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Influence of Weather and Climate on Malaria Occurrence Based on Human-Biometeorological Methods in Ondo State, Nigeria

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Abstract: This study focuses on the influence of weather and climate on malaria occurrence based on human-biometeorological methods was carried out in Ondo State, Nigeria using meteorological and malaria dataset in the state for the period from 1998 to 2008. In addition, sea surface temperatures (SSTs) over equatorial Pacific Ocean were integrated in the analysis. The association between each of the meteorological-biometeorological parameters and clinical-reported malaria cases was examined by using Poisson distribution and log as link function between the two categories of dataset. The next step was the building of a model by using Poisson multiple regression models (GLMs) in order to know the weather variables that lead to statistically changes in clinical-reported malaria cases. The study revealed that an increase of 1 $m \cdot s^{-1}$ of wind speed can lead to an increase of about 164% and 171% in the monthly occurrence of malaria at 95% confidence interval in derived savanna and humid forest zone respectively. Also, an increase of 1 ºC in air temperature and sea surface temperature is associated with 53.4% and 29% increase in monthly malaria occurrence (CI: 95%) in derived savanna while an increase of 1 ºC in air temperature and sea surface temperature is associated with 56.4% and 15.4% increase in monthly malaria occurrence at 95% confidence interval in humid forest zone of Ondo State.

Keywords: Weather parameters, GLMs, malaria, early warning system, Ondo State, Nigeria.

1. Introduction

Some of the environmental hazards facing human activities in recent time are climate-related and in view of this, an understanding of the complex interrelationships between atmosphere and those hazards are therefore vital for the solution of these challenges. Weather and climate act as both a resource and a constraint to human beings. The resource value of weather has to be optimized while the hazards posed by weather have to be managed [1].

The World Health Organisation (WHO) estimates that the warming and precipitation trends due to anthropogenic climate change from the mid-1970s already causing over 150,000 deaths and approximately five million disability-adjusted life years (DALYs) per year [2]. Many prevalent human diseases are linked to climate fluctuations, from cardiovascular mortality [3] and respiratory illnesses due to extreme bioclimatic conditions [4], to altered transmission of infectious diseases and malnutrition from crop failures [5].

Climatic variations and extreme weather events have profound impacts on infectious disease. Infectious agents, such as protozoa, bacteria and viruses and their associated vector organisms such as mosquitoes, ticks and sandflies are devoid of thermostatic mechanisms, and reproduction and survival rates are thus strongly

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affected by fluctuations in air temperature [6, 7]. Air temperature dependencies are seen in correlations between disease rates and weather variations over weeks, months, or years [4, 8, 9] and in close geographic associations between key climatic/weather variables and the distributions of important vector-borne diseases [10, 11].

Malaria which is an ancient disease remains a major killer in many tropical regions of the world today [12], causing around 1 million child deaths annually [13]. In view of this, the government of countries of Africa continent gathered in Abuja, Nigeria to launched "Roll Back Malaria" programme at the Abuja Malaria Summit in April 2000. The goal of Roll Back Malaria is to halve the burden of malaria by 2010. A series of targets for realizing this goal in Africa was set at the Summit, which included the target that 60% of the malaria occurrence be detected within two weeks of onset [14].

In Nigeria, different interventions and policies to reduce morbidity and mortality from malaria disease has been introduced at both national and state levels. Ondo state as an example, use to give insecticide treated mosquitoes net to pregnant women, free treatment of malaria disease for pregnant women and children under the age of 5 years at the state government hospitals [15]. Also, different type of drugs and combination therapies such as "artemether and lumefantrine; artesunate and amodiaquine" for malaria treatment has been introduced by National malaria and vector control Division, Federal Ministry of Health believing to be more effective to combat malaria disease than the traditional "Chloroquine" [16].

Malaria, a protozoan infection, it is transmitted by mosquitoes, which require moisture for breeding. Malaria, along with other vector-borne infections, is strongly affected by weather variables (Table 1), although the relationship is not a simple one.

Increased rainfall can be associated with expansion of malaria breeding sites and an increase in malaria in

Table 1 Environmental factors that determine the survival of vectors of disease-causing agents.

Abiotic	Air temperature, precipitation, relative humidity, wind, solar radiation, topography, fresh water ponds, rivers, lakes
Biotic	Vegetation Hosts (mammals, reptiles, birds) Natural predators, parasites, pathogens of the vector

Source: under the weather: climate, ecosystems, and infectious disease [17].

arid areas. In humid areas, drought can improve breeding conditions for mosquitoes, leading to outbreaks [18, 19]. Natural predators of vectors influence their abundance. If the reproductive cycle of a predator is longer than that of the mosquito, a mosquito population could surge before the predator population could expand to control it. Air temperature, rainfall, and vegetation also affect the abundance of food and the behaviour of predators [18]. Increased rainfall can provide more breeding sites, but excess rain can also destroy breeding sites. Increased air temperature, to a point, can speed the maturation of the mosquito through its various stages and may decrease the extrinsic incubation period for the parasite in the arthropod [19].

The study on the logic of impact of climate change on vector borne diseases with emphasis on malaria revealed that the minimum air temperature required for development of *P. vivax* parasite in anopheline mosquitoes is from 14.5-16.5 ºC while that of *P. falciparum* is from 16.5-18 ºC. Furthermore, the study reported that it will take 55 days for the completion of sporogony *P. vivax* at the air temperature of 16 ºC and about 29 days at the air temperature of 18 ºC, while the process can be completed within 7 days when the air temperature is between 28-30 ºC [20].

