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Predicting Measles Occurrence Using Some Weather Variables in Kano, North western Nigeria

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Abstract The impact of weather variables on some human diseases are now of major concern worldwide. Nigeria cannot be left out because is also home to many infectious diseases. Measles is a highly contagious disease caused by measles virus characterized by fever, fatigue and cough before the onset of rash. This study seeks to clarify the mechanism linking weather and measles occurrence and examine the possibility of predicting the number of expected cases of the disease using some weather variables and the reported cases from standard government hospitals within the study area. Monthly (1997-2012) measles cases in Kano were retrieved from Muhammad Abdullahi Wase Specialist hospital, Kano, a standard government hospital situated at the Centre of Kano city. The weather data during (1997-2012) monthly rainfall, relative humidity, minimum and maximum temperature and wind speed were obtained from Nigerian Meteorological agency. We performed the Spearman rank correlation tests to examine the relationship between monthly incidence and the weather variables, and used the statistically significant variables to develop models. The monthly (1997–2012) measles incidence was modeled using a Poisson regression model combined with Autoregressive moving average model (ARIMA). The results showed a linear effects of maximum and minimum temperature and relative humidity on measles incidence. The relative risk for the measles incidence associated with the 75th percentile of maximum temperature has a temperature window of approximately 38 to 40°C and relative humidity ranging from 19-30% within which the highest risk of measles prevalence is observed in Kano. Low relative humidity is a risk factor of measles morbidity. The months of April and May are month with highest occurrence of measles cases. Of all the models tested, the poison model combinations of all the weather variables used fits the measles incidence data best according to normalized Akaike information criterion (AIC) and goodness-of-fit criteria. Also, ARIMA (0, 0, 1) is observed to be the best fits for measles incidence data according to normalized Bayesian information criterion (BIC) and goodness-of-fit criteria. In all, we found that wind speed is not a limiting factor for measles transmission in Kano. Our findings highlight the need to pay more attention to the weather/climate variations and increase the immunity of susceptible population for possible measles reduction.

Keywords: *weather variables, poison model, ARIMA, measles occurrence, predict*

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1. Introduction

Measles is one of the commonest diseases in the tropical region of the world. In Nigeria the occurrence of this disease is common among the children and it is considered to be one of the diseases that cause death among both the young and the old. Weather varies from season to season and influences populations living under these conditions. It also has impact on individuals in their habitat at the social, psychological and physiological levels, and this may manifest in a range of behaviors [1]. However, little or nothing is in the literature about the relationship between weather and measles in Nigeria. [2] worked on the impact of climate change on the outbreak of infectious diseases among children in Bangladesh and found that incidence of measles like disease was found to have positive correlation with maximum temperature and negatively correlated with average minimum temperature and total annual rainfalls. In Nairobi, Kenya,east Africa, it has been observed that a high number of measles patients were reported between May and September which are cold months, while between December and February corresponding to dry period, very few patients are reported [3]. [4] found that variability in occurrences of many diseases is related to seasonal trends in temperatures, (although significant year-to-year differences do occur. Bronchitis, peptic ulcer, adrenal ulcer, glaucoma, goiter and eczema are related to seasonal variations in temperature [5]. In the Sudan, [6] found that a good correlations exist between some Meteorological variables and asthma, malaria and typhoid fever. Futhermore, seasonal occurrence of dust haze pollution during harmattan season has been documented by many research studies [7,8]. In the West African sub-region, large and recurrent epidemics associated with high mortality have occurred in 2004 in Nigeria [9]. In January 2007, a total of

1,346 patients were admitted to hospital due to measles, of which 62% of cases were aged 1–4 years and 23% were between 5 and 14 years of age [10].

Weather patterns are known to play a significant role in the transmission of Measles viruses [11]. Measles in Nigeria sometimes occurs immediately after the end of the rainy season, and often reaches epidemic proportions in the dry season during February, March and April [12,13]. Weather variables, except the monthly air pressure and the monthly relative humidity, were associated with the measles incidence and that an increased number of measles cases might occur before and after a cold spell [14].

