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GEO-SPATIAL ASSESSMENT OF THE INFLUENCE OF TEMPERATURE AND RAINFALL ON THE OCCURRENCE OF CHOLERA IN KANO STATE, NIGERIA

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ABSTRACT
Temperature and rainfall variability as an important factor that could affect the occurrence of Cholera becomes one of the major concerns globally. This study assessed the influence of these factors on the occurrence of Cholera in Kano State, Nigeria. The researchers employed the used of Cholera surveillance data obtained from Kano State Ministry of Health, the mean monthly temperature, and total monthly rainfall data downloaded from the climatic research unit of the University of East Anglia archive (2010 to 2019). The data were analyzed using Ordinary Least Squares (OLS) regression and Geographically Weighted Regression (GWR) in ArcMap 10.8 environment. Results showed that an increase in temperature by 1 unit positively influences the occurrence of Cholera by 19.69, 11.7 and 18.7 unit during hot/dry, warm/wet, and cold/dry season respectively. Similarly, an increase in rainfall by 1 unit brings about a rise in the outbreak of Cholera by 0.67 and 0.97 unit during hot/dry and warm/wet season respectively. In addition, highest influence of temperature and rainfall on the outbreak of Cholera during warm/wet season with R^2 value of 0.25, and lowest during the cold/dry season with R^2 value at 0.06. Northern part of the State experienced the strongest influence (R^2 values of 0.2) while Southern part recorded the lowest influence with R^2 values of 0.04 to 0.07. Variability in temperature and rainfall in Kano State were directly related with the outbreak of Cholera. Hence, the need for more environmental sanitation programs and public campaign as climate related mitigation and adaptation strategies.

Keywords: Temperature, Rainfall, Cholera, Geo-spatial, Kano State

INTRODUCTION
Climate variability becomes one of the important topics of discussion across the universe, as the physical and biological systems are already being affected by variations in climatic conditions (Asante and Amuakwa, 2014). It is defined as an inherent dynamic nature of climate on various temporal scales which could be monthly, seasonal, annual, decadal, periodic, quasi-periodic or non-periodic (Odjugo, 2010). Variability on the temperature and rainfall of a particular place are the most prominent elements of weather and climate that affects the outbreak of diseases and public health in general. Researchers reported the increase in the global average surface temperature by 0.74 °C in the 20th century (Wu et al., 2014). This could be one of the major reasons behind high rate of disease outbreak globally via pathogen, vector, host and environment interactions (Mensah et al., 2017). This means climate variability is likely to increase health risks in many parts of the universe.
Cholera is an acute diarrheal disease mostly caused by ingesting water or food contaminated with toxigenic forms of *Vibrio cholerae* (Kaper et al., 1995), which produces cholera toxin (CTX). It is an acute intestinal infection often characterized by watery diarrhea, with or without vomiting spreads worldwide in seven main pandemics started from 1817 until today (Rasam et al., 2014). The outbreak and transmission of this disease might be associated with the contamination of water and foods, and the nature of the environment. This is due to the fact that, subsequent transmission of the disease after occurrence were associated with limited access to clean drinking water and poor sanitation (Kaper et al, 1995; Nishiura, et al, 2017). Baker-Austin et al. (2018) reported that V. cholerae, like other pathogens, requires certain environmental conditions, such as 30^{O}C temperature, pH 8.5 and 15% salinity to survive and thrive. This clearly indicated that, the existence of these relevant conditions for the occurrence and transmission of cholera generally relies upon the variability of climatic factors more especially temperature and rainfall. Intergovernmental Panel on Climate Change (IPCC) (2014) noted that outbreaks of cholera and infections by related Vibrio species appear to be linked to the environmental changes of temperature and rainfall. Hence, variability in the pattern of rainfall and temperature as well as other intense and more frequent extreme weather conditions resulted to outbreak of cholera.
The influence of climatic variables, such as temperature and rainfall on the dynamic of cholera in various parts of the world has also been well established by many researchers which include: Griffith et al, (2006) in Bangladesh; Yue et al. (2014) in the Pearl River estuary, South China; and Asadgol et al, (2019) in Qom city, Iran. However, despite the fact that, Kano State suffers from several critical problems in human and infrastructural development that may lead to the occurrence of diseases at epidemic scale (Zakari et al, 2018), and the State have been considered to be among the most vulnerable areas to climate variability in Nigeria through rise in temperature and reduction in the amount and duration of rainfall (Riede et al, 2016; Weber et al, 2018). Researchers in the State with the exception of Abdussalam (2014) in northwest of Nigeria who analysed the influence of climatic elements on the inter-annual variability of cholera and meningitis incidence in the region using Multiple Linear Regressions (MLR) and Generalized Linear Model (GLM) approaches paid less interest in assessing the linkages between climate variability and occurrence of cholera. This study therefore, examine how temperature and rainfall variability influence Cholera outbreak in Kano State.

