Temporal Variability of Rainfall and Cholera Outbreak in Damaturu LGA Yobe State, Northeast Nigeria

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Abstract

This study examines the influence of rainfall variability on cholera incidence in Damaturu, Yobe State (2010–2023) by analyzing trends in rainfall and cholera outbreaks. Using multi-stage systematic random sampling, five political wards were selected, and 384 respondents participated in the survey. Secondary data from meteorological records and hospital reports were utilized, and regression analysis was conducted to establish the causal relationship between rainfall trends and cholera cases. The findings reveal that rainfall significantly affects cholera outbreaks, with 38% of cholera incidence variations attributed to rainfall fluctuations. Increased rainfall, flooding, and poor sanitation exacerbate the spread of the disease, making certain wards (Abacha, Gwange Sabon Pegi, and Nayi Nawa) more vulnerable. The study recommends that meteorological and health agencies collaborate to develop a proactive early warning system for climate-sensitive diseases. Additionally, improved sanitation, mass media campaigns, and community sensitization should be prioritized to mitigate cholera risks and enhance public health resilience in Damaturu.

Keywords: Cholera, Damaturu, Outbreak, Rainfall, Variability

Introduction

Rainfall is a crucial climatic variable affected directly and indirectly by anthropogenic climate change. Variations in climatic conditions significantly alter rainfall distribution across different regions (Thakural *et al.*, 2018). Annual rainfall amounts fluctuate spatially and temporally due to complex oceanic and atmospheric interactions (Adenodi, 2018). In semi-arid regions, climate variability has caused adverse effects on rainfall patterns, exacerbating environmental and public health challenges (Bukar, 2014).

Cholera, an acute diarrheal illness, is primarily caused by ingesting food or water contaminated with Vibrio cholerae. The disease has spread globally in seven major pandemics since 1817 (Rasam *et al*., 2014). Its onset and spread are strongly linked to poor sanitation, inadequate access to clean water, and environmental conditions (Nishiura *et al*, 2017).

According to the Intergovernmental Panel on Climate Change (IPCC, 2014), fluctuations in rainfall patterns correlate with increased cholera outbreaks, driven by extreme weather events such as floods and droughts. Studies indicate that diarrhea-related hospital admissions increase with rising temperatures, particularly in regions with low sanitation and socioeconomic challenges (Hashizume *et al.*, 2007). Furthermore, low-income nations account for over 90% of global diarrheal cases, with nearly 4 billion episodes annually (Dickson & Surawicz, 2014)

In Nigeria, rainfall variability has expanded the geographical range of cholera outbreaks, particularly in the Northeast. Nnandi (2016) noted that intensive rainfall increases the risk of vector-borne diseases by accelerating vector replication and shortening their maturation periods.

The World Health Organization (WHO, 2023) reported 26,072 cholera cases in Nigeria in 2022, with 665 deaths, reflecting a fatality rate of 2.5%. Cholera remains a critical public health threat with a high mortality rate (Kelly et al, 2022).

Considering the temporal variability of rainfall in Damaturu, both the frequency and magnitude of rainfall events have intensified, resulting in a rising trend of climate-sensitive diseases (Ekpoh & Bassey, 2016). Located in northeastern Nigeria's Sudano-Sahelian zone, Damaturu experiences high rainfall variability, which has led to extreme weather conditions, fostering the proliferation of cholera, malaria, and other waterborne illnesses (Nigerian Meteorological Agency, NiMet, 2019).

Previous studies (Mustapha, Bukar and Kazeem., 2021; Jajere, Ismail and Musa, 2015) have investigated rainfall and temperature variability in Damaturu. However, no study has explicitly examined the correlation between rainfall fluctuations and cholera incidence. This study aims to analyze the temporal trend of rainfall variability and its impact on cholera outbreaks in Damaturu over a decade.

