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Relationship between Climatic Parameters and the Occurrence of Malaria and Measles in Urban Katsina, Katsina State, Nigeria

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ABSTRACT

This paper examines the relationship between some climatic parameters and the occurrence of malaria and measles in Urban Katsina in Katsina State, Nigeria. Climatic data (2012-2022) were obtained from archived of the Nigerian Meteorological Agency (NiMet), Umar Musa Yar'adua Airport, Katsina, while data on malaria and measles were obtained from the General Hospital Katsina and Federal Medical Center (FMC) Katsina ranging from 2012-2022. Pearson's product-moment correlation statistics determined the relationship between the climatic parameters (maximum and minimum temperature, rainfall, relative humidity, and wind speed) and the selected diseases (malaria and measles). Findings revealed that climatic parameters influence the occurrence of both malaria and measles in urban Katsina. A low and negligible positive relationship exists between mean temperature and malaria in urban Katsina ($r = 0.098$, $p = 0.774$). Any increase in the mean temperature will lead to an increase in malaria incidence in the study area. Further findings revealed that any decline in the rainfall yield will decrease the spread of measles in the study area. The study concludes that climatic parameters influence the spread and occurrence of malaria and measles in urban Katsina. Spraying insecticide against mosquitoes and the use of mosquito nets at night is recommended, and all children should be vaccinated against measles.

Keywords: Humidity, Malaria, Measles, Rainfall, Temperature, Wind.

INTRODUCTION

The physiological function of the human body responds to changes in climatic parameters. Climate influences disease incidence in two forms: Firstly, it affects the human body's resistance to some diseases. Secondly, climate influences the growth, propagation, and spread of some disease organisms or their carriers (Ayoade, 2004). The climatic elements that directly affect the physiological function of the human body include solar radiation, air temperature, humidity, and wind speed. The indirect climatic elements influencing the body's physiological function are rainfall and atmospheric pressure. Air temperature produces heat dissipation, while relative humidity distress organisms of high environmental temperature (Adebayo, 2001; Ayoade, 2004).

Climate changes, especially temperature, rainfall, relative humidity, and wind speed, have posed a risk to human health in tropical and sub-tropical countries. This is even more so because most people in these areas are poor and more vulnerable to climate change because of their lower adaptive capacity for coping with and adapting to environmental challenges (Abaje, Abdullahi, and Jeje, 2016). About 700,000 to 2.7 million people die of malaria each year; the majority of them, nearly 75%, are African children (Christakos, Ding, and Wu, 2018). The spatial distribution of malaria is sensitive to the seasonality of climatic variables in most African countries and other parts of the world with significant perinatal morbidity and mortality (Ayanlade *et al.,* 2020). Climatic factors such as air temperature, humidity, rainfall, and wind speed affect the life cycle of malaria parasites by altering

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their duration and behavior (Gubler *et al.,* 2001).

The prevalence of malaria incidence across regions in Nigeria is linked to climatic and environmental factors. Rainfall, relative humidity, and maximum and minimum temperatures are predictors of malaria incidence in the tropical rain forests and Guinea savanna area of Nigeria. Malaria incidence is more prevalent during the rainy season, followed by the dry and cool season (Akinbobola & Omotosho, 2013; Akinbobola and Hamisu, 2022).

Measles is a significant cause of child mortality in sub-Saharan Africa; it is responsible for 62,000 deaths in the region annually. It is an endemic disease in Nigeria, with recurrent outbreaks occurring irregularly. Its transmission in Nigeria occurs throughout the year, with peaks in the dry season (February, March, and April) (Ibrahim *et al.,* 2016). Climate variability, particularly temperature, results in some heat-related diseases such as measles, malaria, and other diseases. This shows that temperature is the most determinant for the survival of living organism and their environment.

Malaria and measles are the most prevalent diseases in Katsina State (Dauda *et al.,* 2011), and pregnant women and children under five (5) are at risk of them. Therefore, studying the relationship between climatic variables and diseases (measles and malaria) is critical to proposing solutions to minimize the occurrence and spread of these diseases. This forms the basis of this paper, specifically referencing urban Katsina.

MATERIALS AND METHODS

Study Area

Urban Katsina is located between Latitude 12°58′ 0″N and 13° 04′0″N and Longitude 7°34′ 0″E and 7^0 40′ 0″E. It shares a border with Batagarawa LGA from the South and South-East, Jibia LGA from the West, and Kaita LGA from the North (Figure 1).