MATERIALS AND METHODS
Study Area
Kano State extends from Latitude 10°3′ N to 12°3′ North of the Equator and Longitude 7°35′ E to 9°20′ East of the Prime

meridian with a total land area of about 20,760sq km (Abdullahi, 2023) (Figure: 1). The State is characterized by tropical continental climate with alternating wet and dry seasons. According to Nabegu (2014) Kano state has an annual average rainfall of about 800 mm in the northern part and 1100 mm in the southern part. April is the hottest month in the State with average high and low temperature of about 38.2˚C and 23.6˚C respectively. However, despite the latitudinal variation in the climatic parameters' rainfall in some part of Doguwa local government area amounted to 1300 mm Nigerian Meteorological Agency (NiMet) (2021) which might be associated with ranges of mountain in the area. It has been reported by Weather Atlas (2020) that, the month of December in the Kano have been the coolest with average high and low temperatures of 31.1˚C and 13˚C respectively.

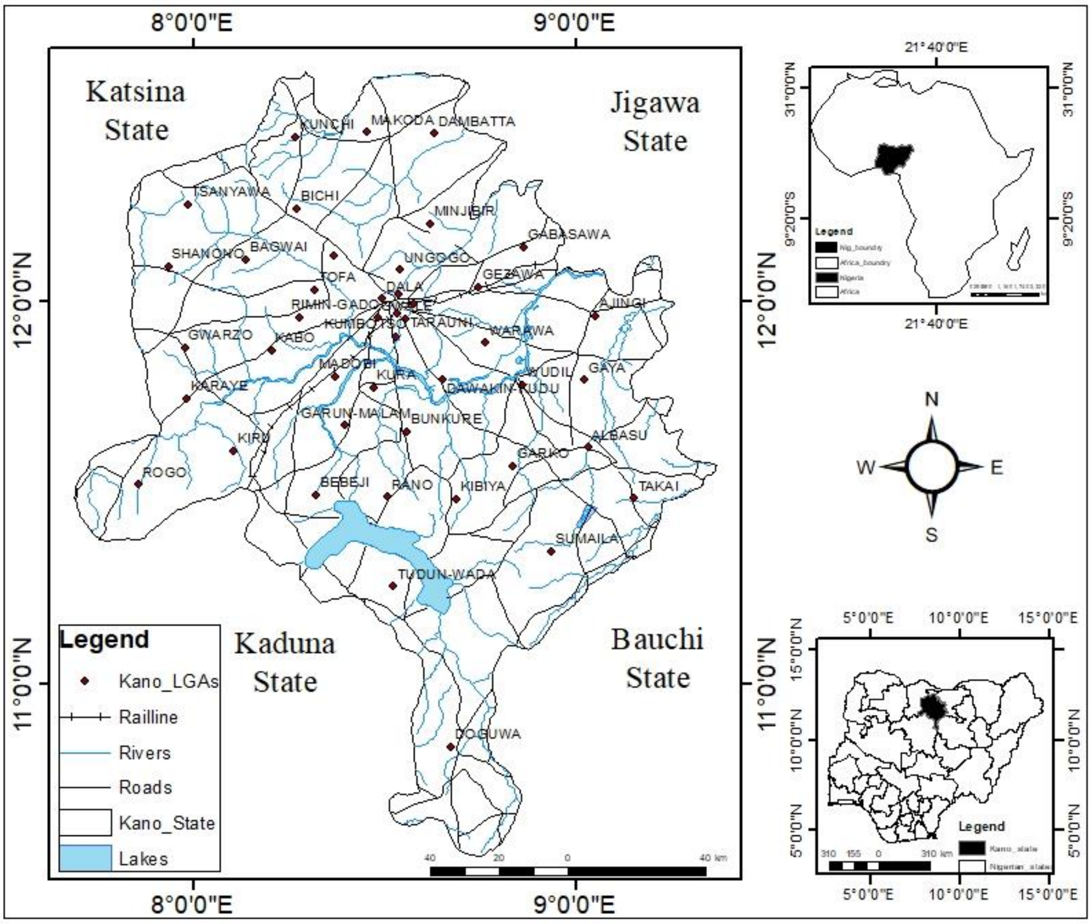

Figure 1: Map of the Study Area

Data Collection

Temperature and rainfall data used for the study were downloaded from Climatic Research Unit of the University of East Anglia (CRUv3.4, 0.5° resolution) archive for 2010 to 2019. CRUv3.4, data has been used due to its advantage of spatial coverage over station data. However, the data has undergone quality control before further analysis using R-based software tool call Rclimdex.r 1.0. The software has been developed and maintained by the Climate Research Division of the Meteorological Service of Canada. About 4% of temperature and 7% of rainfall data were identified to be not really accurate. Corrections were made using station data obtained from six meteorological stations namely: Sokoto, Katsina, Kano, Kaduna, Yelwa and Gusau after interpolation in ArcMap 10.8. The Cholera cases surveillance data (2010 to 2019) for the whole Kano State on the other hand, was obtained from epidemiological unit of Kano State Ministry of Health. The choice of this period has been in line with the missing values and uncertainties in the records of the diseases for the study area prior to this period, which might be associated with poor surveillance system structure.