Material and Methods

Description Study area

Damaturu LGA is situated in the eastern part of Yobe state, located between latitudes 11^0 39' 30'' – 11^0 47' 00'' N and longitudes 11^0 54' 00'' – 12^0 02' 00'' E. It is the state capital of Yobe State, which served as a nodal town connecting different regions of the state and Maiduguri, Borno State. The town covers a total land area of 23.66 km^2 with an average elevation of about 456m above sea level (Jajere, Musa & Ismail, 2014). It shares boundaries with four local government areas. It borders Tarmuwa LGA (Dapchi town) from the North and Borno State from the East, Gujba LGA (Goniri village) to the South and Fune L.G.A (Damagum) from the West as shown in Figure 1.

However, the population is sparsely distributed in some areas and also densely distributed in the central business district area. The population of the 2006 census of the National Population Commission indicated that 55% of the population is male entailing about 48,361 people. The dependent class (working group) between the ages of 15 and 64 represent 53% of the population cohort and mostly dwells in the central business district (Brinkhoff, 2017). Based on the 2016 projection of Thomas Brinkhoff, the population of Damaturu was 124,500 people with a population density of 52.62/km^2 (Brinkhoff, 2017).

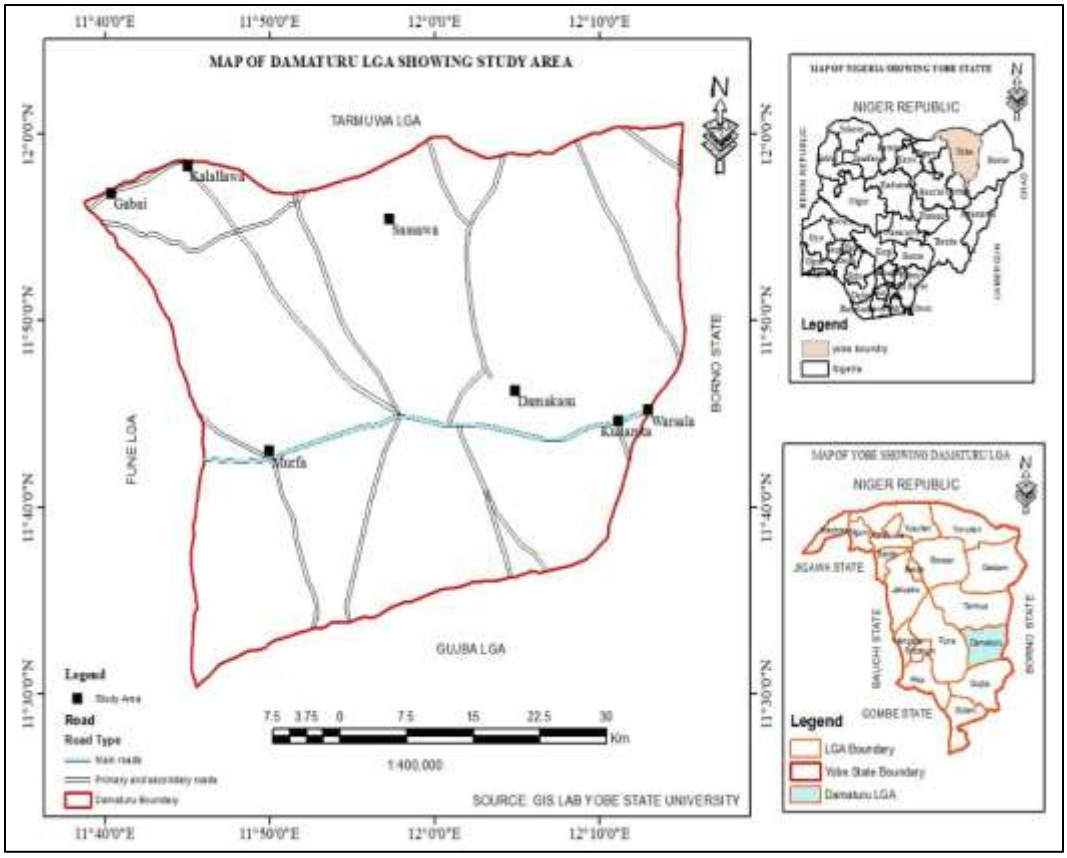

Fig. 1. Study area Map

Source: GIS Lab, Yobe State University,

In terms of climate Damaturu and its neighbouring communities are located in the Sudano Sahelian transitional climatic belts of northern Nigeria. It lies within the tropical wet/dry climate referred to as "Aw" in the Köppen Geiger's system of climatic classification (Monanu, 1975). The climate is influenced by two major trade winds: the warm moist south-west maritime trade winds during the rainy season (June–October) and the north-east continental trade winds during the dry and dusty harmattan season (November–April) period (United Nations Human Settlements Programme, 2012). This has led to the different seasonal patterns experienced which influence the rate at which different diseases spread.

Temperatures are generally high, ranging between 32°C to 40°C. Minimum temperature are mostly experienced between August and December and maximum temperatures between January to July. Annual rainfall averages about 700 millimeters per annum (NiMet, 2016). Rainfall season starts in June and ends in October. Relative humidity is generally high during the rainy season and low during the dry hot season of April, between 70 to 80 percent. The highest figures are experienced during the wet season and the lowest during the dry season (NiMet, 2019).

