INFLUENCE OF CLIMATIC ELEMENTS ON THE INCIDENCE OF MALARIA, MEASLES, MENINGITIS, AND PNEUMONIA IN THE FEDERAL CAPITAL TERRITORY (FCT)

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Abstract

The impact of climate variability on human health is a subject of global concern. Climatic and weather conditions, along with other factors, influence the emergence and re-emergence of infectious diseases. Global temperatures are rising, and weather events are becoming more intense, affecting the dynamics of these diseases. This study explores the relationship between climatic elements and the incidence of malaria, measles, meningitis, and pneumonia in Nigeria's Federal Capital Territory (FCT). The research used secondary data from hospitals and meteorological stations, analyzed using SPSS version 25. A multiple regression analysis was conducted to identify significant climatic influences on disease incidence. The results reveal that malaria incidence has a strong positive correlation with rainfall (81.62%) and relative humidity (76.55%), while it has a very strong negative correlation (-92.28%) with maximum temperature. Measles incidence shows a positive correlation with maximum temperature (84.32%). Meningitis also has a positive correlation with maximum temperature (82%). Pneumonia showed negative correlation relationships with sunshine (26%) and maximum temperature (27%). The study concludes that climatic elements significantly influence the occurrence and seasonal patterns of these diseases in FCT. Recommendations include constructing drainages, promoting the use of treated nets and preventive drugs, encouraging vaccination, and investing in climate change awareness and health education.

Keywords: Relationship. Malaria, Climate, incidence, diseases, Hospital.

INTRODUCTION

The impact of climate variability on human health has garnered significant attention from researchers and policymakers worldwide. Climatic and weather conditions play a crucial role in the emergence and re-emergence of infectious diseases, alongside various human, biological, and ecological factors. Climatologists have observed a steady increase in global temperatures, projecting an unprecedented rise of 2.0°C by 2100, as reported by the IPCC (2013). Weather events are becoming increasingly intense and frequent, with varying impacts on infectious diseases, driven by the growing unpredictability of environmental changes (Adeyemi, 2000; Epstein, 2002). While global climate change is a significant contributor to the spread of infectious diseases, it is recognized as a multi-causal phenomenon. Climate plays a role in influencing host defenses, vectors, pathogens, and habitats (Epstein, 2002). Temperature and rainfall, as key climatic factors, contribute to disease dynamics; however, minor variations in these factors are unlikely to significantly influence disease spread (Bate, 2004). The Federal Capital Territory (FCT) is particularly vulnerable to climate change due to its socio-economic and physical characteristics, rapid population growth, poverty in satellite towns, and exposure to extreme weather events (Kelly-Hope and Thomson, 2008).

Human understanding of the relationship between climate and diseases dates back to 384-322 BC, but the in-depth understanding of the interaction was only achieved through the fast progression of modern technology, and also the ability of man to understand the weather and climate system to the extent of forecasting and predicting the future weather and climate (WHO, 2003). Climatic elements affect the timing or intensity of outbreak of diseases sensitive to weather in the study area with high exposure and risk of fatalities due to the levels of ignorance (Kama, Marcus, Hembe and Yisa, 2024). Before the emergence of anthropogenic climate change, both epidemiologists and climatologists paid little attention to climate-disease relationships (WHO, 2005a). Most studies have focused mainly on investigating the risk factors for infectious diseases in individuals, not populations. According to published research (Pascual, Bouma, M, & Dobson, 2002; Koella, Pascual, & Yunus, 2005a) climate is playing a vital role in the spread of many infectious diseases. Some of these diseases include social risk factors that are driving the transmission and outbreak of these diseases is of great importance, because this will help authorities in the allocation of both human and financial resources in their efforts to control outbreaks (Mabaso, Craig, Ross, & Smith, 2007).

The interplay between climate variability and health outcomes presents a significant challenge in Nigeria, with the Federal Capital Territory (FCT) serving as a critical case study. Climatic changes exacerbate the prevalence of infectious diseases, strain public health systems, and impact socio-economic stability. The FCT's climatic profile, characterized by alternating high and low temperatures and an average relative humidity of 65%, creates a conducive environment for the proliferation of disease vectors. During the rainy season, stagnant water accumulates in drainages, swamps, and ponds, serving as breeding grounds for mosquitoes. Consequently, diseases such as malaria, cholera, meningitis, and pneumonia are prevalent (WHO, 2008).

