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INFLUENCE OF RAINFALL AND TEMPERATURE ON THE INCIDENCE OF MALARIA IN GOMBE AND ENVIRONS

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Abstract

The paper examines the influence of rainfall and temperature on malaria incidence in Gombe and environs for the period of five years (2014-2018). This was achieved by analysing the relationship between rainfall and temperature, pattern of occurrence and seasonality of malaria in the study area. Records of rainfall and temperature were obtained from the National Headquarters of the Nigerian Meteorological Agency while the surveillance records of confirmed malaria cases were obtained from the Gombe State Primary Healthcare Development Agency. Time series analysis was used to examine and assess the trend of rainfall, maximum and minimum temperature and malaria. It was found out that rainfall and rates of malaria cases were on the increase while maximum and minimum temperatures were insignificantly decreasing within the said time. Similarly, correlation between the variables indicated that rainfall has positive relationship with malaria with r value of 0.955 while maximum and minimum temperature indicated negative relationship with r values of (– 0.913 and – 0.238) respectively. The seasonal analysis showed that malaria was more prevalent during late rainy season (August and September) and two months following the rainy season (October and November). October, which was the immediate month after rainy season (September), recorded the highest malaria cases within the timeframe of this study with a mean of 3527.2 cases, while January recorded the lowest cases with mean of 1301.2 cases.
Keywords: Influence, Rainfall, Temperature, Malaria, Gombe.

1. Introduction

According to the National Research Council (NRC, 2001) health and climate have been linked since antiquity. Historically, environmental health concerns have focused on toxicological or microbiological risks to health from local exposures (McMichael et al., 2003). Indeed, the very terms we use today for infectious diseases often preserve ancient notions of disease being caused by environmental change and other external factors. For example, "malaria," is a compound word, that is "mal" and "aria" (bad air); or simply "a cold," the quaintly preserved term for an upper respiratory tract infection (NRC, 2001).

The link between malaria and extreme climatic events has long been a subject of study in the Indian subcontinent. In the early twentieth century, the Punjab region experienced periodic epidemics of malaria which excessive monsoon rainfall and resultant high humidity were clearly identified as major factors in the occurrence of epidemics through enhancement of both the breeding and life span of mosquitoes (Christopher, 1911 in McMichael et al., 2003). The Greek physician Hippocrates (about 400 BC) related epidemics to seasonal weather changes, writing that physicians should have "due regard to the seasons of the year, and the diseases which they produce, and to the states of the wind peculiar to each country and the qualities of its waters" (McMichael et al., 2003). Two thousand years later, Robert Plot, Secretary to the newly-founded Royal Society in England, took weather observations in 1683–84 and noted that if the same observations were made "in many foreign and remote parts at the same time" we would "probably in time thereby learn to be forewarned certainly of divers emergencies (such as heats, colds, deaths, plagues, and other epidemical distempers)" (McMichael et al., 2003).

Climatic conditions affect human well-being both directly, through the physical effects of climatic extremes, and indirectly, through influences on the levels of pollution in the air, on the agricultural, marine and freshwater systems that provide food and water, and on the vectors and pathogens that cause infectious diseases (McMichael et al. 2003).

Climatic factors influence the dynamics of infectious diseases, from season to season and from year to year (Levy and Patz 2015). Weather and climate affect different diseases in different ways. For example, mosquito-borne diseases such as dengue, malaria, and yellow fever are associated with warm weather; influenza becomes epidemic primarily during cool weather; meningitis due to dry environments; and cryptosporidiosis outbreaks which are mostly associated with heavy rainfall National Research Council [NRC] 2001).

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Recent studies of disease variations associated with inter-annual climate variability (such as those related to the El Niño cycle) have provided much useful evidence of the sensitivity to climate of many disease processes. This is particularly so for mosquito-borne diseases (McMichael et al. 2003). Relations between weather and human health have been evident for centuries. Yet these associations are neglected in modern medical practice (Bart and Bourque 1995).

Oluleye and Akinbobola (2010) opined that "weather extremes may have profound effects on patients as to exacerbate its severity, increase hospitalization and cause accelerated death. Weather may have influence in the pneumonia infection not only because of the shaking chill symptom but in creating a favourable atmosphere for the bacteria and virus that cause the infection to thrive. Thus weather may cause an increase in the rate of infection of the disease." Rainfall is one of the major factors influencing malaria transmission in Africa, and its forecasting is central in most of malaria planning and decision processes (Thomson, 2010).