In view of the abundance evidence from literature that links weather and climate to human health and occurrence of some infectious diseases, therefore, there is need to understand the way changes in weather pattern impact on human health through diseases so that adequate intervention strategies can be put in place to ensure health security for the increasing world population [4].

In this study we examined the ways in which the major meteorological and biometeorological variables influence human health and occurrence of malaria in Ondo state, Nigeria. Two important points are worthy of note in any consideration of the effects of meteorological variables on human health. The first point is that meteorological variables are closely interrelated in their influence on human health and disease occurrence. The effect of a given meteorological variable is often modified by the influence of other variables. Also daily or weekly variations in the values of weather elements and disease data are often of greater importance in determining the efficiency of climate-disease model result than the mean values, although mean monthly values were used in this study due to non-availability of daily malaria data. The second point to note is that in considering the climatic environment in which disease occurs, the microclimate immediately around the study area is of vital importance to the model result.

2. Data and Methods

Ondo State (5°45′N and 8°15′N, 4°45′E and 6° 00′E) is situated in the south-western humid forest of Nigeria (Figs. 1 and 2). The state has eighteen Local Government Areas with a population of about 3,441,024 in 2006 population census and land area of about 14,606 km^2 [21]. It has the tropical wet-and-dry climate. The state has a mean annual rainfall of about 1500 mm and 2000 mm in the derived savanna and humid forest zones respectively [22].

Weather variables-air temperature, relative humidity, wind speed, solar radiation and rainfall from 1998 to 2008 used for this study were collected from Agroclimatological and Ecological Monitoring unit of Ondo State, Nigeria, while the sea surface temperatures

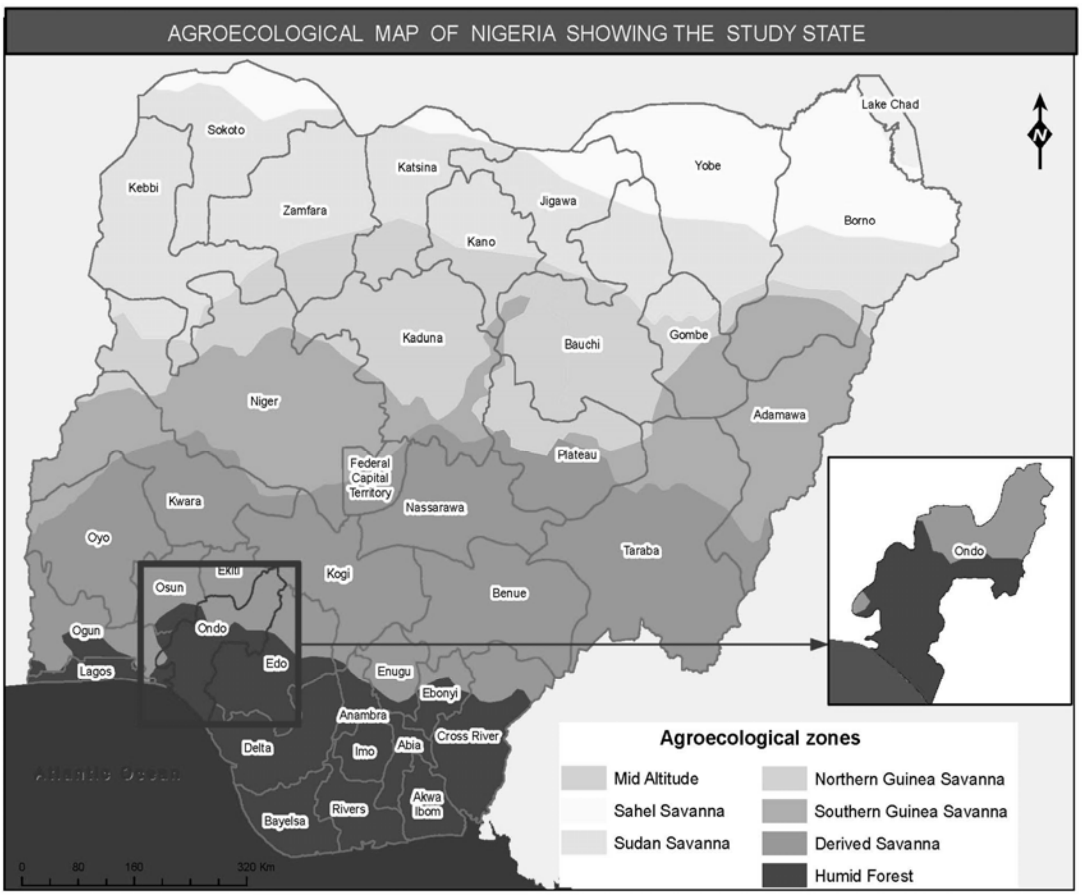

Fig. 1 Map of Nigeria showing the study area (Ondo State).