Data Analysis

Researchers employed two different methods of data analysis which are: The Ordinary Least Squares (OLS) regression and Geographically Weighted Regression (GWR) in ArcMap environment as used by Kala et al (2017). OLS was used to analyse the linear influence of temperature and rainfall on the occurrence of the disease. The tool used to generate tables containing coefficient information and diagnostics which include Akaike Information Criterion (AICc), Coefficient of intercept, Coefficient of Determination, Koenker's Breusch-Pagan statistic and Jarque-Bera statistic. The result of the OLS analyses was presented in form of tables, and interpretations were done based on the above statistical parameters. However, to improve the reliability of the predictions from the OLS models, which analysis data on linear scale. Geographically Weighted Regression (GWR) models were used, due to the fact that, GWR assumes relationship between variables on a spatial extent which helps to present the spatial diversity of the relationship between dependent and explanatory variables. Therefore, GWR tool was used to examine the diverse influence of the climatic variables on the disease outbreak, and to generate an output feature class in

form of colour ramp map and database table with coefficient information and diagnostics. The coefficient raster surface maps created by GWR were used to present the results. Because OLS is a global model, GWR which is more local has been used to improve the reliability of the findings made from the model (OLS).
The mathematical equation of the two models used were obtained after the work of Hasyim et al (2018) and are presented in equation 1 (OLS) and equation 2 (GWR).

$$Rdi = \beta 0 + \beta 1 ti + \beta 2 ri + \varepsilon i \quad (1)$$

$$Rdi = \beta 0(ui, vi) + Xti\beta 1(ui, vi) + Xri\beta 2(ui, vi) + \varepsilon i \quad (2)$$

Where: *Rdi* is the dependent variable
ti and *ri* are the explanatory variables
β (*ui*, *vi*) indicates the vector of the location-specific parameter estimates
(*ui*, *vi*) represents the geographic coordinates of location *i* in space
Xti and *Xri* are the covariate vectors for explanatory variables
εi is the error term with mean zero and common variance σ^2.

