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Dependence of Malaria Disease on Changes in Rainfall and Temperature in Ado Local Government Area of Ekiti State, Nigeria

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Abstract

The issue of malaria disease is a major problem globally and especially in Africa where the favourable environmental condition has led to high infections and the death of millions of people. Thus, this study investigates the impacts of changes in rainfall and temperature patterns on the variations in malaria disease among the youth, adult male and adult female in Ado local government area of Ekiti State, Nigeria. A total population of 207,033 infected people were recorded over 2002-2011 period where 101,943 are youths, 51,199 are adult male while the numbers of adult female are 53,891. The results show good positive correlation between the malaria spread and the intensity of rainfall; thus indicating that increasing rainfall level will raise the numbers of anopheles mosquitoes through availability of more breeding places for the malaria vectors. Also, the disease will spread more under a moderately high temperature while there are fewer infections if temperature is extremely high or too low. The prevalence of the disease could cause huge economic loss and poor standard of education due to low turn-out at schools and at work. Hence, there is need to protect the population, especially the poor, vulnerable youths and pregnant women through improved personal hygiene, provision of treated mosquito nets, insecticides and good medical services at affordable prices.

Keywords: Malaria disease; Mosquito; Rainfall; Temperature; Ado-Ekiti

1. Introduction

The spread and impacts of diseases across the world are matters of global concern, especially in Africa where malaria is a major threat. According to Lucas and Giles (2003), about 300-500 million annual clinical cases are associated with malaria globally; however, almost 80% are reported to be from Africa where the environment favours the spread of the disease. Also, over one million children died annually from the malaria in mostly rural areas of Africa (Nmadu et al., 2015; Fawole and Onadeko, 2001) and about 300,000 of the deaths occurred in Nigeria alone (Oyewole and Ibidapo, 2007) where the disease is widespread. In agreement with these observations, it has been established that children within five years and pregnant women are the most vulnerable groups (Nmadu et al., 2015). Malaria is a vector borne disease which is transmitted by anopheles mosquito that breeds in stagnant water. It starts with a bite from infected female anopheles mosquitos that suck plasmodium from a sufferer's blood and pour it into the circulatory system of the new host (Nmadu et al., 2015) where it enters the liver to mature and reproduce. This is followed by the symptoms of malaria that typically begin 8–25

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days following infection (Fairhurst and Wellems, 2010); but the appearance of the symptoms is delayed if anti-malarial medications had been taking (Nadjm *et al*., 2012). The symptoms of malaria include frequent fevers, joint pain, back pain, headache, cold, sweating, dry cough, spleen enlargement, vomiting, diarrhoea and death when not properly treated with malaria drugs (Fairhurst and Wellems, 2010).

The epidemiology of malaria depends on factors like temperature, rainfall, relative humidity (RH) and wind direction (Lucas and Giles, 2003). For example, the disease is prevalence in the tropical and subtropical regions where rainfall, humidity and temperatures are consistently high, along with presence of stagnant waters in which mosquito larvae could develop (Jamieson *et al*., 2006). The vector of the disease and the plasmodium parasites will spread well within 20^{o}C to 30^{o}C temperature range (Patz *et al.*, 1998) while the interval between the mosquito's blood meals and the incubation period of the parasite in the mosquito will also be shortened. Hence, high cases of malaria in Rwanda have been linked to moderately high temperature (Loevisnsohn, 1994) and to enhanced warming and precipitation in Venezuela (Bouma *et al.*, 1997). However, there is evidence that malaria is more sensitive to increase in the minimum temperature than in the maximum (Paul, 2001**.** This can be due to the relatively small temperature range in which a mosquito may live. It should be noted that warming trends during slightly cold periods may make the transmission of malaria less seasonal, which would increase overall incidence (Gubler *et al*., 2001). Also, the transmission rate of the disease is reduced as the life span of mosquito gets shortened if the average monthly RH is below 55% and above 80% (Dhiman *et al*., 2004).

