positive association. This is because it is commonly believed that mosquitoes thrive better in warmer condition.

Low and negative associations between maximum temperature and reported malaria cases have also been reported elsewhere (See Tay et al., 2012). In all, the positive associations between the variables imply they are probably influenced by similar environmental and site factors, while the negative associations mean that the various variables are not influenced by similar environmental factors. The analysis implies that climatic variables have direct and indirect influence on malaria incidence and these variables can predict malaria incidence and maybe suitable for predicting the malaria occurrence in areas with similar ecological. The analysis reveals that malaria incidence in Calabar for the 29 years period was best explained by wind speed and maximum temperature. Comparatively, wind speed exerts the principal influence on malaria incidence, as it helps to reduce the prevalence of malaria. Furthermore, the temporal association between variables in the rainy season reveals that malaria incidence have low positive and insignificant associations with maximum temperature, minimum

temperature, wind speed, sunshine and evapotranspiration on the one hand, and on the other, it has low negative and insignificant relationship with rainfall amount and relative humidity.

It is deduced from the negative associations mostly between malaria incidence and rainfall, that during the rains, mosquitoes breeding sites are usually destroyed as many pools of water are filled leading to movement. The constant rains may affect the productivity of breeding sites. For dry season, malaria incidence shows high positive and insignificant association with sunshine and a low but insignificant relation with minimum and evapotranspiration. Also, a negative but insignificant association between malaria incidence and climatic variables was observed for minimum temperature, rainfall amount, relative humidity and wind speed. Comparing both seasons, the result reveals a low association between malaria incidence and the selected climatic variables in the dry season, though with an increase in malaria prevalence than what was obtained in the wet season. The rate of reduction in malaria incidence is higher in the dry season than in the wet season; which implies that malaria incidence in the dry season decreases with the decrease in the amount of rainfall and relative humidity.

This is obvious as high relative humidity is expected to prolong the life of the mosquito enabling it to transmit the infection to several persons (Bai et al., 2013). This is evident, as the amount of water in the atmosphere reduces during the dry season. On this note, Yang et al., (2010) alleged that the distribution of mosquitoes is dependent on relative humidity; as it determines the extent of malarial spread. Thus, no malaria transmission occurs where the monthly average relative humidity is lower than 60%. The only climatic variable that is somehow favourable for malaria incidence in the dry season is sunshine. Since, more solar radiation is received during this season; it favours the breeding as well as the reproductive lives of mosquitoes. In the literature, temperature and rainfall are considered major determinants for malaria transmission. The result of this study does not agree with this assertion. In a related study, Zhou et al., (2010) observed no significant relationship between malaria incidence and relative humidity.

In confirmation of this result, Huang et al. (2011) observed that the relationship between malaria incidence and rainfall was not directly and linearly. The analysis observed low associations between malaria incidence and climatic variables have been reported elsewhere. The analysis on temporal associations in malaria incidence and meteorological variables shows that meteorological or climatic variable have low association with malaria incidence. This result is affirmed by the result of Wen et al., (2008), when they reported no associations between meteorological factors and malaria incidence. They further affirmed that land use, elevation and LST (land surface temperature) appeared to be good contributors of malaria incidence. Furthermore, the temporal analysis reveals that although there are variations in monthly cumulative precipitation, monthly mean maximum, monthly mean minimum temperatures, humidity, wind speed, sunshine and evapotranspiration over the 30 years, the changing patterns in climatic parameters are not associated with changes in malaria prevalence, as no significant correlation between malaria prevalence and climatic variables was found.

The result of PCA in the wet season indicated that maximum temperature constitutes the main climatic variable that significantly influenced malaria incidence; while in the dry season, malaria incidence is jointly influenced by rainfall amount and wind speed. The analysis, therefore, identified these climatic variables to be responsible for the discernible pattern in malaria prevalence in the past 29 years in Calabar. In a related study, Bai et al., (2013) observed that variability in temperature, precipitation,

wind and extreme weather events has been observed to be linked with changes of spatial and temporal distribution of malaria in China. The result of this study supports earlier and related studies that proved that weather variables exert great influences on malaria incidence in different regions of the world, though it still remain a debatable issue. It remains debatable because some authors found correlations between climatic variables and malaria incidence (Kuhn et al., 2003; Zhou et al., 2004), while others did not detect any significant relationship (Singh and Sharma, 2002).

The main conclusion here is that meteorological factors that have significant statistical correlations with malaria vary greatly between geographic areas within the world, which would complicate the decision-making process in choosing weather monitoring target. In addition, the study revealed there is a significant linear trend in malaria incidence, and that increase in time period would result in 59 per cent increase in the number of reported malaria cases. The result indicated that over the past 29 years, Calabar experienced an average increase in malaria incidence of about 59 cases per year.

5. Conclusion and Recommendations

In the present study, the interrelationships between malaria incidence and climatic variables showed that reported malaria cases had low positive and insignificant associations with minimum temperature rainfall, humidity and sunshine. It also showed that maximum temperature had low negative and insignificant association with malaria cases; while wind speed had a low negative but significant relationship with malaria cases. Comparing both seasons, the study found a low association between malaria prevalence and the selected climatic variables in the dry season, though with an increase in malaria prevalence than what was obtained in the wet season. The rate of reduction in malaria prevalence was higher in the dry season than in the wet season. The result of PCA in the wet season indicated that maximum temperature constitutes the main climatic variable that significantly influenced malaria incidence; while in the dry season, malaria incidence was jointly influenced by rainfall amount and wind speed.

Based on the findings of this study, the following suggestions are put forward to effectively reduce malaria incidence:

- ❖ More malaria intervention kits (such as ITNs) should be put in place and made readily available to people mostly in the rural area, who may not have the money to access medical care.
- ❖ Malaria intervention plans should be carried out during the outset of the rainy and dry season. These periods are responsible for the increasing trend in malaria.

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