The relationship in both, OLS and GWR between *Rdi* with *ti* and *ri* is assumed to be constant at every possible location of the study area. The values of *β0, β1* and *β2* are considered to be the same. The residuals *εi* are assumed to be independent and normally distributed with a mean of zero.

RESULTS AND DISCUSSION

Linear Influence of rainfall and temperature variability to the Occurrence of cholera

Results of the regression analysis between cholera outbreak and climatic factors (rainfall and temperature) using OLS model were presented in Table 1. Results from Koenker r statistics indicate non-significant p values of 0.097, 0.35 and 0.94 during hot/dry, warm/wet and cold/dry seasons respectively.

Table 1: Linear Influence of Rainfall and Temperature to the Occurrence of Cholera

Parameters	Hot/dry	Warm/wet	Cold/dry
Koenker statistic (P values)	0.096875	0.344851	0.934299
Jarque–Bera statistic (P values)	0.046424*	0.053386	0.000122*
Rainfall coefficient of intercept	0.670193	0.970601	
Temperature coefficient of intercept	19.699827	11.690326	18.690607

* Significant at 0.05

The result also revealed that an increase in 1 unit of rainfall brings about a correspondent increase in cholera outbreak by 0.67 and 0.97 unit during hot/dry and warm/wet season respectively. On the other hand, the finding show that an increase by 1 unit of temperature lead to correspondence increases in cholera by 19.7, 11.7 and 18.7 unit during hot/dry, warm/wet and cold/dry season respectively. Table 1 also showed that, Jarque–Bera statistic returned a non-significant p value of 0.053 during warm/wet which indicated the residuals of the model are normally distributed. While during hot/dry and cold/dry seasons Jarque–Bera statistic returned significant p values of 0.046 and 0.0001 respectively.

Diverse Influence of rainfall and temperature variability to the Occurrence of cholera

The mapping of the values in figure 2 indicated the R^2 values to has been decrease from the Northern part towards Southern region with higher values of 0.18 to 0.2 at Tsanyawa, Bichi, Kunchi, Makoda and Dambatta LGAs and lowest values around Doguwa, Tudun Wada, Sumaila and Rano LGAs. On the other hand, communities in the southern part such as Doguwa, Tudun Wada and Rano recorded lower influence at 0.04 to 0.07.