The rainfall that starts around April in the study area creates conducive environment for the accumulation of stagnant water, the growth of green cover and presence of optimum humidity which favours the breeding of mosquito (Sumana, 2006). In the last three decades, the observed warming-induced intensification of naturally occurring fluctuations like El Nino events, which bring more rainfall to the eastern Tropical Pacific as the region warms; had led to malaria upsurge in many areas (Salau, 2012). The distribution and the abundance of the vector organism and the intermediate hosts are affected by both physical and biological factors in an ecosystem. Changes in climate alter the distribution of the vectors and the spread of the disease into new areas (Ali et al., 2008*).* Also, many social factors like the level of economic development, health facilities and living conditions may influence the occurrences of malaria (Kelly-Hope *et al*., 2008). Nevertheless, the disease is a major public health problem that causes human deaths in the tropical regions despite the successes achieved through research and the discovery of new drugs (Khan et al., 2010). Also, there are growing concerns about the direction of the malaria trend under the future climate change condition. Hence, this study will investigate the impacts of variations in rainfall and temperature on the malaria patterns in Ado local government area (LGA), Ekiti State, Nigeria.

2. The Study Area and the Methodology

The study region is Ado LGA of Ekiti State, Nigeria. The state is located in the south western part of Nigeria between latitude 7.667°N and longitude 5.250°E (Logbaby, 2016) with the capital at Ado-Ekiti (Fig. 1). The state is bounded in the north by Kwara State and Kogi State while Osun State occupies the west and Ondo State lies in the south and extends to the eastern part. Ekiti State has 16 LGAs with an overall population of about 2,384,212 people that spread over an approximately 5887.890 km^2 (EKSG, 2016). The region lies at about 250m above sea level and characterised by tropical type of climate with the dry season between November and March while the wet season is around March-October of each year (EKSG, 2016). The mean monthly temperature is between 21°C and 28°C with high humidity; however, the peak temperature may be higher in the northern area of the state which has more of guinea savannah type of vegetation compared to the cooler and wetter south where tropical forest is found (EKSG, 2016). The land is blessed with water resources which include rivers like Ero, Osun, Ose and Ogbese (Logbaby, 2016). The agricultural products from the state include cocoa as the leading cash crop while forest resources are abundant, part of food crops are yam, cassava and grains like rice and maize (EKSG, 2016).