Furthermore, Damaturu is typically a low-land region with an elevation of 456m above sea level. It is part of an open plain development on young sedimentary rocks of Chad formation which is made up of clay and sand horizon. The basin has arranged depression of between 45m to 75m and separated from Benue valley by Biu plateau (Adam, 2013). The topography of the town is flat with open valleys running on north south-west axis through the town during the raining season, this acts

as stormy water drainage flowing to the north east, water divide is found about few meters below in the area (Ahmad, 2013).

Type and source of Data

The study utilised two sources of data that include direct sources and indirect source. The direct data source collected for the study includes the primary data obtained from the household questionnaires and interviews. The indirect data source include data collected from secondary source that comprises clinical records of cholera outbreak at the primary health care centres within the vicinity of Damaturu from 2010 to 2023. Also, monthly record of rainfall from 2010 to 2023 was collected from Desert Research Control and Management Centre (DRCMC) in Yobe State University and Global Weather Data for SWAT were obtained for Damaturu LGA.

Sampling size

Krejcie and Morgan's formula for determining the sample size of a population was adopted to select the sample size of the study population in Damaturu. Considering Damaturu with a population of 124,500 (2010 projection) and a density of about 51.62/Km^2. At a confidence level of 95% and margin error of 0.5, the sample size of the study is determined to be 384 which were distributed in the selected wards.

Sampling techniques

Multi-stage systematic random sampling technique was used in the research. In the selection of the residential sample unit, the study area was divided into three divisions, in which two wards were selected systematically based on a simple random sampling method as indicated in Table 1. Thus, due to the absence of population data at the ward level, the house numbering of the National Water Rehabilitation Project adopted by Jajere, Musa and Ismai'l (2014) was used to withdraw the respondent randomly at the selected wards. Table 1 shows the number of selected respondents in each district based on its proportional population size.

However, three hundred and eighty-four (384) questionnaires were distributed to the respondents in the study area proportionally based on the population distribution of each district.

Table 1: Sampling frame and proportionate distribution of questionnaires

S/No	Sample wards	No. of houses	Sample size	Total sample size per zone
1.	Ajiyari	305	54	127
	Nayi Nawa	409	73	
2.	Nasarawa	390	69	133
	Sabon Pegi	361	64	
3.	Nya-Nya	440	80	124
	Waziri Ibrahim	250	44	
	6	2155	384	384

Data Analysis

The data collected from the field were analyzed using descriptive and inferential statistical tools. The objective of the research was achieved by examining the thirteen-year trend of rainfall and cholera incidence data recorded over the period.