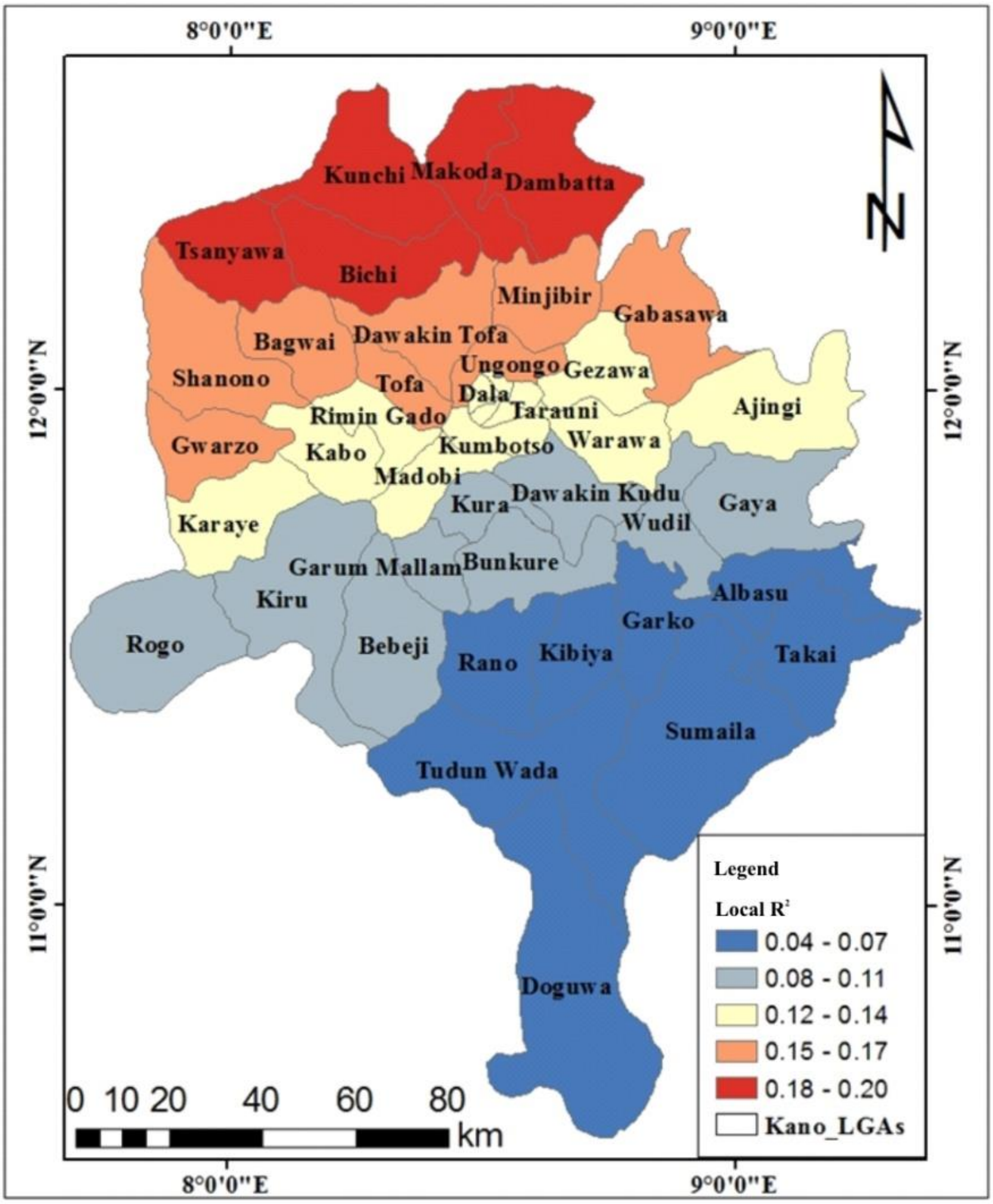

Figure 2: Local R^2 Values for Cholera during Hot/dry Season

The spatial influence of the climatic variables on the cases of cholera presented in figure 3 during warm/wet season showed that both factors influenced the outbreak of cholera with similar degree of influence across all parts of the study area with R^2 values ranging from 0.25 to 0.26. However, communities that received higher total annual rainfall during the warm/wet season such as Doguwa, Tudun Wada, Bebeji, Kiru and Rogo LGAs were experience more influence.