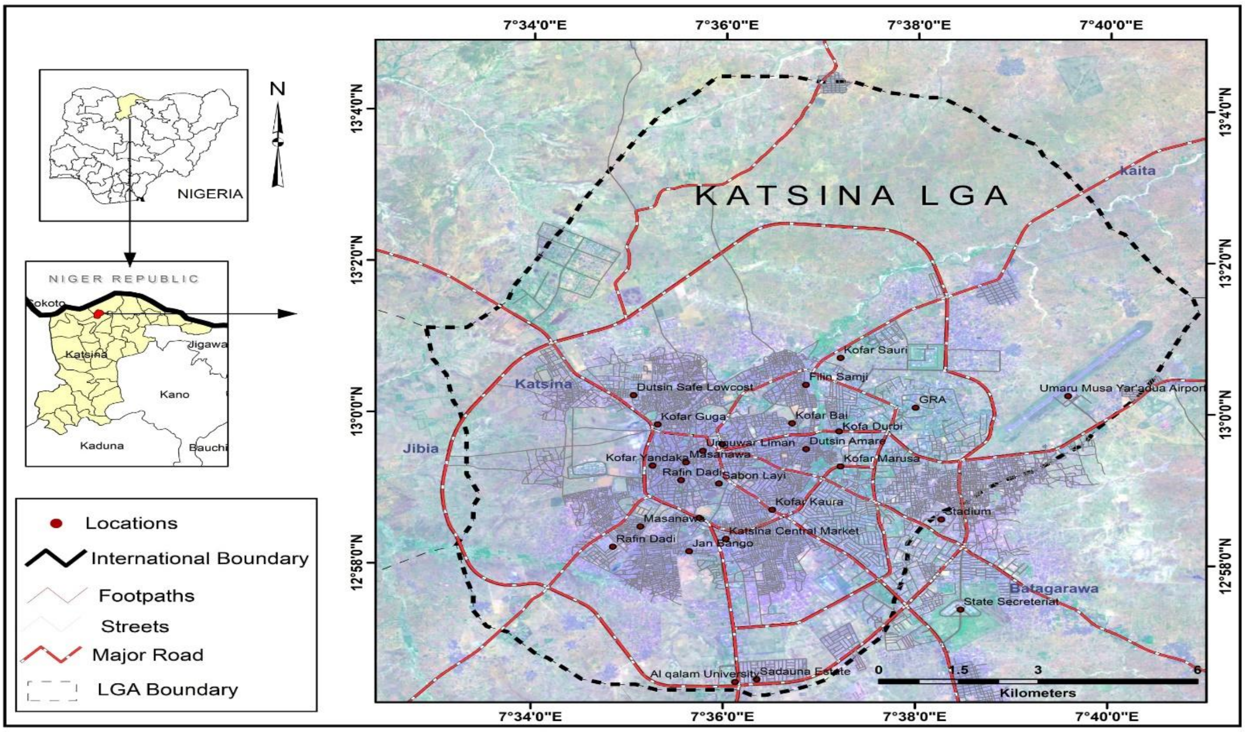

Figure 1: Study Area

Source: Adapted from Katsina State Ministry of Land and Survey (2024).

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The climate of the study area is tropical wet and dry (Koppen Aw Climate). It has an annual rainfall of about 550mm to 700mm per annum (Abaje *et al.*, 2017). The interaction of two air masses directly influences seasonal variation in rainfall: the relative warm and moist tropical maritime (mT) air mass, which originates from the Atlantic Ocean and is associated with southwest winds in Nigeria, and the relatively cool, dry and stable tropical continental (cT) air mass that originates from the Sahara Desert and is associated with the dry, cool and dusty North-East Trades known as the Harmattan (Abaje *et al.*, 2017a). The boundary zone between these two air streams is called the Inter-tropical Discontinuity (ITD). The movement of the ITD northwards across the study area (urban Katsina) in August marks the peak of the rainy season in the area, while its movement to the southernmost part around February marks the peak of the dry season (Abaje et al., 2017b). The temperatures are always high. The highest air temperature is about 38°C – 40°C and above in some years and occurs typically in April/May, and the lowest temperature occurs in December through February. Evapotranspiration is generally high throughout the year. Most evaporation occurs during the dry season (Abaje et al., 2017a&b; Abaje, 2023).