Today, evidence that the earth's climate is changing is leading researchers to revisit the long standing relationship between climate and disease from a global perspective (Intergovernmental panel on climate change [IPCC] 2007b). Increased atmospheric and surface temperatures are already contributing to the world wide burden of disease and premature deaths, and are anticipated to influence the transmission dynamics and geographic distribution of malaria, dengue fever, tick-borne diseases and diarrhoea diseases such as cholera (IPCC, 2007a). Global warming is also accelerating the world wide hydrological cycle, increasing the intensity, frequency and duration of droughts; heavy precipitation events and flooding in some areas (IPCC, 2007a). These weather events may in turn contribute to and increase the risk for a wide range of vector and non-vector-borne diseases in humans and animals (IPCC, 2007b).Diseases such as malaria and pneumonia are leading causes of death in Nigeria in recent times. Malaria pandemic alone has caught the attention of both the local authorities and international agencies (Oluleye and Akinbobola 2010).

In 2017, Nigeria accounted for 25% of all malaria cases worldwide and compared with 2016 Nigeria recorded an increase of greater than half a million cases (World Malaria Report, 2018). Of the 53% of all global malaria deaths in 2017, Nigeria accounted for 19% which was the highest (World Malaria Report 2018).

Transmission of malaria depends on climatic conditions that may affect the number and survival of mosquitoes, such as rainfall patterns, temperature and humidity (World Health Organisation [WHO] 2019). It is clear that malaria is a serious health problem in Nigeria and it is weather sensitive. Several studies in distinct places across the globe have established links between malaria incidences and some of the weather elements.Weather variables (maximum temperature, minimum temperature, rainfall and relative humidity) are positively correlated with cholera in northern Nigeria but maximum temperature and rainfall appear to be most important predictors (Leckebush and Abdussalam 2015; Abdussalam, 2016). Abdussalam et al., (2014a) examined climate influence on Meningitis in Northwest Nigeria and reveals that the most important climatic variables that influence Meningitis are maximum temperature, relative humidity, sunshine and dustiness. A study by Bako (2012) reveals that rainfall, relative humidity and temperature have a collective influence on malaria, typhoid, diarrhoea and meningitis in Kafanchan, Kaduna.

2. The Study Area

Gombe metropolis comprises part of Gombe local government area and Akko local government areas, this is the heart of the State as the State capital is Gombe local government area Gombe metropolis is located on latitudes 10^0 08' -11^0 24' N and longitudes 11^0 01' - 11^0 19' E, with a total area of about 175 km^2 (*Gombe State Government, ministry of land and survey***.** Pp7-25). It shares common boundary with Akko LGA in the South and

West; Yamaltu-Deba to the East and Kwami to the North. Gombe town is well linked by road to other regional centres like Biu / Maiduguri, Potiskum / Damaturu, Bauchi /Jos and Yola /Jalingo. A single gauge railway line on the Bauchi – Maiduguri route also links the town, in addition to an International Airport (see Figure 1). Gombe is the capital of Gombe State and is divided into eleven (11) wards, which are Ajiya, Bajoga, Bolari East, Bolari West, Dawaki, Herwagana, Kumbiya-Kumbiya, Pantami, Jekadafari, Nasarawo, and Shamaki. Gombe metropolis here refers to the entire Gombe local government area and other sub urban areas that are in other local government areas but are parts of the Gombe metropolis and the State capital. These include Jauro Abare, Jauro Kuna, Arawa, Kagarawal, Kundulum, Malan Inna, Barunde, Bye-pass, etc. See Figure 1.The approximate altitudes of Gombe ranges from 400-500m above mean sea level. The topography is mainly mountainous, undulating and hilly in the central and southern parts and open plains in the northern and northeastern parts of the State (Umar, Ibrahim and Ahmed, 2017).