The research objectives were analyzed by obtaining the mean of each of the individual variables involved for each year which was represented using a line graph. Trend line and linear trend line

equations were displayed on the produced line graphs. Also, the overall mean for each of the diseases and weather elements for the corresponding years will be calculated across the seasons and the analysis was presented in a bar graph, pie chart and Table. To account for the nature of seasonal variation of the rainfall trend and cholera outbreak of interest for the corresponding years in the study, three seasons per annum were considered; hot-dry season (February-March), rainy season (April-October), cold-dry season (November-January). Thus, inferential statistics of simple linear regression was used to measure the degree of relationship that exists between the variables of interest (rainfall and cholera outbreak) The data were analyzed using IBM SPSS (version 23.)

Result and Presentation

Temporal Trend of Rainfall Variability in Damaturu from 2010 to 2023

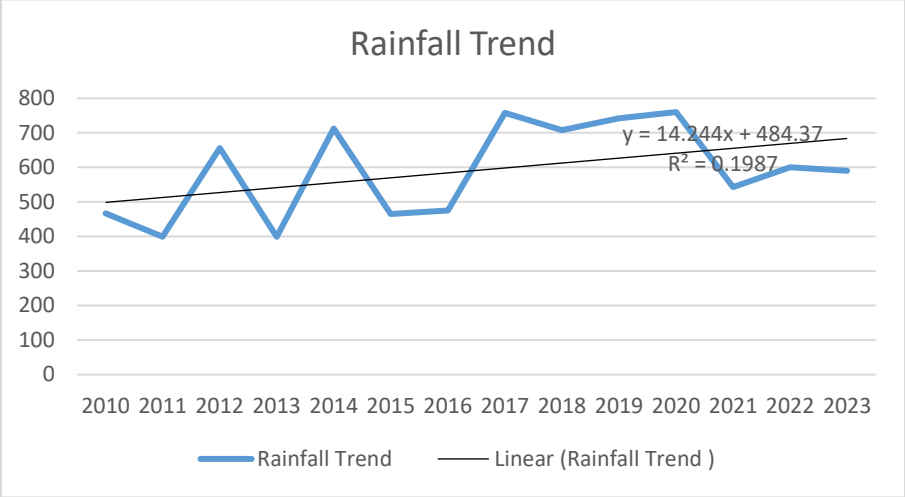

Fig. 2: Temporal trend of rainfall variability in Damaturu

Fig. 2 depicts the trend of mean rainfall amount observed in Damaturu over a decade from 2010 to 2023. The mean rainfall experienced in Damaturu in a decade ranged from 355mm to 755mm. The rainfall pattern of Damaturu has experienced significant variability and fluctuations. High amount of rainfall was recorded in 2012, 2014, 2017, 2018, 2019 and 2020 with the highest mean annual rainfall of 760.3 mm experienced in 2020. A moderate amount of rainfall was observed through the years 2010, 2013, 2015 and 2016 with mean rainfall ranging from 400mm to 500mm. Thus, a low amount of annual rainfall was experienced in 2008 with about 355mm of rainfall record in the year. According to the Nigerian Meteorological Agency (NiMet), the standard precipitation index decadal analysis indicated a significant spread of normal wetter condition which in effect increase extreme weather occurrence during the wet season which includes a high frequency of windstorms that destroy houses and properties as well as intensive flooding, especially in the year 2020 as it's recognized with the highest amount of rainfall through the decade. The intensive amount of rainfall trend experienced in 2020 is affiliated with the severe flooding occurrences not only in Damaturu but also across the country (NiMet, 2021).