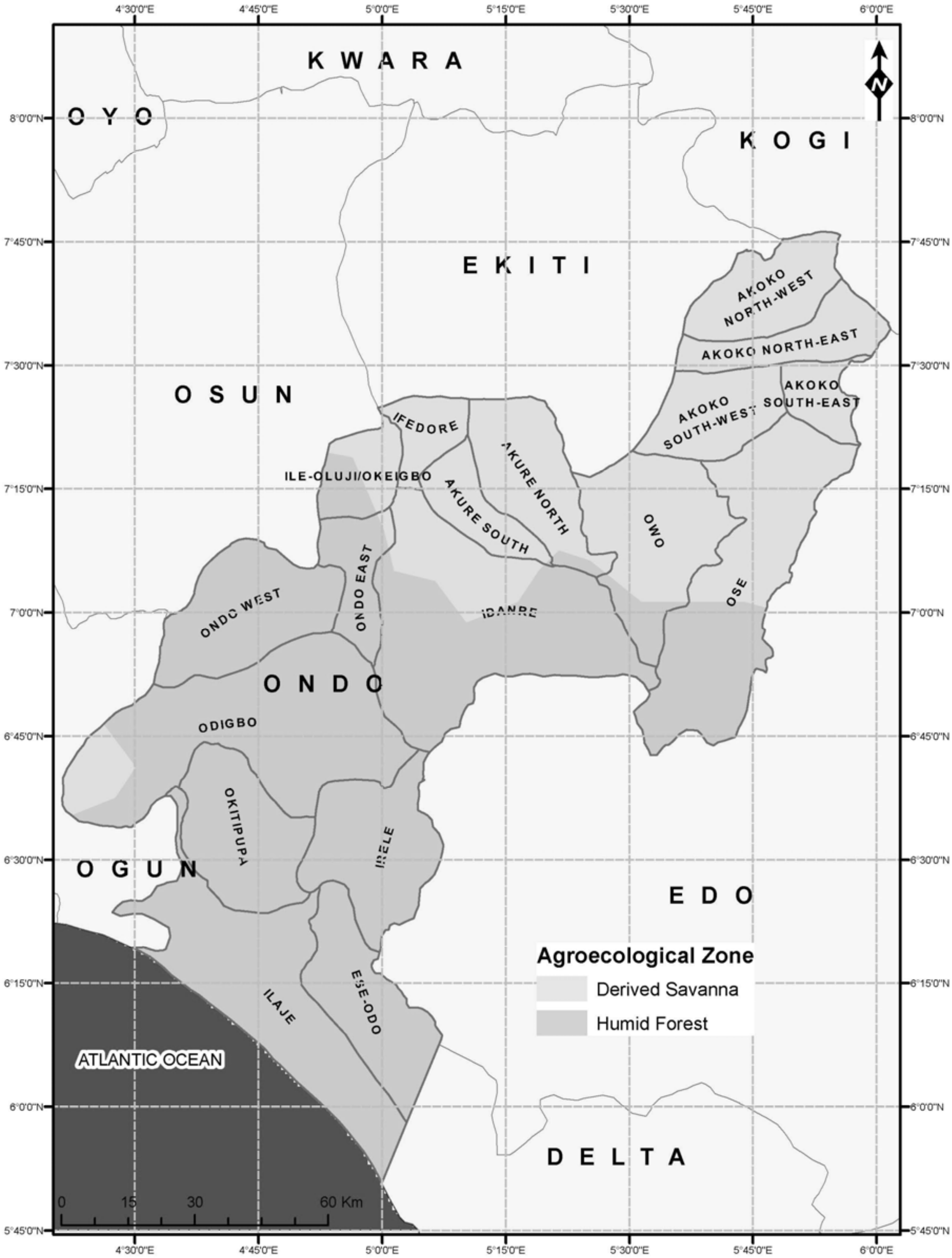

Fig. 2 Map of Ondo State (study area) showing the two eco-climatic zones and local government areas.

(SSTs) over the area 5°N-5°S, 150°-90°W, known as Nino3 region in the equatorial pacific ocean were obtained from this website: http://www.esrl.noaa.gov/psd/data/gridded/. The biometeorological parameters: mean radiant temperature (T_{mrt}) [23-25], physiologically equivalent temperature (PET) [26, 27] and Universal Thermal Climate Index (UTCI) [28] were calculated by using RayMan model [24, 25].

The calculated thermal indices are based on the human energy balance and describe the combined effects of thermal environments on human body [27, 29-31]. The monthly malaria disease data for the 18 local government areas of the state for the period 1998 to 2008 were collected from the Monitoring and Evaluation unit, Ministry of Health, Ondo State, Nigeria.

In this study, the rate of reporting malaria cases from all the 18 local government areas of the state were analyzed and presented in CTIS window for visualization [32]. For further analysis, the 18 local government areas were divided along the two eco-climatic zones in the state (Fig. 2) for simplicity and easy handling of the data. Analysis of data involved the use of several statistical techniques in order to assess the statistical significance of weather variables and the consistency and magnitude of weather effects on malaria occurrence. Time series analysis to assess the periodicity [33] was conducted on malaria data and meteorological-biometeorological variables. The malaria and meteorological-biometeorological data were deseasonalized in order to control seasonality and assess the influence of weather variables on malaria occurrence. The statistical relationship between malaria occurrence and meteorological-biometeorological variables before and after deseasonalization of data were carried out in order to determine correlation coefficient (r), coefficient of determination (R^2) and p-value [34-36]. In order to assess the magnitude of meteorological-biometeorological variables (independent covariates) on malaria occurrence (dependent variable), Poisson multiple regression models in Generalized Linear Models, GLMs [37, 38] was used after deseasonalization of both biometeorological and malaria data.

In the analysis of biometeorological time series data consisting of counts, the underlying mechanism being modelled is a Poisson process with a homogeneous risk λ, i.e. the expected number of counts on day *t*, to the underlying population is assumed. The probability of y_t occurrences on a given day t is defined by

$$prob\ (y_t l \lambda) = \frac{e^{-\lambda} \lambda^{y_t}}{y_t!} \quad (1)$$

The Poisson regression model assumes

$$E(y_t l x_t) = \exp\left(\beta_0 + \sum_{i=1}^{n} \beta_i x_{ti}\right) \quad (2)$$

Where, x_t is the column vector of independent variables on day *t* with regression coefficients β and y_t is the dependent variable on day *t*.