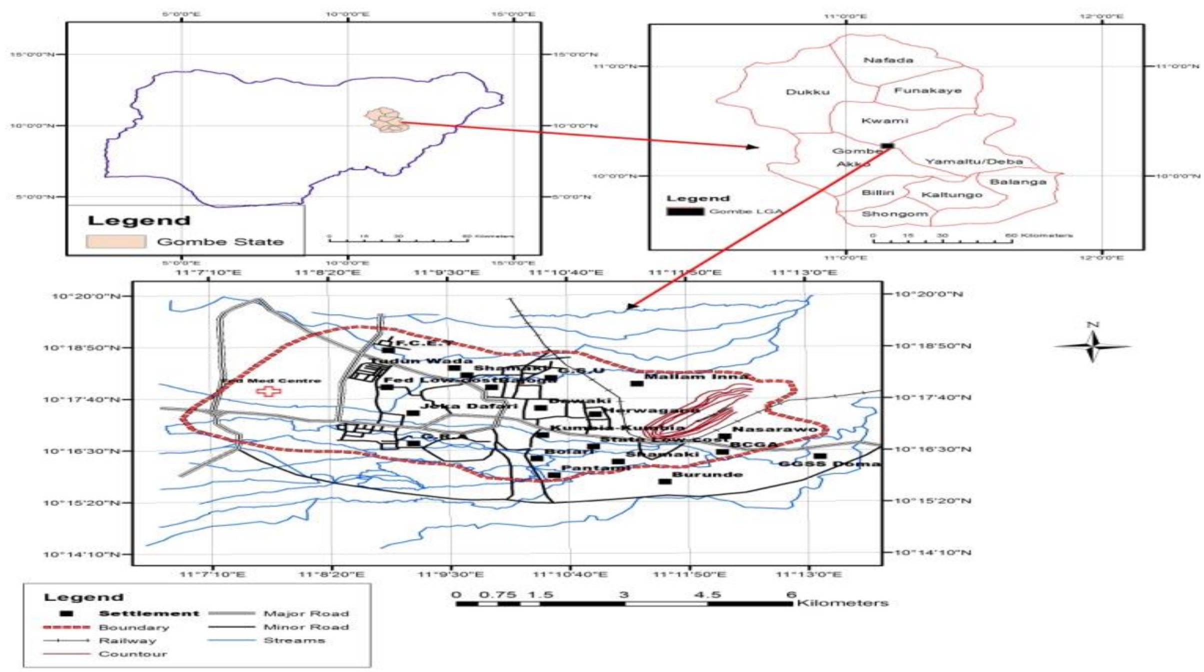

Figure 1: Map Gombe State Showing the Study Area
Source: GIS Lab. Dept. of Geography, GSU.

2.1 Weather and Climate

Nigeria often comes under the influence of two different air masses, namely north easterlies and south easterlies. These two air masses determine the weather conditions of Nigeria, which gives rise to distinct seasons of the year. The north easterlies air masses that bring about harmattan-dust and dryness start usually by November to midst February (Umar, 2012). While the south easterlies air originated from the ocean which makes them moist warm and heavy (due to their source

region). These air masses are associated with rainfall in the country. The two air masses meet at a point called inter-tropical discontinuity (ITD). It is the movement of ITD that causes variations in the weather conditions of the country.
Gombe State, being located geographically within the sub-Sudan climatic zone, experiences the influence of these air masses from October to March and the influence of the southwestern air masses from April to September. It receives an average precipitation between 850-1,020mm in 7 months per year. There are monthly and daily rainfall variations all over the State. Thus annual rainfall could be as low as 850mm as recorded in 1970 and 1989 or as high as 1200mm as in 1953. The rainfall is concentrated between April/May to October with a single maximum in August or September (NIMET, 2018). The dry season covers November to early March and April, which are usually the hottest months. This means that rains begin and end between first week of May and fourth week of October respectively. The mean maximum monthly temperature of 37ºC was recorded in April and March, while the minimum monthly temperature was about 21ºC around December and early February which is considered as tropical wet and dry type coded Aw according to Koppen's classification system. The mean temperatures of 30.6 ºC and 38.4 ºC were recorded in 2019 (NIMET, 2019).