[15] found that maximum number of patients with respiratory problems occurred during the dry winter months while the minimum was in rainy season. The increasing intensity of thick dust veils which laboratory analysis has shown to be carcinogenic (cancer causing) apart from confirmed presence of DDT, Alderin and other chemicals used as pesticides and herbicides is a major threat to health conditions. Temperature is a major factor in human well-being. Hot weather extremes have a more substantial impact than cold weather and many heat stress indices have been developed to assess the degree of impact [16,17,18]. In most homes, the indoor temperature ranges between 17°C and 31°C. Human being cannot comfortably live in temperature outside this range. The tolerance range on any individual is usually less than this and tends to get narrower with age of infirmity. The temperature of surrounding air is the most significant factor for human comfort. Outside the comfortable range, as temperature increases, thermal stress leads progressively to greater discomfort, physiological stress, ill health and even death. Heat can cause several clinical syndromes. Heat stroke which occurs when the body temperature exceeds 40.6°C, it is usually fatal. A record breaking heat wave in June 1998 in central Russia caused more than 100 deaths [19]. Urban populations are more vulnerable than rural populations because they experience higher temperature. Furthermore, individuals are more vulnerable to heat stress if they are in poorly designed housing, with no access to air conditions or well ventilated and cooler buildings. This is a common situation in Nigeria. From the above, it is clear that few studies have been done in this area of study despite the convincing impact of weather/climate on the prevalence of this disease. Therefore, this study will be the first to use a more convincing method to explore the impacts of weather on the prevalence of measles in Kano, Nigeria. It will also examine the possibility of predicting the number of expected cases of the disease using the reported cases from standard government hospitals within the study area to improve health care assessments for future planning purposes.

2. Methodology

2.1. Study Area

Kano (11.9964^{0}N, 8.51667^{0}E) is the capital city of Kano state in the northwestern Nigeria, located in the Sahelian geographic region of the Sahara. The region features savanna vegetation and a hot, semi-arid climate. Kano has an average of about 690 mm (27.2 in) of precipitation per year, the bulk of which falls from June through September. Kano is typically very hot throughout the year, though from December through February, the city is noticeably cooler. Nighttime temperatures are cool during the months of December, January and February, with average low temperatures of 11°-14 °C. The average relative humidity of Kano during dry season is ranging from 16-23% while during rainy season is ranging from 48-66%. The main dry season is accompanied by harmattan winds (with dust sometimes) from the Sahara Desert, which between November and early March can be quite be strong. Kano is 481 meters (or about 1580 feet) above sea level, influence by wet warm wind from the ocean which blow southwest and cool dry wind from the Sahara desert which comes from northeast all as a result of oscillation of Inter Tropical Discontinuity (ITD).

2.2. Data

Monthly reported clinical cases of measles were collected from Muhammad Abdullahi Wase Specialist hospital, Kano, a standard government hospital situated at the centre of Kano city for the period of 1997 – 2012. The hospital was chosen because of its location, consistency and availability of data. No missing data was seen in the record. However, limitation in the medical data set can arise from the fact that some people when they are sick do not visit hospital, they prefer using traditional methods or visit pharmacies. Monthly data of temperature (Maximum and minimum), relative humidity, rainfall amount and wind speed for Kano were accessed from Nigeria Meteorological Agency, Oshodi, Lagos for the same years.

2.3. Method of Analysis

2.3.1. Statistical Analysis

We performed the Spearman rank correlation tests to examine the relationship between monthly measles incidence and the weather variables. The monthly (1997–2012) measles incidence was modeled using a Poisson regression model. Akaike information criterion for Poisson (AIC) was used to choose the best model. The effects of monthly maximum and minimum temperature, relative humidity, rainfall and wind speed were controlled for the measles cases. We fitted a model for each combination of weather variables (the monthly maximum and minimum temperature, rainfall, relative humidity and wind speed) and the incidence of measles and used the combinations of lowest AIC. All statistical tests were two-sided, and $P < 0.05$ was considered statistically significant.

2.3.2. Autoregressive Moving Average (ARIMA)

After identifying the most significant combinations, then, Logarithmic transformation was applied to the measles incidence and the weather variables to be sure of the normality and homogeneity of variance of the residuals using the equation

$$Xt = \log(Xt + 1) \quad (1)$$

Where Xt is the variable.