In Nigeria, malaria remains a pervasive health issue, affecting over 50% of the population annually and accounting for 45% of outpatient visits. Confirmed malaria cases totalled 2.4 million in 2000, with the disease contributing to an estimated 1.3% annual reduction in economic growth due to healthcare expenses and lost productivity (FMH, 2001). The financial burden is immense, with costs exceeding 132 billion Naira annually (ND and HS, 2011).

Given the established connection between climatic factors and disease outbreaks particularly malaria, measles, meningitis, and pneumonia this study explores how climatic conditions influence human physiological processes and the prevalence of diseases within the Federal Capital Territory (FCT). The research aims examines the health implications arising from the interplay between climatic elements and disease incidence in the FCT.

MATERIALS AND METHOD

The Study Area

Abuja, situated in Nigeria's Middle Belt Region, lies geographically at the heart of the country. Its coordinates span between latitudes 8°25' and 9°20' North of the equator, and longitudes 6°45' and 7°39' East of the Greenwich Meridian. Covering a landmass of approximately 7,315 km², the actual city occupies 275.3 km². Located north of the confluence of the Niger and Benue Rivers, Abuja shares borders with Niger State to the northwest, Kaduna State to the northeast, Nasarawa State to the southeast, and Kogi State to the southwest. The Federal Capital Territory (FCT) is administratively divided into six Municipal Area Councils: Abuja Municipal, Bwari, Abaji, Kuje, Gwagwalada, and Kwali (figure 1.1).

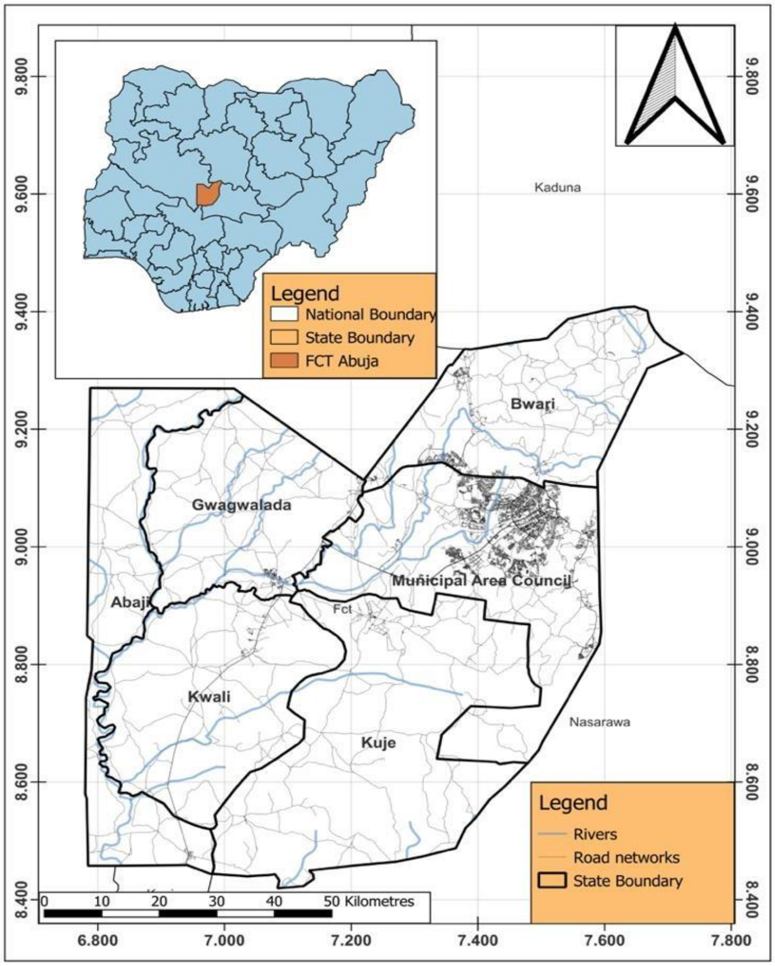

Figure 1.1: Federal Capital Territory showing Area Councils
Source: NASRDA, (2023)

Types and Sources of Data

The data source for this study was secondary data obtained from hospitals and meteorological stations. Additional secondary data sources included journals, books, articles, newsletters, internet publications, magazines, and both published and unpublished materials. The data collected encompassed:

Climatic Data composed of information on maximum and minimum temperatures, relative humidity, and rainfall records for the period 2005–2022 across all Area Councils. These records were sourced from the Nigerian Meteorological Agency (NIMET) Headquarters located at the Nnamdi Azikiwe International Airport, Abuja.