Relationship between rainfall trend with cholera outbreak from 2010 to 2023 in Damaturu

Cholera is among the major causes of morbidity and mortality, particularly in developing nations. Hashizume *et al* (2007) investigated the relationship between Cholera and climate variables which indicated that the cases of hospital admission increase with an increase in temperature and rainfall, especially in those of lower sanitation, social and economic status. Thus, the temporal variability

of rainfall occurrence in Damaturu, the correlation between the cholera outbreak and rainfall trend is analyzed in Figure 2.

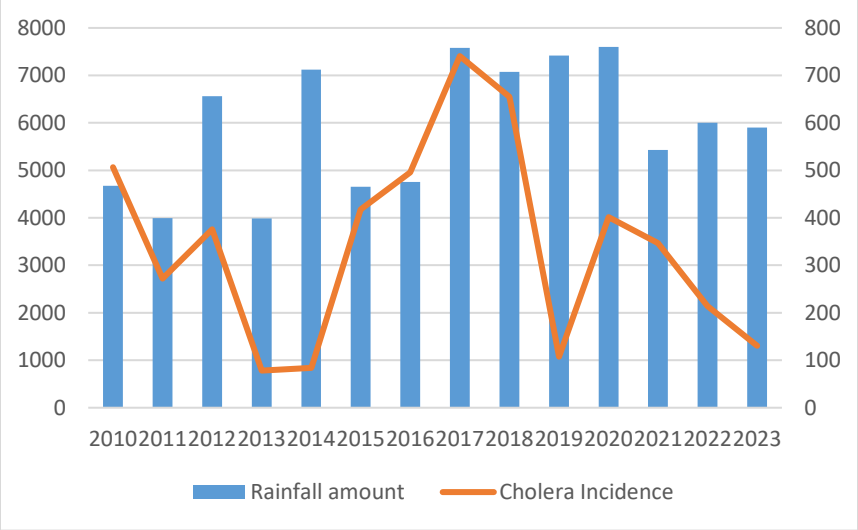

Fig. 3 Comparative analysis of the trend of rainfall and cholera incidence in Damaturu

Fig. 3 indicated that significant fluctuation was noticed in the changes in cholera outbreak with rainfall occurrence in Damaturu over the decade, based on temporal trend, a high incidence of cholera epidemiology in Damaturu was recorded by the Primary Health Care Centers in 2015 and 2018 with more than 7000 patients recorded in 2017, whereas low cholera incidence was recorded in 2013 and 2010. Furthermore, the analysis indicated that most cholera incidents are recorded in August and April which might be due to the variability of rainfall and temperature in the two months (temperature increase in April) as well as the intensive amount of rainfall experienced during August. Thus, this vividly indicates gradual increases in the number of cholera outbreaks recorded by primary health care centers in Damaturu.

However, the increase in the incidence of cholera outbreaks recorded in 2017 and 2018 is associated with the sudden increase in the average rainfall amount over the years. Whereas the decrease in the incidence of cholera outbreak records in 2013 and 2014 is associated with the fluctuations of rainfall of the years as well as the impact of insurgency in the region which made some healthcare centers not function for that period. According to Obi and Eboreime, (2017), about 788 healthcare facilities have been lost to insurgent activities in the northeast. In a related report by the World Bank, in 2016, about 201 health centres were damaged in Borno State due to insurgency (Bakare, 2020). The high percentage of damage to healthcare centers coupled with anxiety and psychological trauma due to frequent insurgency attacks was a factor that caused a decrease in the number of recorded disease incidents in the early decadal years.

Table 2: Coefficient of r' in regression analysis

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.175[a]	.038	-.050	136.96795
a. Predictors: (Constant), Cholera incidence				

Table 2 shows that 38% of variances in cholera outbreak can be explained by the variability of rainfall occurrence in the Damaturu. Thus, the temporal trend of rainfall to some extent affects the incidence of cholera over decades in Damaturu. This is because rainfall variability has a significant profound influence on people's livelihood and environment. However, the studies of Ayanlade Adeoye and babatimehin (2013) observed that not all effects of rainfall are negative on human health since moderate or mild weather conditions help the human immune system to wade off certain diseases and enhance recuperation from illness. The report of the Nigerian Meteorological Agency, seasonal rainfall prediction report (NiMet, 2019) explained that Cholera outbreak is among the 77 global climate-sensitive diseases as well as neglected tropical diseases that affect the living condition 50 million poorest people in Africa.