The above Eq. (2) could also be formulated as a Generalised Linear Model (GLM) [38],

Link function

$$E(y_t l x_t) = \mu_t$$
$$\log(\mu_t) = \beta_0 + \sum_{i=1}^{n} \beta_i x_{ti} \quad (3)$$

Variance function

$$V(y_t) = \mu_t \quad (4)$$

The usefulness of Poisson regression in biometeorology is that it provides an estimation of the relative risk (RR) as $RR_i = \exp(\beta_i)$ where β_i is the regression coefficient associated with a unit increment in meteorological variables. All statistical analyses were performed using Microsoft excel and STATISTICA 8.0 [39].

3. Results

Fig. 3 presents the monthly pattern of reported clinical cases of malaria from all the 18 local government areas of Ondo state, Nigeria for the period 1998 to 2008. The analysis of the study indicates that derived savanna zone accounted for 54.5% of the reported cases of malaria while humid forest zone accounted for 45.5%. It could be noticed from Figs. 4 and 5 that there was an upward surge in the occurrence of malaria cases from year 2005 to 2008, this period which is just four years out of the eleven years accounted for about 48% of the reported malaria

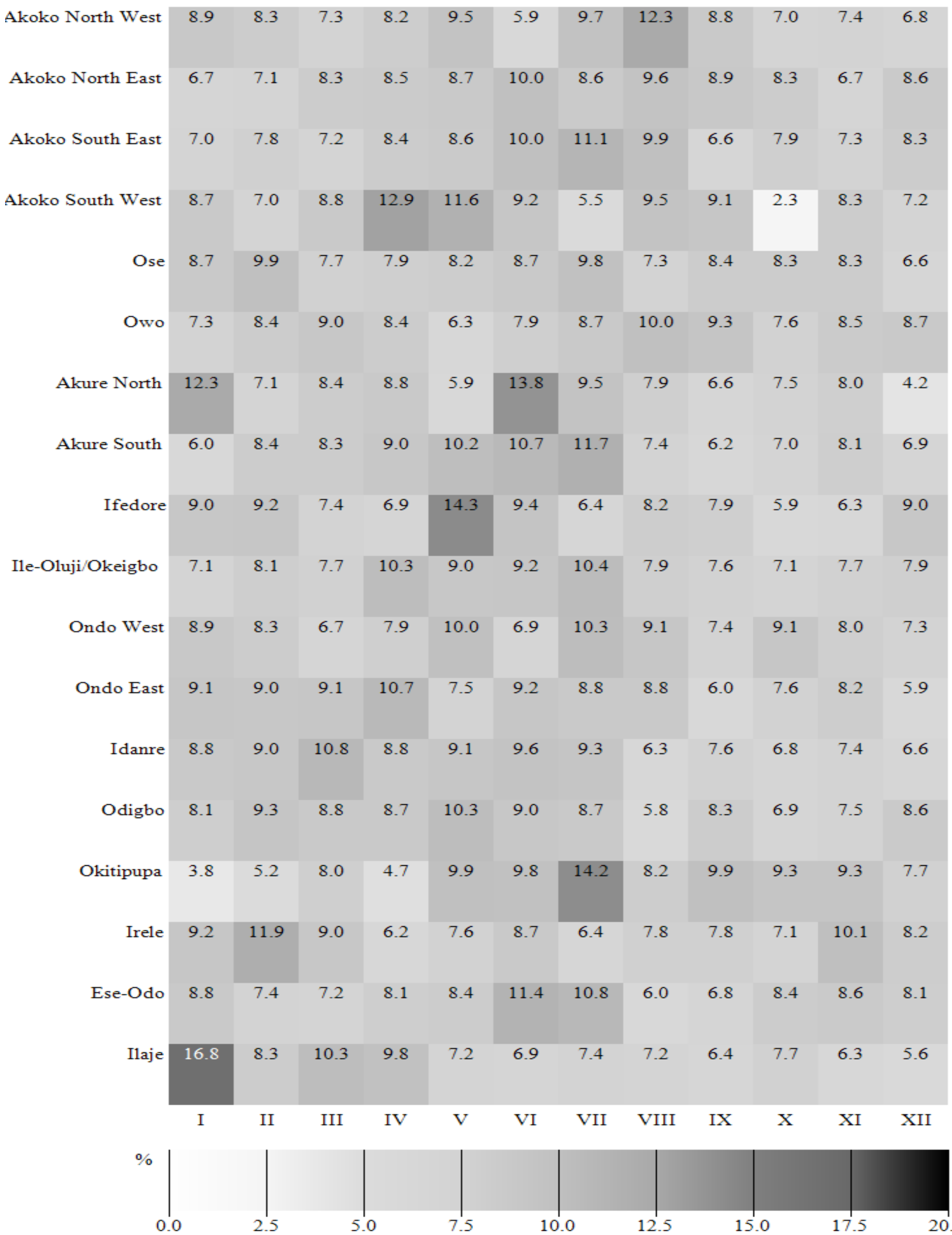

Fig. 3 Rate of reporting clinical malaria cases in the 18 local government areas of Ondo state, Nigeria for the period 1998 to 2008.

cases while the remaining seven years (1998 to 2004) accounted for about 52% of the reported malaria cases.