Medical Records composed of data on inpatient and outpatient cases of malaria, measles, meningitis, and pneumonia in the Federal Capital Territory during the same period (2005–2022). These records were obtained from the Health Departments of the Area Councils, both Government and Private Health Facilities, National Hospital, and the University of Abuja Teaching Hospital, Gwagwalada.

A hierarchical stratified random sampling technique was employed. The Federal Capital Territory was stratified into its six Area Councils. Hospitals were purposively selected within these councils, prioritizing those that submitted complete monthly disease incidence records during the reconnaissance survey. Hospitals meeting the criteria for data availability and accessibility both

Government and Private were included. Similarly, climatic data were collected from the NIMET Headquarters at the Nnamdi Azikiwe International Airport, selected for its advanced equipment and reputation as one of Nigeria's most sophisticated meteorological stations.

Applications for medical records were submitted to the Ethical Committees of selected hospitals, accompanied by a study proposal and application fees as required for ethical clearance. Requests for climatic data were submitted to NIMET Headquarters. The climatic data collected included daily and monthly records of sunshine duration, maximum and minimum temperatures, rainfall, and relative humidity from January 2005 to December 2022.

The data collection process involved extensive collaboration with responsible units and departments, spanning several months. Challenges were encountered in accessing disease incidence data, particularly due to missing or incomplete records in some hospitals, which provided monthly rather than daily records; Consequently, the study duration was reduced to 15 years to ensure data uniformity.

The collected data were analyzed using the Statistical Package for Social Sciences (SPSS), version 25. Both descriptive and inferential statistical methods were applied to interpret the findings. Descriptive statistics were used to summarize the data, with the results presented in tables for enhanced clarity and ease of understanding. For inferential analysis, multiple regression techniques were employed to determine which climatic elements had the most significant influence on the incidences of malaria, measles, meningitis, and pneumonia in the Federal Capital Territory (FCT) over the period from 2005 to 2022. This technique enabled the determination of variable contributions, reducing explanatory and predictive variables that were statistically insignificant to develop a focused regression model. Statistical significance was evaluated at a 95% confidence level, with a threshold of 0.05. Variables with p-values below this threshold were considered insignificant and discarded.

Table 1. Hospitals and Clinics by Ownership and Level of Care

	PUBLIC				PRIVATE				
LGA	**Primary**	**Secondary**	**Tertiary**	**Sub-Total**	**Primary**	**Secondary**	**Tertiary**	**Sub-Total**	**Grand Total**
Abaji	31	2	0	33	5	2	0	7	40
AMAC	86	14	2	102	279	41	4	324	426
Bwari	55	2	0	57	33	23	0	56	113
Gwagwalada	34	0	1	35	32	8	0	40	75
Kuje	49	2	0	51	5	7	0	12	63
Kwali	44	1	0	45	3	2	0	5	50
Grand Total	299	21	3	323	357	83	4	444	767

Source: Authors Fieldwork, 2022

RESULTS AND DISCUSSION

Relationship between Climatic Elements and the Incidence of Malaria, Measles, Meningitis, and Pneumonia in FCT

Pearson Moment Correlation Analysis was used to establish the relationship existing between climatic elements and disease incidences. This indicates when the relationship is positive or negative among the variables. The results on Table 1. showed that rainfall and relative humidity had the highest correlation at 93.89%, this is because when it rains, relative humidity is 100%, which is why the clouds are unable to hold any more water. When it rains, it will increase the relative humidity because of evaporation. However, the longer it rains, the more the humidity will increase because of the air constantly drawing the water. Malaria has a strong positive correlation with rainfall (81.62%) and relative humidity (76.55%) but a weak negative correlation with minimum temperature (-12.96%) as presented in Table 1. It however has a very strong negative correlation (-92.28%) with maximum temperature. This indicated that high temperatures, especially extreme heat, do not favour breeding and spread of mosquitoes.