Scattered shrubs, thorns of acacia species, tamarind, and baobab, among others, characterize the vegetation. The trees are xerophytic interspersed with short seasonal grasses (Abaje et al., 2023). The landforms are sandy plain, but it is common to find deposits of dunes of varying degrees in the area. These dunes are formed from the deposition of erosive materials by strong winds across the Sahara Desert, especially during harmattan (Ibrahim & Abaje, 2022). The soils are coarse deposits influenced by the Aeolian process. These soils are well suited for the production of millet (*Pennisetum typhoid*), groundnut (*Arachis hypogeal*), sorghum (*Sorghum bicolor*), cowpea (*Vigna unguiculata*), and sweet potatoes (*Ipeoma batatas*) (Ibrahim & Abaje, 2022; Abaje, 2023).

Data Collection

Secondary data were used for this study. The data include monthly climatic data (rainfall, temperature, humidity, and wind) and disease data (malaria and measles). The eleven-year climate data (2012-2022) were sourced from the Nigerian Meteorological Agency (NiMet) archive, Umaru Musa Yar'adua Airport, Katsina. Data on malaria (2014 -2021) and measles (2012–2022) were obtained from the Federal Medical Center (FMC), Katsina and General Hospital, Katsina. There was no missing record of data in the selected period; a purposive sampling technique was employed to select these hospitals out of the many hospitals (healthcare facilities) in urban Katsina. This is because they are the oldest government hospitals, most patronized with cases of malaria and measles, well-equipped, and with a reliability of data.

Data Analysis

Linear regression was used to determine the linear trends of weather parameters (maximum and minimum temperature, rainfall, relative humidity, and wind) and selected diseases (malaria and measles). The formula for the linear regression is given as:

$$y = a + bx \quad \text{………………….……… eq. 1}$$

Where a the intercept of the regression line on the y-axis and b is the slope of the regression line. The values of a and b can be obtained from the following equations:

$$a = \frac{\sum y - b(\sum x)}{n} \quad \text{..………………..…. eq. 2}$$

$$b = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2} \quad \text{…….…….. eq. 3}$$

Pearson's product-moment correlation was used to determine the relationship between weather parameters (temperature, rainfall, relative humidity, and wind speed) and selected diseases (malaria and measles). It is computed as:

$$r = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2}\sqrt{\sum (y-\bar{y})^2}} \quad \text{………... eq. 4}$$

Where: r = correlation coefficient

x and *y* = individual observations of dependent and independent variables, respectively

$\bar{x}$ and $\bar{y}$ = mean of dependent *(x)* and independent *(y)* variables respectively.

Selected diseases (malaria and measles) were used as dependent variables, while climatic variables (temperature, rainfall, relative humidity, and wind speed) were used as independent variables.

Furthermore, a 2-year moving average was calculated and plotted using Microsoft Excel 2013 to smoothen the time series, thereby reducing the irregular fluctuations and highlighting regular ones. Given a set of numbers $y_1, y_2, y_3, - - - y_n$, a moving average of order *n* is defined by the sequence of arithmetic means:

$$\frac{y_1 + y_2 + - - - + y_n}{n}, \frac{y_2 + y_3 + - - - + y_n + 1}{n}, \frac{y_3 + y_4 + - - - + y_n + 2}{n}, etc. \quad \text{… eq. 5}$$

The sum in the numerators of equation 5 is called moving totals of order *n*. Here, the order is 2.

RESULTS AND DISCUSSION

Trend of Climatic Variable

Rainfall

The rainfall pattern revealed an increasing trend at the rate of 20.24mm year-[1,] and the series contributed 24.88% to the model. Maximum and minimum rainfall yields of 887.8mm were recorded in 2018 and 497.6 in 2018 and 2016, respectively. A 2-year moving average was used to smoothen the series (see Figure 2). Examining the 2-year moving average also revealed an increasing trend in recent years. The result is in this form because the data is from an urban center where there are a lot of human activities, which resulted in the Urban Heat Island effect. The increase in rainfall could result in the stagnation of many water points, which become a breeding point for the propagation of mosquitos, and high humidity aids the spread of measles in the study area.