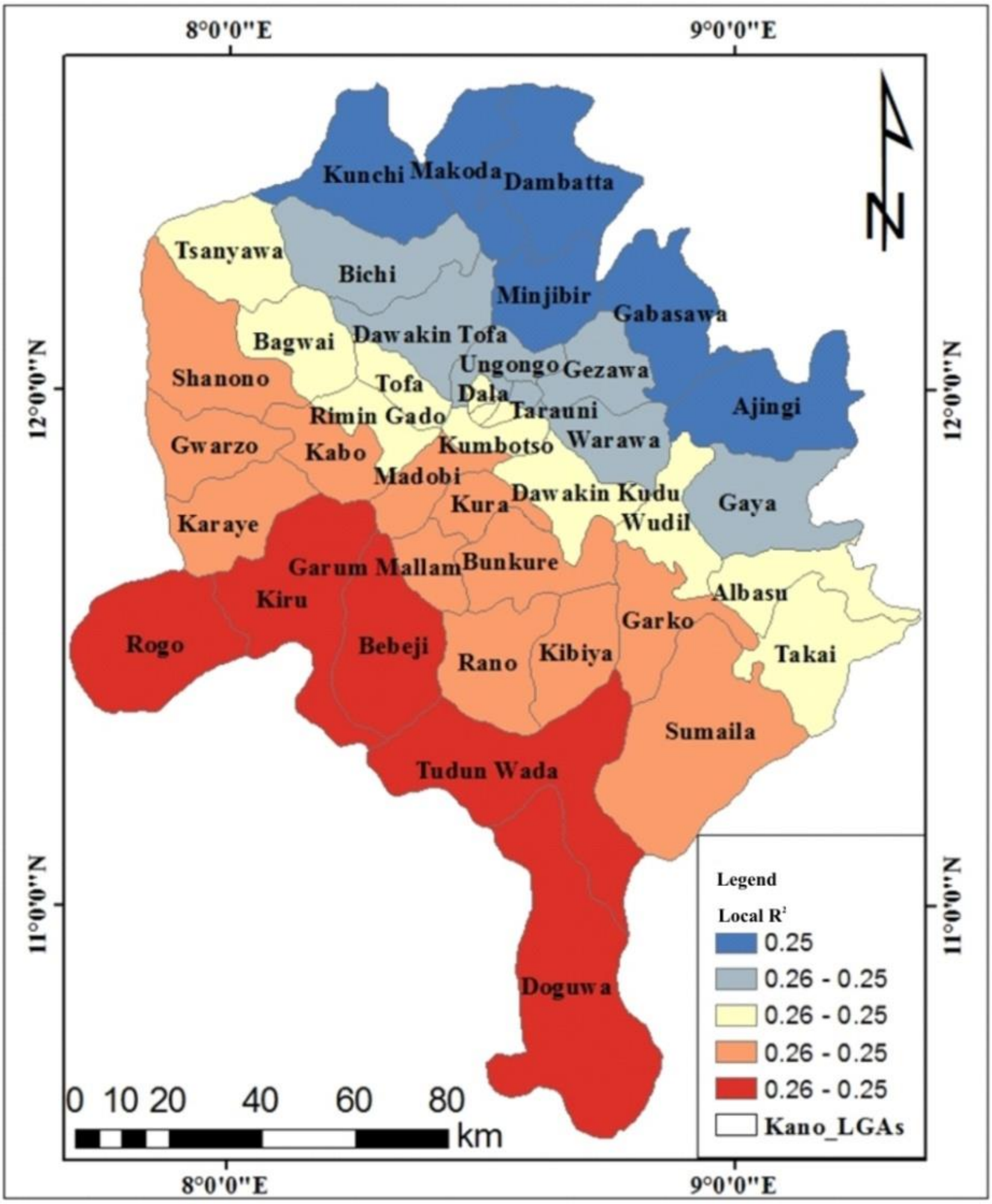

Figure 3: Local R^2 Values for Cholera during Warm/wet Season

The result of the analysis in figure 4 revealed R^2 values of 0.01 to 0.02 during cold/dry season when rainfall is completely absent temperature is poorly related with cholera in the whole State.

