

## **Assessment of the Relationship between Cerebrospinal Meningitis and Climate Variables in Kaduna State, Nigeria**

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. Author JIN designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors ASA and FOA managed the analyses of the study. Author BYM managed the literature searches. All authors read and approved the final manuscript.*

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### **ABSTRACT**

This study examines the relationship between Meningitis and weather parameters (air temperature, maximum temperature, relative humidity, and rainfall) in Kaduna state, Nigeria on a weekly basis from 2007–2019. Meningitis data was acquired weekly from Nigeria Centre for Disease Control (NCDC), Bureau of Statistics and weather parameters were sourced from daily satellite data set National Oceanic and Atmospheric Administration (NOAA), International Research Institute for Climate and Society (IRI). The daily data were aggregated weekly to suit the study. The data were analysed using linear trend and Pearson correlation for relationship. The linear trend results revealed a weekly decline in Cerebro Spinal Meningitis (CSM), wind speed, maximum and air temperature and an increase in relative humidity and rainfall. Generally, results reveal that the most important explanatory weather variables influencing CSM amongst the five (5) are the weekly maximum temperature and air temperature with a positive correlation of 0.768 and 0.773. This study recommends that keen interest be placed on temperature as they play an essential role in the transmission of this disease and most times aggravate the patients' condition.

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## 1. INTRODUCTION

### 1.1 Background to the Study

Meningococcal meningitis (CSM) is defined as an acute bacterial disease with fever, severe headache, nausea, and stiff neck [1]. Meningitis is one of the most important causes of morbidity and death in African [2]. The challenges of meningitis and climate relationship is now an issue of concern worldwide. Past studies suggest that intra-annual and inter-annual climate variability influences meningitis occurrences [3,4,5]. Therefore, an analysis of climate and meningitis could help understand its local spread and possible mitigation.

A previous study has established that CSM remains a health threat Sudano-Sahelian belt of West Africa, with the mean annual incidence of around 70 cases per 100,000 persons [6]. It is understood that the attack rates during epidemics range from 100 to 1,000 per 100,000 inhabitants per year [6]. According to Abdussalam et al. [7], Nigeria lies within the meningitis belt. The authors further averred that the CSM affects Nigeria during the dry months, beginning with the Harmattan in November and continuing through May with peak incidence during the hottest months of March and April. Similarly, the World Health Organization (WHO) reported that Adamawa, Bauchi, Kano, Kaduna, Katsina, Kebbi, Kwara, Niger, Sokoto and Taraba States are the frontline states in Nigeria. It is estimated that the fatality rates of CSM ranged from 2.5 per cent to 30 per cent in the different States.

The study of climate and disease has long been of research interest worldwide. Ejembi et al. [8] used monthly maximum and minimum temperature records. They reported Meningitis and Measles in Zaria, Kaduna State, for 10 years (1999-2008) to determine the influence of temperature on these two diseases' outbreak. The results show that the reported cases of Meningitis and Measles are highest between March and April when the temperatures are high. Seefeldt et al. [9] evaluated the variation of relative humidity across West Africa during the dry season using the Modern-Era Retrospective Analysis for Research and Applications (MERRA) dataset and its self-organising method maps. Basse et al. [10] averred that children are most often affected by epidemic meningococcal

Meningitis despite vaccines' availability. The authors describe the pattern of the epidemic meningococcal meningitis outbreak in Northern Nigeria in 2009. Laura et al. (2019) studied the Spatiotemporal Analysis of Serogroup C Meningococcal Meningitis Spread in Niger and Nigeria. Implications for Epidemic Response used data on suspected and laboratory-confirmed cases in Niger and Nigeria from 2013 to 2017. Their results show that the reported cases of Meningitis and Measles are highest between March and April when the temperatures are high.

Bacterial meningitis being one of the major causes of death in sub-Saharan Africa and a medical emergency around the world, to increase the number of recoveries and/or reduce the number of sequelae, and deaths, effective antibiotics is needed. A mathematical model for bacterial meningitis to include nonlinear recovery rate was proposed so as to show instances for forward and backward bifurcation. Also, the sensitivity heat map was implored which showed that the most sensitive state variable to all parameters in the model during none seasonal transmission is the recovery class followed by the susceptible class; and that the most sensitive state variable during seasonal transmission is the susceptible class followed by the carrier-class [11].