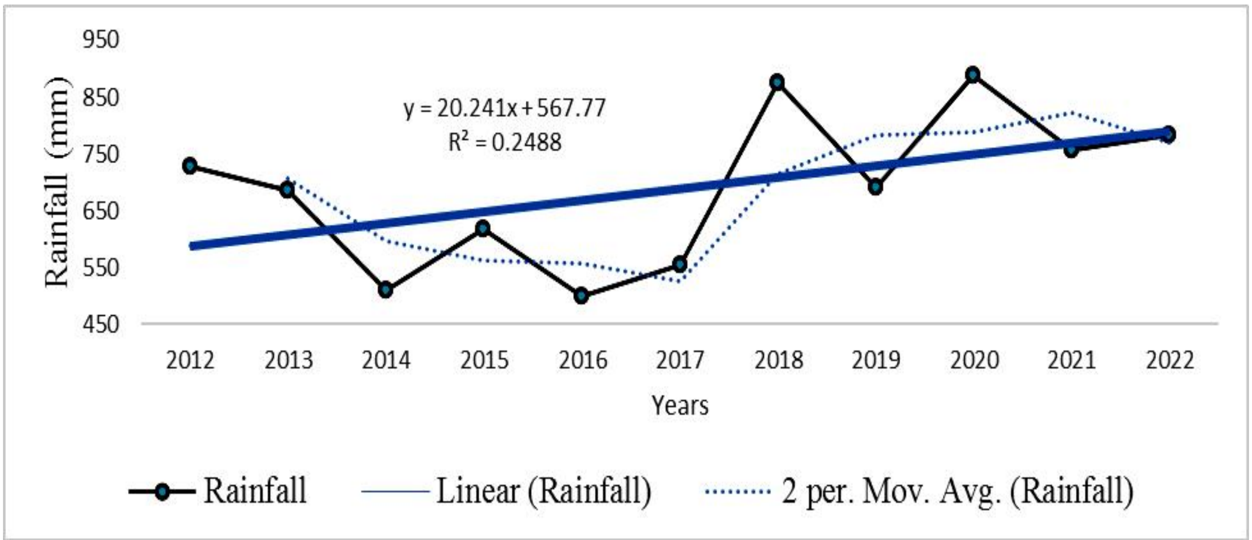

Figure 2: Trend of Rainfall, 2012 - 2022

This finding is in agreement with the results of Abaje and Ogoh (2018), who revealed an increase in the rainfall yield in Katsina, and Abaje and Oladipo (2019) also found an

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upward trend in annual rainfall yield in Kafanchan, Zaria, and Kaduna stations. Abaje, Achiebo, and Matazu (2018) revealed that there had been an increase in annual rainfall amount in recent years in Kaduna state, while Bello, Msheliza, and Abaje (2020) observed a decreasing trend of annual rainfall in Billiri Town, Gombe State and also Abaje, Ishaya and Usman (2010) reported that rainfall yield in Kafanchan is declining over the years. This means that the result of this study is in line with the global trend of increasing rainfall patterns.

Temperature

The mean temperature pattern of the study area is presented in Figure 3. It shows an increasing trend from the beginning to the end of the data series with an increasing rate of 0.09°C/year, and the series contributes 36.08% to the variation of the model. The maximum temperature value (21.6°C) was recorded in 2019, and the minimum temperature of 20.1°C was recorded in 2012. The 2-year running means was used to smoothen the series; the 2-year moving average showed an increasing trend from the beginning of the data series to the end of the study period.