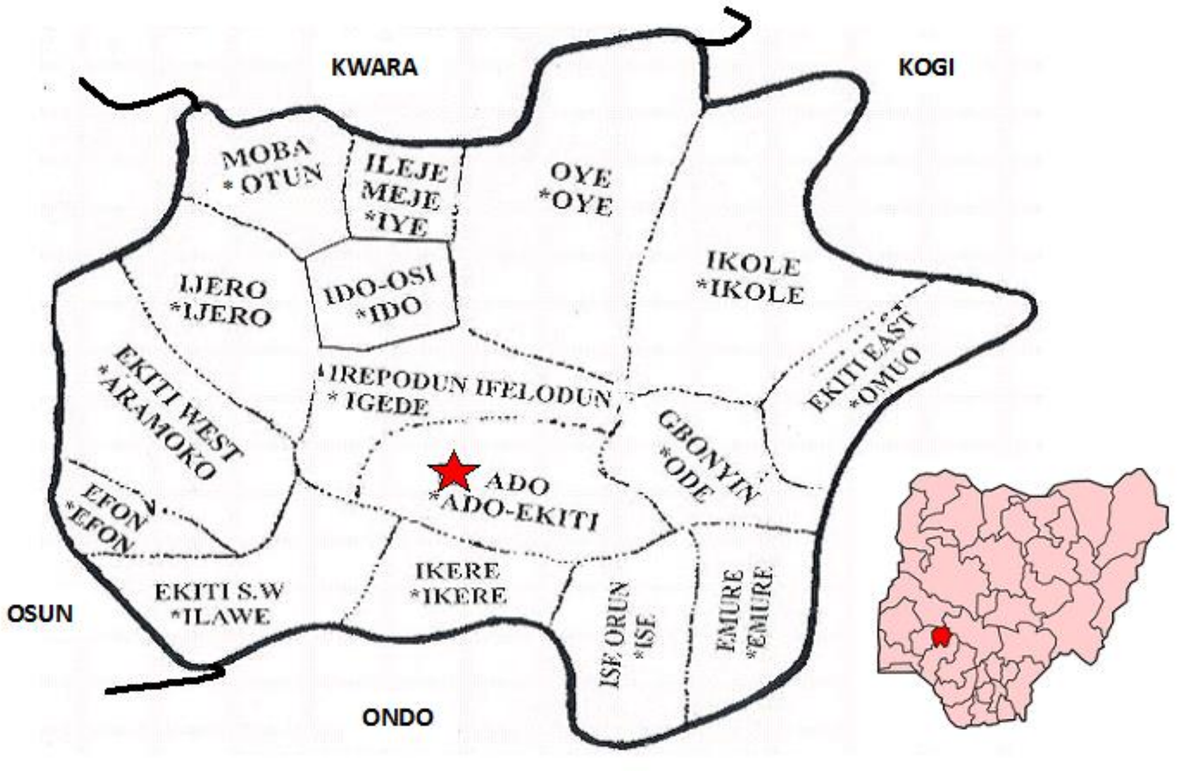

Figure 1: The map of Ekiti State showing the Local Government Areas (LGAs) with their headquarters marked with stars (*) while the study area and the state capital is shown with a red star (adapted from nigerianmuse.com). Inserted is the map of Nigeria with location of Ekiti State in red (source: www.ngex.com/nigeria).

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The Ado LGA is one of the sixteen LGAs in the state. The 2006 census confirmed that the local government (LG) is the most populous one in Ekiti State with population of about 308,621 people (EKSG, 2016). Geographically, the LG is bounded in the north and west by Ifelodun/Irepodun LG and in the east by Gbonyin LG while Ikere LG, Ekiti south west LG and Ise-Orun LG are found in the south (Fig. 1). The 2002-2011 data used for this study is obtained from the Federal Ministry of Agriculture in Ado-Ekiti. The data include the observed rainfall, numbers of rainy days, RH, the reported cases of malaria among the youths, adult males and adult females together with the corresponding minimum temperature, maximum temperature while the mean temperature [0.5(minimum temperature+maximum temperature)] is calculated. The plots of the malaria cases are compared with those of rainfall and temperature from Ado LGA; the aim is to understand the impacts of variations in the rainfall and temperature on the malaria distribution in Ado LGA.

3. Results and Discussion

A. The Variations in the Malaria Patterns

The variations in the reported cases of malaria over 2002 to 2011 are shown in Figure 2. The results indicate that the spread of malaria dropped steadily between 2002 and 2003 among all the groups with the least values of 3784 and 4572 recorded in male and female adults respectively. The year 2004 brought about a remarkable increase in the population of female adult infected with the malaria compared to other cases where slight increase in each group is recorded. The infections in youth and male adults dropped slightly after 2004 and increases gradually from 2005 till 2008; but the reduction in female adults continues till 2006 before a slight rise. Year 2008 is followed by small reductions in the infections in male and female adults while a strong drop to the least value of 1287 is seen in the youth's case in 2009. The malaria cases later rose to the highest peak (above 15,000) among the youths and male adults (6701) in 2010; the exception is seen in women adults where the peak value of 6209 in 2010 is secondary compared to the 6745 observed in 2004. The results ended with slight downward trend of the peak value in all cases between the 2010 and 2011. Overall, the cases of malaria observed in the adult male and female populations are lowest in 2003 while the female peak in 2004 is shifted to 2010 in adult male and among youths.