3. Materials and Methods

Two sets of data obtained from secondary sources were used in this research; these are meteorological data (rainfall and temperature) and surveillance record of confirmed malaria cases.The meteorological data was obtained from the National Headquarters of the Nigerian Meteorological Agency (NIMET) and the surveillance records of confirmed malaria cases were obtained from Gombe State Primary Healthcare Development Agency. Pearson Product Moment Correlation Co-efficient was used to measure the degree of relationship that exists between the variables of interest (rainfall and temperature/ malaria). Data was analysed using IBM SPSS statistical software. The pattern of occurrences and seasonality of malaria in the study area was achieved by getting the monthly mean of the disease for the corresponding and overall years, which were presented, in a bar graph. To account for the nature of seasonal variation of malaria in the study area, two seasons per annum were considered; rainy season (April-September) and dry season (October-March).

4. Results and Discussion

Malaria cases were relatively low in August and September in study area as revealed by Table 1, this could be due to heavy down pours where most of the mosquito lavas were washed away by rains, thereby reducing the population of the potential reproductive mosquitoes within the two months of peak rainfall. From Figure 2 it can be observed that malaria cases were on increase throughout the years in the study area but with fluctuating characteristics. The trend as indicated by the trend line and linear trend line equation
$y = 2.0883x – 86691$ is that the occurrence of malaria within a time frame of this study was on the increase.

4.1 Trend in the Occurrence of Malaria (2014-2018)

Table 1: Monthly malaria data for Gombe

	2014	2015	2016	2017	2018
Jan	547	282	1656	2151	1870
Feb	1607	1131	1845	1771	3188
Mar	1144	1184	2224	1732	2064
Apr	925	651	2183	1193	1596
May	1017	1522	1481	1743	1371
Jun	1228	1308	1644	1776	1678
Jul	981	1355	2149	2171	3423
Aug	218	1222	1533	3689	7674
Sep	251	1915	2341	2605	6775
Oct	1862	2603	2724	3050	7397
Nov	862	2552	3141	3346	7257
Dec	169	1567	2131	717	5078

Source: Gombe State Primary Healthcare Development Agency (2019).

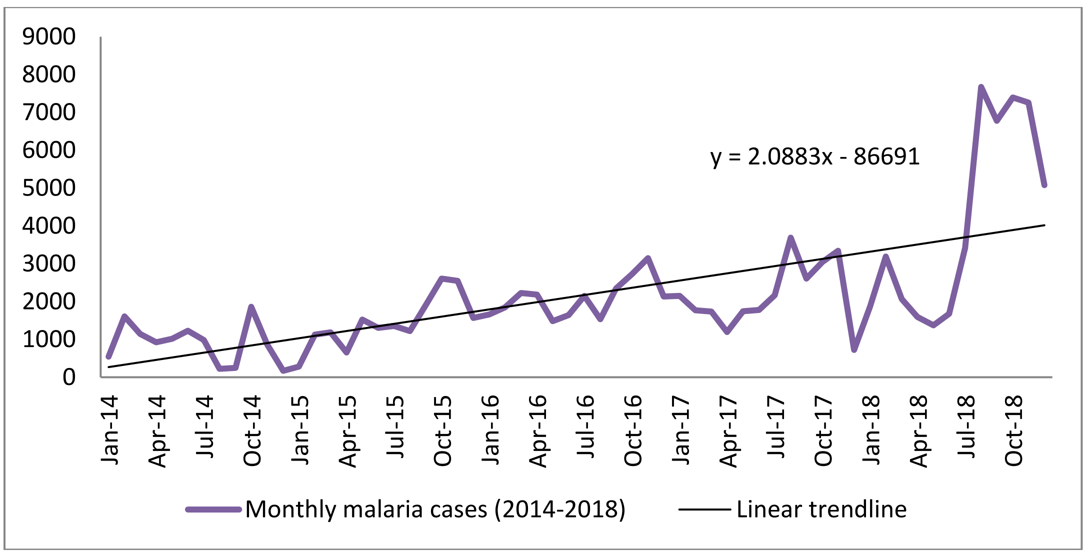

Figure 2: Monthly malaria trend in Gombe (2014-2018)
Source: Fieldwork, 2019.

From Table 2 it could be observed that mean annual incidence of malaria keeps on increasing year in year out. For example 900.92 (2014); 1441 (2015); 2087.67 (2016); 2162 (2017) and 4114 (2018). It however, ranges between 540.8 and 646.7 cases in 2014 and 2017. The value was more than double (1,952) cases in 2018.