Table 3: Coefficient of Regression

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	552.846	72.231		7.654	.000
	Cholera incidence	.011	.018	.175	.616	.549
a. Dependent Variable: Rainfall Amount						

Based on Table 3, the regression coefficient indicated that the cholera incidence diseases incidence measured is strongly correlated with the occurrence of rainfall variability in Damaturu as the F-value is 0.549 which is greater than the significance level of 0.05. This explains that the occurrence of the cholera outbreak and an increase in rainfall can cause an increase in cholera incidence.

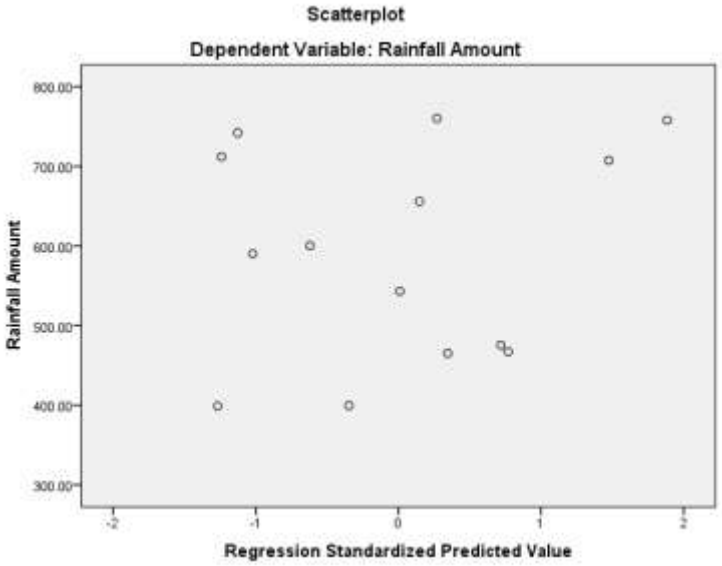

Fig. 4: Cholera outbreak with Rainfall variability.

Figure 4 shows that the occurrence cholera outbreak is influenced by the occurrence of rainfall in the study area considering that with the increase in rainfall amount, the occurrence of a cholera outbreak also proliferates.

Discussion of Findings

Rainfall variability plays a pivotal role in the prevalence of cholera incidence in Damaturu, findings of the study indicated that the temporal trend of rainfall variability in relation to cholera incidence explained that a significant fluctuation in weather variables was experienced and determined the incidence of cholera outbreak through all the years.

However, the mean annual rainfall amount experienced in Damaturu indicated an increasing trend in the amount of rainfall received over the decade, which ranges from 355mm recorded in 2008 to 755mm recorded in 2017. The variability in rainfall is in line with the global trend of weather occurrence as noted by the IPCC report. Thus, the seasonal prevalence of cholera incidence in Damaturu depicts a linear increase as compared to the trend of rainfall variability. A high number of cholera incidences were observed in years that are related to high rainfall variability. For instance, a high incidence of cholera cases was recorded from 2016 to 2017, which corresponds to the significant experience in rainfall. According to the NOAA report (2018) and the World Health Organization report (Cop24) in 2018. The years 2014, 2015, 2016, 2017 and 2018 were the sequential years in which a significant increase in weather variables was noticed since 1851 (Monaco *et al.*, 2021).

Based on the established data, the significant changes in rainfall variables are related to the changes in the seasonal pattern of cholera incidence observed. most of the cholera incidences are related to changes in weather patterns. The studies of Oluleye and Akinbobola, (2010) also explained that the correlation between cholera occurrence and weather variables is high during March, April and August. Change in climatic parameters especially temperature and rainfall are anticipated to cause change in the outbreak of certain common diseases such as Malaria and Cholera outbreak (Monaco *et al.*, 2021).