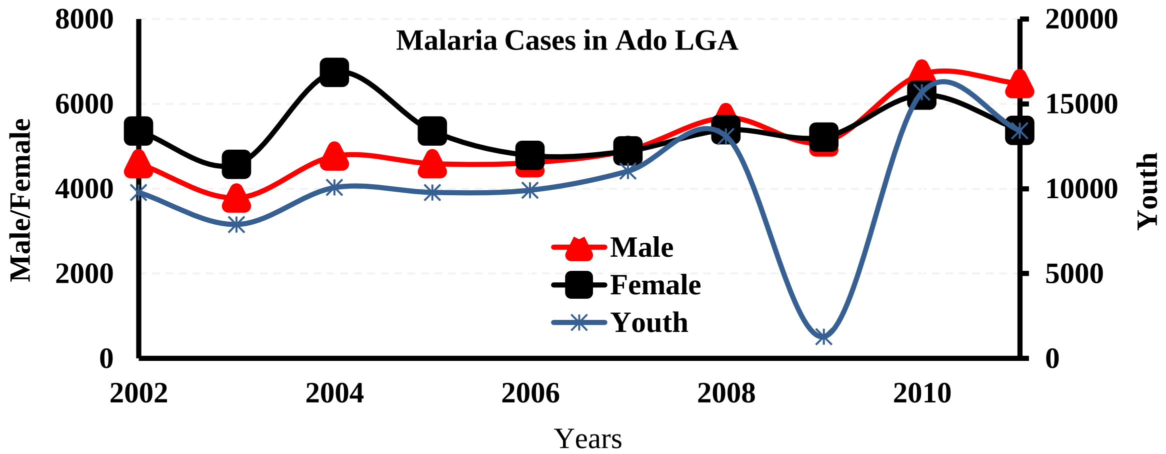

Figure 2: The malaria trends among Youth, Male and Female adults between 2002-2011. (Note the difference in the scale used for the youth compared to the other cases).

B. The Variations in the Rainfall and Temperature Patterns

An investigation into the influence of rainfall and temperature (minimum and maximum) on the malaria cases is seen in Figure 3. The comparison of the rainfall levels with the malaria infections show similar patterns between the two variables over the years of study (Fig. a, Fig. 3), suggesting that a rise in rainfall intensity will increase the malaria spread while the malaria is lowered under low precipitation. For instance, the spikes in 2004, 2007 and 2010, which correspond to periods with strong rainfall, also appeared in the amount of malaria infections that rose in those years with the exception of 2007 during which the rising cases of malaria continued till 2008 under strong rainfall (Fig. 2 and Fig. 3). Also, year 2004 with the strongest rainfall also have the highest cases of malaria among adult female which have the best agreement with the rainfall patterns; the high value in female adult is maintained until 2009 after which more infections are seen in male adults compare to the female. The remaining years show simultaneous reduction in the intensity of the rainfall and the corresponding cases of malaria in the study area. Furthermore, the shape of the minimum temperature within 2002-2007 indicates that the temperature is out of phase with both malaria spread and the rainfall pattern while periods from 2008 indicate that low (high) temperature and low (high) rainfall are associated with corresponding changes in malaria cases.

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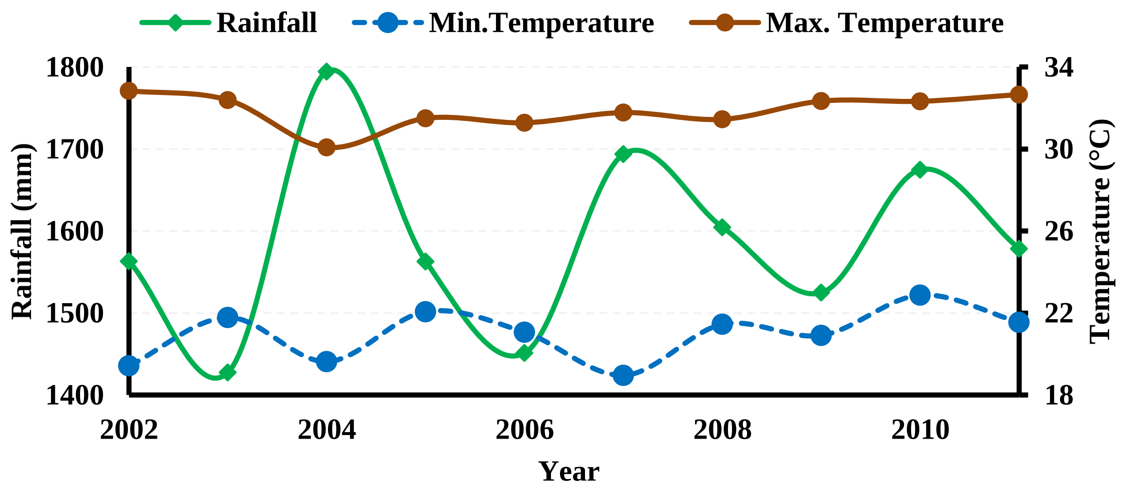