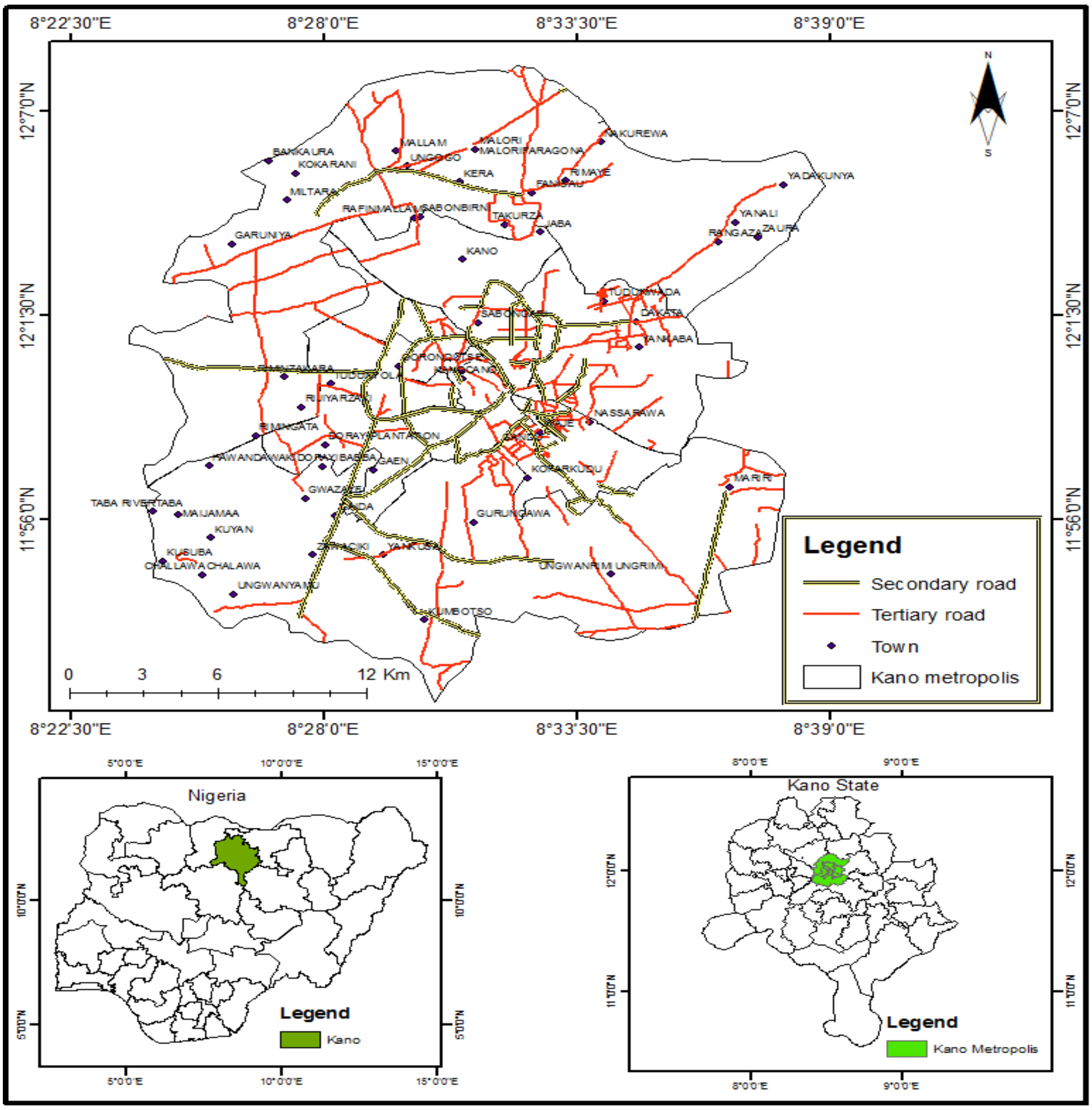


Figure 1. Map of the study Area

Autoregressive integrated moving average (ARIMA) models were used to evaluate the relationship between weather factors and monthly measles incidence. An ARIMA model was fit first to the predictor variable. The model was then applied to the dependent variable before the two series were cross-correlated to determine whether an association exists. Modelling with ARIMA involves the estimation of a series of parameters to account for the inherent dynamics in the time series, including the trends and autoregressive and moving average processes. The general model introduced by (20) includes autoregressive and moving average parameters, and explicitly includes differencing in the formulation of the model. An ARIMA (p, d, q) model comprises three types of parameters: the autoregressive parameters (p), number of differencing passes (d), and moving average parameters (q). In the notation introduced by Box and Jenkins, models are summarized as ARIMA (p, d, q); so, for example, a model described as (0, 2, 1) means that it contains 0 (zero) autoregressive (p) parameters and two moving average (q) parameters which were computed for the series after it was differenced once. We computed various permutations of the order of correlation (AR), order of integration (I) and order of moving average (MA), and chose the optimal combination of parameters. The selection of ARIMA processes was conducted using normalized Bayesian criterion (BIC), which measures how well the model fits the series.