The change in rainfall patterns has an indirect effect on the communities as extreme weather occurrences such as flooding led to the destruction of buildings, latrines and properties which inadvertently diffused contaminants into the food and water source of the communities. Such incidences have frequently been noticed in some wards of Damaturu (Nayinawa and Gwange wards) where annual flash-flooding led to high incidence and spread of cholera and diarrhea in the communities especially during the rainfall season.

Furthermore, the combination of higher rainfall variability, prolonged dry season and floods coupled with scarce water resources and poor sanitation make some wards more vulnerable to outbreaks of cholera incidence. Stagnant water in traditional places such as Ajari, Pawari, Nayi-Nawa, Babba Tsangaya and Pawari harbors the growth of phytoplankton which serves as a reservoir for cholera bacteria and plasmodium parasite

The regression coefficient r^2 indicates that 38% of cholera incidence results from the influence of rainfall in Damaturu. This depicts that rainfall has a profound significant effect on the cholera outbreak in Damaturu. Similar studies by Adelowo et al (2023) indicated that the incidence of diarrhea and fever where much less than the prevalence of blood pressure among aged people in Lagos state. The result of his regression indicates that 11.5% of variations in climate-related diseases are caused by the variability of temperature and rainfall (Adelowo *et al*, 2023).

Apart from cholera epidemiology, rainfall variable affects human livelihood from different aspects. For instance, extreme weather occurrences such as flooding, windstorms, sandstorms and squalls in Damaturu have affected the livelihood of people by causing damage to trees, buildings and infrastructures, obscuring visibility and socioeconomic likelihood.

Thus, variability in weather elements and the associated health risks are formidable challenges for health and environmental officials as well as the government have been identified as key players in building adaptation. Yet, little research has empirically tracked the level of human health adaptation rainfall in Damaturu. The study recommended that healthcare care facilitators and officials undertake vulnerability assessments to identify vulnerable regions that may easily succumb to rainfall effects for appropriate capacity building and resource allocation.

Meteorological agencies in collaboration with health organizations, shall develop a program that involves an innovative approach to analyze weather and climate in the context of human health to design proactive mitigations. This will enable reliable forecasting and projection of the vulnerability of the population to climate-sensitive diseases and infections.

Considering the scope of the research on the temporal trend of rainfall variability and cholera incidence focusing on the limited number of diseases which is not the only prevalence that are being influenced by rainfall variability in Damaturu, the researcher recommended that the scope can be broadened to cover other aspect of human diseases that are influenced by climatic variables and environmental condition.

Conclusion

This study has demonstrated a statistically significant relationship between rainfall variability and cholera incidence in Damaturu, Yobe State, with rainfall fluctuations accounting for approximately 38% of cholera outbreak variability. The identification of cholera hotspots—such as Abacha, Gwange Sabon Pegi, and Nayi Nawa—highlights the influence of poor drainage, inadequate sanitation, and unsafe water sources, particularly during the rainy season. These findings corroborate previous research across northern Nigeria, reinforcing the growing public health risks posed by climate-sensitive diseases in semi-arid regions.

Recommendations

Based on the findings, the following recommendations are made:

i. To address these challenges, there is a critical need for integrated approaches that combine meteorological data with health surveillance to develop early warning systems for disease outbreaks.

ii. Community-level interventions, including improved water and sanitation infrastructure and hygiene promotion, are also essential.

iii. Future research should adopt multi-disease and multi-sectoral frameworks, employing predictive modelling techniques to enhance preparedness and response strategies.

iv. Overall, climate-informed public health planning is vital to mitigating the impacts of rainfall variability on vulnerable populations in the face of ongoing climate change.

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