The pattern in the time series plot in Figs. 4 and 5 revealed that malaria cases are common to both zones of the state and it occurs throughout the year. Out of the 12 peaks period identified in the series in the derived savanna zone, 3 occurred in the month of May (1999, 2000 and 2001) and June (2003, 2005 and 2007), 2 in

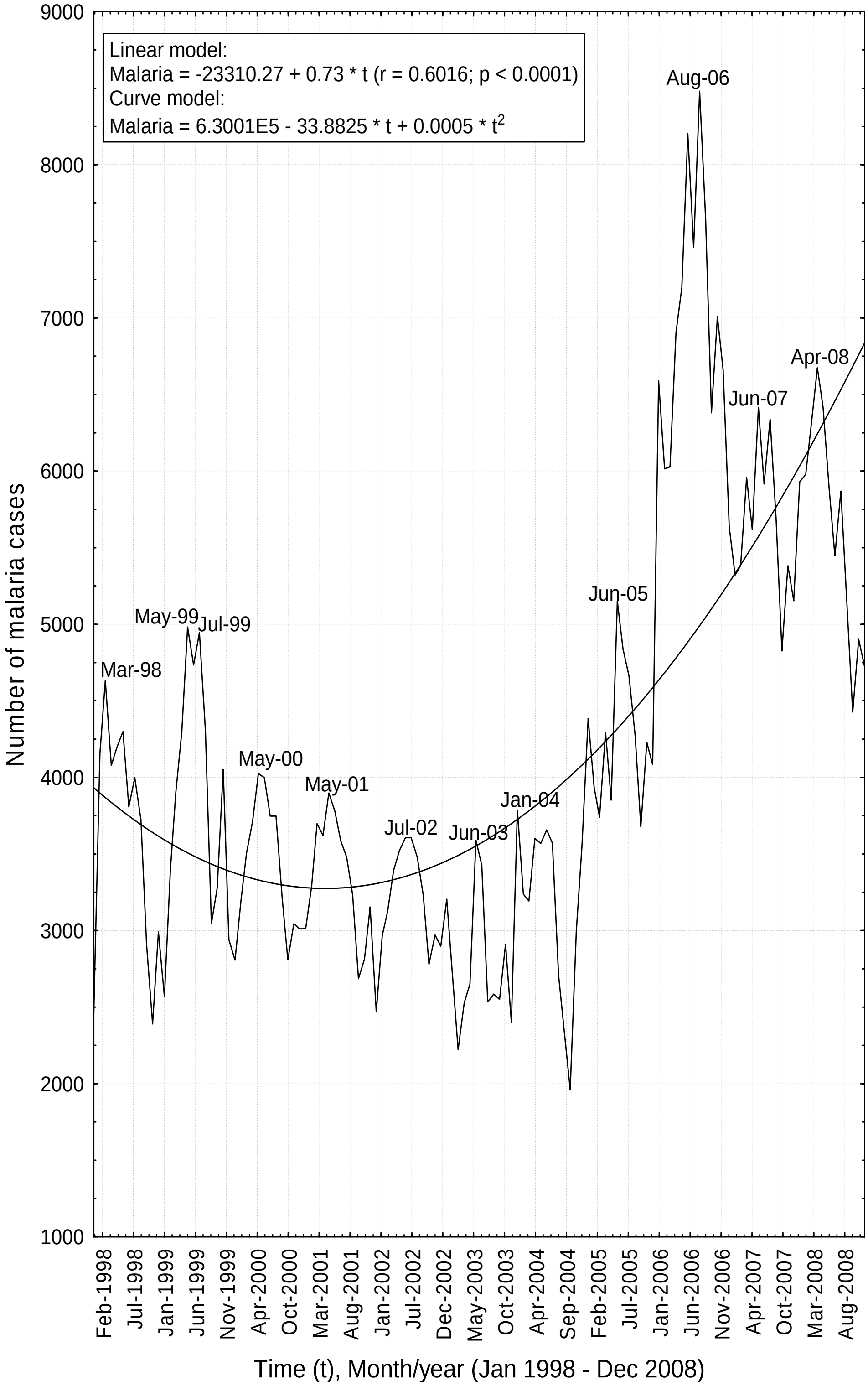

Fig. 4 Time series of reported malaria cases in derived savanna zone of Ondo state, Nigeria.

the month of July (1999 and 2002) and 1 in the month of January 2004, March 1998, April 2008 and August 2006. Out of the 12 peaks period identified in the humid forest zone (Fig. 5), 7 occurred in the month of July (1998, 2000, 2001, 2002, 2003, 2004 and 2005), 2 in the month of May (2006 and 2007), 1 in the month