In [12], Asamoah et al. used nonlinear deterministic model with time-dependent controls to describe the dynamics of bacterial meningitis in a population. The model was shown to exhibit a unique globally asymptotically stable disease-free equilibrium  $E_0$ , when the effective reproduction number  $R_{VT} \leq 1$ , and a globally asymptotically stable endemic equilibrium  $E_1$ , when  $R_{VT} > 1$ ; and it exhibits a transcritical bifurcation at  $R_{VT} = 1$ . This implies that carriers of the bacteria have a higher chance of spreading the infection than those with clinical symptoms who will sometimes be bound to bed during the acute phase of the infection. Therefore, stakeholders are advised to press hard for the production of existing/new vaccines and antibiotics and their disbursement to areas that are most affected by bacterial meningitis, especially Sub-Saharan Africa; furthermore, individuals who live in communities where the environment is relatively warm (hot/moisture) are advised to go for vaccination against bacterial meningitis

Generally, this study aims to establish the relationship between weather parameters and CSM in Kaduna state, Nigeria. This study establishes the relationship between Meningitis and Climatic variables over Kaduna state and their impact on the disease's prevalence.

## 2. MATERIALS AND METHODS

### 2.1 The Study Area

The study area is represented in Fig. 1. Kaduna State, a Northern Nigerian state, is located around latitude 7.45°N and longitude 10.55°N. It is the 18th state of the Federal Republic of Nigeria, located in its northwest zone. The state takes its name from Kaduna's capital; hence it is usually referred to as Kaduna State to differentiate the state and capital. It is categorized 4th by land area and 3rd by population in Nigeria. The state capital was the former capital city of the British protectorate of the Northern Nigerian Region (1923-1966).

The state's economy was ranked 15th largest in the Nigerian economy from 2002 to 2008. It made up about 3.3% of the Nigerian Gross Domestic Product (GDP), while agriculture contributed 30% of SGDP in Kaduna. Kaduna state has cotton and peanuts (groundnuts) for exporting and domestic extraction of peanut oil.

In terms of population, Kaduna State is populated by about 59 to 63 different ethnic groups, if not more, with the accuracy of the number requiring further verification through genuine fieldwork (Hayab, 2014).

The average total Annual Rainfall amount over Kaduna state is about 1172.9mm, with November to January recording the least rainfall and the highest amount being recorded in August at approximately 306.3mm. The average maximum temperature is about 31.8°C, recording the least in July and August and highest in March. The average minimum Temperature over the state is about 19.4°C. The least temperatures are experienced in January. Averagely, Relative Humidity reaches its highest value in August and the least value in February.

### 2.2 Data Types and sources

The maximum temperature, air temperature, relative humidity, rainfall amount and wind speed data for thirteen (13) years (2007-2019) were sourced online from the database of

NOAA, International research institute for climate and society (IRI). The choice of the years was due to the availability of data for meningitis cases. Meningitis data were gathered from the Nigeria Centre for Disease Control (NCDC) and Bureau of Statistics period for thirteen (2007-2019) years over Kaduna, Nigeria. The data were grouped weekly for trend analysis.

### 2.3 Method of Data Analysis

The weekly data for weather parameter and meningitis were subjected to linear trends. Pearson's Correlation was also used to test the relationship between weather parameters (maximum temperature, air temperature, relative humidity and rainfall) and meningitis occurrence in the study area.

Correlation Coefficient ( $r$ )

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{n(\sum x^2) - (\sum x)^2} \sqrt{n(\sum y^2) - (\sum y)^2}} \quad (1)$$

The quantity  $r$ , called the linear correlation coefficient, measures the strength and direction of a linear relationship between the two variables, hence the independent dependent.

The strength of the relationship between meningitis occurrence, the dependable variable, and other independent variables like wind speed, Relative Humidity, rainfall, and Temperature was established.