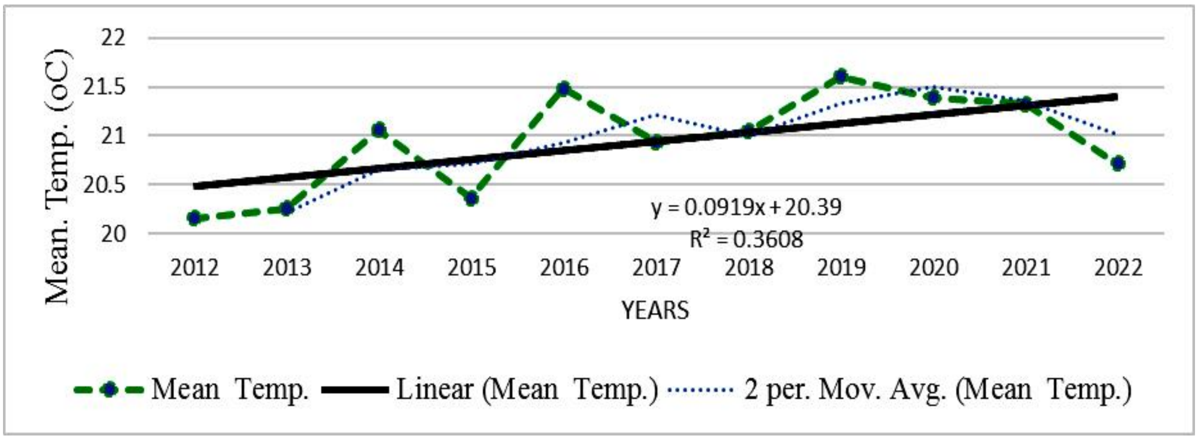

Figure 3: Trend of Mean Temperature, 2012 -2022

The urban center is a concrete jungle with a lot of heat-trapping, which makes it hotter due to the nature of the structure, the material used, and the presence of many automobiles. These factors influence the increasing temperature in urban Katsina. This result implies a conducive atmosphere for the production and survival of mosquito lava is created. This is in line with the findings by Rajini, Geetanjali, and Abdullah (2017), who reported that an increase in temperature was observed in recent years. The increasing temperature in Katsina town is in line with contemporary temperature patterns on the global scale.

Humidity

Figure 4 presents the pattern of humidity from 2012 to 2022. The humidity trend fluctuated from the beginning to the end of the series. The maximum humidity of 49% was recorded in 2012 and 2013, and a minimum of 39.5% was recorded in 2017.

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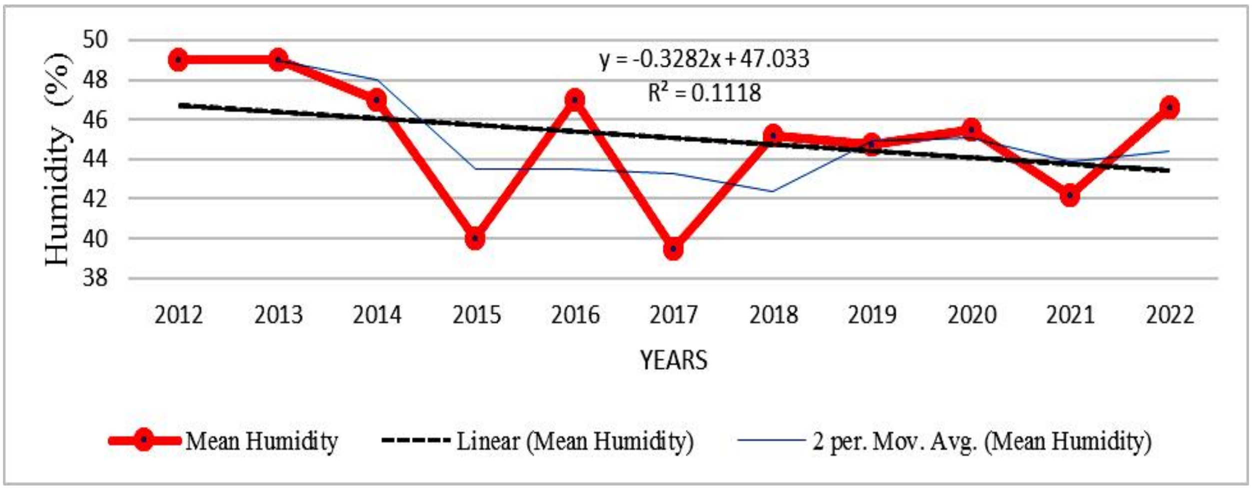

Figure 4: Trend of Humidity in the Study Area, 2012 -2022

The pattern revealed a decreasing trend at the rate of – 0.328 % /year. The series contributes 11.18% to the variation of the model (Figure 4). Examining the 2-year moving average revealed a decreasing humidity trend in recent years. The increasing temperature and wind speed resulted in increasing evaporation, which influenced the decreasing nature of the humidity in urban Katsina. The decline in humidity in the air resulted in the drying condition of the area, which could affect the production of mosquitoes and the spread of the measles virus in the study area.