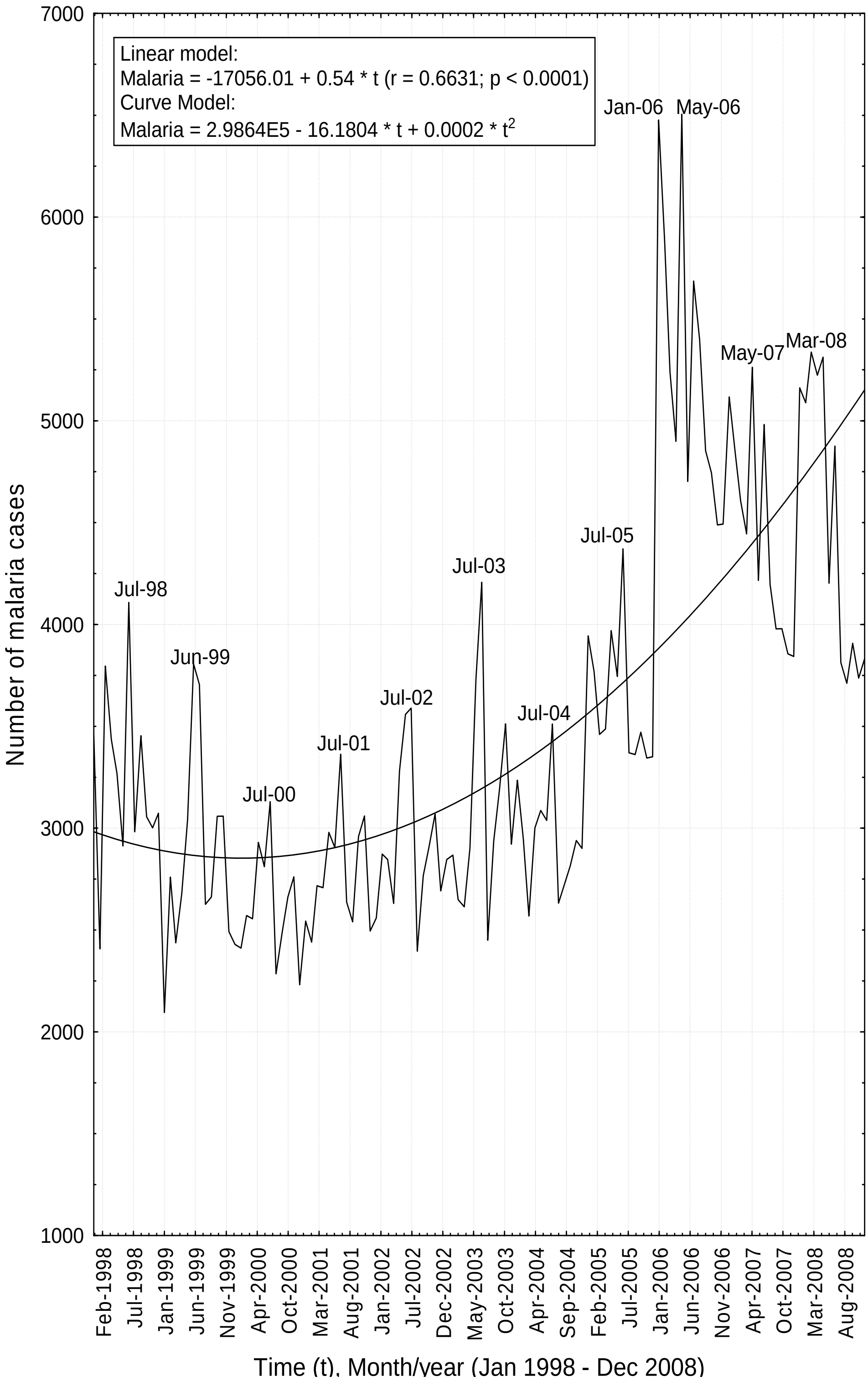

Fig. 5 Time series of reported malaria cases in humid forest zone of Ondo state, Nigeria.

of January 2006, March 2008 and June 1999. The peaks in the time series plots suggest that there is a seasonal pattern.

Time series analysis of meteorological-biometeorological variables in the two eco-climatic zones of the study area from January 1998 to December 2008 suggests a strong seasonal pattern.

Tables 2 and 3 show that wind speed and sea surface temperature are two meteorological variables that show significant interest in both derived savanna and humid forest zones of Ondo state before deseasonalization of data while physiologically equivalent temperature, solar radiation, relative humid, vapour pressure and mean radiant temperature become significant after deseasonalization of data in addition to wind speed and sea surface temperature in the derived savanna zone. In humid forest zone, physiologically equivalent temperature, solar radiation, mean radiant temperature and universal thermal climate index become significant after deseasonalization of data in addition to wind speed and sea surface temperature.

The Poisson multiple regression model (GLMs) results of malaria occurrence with different meteorological-biometeorological parameters in derived savanna and humid forest zones of Ondo state area presented in Tables 4 and 5 respectively. The results in Tables 4 and 5 showed that changes in the amount of monthly rainfall values and relative humidity are less important to the occurrence of malaria in both derived savanna and humid forest zone of Ondo state, Nigeria. Model A, B, and C in Table 4 shows that an increase of 1 ºC in PET, UTCI and T_{mrt} will lead to about 82%, 41.4% and 35% increase in monthly malaria cases at 95% confidence interval respectively while the SST will lead to 24.1%, 20% and 27.4% increase in monthly malaria cases at 95% confidence interval in model A, B and C. The model D in Table 4 shows that wind speed appears to be the

Table 2 Statistical relationship between malaria and biometeorological variables before and after deseasonalization of data in derived savanna zone of Ondo state, Nigeria.

Biometeorological variables	r	R^2	p-value	*r	*R^2	*p-value
Physiologically equivalent temperature (PET)	-0.0550	0.0030	0.5290	0.2811	0.0790	0.0011
Solar radiation (SR)	0.1131	0.0128	0.1968	0.2934	0.0861	0.0006
Relative humidity (RH)	0.1509	0.0228	0.0841	-0.245	0.0600	0.0046
Air temperature (Ta)	-0.0901	0.0080	0.3104	0.1132	0.0128	0.1963
Mean radiant temperature (Tmrt)	0.0150	0.0002	0.8660	0.3336	0.1113	0.00009
Wind speed (v)	0.4000	0.1600	0.00000	0.5809	0.3375	0.00000
Vapour pressure (VP)	0.1483	0.0220	0.0897	-0.218	0.0475	0.0120
Rainfall (Rfall)	0.1088	0.0118	0.2144	-0.1394	0.0194	0.1108
Universal thermal climate index (UTCI)	0.0760	0.0060	0.3880	0.0339	0.0012	0.6994
Sea surface temperature (SST)	0.3250	0.1060	0.0001	0.3881	0.1506	0.00000

* After deseasonalization of data.

Table 3 Statistical relationship between malaria and biometeorological variables before and after deseasonalization of data in humid forest zone of Ondo state, Nigeria.