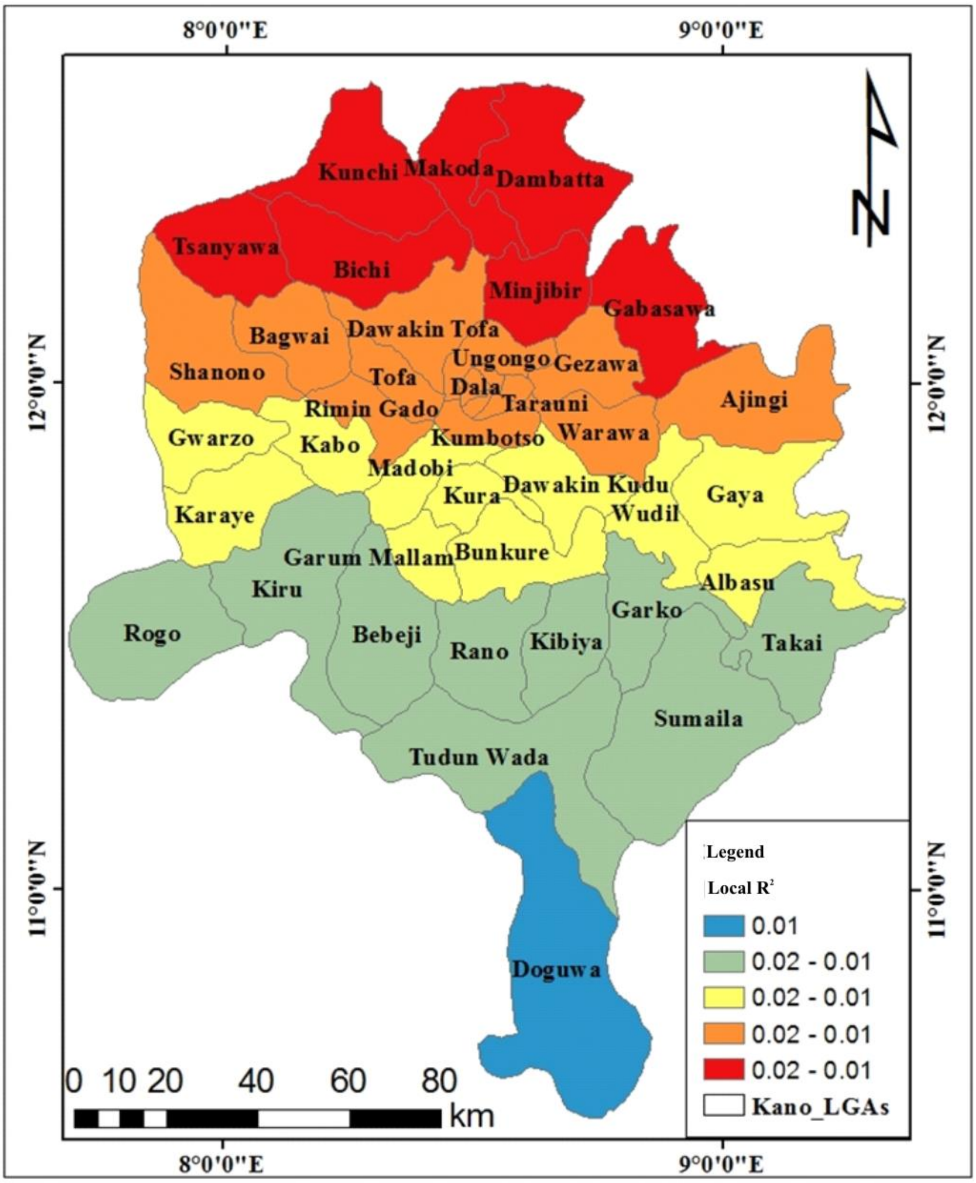

Figure 4: Local R^2 Values for Cholera during Cold/dry Season

Discussion

The findings of this study using OLS, which shows that an increase in 1 unit of rainfall resulted to a rise in cholera cases by 0.67 and 0.97 unit during hot/dry and warm/wet season respectively implies that, the relationship between rainfall with cholera cases in the study area was consistent and therefore, an increase in rainfall in the study area brings about a correspondent increase in cholera outbreak. The explanation for this is that rainfall is an important factor with respect to predicting the outcome of cholera in the study area. The strength and direction of the influence based on these findings showed a weak positive relationship between rainfall and cholera outbreak in the study area. This result may be due to the fact that during hot/dry and warm/wet seasons there is rainfall which may drained contaminated substances and other waste materials into public water supplies and consequently contaminates the water through the activities of bacteria and other parasites. This statement supports Lipp and Rose (1997) who stated that changes in surface water quality and quantity are likely to affect the incidence of diarrheal diseases. The finding was also agreed with that of Adjei et al, (2017) and Mukhopadhyay et al, (2019) who reported that rainfall variability positively influences the spatial and temporal distribution of cholera disease.