3. Results

3.1. Descriptive Statistics Results

A total of 658 measles cases were reported in Kano during 1997-2012.The descriptive statistics for monthly weather conditions and the monthly incidence of measles are shown in Table 1. The average of monthly weather conditions during 1997–2012 were as follows: maximum temperature, 33.7°C; minimum temperature, 20.4°C; relative humidity, 33.7%, rainfall 109.6mm and wind speed is 10m/s. 205(31.15%) cases were reported in the months of April and 216 (32.82%) cases were reported in the months May.

Table 1. Descriptive statistics of variables

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
RR	12	0	109.6	43.3	149.9	0.0	0.0	21.1	205.8	396.3
Tmax	12	0	33.708	0.930	3.220	29.397	30.659	33.406	36.138	39.606
Tmin	12	0	20.36	1.13	3.90	13.49	16.94	21.64	23.39	25.35
RH	12	0	33.74	5.46	18.91	13.19	19.45	25.97	54.98	65.56
WS	12	0	10.019	0.342	1.186	7.712	9.228	9.863	11.185	11.775
Measles	12	0	54.8	22.2	76.8	0.0	5.8	14.0	72.3	216.0

3.2. Correlation Analysis Results

According to the Spearman correlation analysis monthly maximum temperature was strongly but positively associated with measles occurrence which agrees with [2] with the lowest p-value among the other weather variables while rainfall has the least correlation coefficients with the highest p-value suggesting that maximum temperature relates stronger with measles occurrence than other weather variables with the least observed with rainfall. It is well known that relative humidity has been proved to have an influence on occurrence and transmission of some viruses, [14] therefore effects of relative humidity cannot be neglected.

Results of cross correlations between measles occurrence and weather variables are presented in Figure 2. By fitting each of the weather input series, at lags of 1 month to 12 months, respectively, in the ARIMA model of monthly measles incidence, a total of five input series were found to be significantly associated with measles. Two input series, maximum temperature and minimum temperature have almost the same trend of association but stronger with maximum temperature in the station. Rainfall and relative humidity have a negative correlation at lag 1 month.