Malaria has shown a positive coefficient of relative humidity and negative coefficient of minimum temperature and sunshine. This means that a unit increase in relative humidity increases malaria incidence by (13); while a unit increase in minimum temperature would result in a decrease in malaria incidences.

The warm and rainy seasons are particularly important because they have the highest incidence of malaria in the study area. This also agreed with Kama et al; (2024) reported that Malaria incidence was notably higher during the rainy season, while meningitis outbreaks were more prevalent during warmer months.

However, the correlation shows rainfall, relative humidity, minimum temperature to be significant, while sunshine and maximum temperature is not. Minimum temperature has a negative relationship with malaria. The findings are in agreement with findings by a study carried out by Van Lieshout, Kovats, and Livermore, (2004) indicating that beyond a given threshold of heat, mosquito breeding and development are negatively impacted and therefore transmission of malaria is reduced.

Measles has positive relationship with sunshine (6.95%), maximum temperature (84.32%) and minimum temperature (48.80%), but has a negative relationship with relative humidity (59.30%) and rainfall (64.12%). Both maximum and minimum temperature returned positive coefficient values. A unit increase in maximum temperature 10ºC results in an increase of 75 incidences of Measles in the study area (Appendix 1).

The variables that showed positive significance are sunshine, maximum and minimum temperature. The p-value (0.829947) for sunshine is not significant but has a positive coefficient of 0.119891; the seasonal distribution for measles indicates that the warm season is a period that requires attention. However, the incidence did not show any seasonal preferences.

Meningitis has a positive correlation with maximum temperature (82%) and minimum temperature (27%), but a strong negative correlation with relative humidity and rainfall, while sunshine has a weak negative correlation. Rainfall was negative with coefficient of -0.05688 but significantly related to incidence of meningitis at p-value 0.019598 (Appendix 2), while temperature was found to be positively and significantly related to the reported cases of meningitis incidence. 10 units increase in temperature will increase incidences of meningitis by 9 people (Appendix 2). On the other hand, any 10 units increase in rainfall which in this case is 100mm will reduce the number of people suffering from meningitis by about 5 incidences in the study area. Also, according to Kama, (2022) he reported that yearly occurrence of the disease could probable be due to the fact that the same climatic and socio-economic conditions prevail in the study area which may necessitate the annual pattern of CSM disease in the study area.

Pneumonia showed negative correlation relationships with sunshine (26%) maximum temperature (27%), positive relationships with minimum temperature (2.59%), relative humidity (18%) and rainfall (40%). Pneumonia is regarded as a disease that thrives better in cold climatic conditions, which the study area does not experience for most periods of the year. Usually, the conditions in the region are hot and dry. It therefore makes sense that there are no significant relationships or coefficients in the region. There are no seasonal variations in the distribution of pneumonia incidences. Hypothesis has also shown that pneumonia is usually an infection that could be managed over a long period of time without grave consequences. However, it is known to be exacerbated by several factors, among climatic elements.

Pneumonia has negative coefficients by which a unit increase in minimum temperature would reduce pneumonia infection. Minimum temperature (2.59) has the strongest of the relationships with pneumonia among the four variables that can lead to incidences of pneumonia attack. Pneumonia showed significance only with minimum temperature and did not have a significant relationship with other climatic variable studied. The regression statistics in Appendix 3 indicates that only rainfall is significant (α = 0.024579).

As already established, humidity and rainfall are both types of precipitation and they feed off each other in a relationship where the higher the humidity, the higher the probability of rainfall.