Table 2: Mean annual malaria

	2014	2015	2016	2017	2018
Malaria	900.92	1441	2087.67	2162	4114

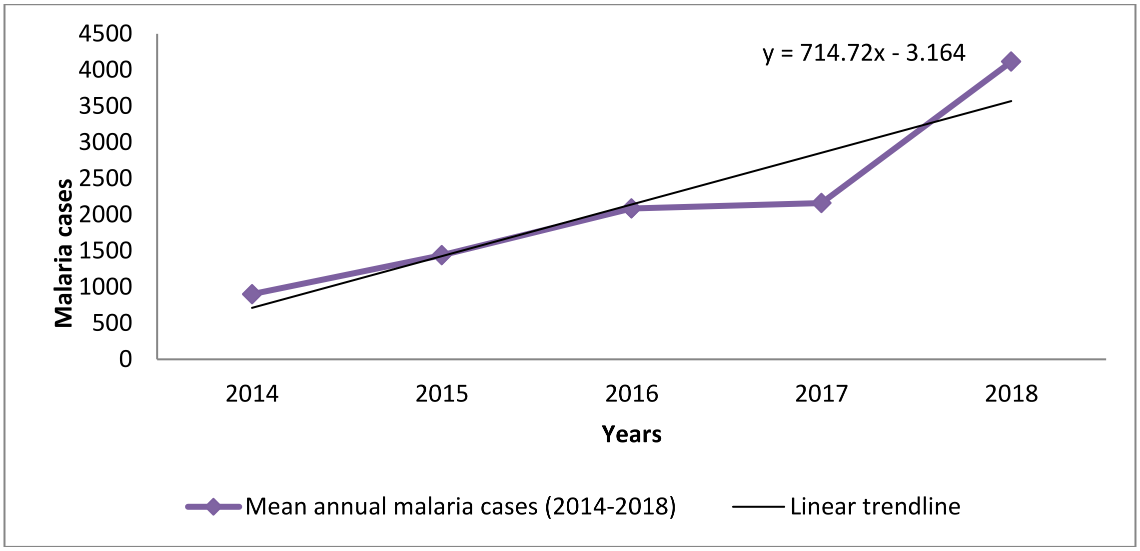

Figure 2: Mean annual malaria trend in Gombe (2014-2018)
Source: Fieldwork, 2019

Figure 2 shows that malaria was generally high in the study area; the trend line indicated a significant increase in the disease occurrence within the stipulated period of this study. The lowest malaria cases were recorded in 2014 (900.92) and the highest were recorded in the year 2018 (4114.25).The increase in the malaria incidence may be due to a significant increase in rainfall amount in the study area during the study period since malaria is associated with stagnant water, which usually occurred when there is high rainfall coupled with other factors like poor water drainage systems, dirty environment, among other things.

4.2 Relationship between Rainfall and the Occurrence of Malaria

From Table 3 the correlation between rainfall and malaria was 0.955, which was significant at 0.05 level of significance. This means that there was a strong positive relationship between rainfall and the occurrence of malaria in the study area. An increase in rainfall could lead to an increase in the occurrence of malaria, which implies that malaria was highly dependent on the amount of rainfall received in the study area.

Table 3: Correlation between Rainfall and Malaria

Correlations		Malaria	Rainfall
Malaria	Pearson Correlation	1	955*
	Sig. (2-tailed)		011
	N	5	5
Rainfall	Pearson Correlation	955*	1
	Sig. (2-tailed)	011	
	N	5	5

*. Correlation is significant at the 0.05 level (2-tailed).

4.3 Relationship between Maximum Temperature and the Occurrence of alaria

Table 4 presents the relationship between maximum temperature and malaria occurrence in the study area. The correlation coefficient (r) between maximum temperature and the occurrence of malaria was – 0.913, which was significant at 0.05 level of significance. This implies that there was strong negative relationship between maximum temperature and occurrence of malaria in the study area. Hence, a change in maximum temperature negatively influences the malaria occurrence during the study period.