$x$  = values of the independent variable, which are the climatic variables (Air temperature, Relative humidity, maximum temperature, wind speed and rainfall)

$y$  = values of the mean of the dependent variable, which is Meningitis cases

$\sum x$  = Sum of individual weather variable

$\sum y$  = Sum of Meningitis cases

$\sum x^2$  = Sum of squared of each weather variable.

$\sum y^2$  = Sum of squared of Meningitis

$n$  = Number of pairs of variables

## 3. RESULTS AND DISCUSSION

### 3.1 Trends in CSM and Weather Parameters

Fig. 2 represents the weekly trend of CSM for thirteen years (2007-2019). The figure suggests that CSM has declined over the study periods. The decline in the CSM could be attributed to

public enlightenment and good management practices. The peak occurrence of CSM was in week 11-15. Generally, from week 16 onward, the CSM witness a decline.

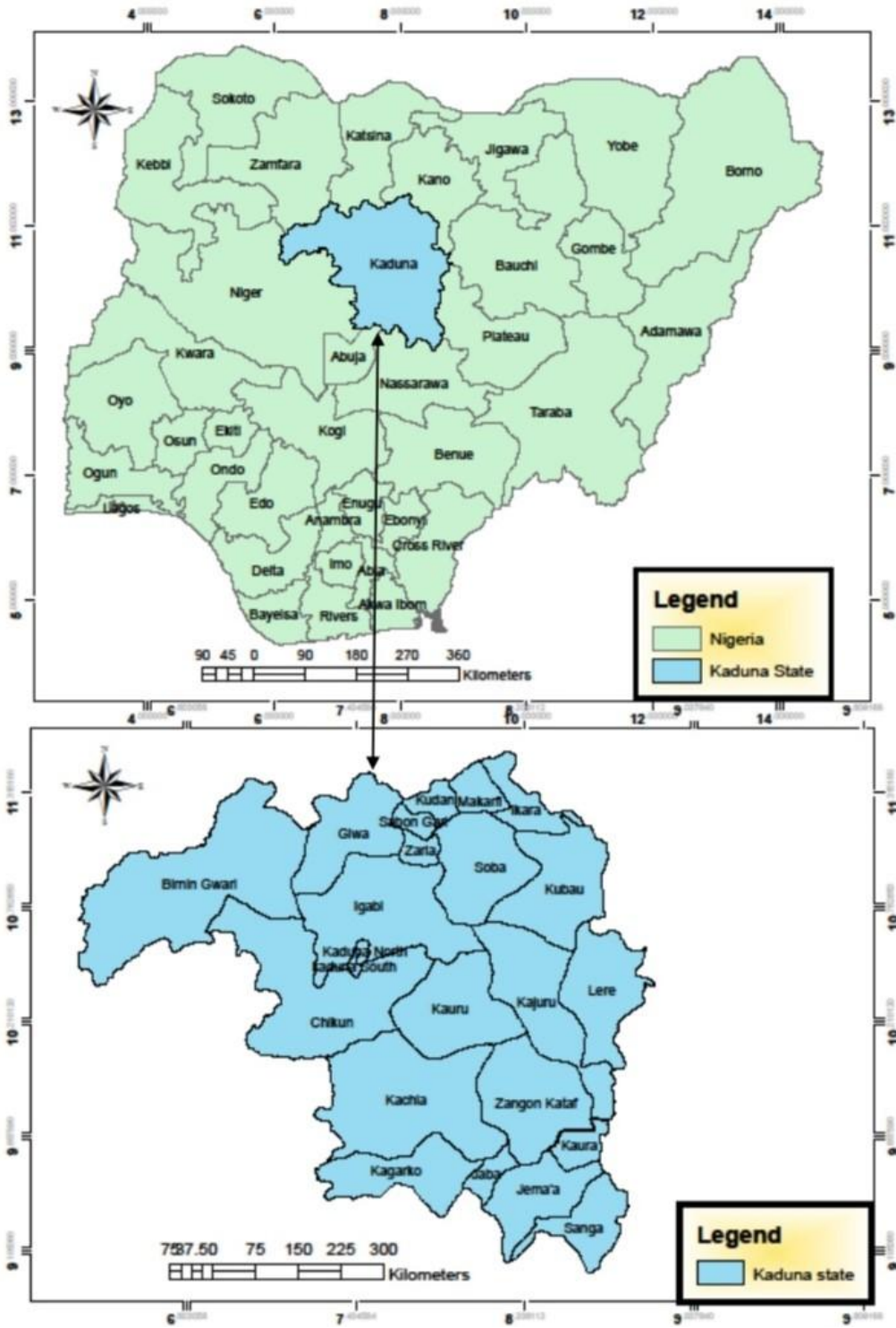
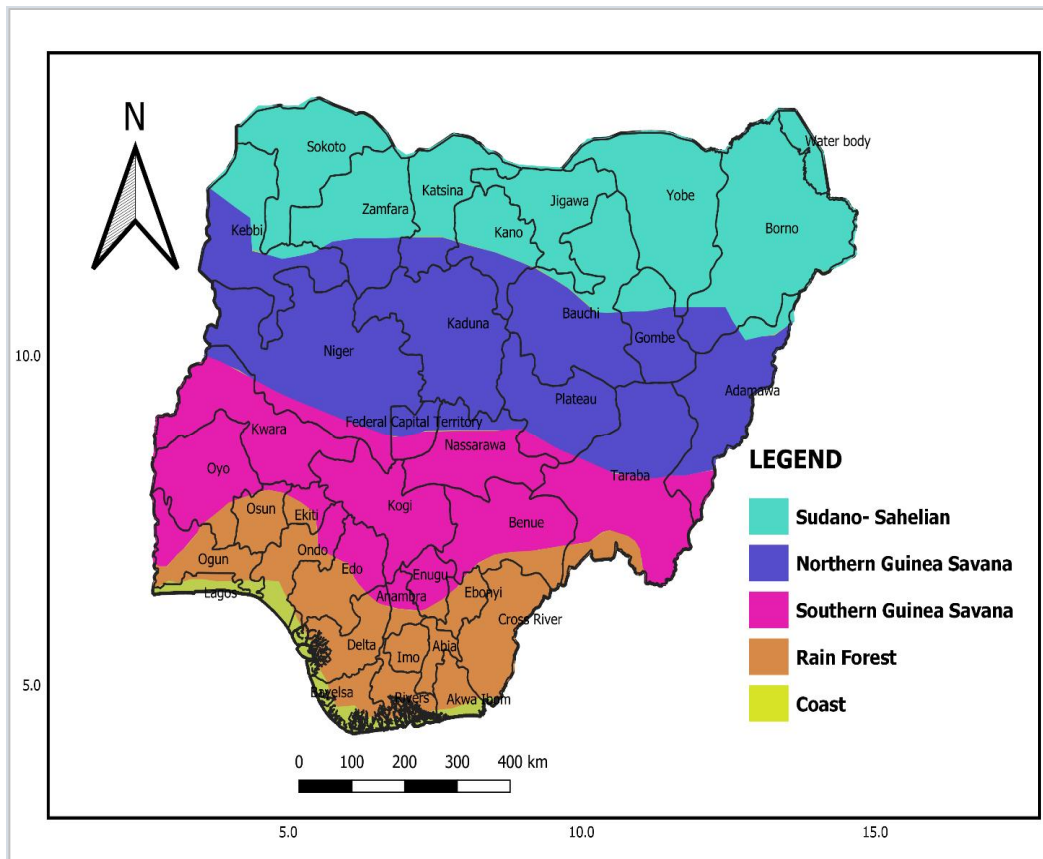
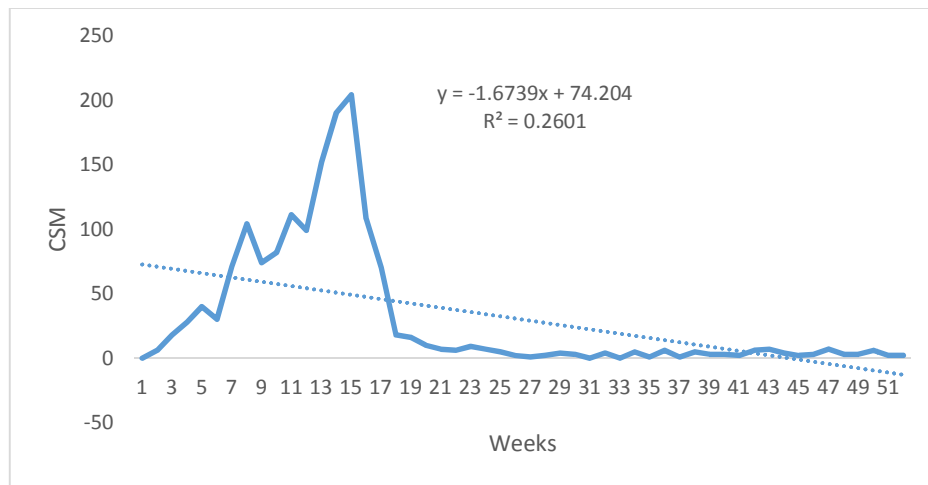