Biometeorological variables	r	R^2	p-value	*r	*R^2	*p-value
Physiologically equivalent temperature (PET)	0.024	0.0006	0.7900	0.2385	0.0569	0.0059
Solar radiation (SR)	0.1637	0.0268	0.0608	0.2649	0.0702	0.0021
Relative humidity (RH)	0.0550	0.0030	0.5313	0.0883	0.0078	0.3143
Air temperature (Ta)	-0.0120	0.0002	0.8870	0.0956	0.0091	0.2755
Mean radiant temperature (Tmrt)	0.107	0.0114	0.223	0.3739	0.1398	0.00001
Wind speed (v)	0.3400	0.1133	0.0000	0.6731	0.4530	0.0000
Vapour pressure (VP)	0.0696	0.0048	0.4280	0.1191	0.0142	0.1736
Rainfall (Rfall)	0.0339	0.0011	0.7000	-0.1039	0.0108	0.2356
Universal thermal climate index (UTCI)	0.051	0.003	0.562	0.3327	0.1107	0.0001
Sea surface temperature (SST)	0.22	0.048	0.011	0.3016	0.0910	0.0004

* After deseasonalization of data.

Table 4 Poisson regression model results of malaria occurrence with different meteorological/biometeorological parameters in derived savanna zone of Ondo state, Nigeria.

	Model terms	Estimate coefficients	95% CI	p-value
A	(Constant)	-26.2467	-34.9856 to -17.5078	0.000000
	PET	0.8199	0.5878 to 1.0521	0.000000
	Rfall	-0.0009	-0.0018 to -0.0001	0.025715
	SST	0.2412	0.1849 to 0.2975	0.000000
B	(Constant)	-11.6266	-24.4222 to 1.169136	0.074932
	UTCI	0.4135	0.0807 to 0.746338	0.014877
	Rfall	-0.0010	-0.0020 to -0.000068	0.035919
	SST	0.1966	0.1293 to 0.263867	0.000000
C	(Constant)	-12.4882	-16.2652 to -8.71114	0.000000
	Tmrt	0.3473	0.2724 to 0.42217	0.000000
	Rfall	-0.0006	-0.0014 to 0.00017	0.124959
	SST	0.2738	0.2222 to 0.32547	0.000000
D	(Constant)	-22.2784	-36.3177 to -8.23906	0.001870
	SR	0.0270	0.0227 to 0.03128	0.000000
	RH	-0.0020	-0.1312 to 0.12723	0.976002
	Ta	0.5344	0.3249 to 0.74386	0.000001
	V	1.6367	1.3092 to 1.96413	0.000000
	Rfall	-0.0002	-0.0006 to 0.00031	0.490678
	SST	0.2888	0.2088 to 0.36893	0.000000

95% CI: Confidence interval at 95% level for estimated regression coefficient.

Table 5 Poisson regression model results of malaria occurrence with different meteorological/biometeorological parameters in humid forest zone of Ondo state, Nigeria.

	Model terms	Estimate coefficients	95% CI	p-value
E	(Constant)	-7.14281	-12.5190 to -1.76666	0.009213
	PET	0.36487	0.2154 to 0.51437	0.000002
	Rfall	-0.00029	-0.0008 to 0.00026	0.304855
	SST	0.14096	0.0907 to 0.19121	0.000000
F	(Constant)	-17.6852	-25.6828 to -9.68756	0.000015
	UTCI	0.6591	0.4362 to 0.88191	0.000000
	Rfall	-0.0002	-0.0007 to 0.00035	0.509238
	SST	0.1360	0.0886 to 0.18345	0.000000
G	(Constant)	-3.53704	-6.05734 to -1.01675	0.005948
	Tmrt	0.20384	0.15275 to 0.25493	0.000000
	Rfall	-0.00028	-0.00076 to 0.00021	0.263302
	SST	0.16630	0.12210 to 0.21050	0.000000
H	(Constant)	-32.8157	-52.1924 to -13.4390	0.000902
	SR	0.0138	0.0102 to 0.0175	0.000000
	RH	0.2231	0.0528 to 0.3933	0.010247
	Ta	0.5644	0.2965 to 0.8324	0.000036
	V	1.7082	1.3814 to 2.0351	0.000000
	Rfall	0.0000	-0.0003 to 0.0003	0.976017
	SST	0.1540	0.1234 to 0.1846	0.000000

95% CI: Confidence interval at 95% level for estimated regression coefficient.

meteorological parameter with the highest effect on malaria occurrence. An increase of 1 $m \cdot s^{-1}$ in wind speed will cause about 164% increase in monthly malaria occurrence at 95% confidence interval while an increase of 1 °C in air temperature (Ta) and SST will cause 53.4% and 29% increase in monthly malaria occurrence in model D of Table 4.

Table 5 shows that an increase of 1 ºC in PET, UTCI and T_{mrt} is associated with 36.5%, 66% and 20.4% increase in monthly malaria occurrence at 95% confidence interval in model E, F and G. Model H in Table 5 indicates that an increase of 1 $m \cdot s^{-1}$ in wind speed is associated with 170.8% increase in monthly malaria occurrence at 95% confidence interval while an increase of 1 ºC in air temperature (Ta) and SST is associated with 56.4% and 15.4% respectively. From the foregoing results, model D in Table 4 and model H in Table 5 seems to be the best models among all the models.

4. Discussion

The present study revealed that the pattern of reported clinical malaria cases at both humid forest zone and derived savanna zone of Ondo state are similar but differs in order of magnitude. The results show that the number of reported clinical malaria cases is higher in derived savanna zone of the state within the study period. The differences noticed in reported clinical malaria cases in two zones can be linked to socio-economic life style of the inhabitants and the variation in the weather conditions.