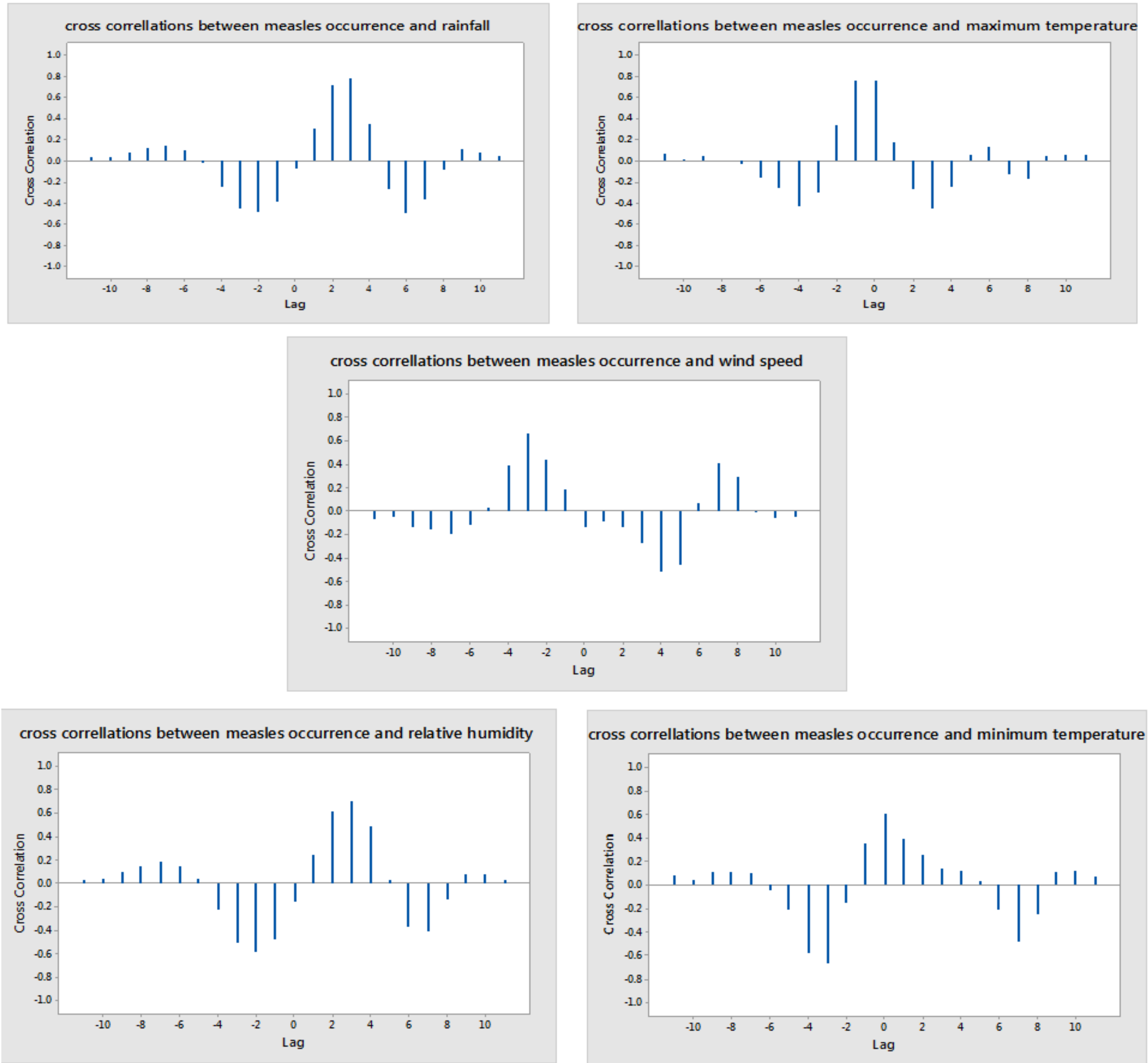


Figure 2. Cross correlations of measles incidence and meteorological parameters

Table 2. Correlations coefficients between measles and weather variables

	RR	Tmax	Tmin	RH	WS
Measles	-0.069	0.758	0.598	-0.160	-0.133
p-value	0.831	0.004	0.040	0.620	0.680

3.3. Variations of Measles Occurrence and Weather Variables

The average monthly pattern of measles incidence in Kano is shown in Figure 3 while Figure 4 shows the combinations of weather parameters which reveals the optimum condition for the prevalence of the disease. There are two main seasons but for the purpose of this work we will categorize it into three seasons: a rainy season (June–October), a dry-cool season (November– January), and a dry-hot season (February–May). Seasonal variations are apparent in measles incidence and the weather variables. Rainfall and relative humidity have their highest values in the rainy season and lowest in the dry cool season. Other weather variables have their lowest values during the rainy season and highest in the hot dry season. Measles incidence is observed to have a double peak, the first peak occurred in May, a dry hot season and second is observed in November, a dry-cool season. The first peak is over 75% more than the second peak

From Figure 4 a and Figure 4b, it is observed that maximum occurrence of measles seen at a high maximum temperature and low relative humidity, same is also observed with rainfall.