Fig. 1. Geographical location of the study area (Kaduna)



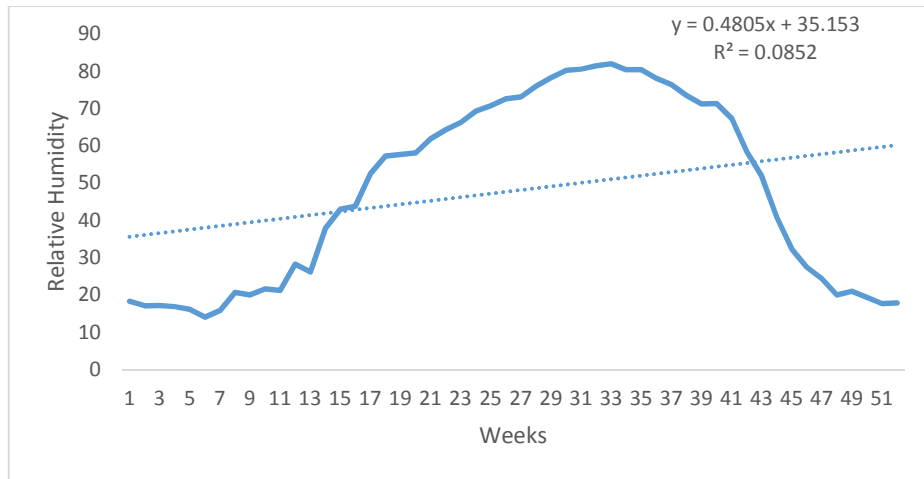
**Fig. 1.1. The Agro-climatic zones of Nigeria**



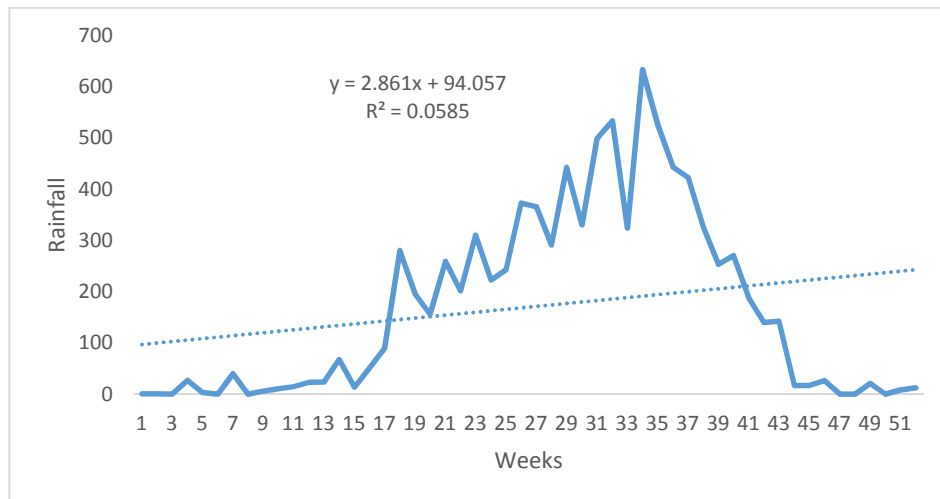
**Fig. 2. Weekly trend of CSM**

Fig. 3 represents the weekly trend of relative humidity for thirteen years (2007-2019). The general pattern of relative humidity indicates an increasing trend. The increasing trend peak between weeks 17-41.