Table 2. Correlation Analysis for Climatic Elements and Disease Incidences in FCT

	sunshine	R/hum	max_temp	min_temp	rainfall	Malaria	Measles	Meningitis	Pneumoni
Sunshine	1								
9986686+2R/hum	-0.34938	1							
max_temp	0.358939	-0.90143	1						
min_temp	-0.44124	0.329355	0.046893	1					
Rainfall	-0.5452	0.938985	-0.93031	0.260487	1				
Malaria	-0.30176	0.765548	-0.9228	-0.12965	0.816239	1			
Measles	0.069547	-0.59304	0.843281	0.488034	-0.64128	-0.86007	1		
Meningitis	-0.12751	-0.7009	0.829678	0.279404	-0.66007	-0.82959	0.788983	1	
Pneumonia	-0.26356	0.182242	-0.27947	0.025986	0.400141	0.276176	-0.24767	-0.13135	1

Source: Authors Fieldwork, 2022

Period of Impacts on Public Health

Climatic seasons have impact on the public, climatic elements and disease incidences. Periods of incidences and impacts are of great public health interest. Malaria is an infectious disease whose parasite is injected into the human blood system by mosquitoes. Measles is also an infectious disease that is highly contagious and is the cause of death of many infants and children. It is therefore worthy of note that, the nature of the relationships between these diseases and climatic elements may be at the centre of development and spread in order to clearly understand their implications. This will allow the monitoring of the important climatic variables as markers or red flags to possible outbreak of epidemics or periods of serious infections.

The findings of this study suggest that an increase in minimum temperature should indicate possible increases in malaria incidence in FCT especially for the warm and rainy seasons (Appendix 4). Increase in maximum temperature and rainfall indicates possible increases in measles cases, while minimum temperature and relative humidity also indicates the same. Decrease in minimum temperature should be cause for concern in FCT for pneumonia, although the study area was found to be relatively hot throughout the year; a weather condition that does not favour incidences of pneumonia.

The rainy and cold seasons are found to be significant months in terms of incidences of diseases in FCT, especially high incidences for malaria. The rainy seasons are particularly critical because they have the highest number of malaria incidences in the study area. This is important because it allows for discernment of the pattern of spread of these diseases. The months between February and September are especially significant for infections; while measles is prevalent from

January to May as found in the study area. Recent increase in global temperature is likely due to the effect of human activities and population increase and the built-up structures absorb this heat during the day and radiate it out at night, raising night time temperatures, which have been epidemiologically linked with mortality in meningitis and other diseases. The seasonal distribution for pneumonia shows months that allows attacks to individuals with underlying illnesses.

CONCLUSION AND RECOMMENDATIONS

The study carried out, found that climatic elements have significant relationship with diseases incidence in this study area. The climatic elements in FCT play a significant influence on disease occurrence, malaria, meningitis, measles and pneumonia. Malaria is the most significant disease incidence in the study area. Climate has a direct impact on the intensity of transmission and the seasonality of these disease incidence as influenced by variations of climatic elements. The study indicates that an increase in minimum temperature should indicate possible increases in malaria incidence especially for the warm and rainy seasons. Increases in maximum temperature indicate outbreak of meningitis and possible increases in measles cases while decrease in minimum temperature should be of particular concerned for pneumonia in the study area. Hence, climatic elements are very important and should be considered along with other factors in mitigating the spread of common diseases such as malaria, meningitis, measles and pneumonia in the study area.

The study recommends that both government authorities and individuals construct adequate drainage systems in and around residential areas to prevent the accumulation of stagnant water, which serves as breeding grounds for mosquitoes and other disease vectors. Furthermore, precautionary measures should be adopted, especially for those more susceptible to malaria during the rainy season, by promoting the use of insecticide-treated nets and preventive medications. Vaccination campaigns for measles and meningitis should also be intensified. In addition, investments in climate change awareness and mitigation, health education, the enhancement of social capital, and the strengthening of public health systems are crucial to empowering communities in the study area to effectively cope with the health impacts of climate change.