Table 4: Correlation between maximum temperature and malaria

Correlations		Malaria	Maximum temperature	
Malaria	Pearson Correlation	1	-.913*	
	Sig. (2-tailed)		.030	
	N	5	5	
Maximum temperature	Pearson Correlation	-.913*	1	
	Sig. (2-tailed)	.030		
	N	5	5	

*. Correlation is significant at the 0.05 level (2-tailed).

4.4 Relationship between Minimum Temperature and the Occurrence of Malaria

Table 5 shows the relationship between minimum temperature and the occurrence of malaria in the study area. The Pearson Product Moment Correlation Co-efficient (r) between minimum temperature and the occurrence of malaria was – 0.238 indicating a weak negative relationship. This implies that a change in minimum temperature weakly and negatively influences changes in the occurrence of malaria

Table 5: Correlation between minimum temperature and malaria

Correlations		Malaria	Minimum temperature	
Malaria	Pearson Correlation	1	-.238	
	Sig. (2-tailed)		.700	
	N	5	5	
Minimum temperature	Pearson Correlation	-.238	1	
	Sig. (2-tailed)	.700		
	N	5	5	

4.5 Seasonality of Malaria in the Study Area

From Figure 3 and Table 6, it can be observed that malaria were recorded throughout the year, the frequency of the disease was higher during early dry and late dry season, this is not in line with the preceding years which have their peaks during rainy season and usually two months preceding the rainy season (October and November). The lowest malaria cases in 2014 were recorded in the late rainy season (August and September) due to heavy downpours, which affects mosquito larvae. The values were also lower in the drier month of December due to low temperature.

Table 6: Mean monthly malaria (2014)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
17.64	57.39	36.90	30.83	32.81	40.93	31.65	7.03	8.36	60.6	28.73	5.45

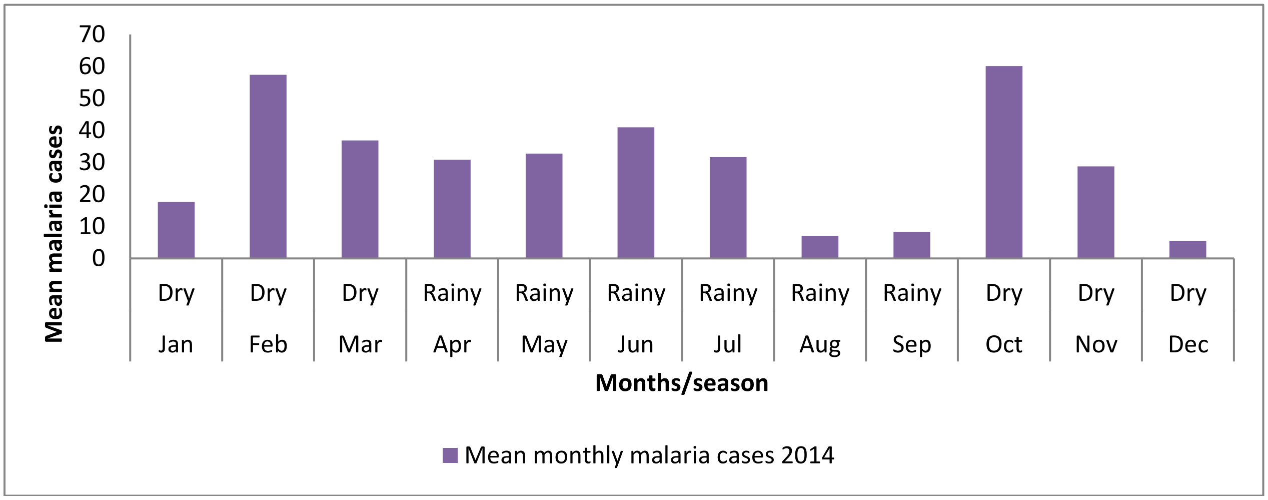

Figure 4: Seasonality of malaria (2014)

The study reveals that rainfall and temperature were all fluctuating during the study period and that temperature was not fluctuating as much as rainfall. Both the monthly and mean annual trend of rainfall showed an increment trend while that of maximum and minimum temperatures showed an insignificant decrease with r value of 0.955, while with maximum and minimum temperature indicated negative relationship with r values of (– 0.913 and – 0.238) respectively. The increase in rainfall amount observed in the study area was in agreement with the work of Umar, et al. (2017) which found out that there was a general increase in rainfall amount in the study area from 1975-2014. They also asserted that the increase in annual rainfall yield could be the predominant factor resulting into the substantial increased of rainfall in September. This factor coupled with inadequate drainages and residential encroachments to waterways were responsible for the recent flooding events in Gombe metropolis.