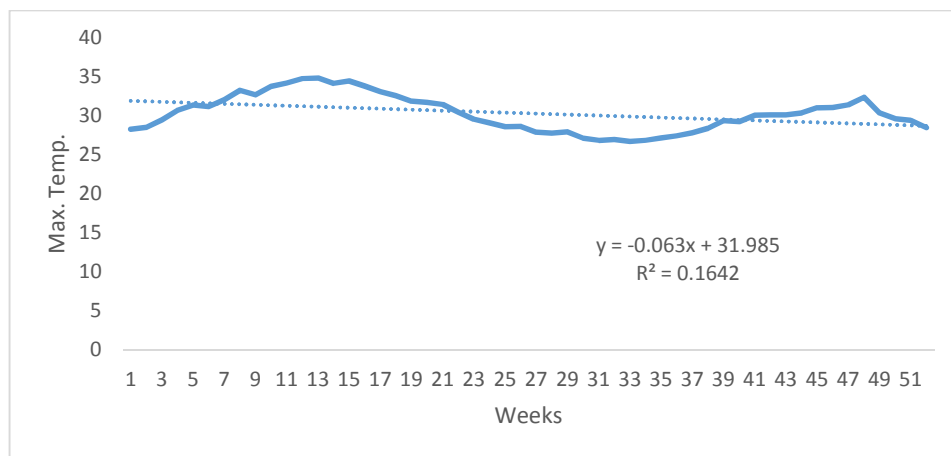
Fig. 4 represents the weekly trend of rainfall for thirteen years (2007-2019). The general pattern of rainfall indicates an increasing trend. The increasing trend peak between weeks 11-51.



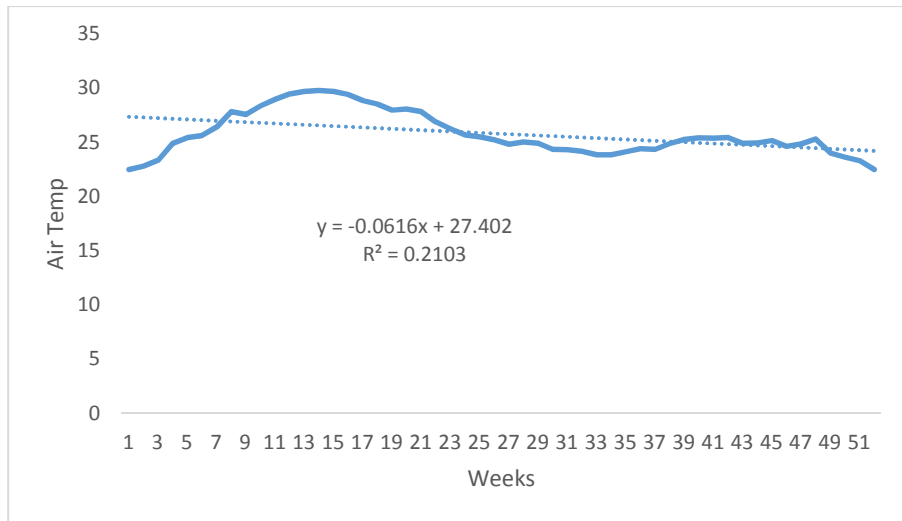
**Fig. 3. Weekly trend of relative humidity**