This result agrees with the findings of Farooq and Kumar (2021), indicating a statistically significant falling trend of relative humidity from March to December. The decline in humidity resulted from increasing temperature, which caused a lot of evaporation and transpiration, which influenced the drying condition of the air. Also, the increasing wind speed in the study area facilitates the drying condition of the air. These are some of the reasons humidity is declining in urban Katsina.

Wind Speed

Figure 5 presents the trend of wind speed from 2012 to 2022. The figure shows that the highest wind speed (5883.56 Kn) was recorded in 2016, while the lowest wind speed (2962.5 Kn) was recorded in 2012. The 2-year moving average showed an increasing trend from the beginning of the data series to the end of the study period.

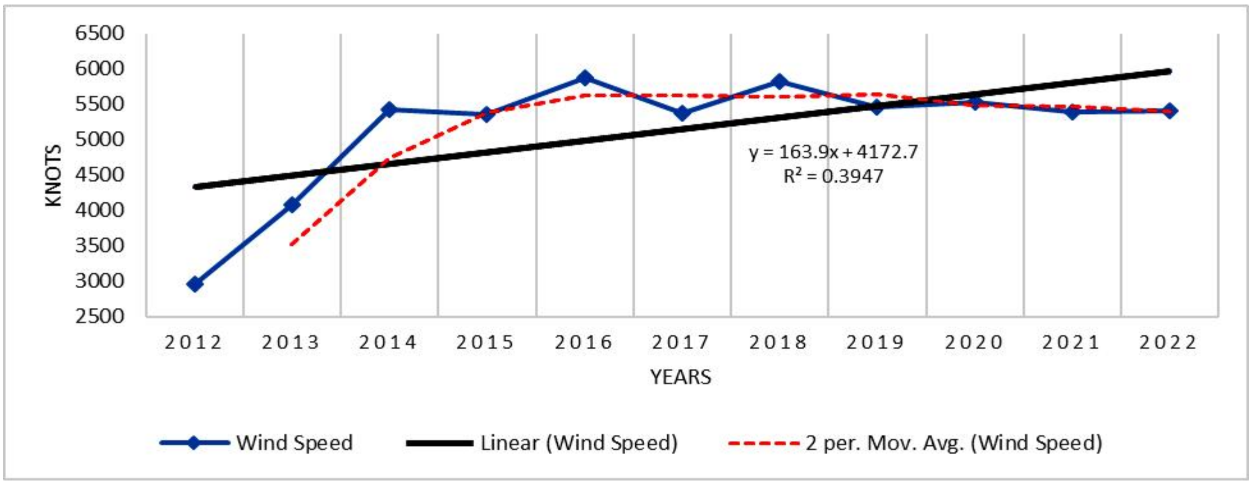

Figure 5: Trend of Wind Speed, 2012 - 2022

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The pattern of the wind speed trend fluctuates from the beginning to the end of the series with an increasing rate of 163.9 Kn /year and contributes 0.394% to the model. The increasing wind speed results from insufficient vegetation cover, which could have saved a windbreaker. Therefore, it reduces the moisture in the air and prevents mosquitoes from causing harm to the place. The findings of this study relate to an increased wind speed trend in Makurdi. This finding also relates to the result of Young, Zieger, and Babanin (2011), who observed an increasing trend of wind speed at a global scale. Also, Bello and Adebayo (2023) observed an increasing wind speed in Katsina Central. The increasing wind speed in Katsina town aids the distribution of measles and malaria diseases.

Trend of Malaria and Measles

Figure 6 revealed the trend of malaria in the study area. The trend of malaria has fluctuated from the beginning to the end of the series. The maximum peak was recorded in 2020, while the lowest was in 2017. The series indicates an increasing pattern at the rate of 505.05 malaria cases, and the study contributes 12.6% to the variation in malaria cases. This finding follows Weli and Efe (2015), who reported an increasing trend of malaria in Port Harcourt, River State, Nigeria.