The negative relationship between maximum temperature, minimum temperature and malaria does not mean that there is no any relationship between them; rather it implies that there was no linear relationship between them in the study area.

The study further indicated that the malaria occurrence in the study area within the time frame of this study was fluctuating, this might be as a result of fluctuations of weather elements especially rainfall. Like rainfall, malaria occurrence in the study area also indicated a significant increase. From Tables 3, 4 and 5 only rainfall data showed a positive relationship with the occurrence of malaria where by both maximum and minimum temperatures showed negative relationship with the disease. These finding is in agreement with that of Abaje, Abdullahi and Jeje (2016) which found out that rainfall was the major determinant factor for the prevalence of malaria in Funtua Local Government Area of Katsina State. Similarly, Himeidan, Hamid, Thalib, Elbashir and Adam (2007) also found rainfall to be significant climatic variable in malaria transmission in New Halfa, Eastern Sudan where temperature was not found significant. However, the study is also in total contrast with that of Klutse, Aboagye-Antwi, Owusu and Ntiamoa-Baidu (2014) which suggests maximum temperature as better predictor of malaria than minimum temperature or precipitation at Ejura and Winebba ecological zones in Ghana. Other studies that found both rainfall and temperature as significant factors in malaria transmission include: Efe and Ojoh (2012), Oluleye and Akinbobola (2010) and Weli and Efe (2015).

Figures 4 shows that malaria was more prevalent in the study are during late rainy season (August and September) and rainy-dry transition months particularly October and November. The malaria cases peaked within the rainy season or the two months following it with the exception of 2014 which had its peak in early dry season, specifically February.

5. Conclusion

The work was achieved through analysing the trends of weather elements (rainfall and temperature) and malaria, the relationship between the weather elements and malaria as well as the seasonality in the occurrence of malaria. Time series analysis was used to examine and assess the trend in the occurrence of weather elements of interest and malaria respectively. From the results obtained, rainfall showed a significant increasing trend while maximum and minimum temperature showed a slight decreasing trend. Pearson Product Correlation Coefficient was used to test the relationship between the variables of interests and the results obtained showed that rainfall has a positive relationship with malaria with an (r) value of 0.955 where by maximum and minimum temperature showed no significant relationship with malaria with (r) values of – 0.913 and – 0.238 respectively. The seasonal analysis revealed that malaria is more prevalent in the late rainy season (August and September) and the rainy-dry transition months (October and November). It also showed that malaria cases tend to drop in the beginning of rainy season and usually attained its peak in either of the two months that followed the rainy season (October and November). During the study period, the month of October which was the first month that followed the last rainy month (September) in the study area recorded the highest cases of malaria with a mean of 3527.2 cases while January recorded the lowest cases with mean of 1301.2 cases. The research further investigated the influence of weather on malaria occurrence in Gombe and environs and it revealed that malaria prevailed throughout the years in the study area with an increasing trend and fluctuating characteristics within the period of this study. Rainfall also showed an increasing trend which consequently led to the corresponding increase in the prevalence of malaria in the study area. Thus, an increase in rainfall enhances mosquito development and improved breeding sites leading to incidence of malaria. On this premise, the study concluded that rainfall was the major climatic variable that influences malaria occurrence in the study area.

6. Recommendations

Based on the research findings, the following recommendations were made:

i. Regular clearing of drains and surrounding environment should be intensified by the populace, especially during rainy season.
ii. Residents should embrace the various health programmes of reducing mosquitoes as specified in the local, state and federal government health policies.
iii. Gombe State Governments should come up with programmes that involve developing innovative approaches to analyse weather and climate in the context of human health in order to design a seasonal pro-active mitigation which would be based on vector control.
iv. Government should ensure regular administration of seasonal malaria chemoprevention (SMC) for children less than five years of age across the study area.
v. Antimalarial treatment and prevention courses (such as using nets) should be improved and encouraged to the people especially the most vulnerable ones (pregnant women, infants and children) in order to reduce the impact of the malaria.

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