Figure 3: The plots showing the comparisons between the temperature and rainfall.

Further investigation done by comparing the numbers of rainy days with the total malaria cases per year (obtained by adding all the infected people for each year) is shown in Figure 4. The result shows good agreement between the numbers of rainy days and the total malaria cases. There has been an unstable pattern of rainfall within Ado LGA such that year 2003 with low infections have the least rainfall with just 77 rainy days while year 2004 recorded the maximum rainy days in the decade with 142 days and the high malaria occurrence in that year is also strongest in female adults (Fig. 4). However, the total malaria infections is 21,580 in 2004, a value below those obtained in 2008 (24,138), 2010 (28,600) and in 2011 (25,263) where the respective numbers of rainy days are 98, 86 and 88 (Fig. 4). The elevated levels of infections in those years might be explained by the enhanced breeding of mosquitoes caused by the rainfall that are well distributed throughout the rainy seasons while all the rainfall in 2004 might occur within short period of the rainy season.

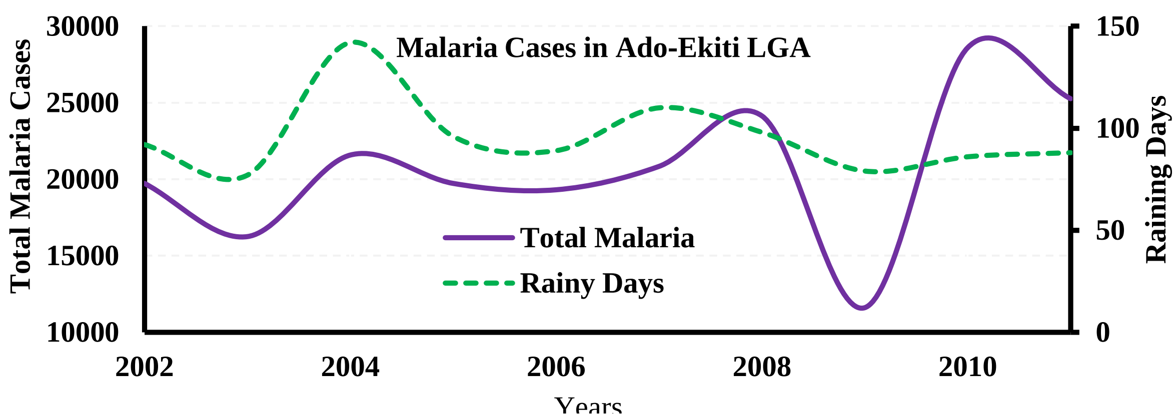

Figure 4: The comparison between the total malaria infections and the numbers of rainy days.

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C. The Correlations between the Malaria Cases and the Climate Variables

The correlation between the malaria infections and the magnitudes of the rainfall is approximately 0.40 in the case of youths and 0.38 in male adults while the strongest correlation of 0.80 is obtained from the female adults. Also, a positive correlation of 0.51 is observed between the total malaria cases and the rainfall whereas 0.63 is seen between the female cases and the numbers of rainy days. However, the minimum temperature has positive correlation of 0.25 with the youth, 0.40 with adult male and none with female which actually indicates that the disease will spread under moderately low temperature. The negative correlation obtained between the malaria and maximum temperature is very weak in the case of youth but good in male adults (-0.45) while it is 0.22 for female adults. These results imply that the temperature cools under the cloudy sky that comes with the rainfall (Salau et al., 2016) which creates pools of water that favours breeding of mosquitoes and hence the spreading of the disease. Though, model results have shown that increasing temperatures could progressively extend the distribution of malaria and the spread of mosquitoes (Paul, 2001); however, this study indicates that there is a limit to how high the temperature could rise to support such spread after which the temperature will become too hot for the vectors to survive. According to the results, rainfall data have potential use for malaria prediction; however, the relationship between the rainfall and numbers of malaria cases is indirect and complex. The study shows that rainfall has a great impact on the spread of the malaria disease in Ado LGA, its environment and in other places with related climate.