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APPENDICES

Appendix 1 Summary of Output for Measles Incidence in FCT

Regression Statistics	Sunshine	Relative Humidity	Maximum Temperature	Minimum Temperature	Rainfall
Multiple R	0.069547	0.593037	0.843281	0.488034	0.64128
R Square	0.004837	0.351692	0.711123	0.238177	0.41124
Adjusted R Square	-0.09468	0.286862	0.682235	0.161995	0.35236
Standard Error	2.741026	2.21364	1.476804	2.398242	2.10831

	Df	SS	MS	F	Significance F
Regression	5	69.16723	13.83345	13.11191	0.00351
Residual	6	6.330176	1.055029		
Total	11	75.4974			

	Coefficients	Standard Error	t Stat	P-value
Intercept	-10.9123	24.81672	-0.43972	0.675539
Sunshine	0.119891	0.543817	0.220462	0.829947
R/hum	-0.07758	0.033308	-2.32911	0.042114
max_temp	0.752017	0.15157	4.961529	0.000529
min_temp	0.589159	0.333202	1.768167	0.107424
Rainfall	-0.01377	0.005212	-2.64289	0.024612

Source: Fieldwork, 2022

Appendix 2 Summary of Output for Meningitis Incidence in FCT

Regression Statistics	Sunshine	Relative Humidity	Maximum Temperature	Minimum Temperature	Rainfall
Multiple R	0.967873	0.660075	0.967874	0.279404	0.660075
R Square	0.936773	0.435699	0.936779	0.078067	0.435699
Adjusted R-Square	0.900653	0.379269	0.884095	-0.01413	0.379269

Standard Error	3.313	8.28125	3.578452	4.229939	8.28125

	Df	SS	MS	F	Significance F
Regression	5	1138.460	284.6153	25.93071	0.000272
Residual	6	76.83193	10.97599		
Total	11	75.4974			

	Coefficients	Standard Error	t Stat	P-value
Intercept	-201.984	68.37023	-2.95427	0.021277
Sunshine	-5.61190	1.361385	-4.12220	0.004447
R/hum	0.802150	0.412536	1.944437	0.099826
max_temp	9.057919	2.619040	3.458488	0.010569
min_temp	1.353282	1.470635	0.920202	0.379130
Rainfall	-0.05688	0.020472	-2.77868	0.019495

Source: Fieldwork, 2022

Appendix 3 Summary of Output for Pneumonia Incidence in FCT

Regression Statistics	Sunshine	Relative Humidity	Maximum Temperature	Minimum Temperature	Rainfall
Multiple R	0.263563	0.182242	0.279467	0.025986	0.840262
R Square	0.069465	0.033212	0.078102	0.000675	0.706040
Adjusted R-Square	-0.02359	-0.06347	-0.01409	-0.09926	0.461073
Standard Error	9.181679	9.358827	9.138971	9.515008	6.662305

	Df	SS	MS	F	Significance F
Regression	5	1138.460	284.6153	25.93071	0.000272
Residual	6	76.83193	10.97599		
Total	11	75.4974			

	Coefficients	Standard Error	t Stat	P-value
Intercept	176.0939	12.03593	14.65068	4.44E-08
Sunshine	-1.57391	1.821636	-0.86401	0.407830
R/hum	0.082584	0.140901	0.586116	0.570789
max_temp	-0.86333	0.937966	-0.92043	0.379018
min_temp	0.10867	1.321977	0.082202	0.379018
Rainfall	0.26785	0.089828	2.981813	0.024579

Source: Fieldwork, 2022

Appendix 4 Summary of Output for Malaria Incidence in FCT

Regression Statistics	Sunshine	Relative Humidity	Maximum Temperature	Minimum Temperature	Rainfall
Multiple R	0.127514	0.765548	0.922766	0.129646	0.816239
R Square	0.01626	0.586064	0.851552	0.016808	0.666246
Adjusted R Square	-0.08211	0.544671	0.836707	-0.08151	0.632871
Standard Error	10.93404	728.641	436.380	1122.967	654.00

	Df	SS	MS	F	Significance F
Regression	5	11827856	2365571	14.21805	0.002827
Residual	6	998268.2	166378		
Total	11	12826124			

	Coefficients	Standard Error	t Stat	P-value
Intercept	44817.31	9855.079	4.547635	0.003902
Sunshine	-0.88194	179.2743	-0.40656	0.692899
R/hum	41.27738	47.02345	3.762758	0.003705
max_temp	-1015.08	364.063	-3.31273	0.012893
min_temp	-64.5092	220.9959	3.977118	0.106943
Rainfall	7.226421	5.49964	4.46791	0.001201

Source: Fieldwork, 2022