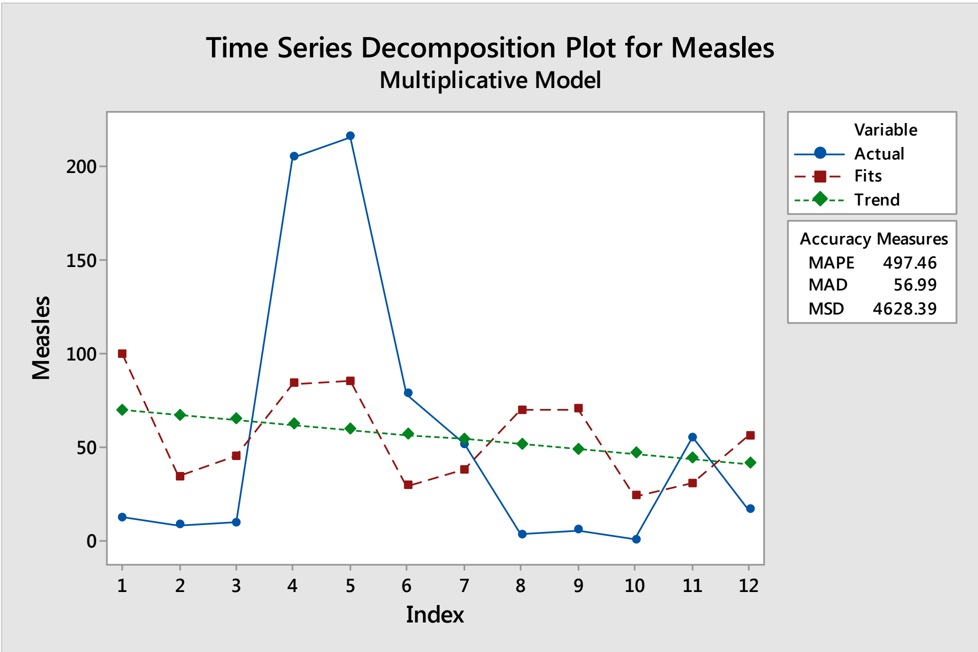
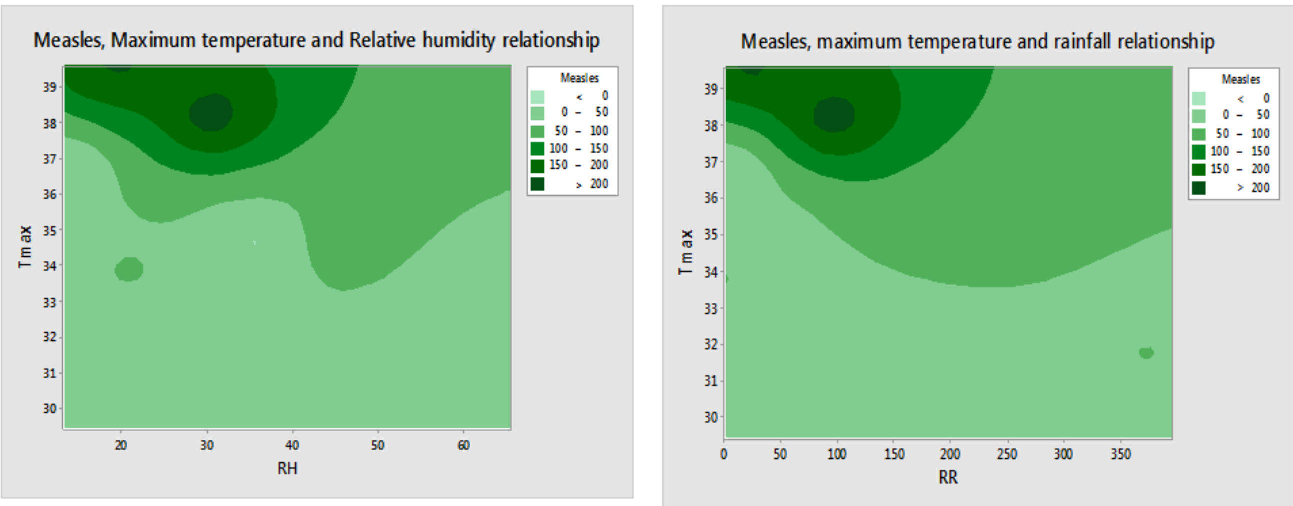


Figure 3. Average monthly pattern of measles incidence in Kano



a b

Figure 4. Weather-disease relationship (a) Tmax, RH, (b) Tmax, RR

Table 3. Comparison of various selected Poison models using their model summary for Kano

S/NO	Parameter Combinations	R-Sq	R-Sq(adj)	AIC
1	Tmin	55.37%	55.27%	506.05
2	Tmax	64.65%	64.55%	413.20
3	RR	0.58%	0.48%	1054.05
4	RH	3.18%	3.08%	1028.12
5	WS	2.07%	1.97%	1039.16
6	Tmin and Tmax	70.85%	70.55%	355.20
7	Tmin and RR	63.86%	63.66%	423.13
8	Tmin and RH	69.54%	69.34%	366.33
9	Tmin and WS	66.62%	66.42%	395.51
10	Tmax and RR	72.82%	72.62%	333.53
11	Tmax and RH	69.66%	69.46%	365.11
12	Tmax and WS	65.80%	65.60%	403.67
13	RR and RH	10.88%	10.68%	953.08
14	RR and WS	5.30%	5.10%	1008.89
15	RH and WS	22.41%	22.21%	837.76
16	Tmax, Tmin and RR	73.58%	73.28%	327.90
17	Tmax, Tmin and RH	69.71%	69.51%	364.59
18	Tmax, Tmin and WS	70.85%	70.55%	355.20
19	Tmin, RR and RH	72.50%	72.20%	338.65
20	Tmin, RR and WS	69.12%	68.82%	372.51
21	RR, RH and WS	67.92%	67.62%	384.50
22	Tmax, Tmin, RR, RH and WS	73.82%	73.42%	327.47

3.4. Poison Model Identification

We fitted a model for each combination of all the variables, of all the models tested, the poison combination model for measles incidence that fits best is serial no 22 in Table 3 according to normalized Akaike information criterion (AIC) and goodness-of-fit criteria. Serial nos 6, 10, 16, 18 and 19 are also good. AIC is a general measure of the overall fit of a model that attempts to account for model complexity. It is a score based upon the mean square error and includes a penalty for the number of parameters in the model and the length of the series. The penalty removes the advantage of models with more parameters, making the statistics easy to compare across different models for the same series.