4. Conclusions and Recommendations

This study investigates the annual variations in malaria disease over 2002-2011 and relates the results with the corresponding changes in the rainfall and temperature patterns over the study period in Ado LGA, Ekiti State, Nigeria. In all, total population of 207,033 infected people were recorded out of which 101,943 are youths and 51,199 adult males were affected while the numbers of adult female are 53,891 during the years of study. The overall results and the correlations suggest that malaria cases will drop when temperature is too high while the disease spreads more under a moderately low temperature. It is also clear from the good positive correlations that high level of rainfall favours malaria increase. This is seen in the correlation of 0.51 seen between the rainfall and total malaria cases and more pronounced in the strong value of 0.80 observed between the rainfall and the malaria infections among the female population which also revealed 0.63 when compared to numbers of rainy days.

The outcomes also suggest that the youths or children are the most vulnerable to malaria infection while women, especially the pregnant ones, are also at high risk. In agreement with other reports, the widespread of the disease among the young population has been attributed to their less developed immune system when compared to the adults (Krongstad, 1996; Nmadu et al., 2015). However, the above figures might be below the ideal situation in each age group since many cases of malaria diseases are not reported in the hospital due to self-medication where people buy self-prescribed drugs and use them directly at home. For instance, the slightly lower infections among adult men than in women might be due to self-medication which might be more practice by male adults while women, especially the pregnant ones will mostly report their cases in the hospital. Also, poverty seems to play a very big role in the vulnerability of the poor or a community to climate induced variability in malaria spread due to lack of money to visit hospital for treatment or for buying good malaria drugs.

Furthermore, the results show that the geographical landscapes and complex climate situations provide the favourable breeding conditions for mosquitoes in Ado LGA. The observed positive correlations indicate that rainfall is the major factor behind the spread of malaria in Ado LGA while the frequency and severity of the malaria might rise in a slightly warm condition. According to this investigation, the rainfall really play a vital role in the distribution and breeding of mosquitoes and hence in the spreading of the disease. This is such that an enhanced malaria level is associated with increase in rainfall intensity which raises the numbers of anopheles mosquitoes through availability of more breeding places like pools of water. In addition, the spreading of the disease under a moderate temperature reduces as the condition becomes less conducive for the vectors during extremely high temperature and in a very cold atmosphere. It is therefore very imperative to control the prevalence of the disease since it could affect the standard of education of our society due to low turn-out of children at schools during high infections while it might lead to huge economic loss through absenteeism at work or loss of manpower (Nmadu et al., 2015). The disease also brings financial hardship to families in communities where it dominates through loss of revenue due to money spent on treatments (WHO, 2000).

In general, malaria disease could be reduced generally (and especially in youths and pregnant women) by providing and encouraging the use of treated mosquito net, insect repellents and spraying appropriate insecticides to reduce mosquito population, their bites and hence the overall infections (Caraballo, 2014) while un-authorised self-medication should be discouraged. Attentions should be given to the most vulnerable members of the society by making more drugs available for the youth and pregnant women. Similarly, communities might be thought about the control and coping strategies on malaria through health education (Lalloo et al., 2006) while improved personal hygiene, provision of free or affordable excellent medical facilities, domestic cleanliness, proper ventilation, clean food and water, refuse and drainages evacuation will all help in reducing malaria disease. However, this study will be later extended to other regions of the state as data becomes available, so as to improve our understanding of the malaria distribution in the state which will help the policy makers in their strive to curb the spread of the disease.

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