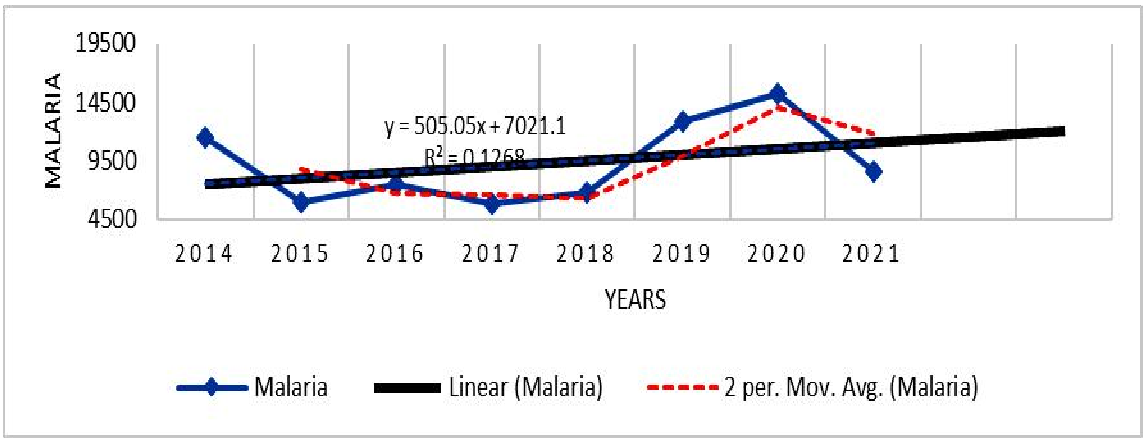

Figure 6: Trend of Malaria Prevalence, 2012 – 2022

The trend of measles cases fluctuated from the beginning to the end of the series (Figure 7). The maximum (501) prevalence was recorded in 2020, and the minimum (27) was recorded in 2014. The two-year running means revealed that the patterns of Measles disease increased for the period under investigation.

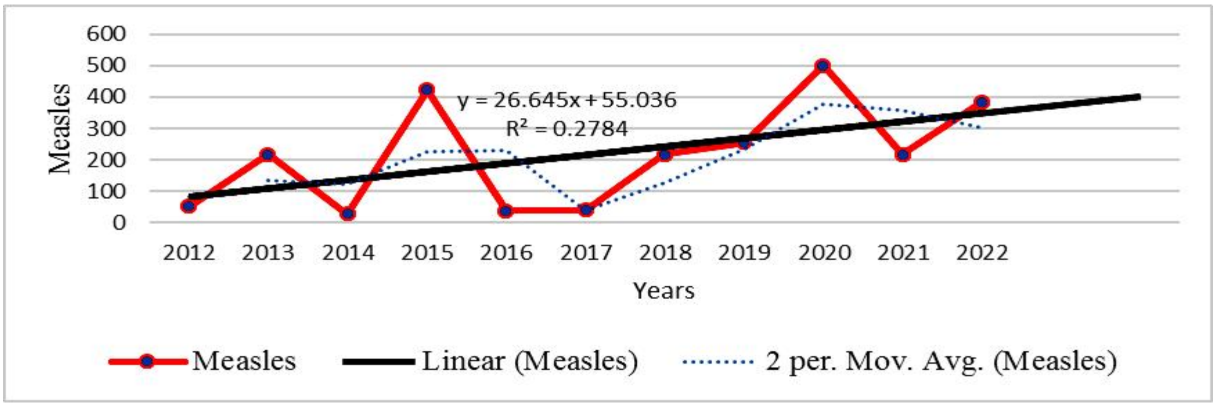

Figure 7: Trend of Measles Prevalence, 2012 – 2022

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The series revealed an increasing trend of measles at the rate of 26.65/year and contributed 27.84% to the variation of the model. This means that the prevalence of measles has been increasing for the period under review. This result did not conform to the findings of Ori et al. (2021), who observed a declining trend in the monthly prevalence of measles cases in Bauchi town. This may not be unconnected with the active campaign, immunization, and other preventive measures to ensure compliance with the population in Bauchi, even though the environmental conditions for the prevalence of measles are still present. The implications of these results show that the infections of measles diseases will continue to spread in Katsina in the years to come until preventive measures are put in place.

Relationship between Rainfall, Temperature, and Malaria

Table 1 shows the relationship between rainfall, temperature, and malaria. The relationship between rainfall and malaria is low, positive, and insignificant at 0.05 (see Table 1). This result implies that any increase in rainfall may lead to an increase in the occurrence of malaria in urban Katsina. This finding aligns with Ayanlade *et al.* (2020) and Ngarakana-Gwasira *et al.* (2016) that rainfall influences the occurrence and transmission of malaria. A markedly low and negligible positive relationship exists between mean temperature and malaria in urban Katsina (Table 1), which is not significant at 0.05 level. Any increase in the mean temperature will lead to a rise in malaria incidence in the study area. This result is related to Ngarakana-Gwasira *et al.* (2016), who reported that temperature aids in malaria transmission.