3.5. Autoregressive Moving Average Result

Of all the models tested, the ARIMA (0, 0, 1) model for measles incidence fits the data best according to normalized Bayesian information criterion (BIC) and goodness-of-fit criteria as presented in Table 4. BIC is a general measure of the overall fit of a model that attempts to account for model complexity. It is a score based upon the mean square error and includes a penalty for the number of parameters in the model and the length of the series. The penalty removes the advantage of models with more parameters, making the statistics easy to compare across different models for the same series.

Table 4. Comparison of various selected ARIMA models using their model fit parameters for Kano

Serial no	Model ARIMA(p,d,q)	Stationary R-squared	R-squared	RMSE	MAPE	Normalized BIC
1	0,0,0	.664	-.656	133.841	278.091	11.036
1	0,0,1	.820	.245	98.979	162.656	**10.639**
2	0,1,1	.758	-34.386	745.883	542.140	14.755
2	1,1,1	.800	-35.367	873.123	981.933	15.288
4	1,0,0	.759	.142	105.544	202.073	10.768
5	1,1,0	.713	-28.054	675.858	1225.632	14.558
6	1,0,1	.826	-.336	147.238	203.423	11.641

Figure 5a shows the best models while Figure 5b shows the worst as presented in Table 4.

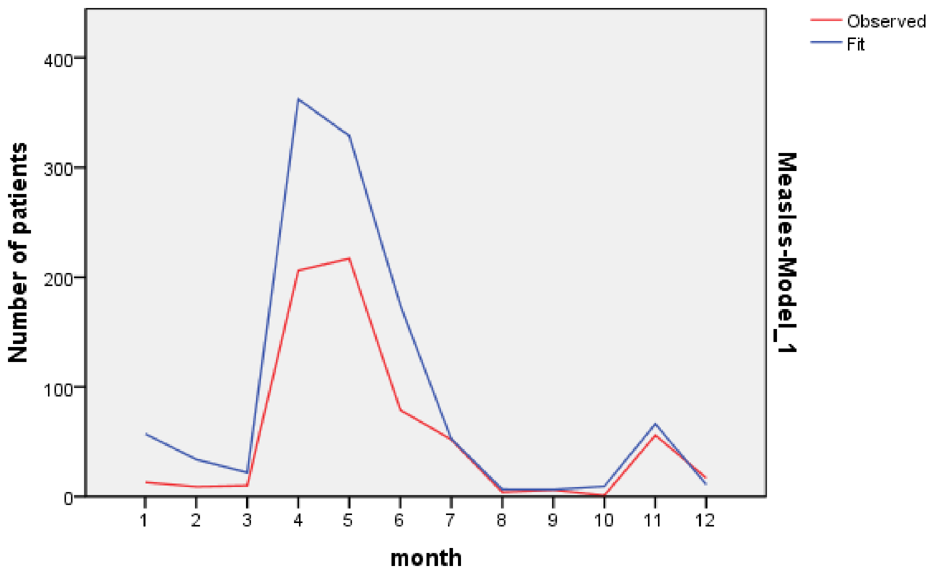


Figure 5a. Monthly results of the best-fit model

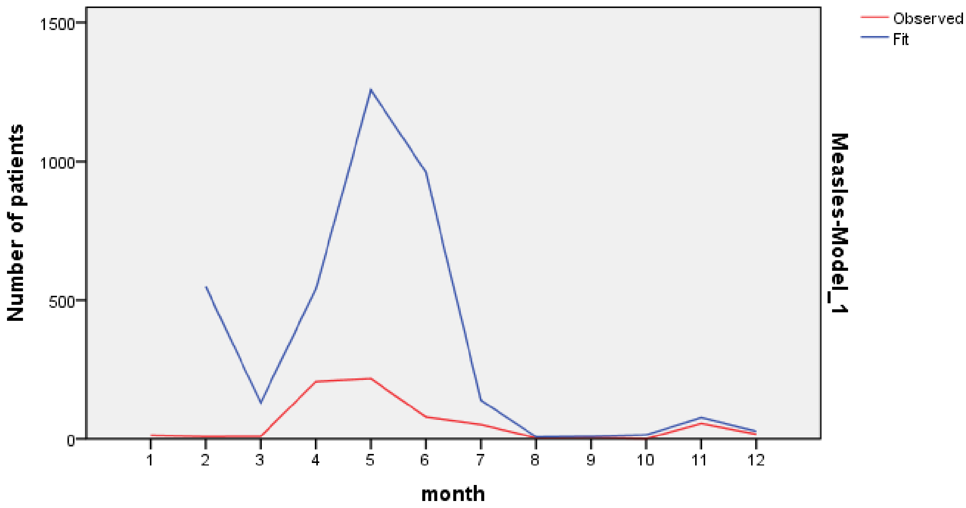


Figure 5b. Monthly results of the worst-fit model

3.6. Discussion

From this study there is a clear seasonality in the time series of measles incidence in this station of Nigeria. Besides the major incidence peak in the dry hot season, there is also a minor peak in the dry-cool season. This does not agree with the study of (14) carried out in Guangzhou, Southern China in which both hot and cold temperatures resulted in decreases in the incidence of measles, and the most dangerous range of mean temperature was approximately 18 to 20°C. In this study the most dangerous range of temperature for measles incidence is between 38°C and 40°C while that of relative humidity are between 19% and 30%. The decrease observed in both hot and cold condition in Southern China may be due to many national plans and measures which are implemented to meet the World Health Organization's (WHO) goals for measles elimination, as a result of many measles outbreak that occurred over the past few years. Relative humidity and rainfall have an inversely associated relationship with incidence of measles which agrees with [14]. Cross correlations are correlations between two time series shifted in time relative to one another; this reveals the association between measles incidence and weather parameters at different time lags. The method is an important step in our understanding of how to plan proactively for measles incidence at any time. Successful modelling using an ARIMA model in this study was the basis for the conclusion of the effects of climate variability on measles. Maximum temperature generally enhances the prevalence of this disease. This study has shown that maximum temperature is a principal factor for measles occurrence. Even though some variations were observed in the relationship between measles incidence and