Furthermore, the sudden increase in the number of reported clinical malaria cases from 2005 to 2008 compared to previous years is similar to the result observed by Ayeni [40] on the malaria morbidity in Akure, Southwest, Nigeria. This increase could be as a result of government policies for free treatment of malaria disease for children under the age of five years and pregnant women as well as free distribution of insecticide treated mosquitoes net to pregnant women in the state government hospitals across the state and because of this patients under this categories may prefer to go to government hospital for the treatment of malaria so that they can benefit from government health policies. The other reason could be because malaria cases are treated at home [41] due to poor financial status of the people and chloroquine which is the mainstay of malaria treatment for many decades has proved to be ineffective in many parts of the world. In view of this, the rate of increase in morbidity and mortality from malaria disease is alarming; therefore people may now prefer to seek for medical advice in the hospital rather than traditional ways of treating malaria at home.

The pattern of reported clinical malaria cases shows that malaria is a serious public health problem in the study area because it occurred throughout the year but more prevailing at beginning of rainy season. The above results show similarity with the result of Thomson et al. [42] who stated that the month of March to April is the period of peak malaria transmission in Botswana and the study of Dery et al. [43] that malaria occurred throughout the year but the prevalence was highest in the months of May to October (rainy season) in the forest-savanna transitional zones of Ghana.

The association between sea surface temperature (SST) and reported clinical malaria cases in the study area confirmed the report of Thomson et al. [42]. According to them, rainfall and sea surface temperature accounts for more than two-thirds of the inter-annual variability in standardized malaria incidence in Botswana. The result of this study showed that changes in monthly rainfall amount are less important in the study area because there is available moisture for the propagation of malaria vector (mosquitoes) throughout the study period. The association between sea surface temperature and reported malaria cases is indication that climatic fluctuation due to El Nino phenomenon that originating from the tropical Pacific Ocean has health implication in the study area; the reason for this could be because the study area shares a border with Gulf of Guinea in the North Atlantic Ocean. This pattern of high prevalence of malaria with sea surface temperature agreed with hypothesis on a possible role of El Nino in the occurrence of influenza pandemics as reported by Mazzarella et al. [44]. The relationship between sea surface temperature over Nino3 (equatorial Pacific Ocean) and reported clinical malaria cases in Ondo state, Nigeria suggest that there is teleconnection between Ocean-atmosphere interaction over Pacific Ocean and that of North Atlantic Ocean.

The relationship between air temperature, solar radiation and reported clinical malaria cases indicates the importance of photoperiod in malaria transmission.

The report from NIMRI [20] on the logic impact of climate change on vector-borne diseases put the air temperature range for peak malaria transmission in between 28 ºC and 30 ºC; the findings of Parham and Michael [45] identified a temperature window of around 32 ºC-33 ºC within which the rate of malaria spread is significantly increased in Tanzania. The implication of the above results is that the range of air temperature of Ondo state, Nigeria is appropriate for transmission of malaria.

The meteorological parameter with the highest effect on malaria occurrence in the study area is wind speed. The association between wind speed and malaria occurrence is an interesting one, this means that the rate of speed at which mosquito will fly is very important in the transmission of malaria. The wind speed of the study area is generally low, this means that low wind speed or gentle wind is more comfortable or suitable for malaria vector (mosquito) to fly due to the nature of mosquito.

Based on the above result, the findings of this study are consistent with statement of Gubler et al. [7] and Koenraadt et al. [46] who stated that environmental variables such as air 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 on human, vector, or parasite behaviour.

Taking into account the relationship between biometeorological indices and reported clinical malaria cases in the two eco-climatic zones of Ondo state, Nigeria. The result shows that malaria is more prevalence when the physiologically equivalent temperature (PET) based on mean daily assessment is between 28.5 ºC and 32.9 ºC, in term of thermal perception this range of PET falls into the classes of slightly warm and warm and in term of grade of physiological stress it falls into the classes of slight heat stress and moderate heat stress [47, 48]. Using universal thermal climate index (UTCI), malaria is more prevalence when the UTCI values is between 28.2 ºC and 32.8 ºC, the implication of this is that there is strong heat stress and moderate heat stress during this period [28]. This situation will make the condition of malaria disease patients' worst because heat itself is a serious health problem to human beings. The connection between mean radiant temperature (T_{mrt}) and reported clinical malaria cases shows that there is high occurrence of malaria when the mean radiant temperature is between 33.0 ºC and 37 ºC.

5. Conclusion

Based on the findings of this study, it is obvious that some weather parameters have influence on malaria disease. The results show there is significant association between wind speed, sea surface temperatures, air temperature, solar radiation, mean radiant temperature, physiologically equivalent temperature and universal thermal climate index and malaria cases for the eleven years examined. Malaria transmission in the two eco-climatic zones of Ondo state, Nigeria for the period 1998 to 2008 is high and occurs all-year round but more prevalence at the beginning of rainy season.

The results from this study provide clear evidence that variations in weather parameters and thermal indices influence the occurrence of malaria in Ondo state, Nigeria. In view of this, climate should therefore not be dismissed as a potential driver of observed increases in malaria seen in the study area during recent decades.

This study stresses the need for further investigation to explore the role played by meteorological/biometeorological factors on day-to-day basis in order to actually determine the weather transition period that have most significant effects on malaria disease in the study area and possibility of identifying thresholds for various meteorological parameters and biometeorological indices for which there will be high transmission/prevalence of malaria disease in the study area. This study will be necessary more so that the target of reducing malaria disease in Africa countries by 60% in the year 2010 is not yet realised.

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