On the other hand, the finding which shows an increase by 1 unit of temperature brings about an increase in cholera by 19.7, 11.7 and 18.7 unit during hot/dry, warm/wet and cold/dry season respectively, also implies positive relationship between temperature variability and choler outbreak in Kano State. This might be related with the fact that; higher temperature usually alters the geographical distribution and transmission of not only vector-borne diseases also even water-borne diseases through looking for convenient environment to survive. This finding is in line with that of Colwell (1996) who reported that cholera outbreak is also related with positive surface temperature anomalies in coastal and inland lake waters. The result of this study also supports the findings of Xu et al, (2015) that temperature variability is positively related with the occurrence of cholera disease.

Findings using GWR indicated that, values of the coefficient of determination (R^2) were not homogeneously distributed and local fitted strengths varied spatially in the study area. The mapping of the values indicated the spatial influence of the temperature and rainfall variability to the occurrence of cholera throughout the study area in different degrees. During hot/dry season were R^2 values range from 0.04 to 0.20 for instance, temperature has more influence than rainfall due to the fact that the Southern part receive more rainfall and the Northern region records more temperature. However, during warm/wet season the study indicated that both factors influenced the outbreak of cholera epidemic with similar degree of influence across all parts of the study area. This might be linked with flooding which helps in contaminating the available water for domestic activities. The result also showed that even though temperature variability also affects cholera occurrences in the study area, rainfall exerts more influence during warm/wet season. In other words, the explanation to these findings is that although temperature and rainfall played significant influence on the outbreak of cholera during warm/wet season, rainfall becomes high which moderates the relative influence of temperature.

Temperature variability as one of the major climatic factors that play a role in the outbreak of cholera disease in the study area may be associated with the heat wave generation, water and food contamination in the region. This supports Mensah et al, (2017) who reported that climate variability impacts human health through factors such as transmission of vector borne, food- and water-borne diseases, and changes in the prevalence of diseases associated with air pollutants and aeroallergen. This is in line with the report of Oger and Sudre (2013) that hot/dry conditions lead people to use drinking and cooking water from sources with higher risk of contamination, which includes stagnant waters and wells with lower depths. The finding also supports Bentham and Langford (2001) who reported higher temperature as one of the factors associated with higher transmission of enteric diseases. During cold/dry season on the other hand, the finding of GWR is in line with the finding under OLS analysis that temperature and rainfall influence the outbreak of cholera. This is because; the R^2 values of 0.01 to 0.02 indicated that during cold/dry season when rainfall is completely absent temperature is poorly related with cholera in the whole State. This therefore means that the dependent variable (cholera disease) cannot be predicted from the independent variable (temperature) only which is low during the season.

As a whole, the findings which indicated that during warm/wet (R^2 values 0.25 to 0.26), rainfall has more influence on occurrence of cholera in areas which receive more rainfall may be due to the fact that, when rainfall becomes high, waste materials both solid and liquid are washed into open water sources such as wells and rivers which serve as sources of water to rural people in Kano State. Therefore, drinking or bathing with such contaminated water may increase cholera infection. This supports Tamunoberetonari et al, (2013) who reported that polluted water sites serve as a pathway for the spread of various infectious diseases especially cholera. The findings of this research coincide with the finding of Hassan et al, (2016) in Malaysia who examined the influence of temperature and precipitation on cholera cases from 2004-2014. The study revealed a positive correlation between the climatic factors and the disease occurrence with significant p value of <0.001 for temperature variability and 0.022 for variability in precipitation.

CONCLUSION

The study concluded that a 1 unit increase in temperature and rainfall may increase the outbreak of cholera by 19.69 unit and 0.67 unit respectively during hot/dry season in the study area. Furthermore, temperature and rainfall have more influence to the outbreak of cholera in the Northern part of the State than the Southern part. Hence, the study recommended the provision of more climate related mitigation and adaptation strategies such as environmental sanitation programs in the State.

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