other weather variables, it was still possible to show that these variables have a linear response effect on fluctuations in measles incidence. It was observed that the effects of weather conditions on the measles incidence were linear, except for wind speed. In this study, the risk of the measles incidence increased with increased maximum temperature (between 37-40°C). Relative humidity was inversely associated with the incidence of measles. There are biological evidences to support the two findings. The virulence and survival of measles virus in air are mainly influenced by temperature and relative humidity. Measles virus is temperature sensitive [19]. High temperature has influence on the survival of measles virus. Studies also show that measles virus survival is remarkably dependent on relative humidity, and virus survives well at low relative humidity [19]. Therefore, with an increase in relative humidity, the incidence of measles decreases which agrees with our study. In this study, the relationship between the average monthly wind speed and measles incidence is not exactly consistent. The reason may be that, measles virus is not strongly resistant to the external environment, and will be inactive half an hour in the sun [22] which suggests that wind speed might be inversely associated with measles incidence. However, it is well known that measles is a common childhood infections. Most children usually stay indoors. They spend more time indoor than outdoor in the daytime. Therefore, wind speed might not have much influence on the incidence of measles and the little effects observed might be as a result of the interactions of other meteorological factors and wind speed. The study has two short comings. First, the measles data is available on a monthly basis only instead of daily which could reveal a shorter time relationship and variation. Second, other factors, such as land cover changes and public health intervention measures, may have influenced measles incidence and may have been associated with the weather factors examined in this study. Because of the lack of such historical data, these factors were not adjusted for in the regression modelling. Finally decision makers in Nigeria especially in the cities must consider measures to protect the vulnerable populations from weather transformations.

4. Conclusion

This study shows that models of a climate–measles link varied from weather condition to another. One model could not fit all weather conditions. Maximum and minimum temperatures, rainfall, relative humidity and wind speed are predictors for measles incidence in the savanna areas of Nigeria. The effect of wind speed on measles incidence is not well pronounced in the station. Measles incidence is more prevalent in the hot dry season and dry cool season.

From the final poison model, we found that the combination of all the weather variables used constitute the best model developed while ARIMA model (0,0,1) is the most suitable for predicting measles occurrence. ARIMA models therefore provide useful tools for predictions that aid proactive anti-measles planning.

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