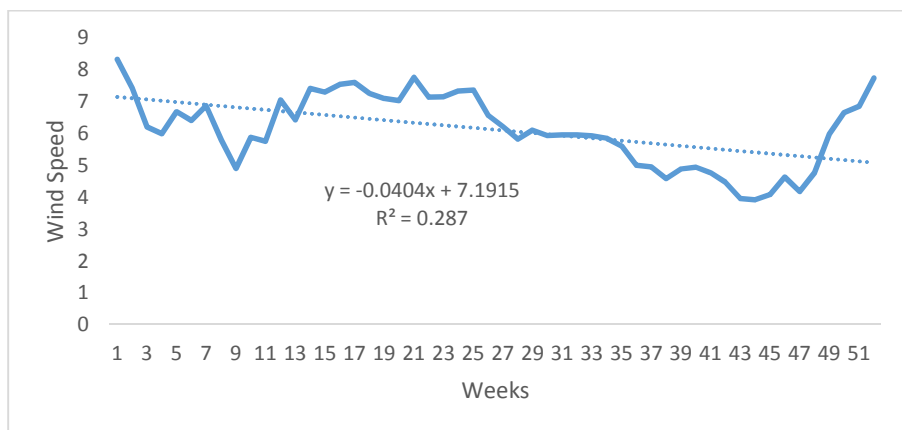
**Fig. 4. Weekly trend of Rainfall**



**Fig. 5. Weekly trend of maximum temperature**



**Fig. 6. Weekly Trend of Air Temperature**



**Fig. 7. Weekly Trend of Maximum Temperature**

rainfall trend underscores the inter-annual rainfall variability in the study area.

Fig. 5 represents the weekly trend of maximum temperature for thirteen years (2007-2019). The general pattern of maximum temperature indicates a decreasing trend. The decreasing trend occurs between weeks 21-39. The pattern follows a common weekly pattern over the country.

Fig. 6 represents the weekly trend of air temperature for thirteen years (2007-2019). The general pattern of air temperature indicates a decreasing trend. The decreasing trend occurs between weeks 21-37.

Fig. 7 represents the weekly trend of wind speed for thirteen years (2007-2019). The general

pattern of wind speed indicates a decreasing trend. The decreasing trend peak between weeks 27-45.

### 3.2 Relationship between CSM and Weather Parameters

Table 1 shows climatic variables like relative humidity, rainfall amount, maximum temperature, and air temperature are statistically significant at 0.009, 0.003, 0.000, and 0.000, respectively, except for wind speed that is short of being significantly correlated with Meningitis with an error of 7%. Relative humidity and rainfall amount have a negative relationship with a weak correlation coefficient of -0.359 and -0.410. This implies that as relative humidity and rainfall amount increases, there is a

**Table 1. Relationship between climatic variables and meningitis**

Kaduna	Correlation	P-value
Relative Humidity	-0.359	0.009
Rainfall Amount	-0.410	0.003
Maximum Temperature	0.768	0.000
Air Temperature	0.773	0.000
Wind speed	0.248	0.077

Source: Author's computation, 2020.

**Table 2. climatic variables' impact on meningitis cases**

S/NO	State	R <sup>2</sup> Value	R <sup>2</sup> (%)	F Test
1	Kaduna	0.708	70	0.00000000004

corresponding drop in meningitis cases. However, the relationship is weak. Maximum temperature and air temperature have a very strong positive correlation with Meningitis at 0.768 and 0.773, respectively. The finding is similar to [7]. An increase in wind speed, air temperature, and maximum temperature over Kaduna influences a corresponding rise in CSM weekly. The strength of the association between air temperature and Meningitis is slightly stronger compared to the maximum temperature.

Table 2. represents climatic variables' impact (Air temperature, maximum temperature, Rainfall amount, relative humidity and wind speed) on meningitis cases (Multiple Regression). The result below depicts the impact of the five climatic variables combined on meningitis cases in Kaduna.

For Kaduna state, climatic factors have an R<sup>2</sup> value of 0.708. This denotes that 70.8% of the observed variation in meningitis cases in Kaduna state is accounted for by combining climatic variables like relative humidity, rainfall amount, maximum temperatures, air temperatures and wind speed. In comparison, 30.2% is accrued to other factors. However, it is also significant at a 0.05 level of significance.

#### 4. CONCLUSION

This study established the relationship between CSM and weather variables in Kaduna state, Nigeria. Past studies have established a relationship between climate and CSM, underscoring the need for continuous study on climate and diseases. One of the optimal forms of disease transmission is climate. This study established that over 70% of the cause of the prevalence of Meningitis in Kaduna state.

Climate change appears to tip the scales in the number of CSM cases in the state, henceforth paying more attention to these variables. Being up-to-date on these climatic variables' changes will ensure the effectiveness of Early Warning Systems for Disease Medical facilities, and relevant bodies should include collecting weather advisories as part of their routine to monitor and respond to new outbreaks.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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