Table 1: Relationship between Climatic Variables and Malaria

Climatic Variable		Malaria
Mean Temperature	Pearson Correlation	0.098
	Sig. (2-tailed)	0.774
Rainfall	Pearson Correlation	0.492
	Sig. (2-tailed)	0.124
Humidity	Pearson Correlation	-0.446
	Sig. (2-tailed)	0.169
Wind Speed	Pearson Correlation	0.364
	Sig. (2-tailed)	0.272
	N	**11**

Relationship between Humidity, Wind Speed, and Malaria

A low and negative relationship exists between humidity and malaria cases in urban Katsina, which is insignificant at 0.05 level (see Table 1). These results imply that any decrease in humidity will reduce malaria infection within the study area. Ayanlade *et al.* (2020) also revealed that high relative humidity increases mosquito survival, flight activity, and host-seeking behavior. The relationship between wind speed and malaria is low and positive (r = 0.364, P = 0.272) and insignificant at a 0.05 confidence level. This result implies that any increase in wind speed may lead to increasing incidences of malaria in urban Katsina.

Relationship between Rainfall, Temperature, and Measles

A moderate negative relationship exists between rainfall and measles incidence within the study area and is significant at 0.05 (Table 2). This means that any decline in the rainfall yield will decrease the spread

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of measles in urban Katsina. This result agrees with the findings of Alhaji and Nasir (2019), who observed a negative and significant relationship between rainfall and the measles outbreak in Wudil.

The relationship between mean temperature and measles (Table 2) is positive but very low and insignificant at a 0.05 significance level. By implication, any increase in the mean temperature will increase measles cases in the study area. This result is in line with the findings of Yang *et al.* (2014), who noted that a positive relationship exists between temperature and incidence of measles, and Adebayo (2001), who also revealed that temperature positively influences the outbreak of measles, and the relationship is significant. This does not agree with an earlier finding by Alhaji and Nasir (2019), who reported a negative and significant relationship between measles incidence and temperature.

Table 2: Relationship between Climatic Variables and Measles

Climatic Variable		Measles
Mean Temperature	Pearson Correlation	0.153
	Sig. (2-tailed)	0.652
Rainfall	Pearson Correlation	-0.671*
	Sig. (2-tailed)	0.024
Humidity	Pearson Correlation	0.293
	Sig. (2-tailed)	0.382
Wind	Pearson Correlation	0.169
	Sig. (2-tailed)	0.620
N	11	

*Significant at 95% confidence level

Relationship Between Humidity, Wind Speed and Measles

A very low positive relationship between humidity and measles was observed, which is insignificant at a 0.05 confidence level (Table 2). This result implies that a unit increase in humidity will lead to an increasing incidence of measles within the study area. Since measles is a communicable disease, the presence of high moisture in the air will aid the spread of the disease in the study area. This finding agrees with the result of Yang et al. (2014) that relative humidity positively influences the occurrence of measles but does not agree with Galadima and Kolo (2014), who reported that measles has a negative relationship with relative humidity. The relationship between wind speed and measles (Table 2) is negative but very low and insignificant at a 0.05 confidence level. The implication is that any decrease in the wind speed will reduce the spread of measles cases in urban Katsina.

CONCLUSION

This paper concludes that climatic variables influence the occurrence of both malaria and measles in urban Katsina. If climate change continues unabated, the range of these deadly diseases (malaria and measles) will likely expand or shift, resulting in death as populations without pre-existing immunity are increasingly affected. An increase in rainfall always leads to an increase in the occurrence of malaria, while a decrease in the amount of rainfall will lead to a reduction in the spread of measles in urban Katsina. A decrease in humidity will lead to a reduction of malaria infection within the study area. In contrast, an increase in temperature will lead to a rise in measles cases in the study area. Spraying insecticide against mosquitoes and using mosquito nets at night is recommended to reduce the occurrence of malaria, and all children should be vaccinated against

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measles. Measles-mumps-rubella (MMR) vaccine is recommended.

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