Available online at www.worldscientificnews.com

World Scientific News

WSN 55 (2016) 89-100 EISSN 2392-2192

Regional Distribution of Malaria in Ekiti State, Nigeria

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ABSTRACT

The impacts of fluctuations in weather and climate on malaria prevalence under a future climate change have been an issue of major interest because the disease is a public health problem. Thus, this study investigates the impacts of rainfall on the regional variations of malaria in Ekiti State, Nigeria using 2001-2011 data. The data are for the Central, Eastern, Northern, Western and Southern parts of Ekiti State which are represented by Ado, Ekiti East, Oye, Ekiti South West and Ijero LGAs respectively based on the available data. The results indicate that the total infections over the study period in Ado, Ekiti East, Oye, Ekiti South West and Ijero LGAs are 207033, 67890, 80827, 55986 and 87521 cases respectively. The malaria disease is most rampant among the youths in all the LGAs while the observed cases within the female populations are also slightly higher than the mean infections in the male group. Similarly, an increase in rainfall intensity will lead to corresponding rise in the malaria cases while the spread of the disease seems to also depend on population distribution with the highest seen in the highly populated Ado LGA and among the youths that has the most population in the age groups. However, the disease could be reduced through improved personal hygiene, good drainage system, sleeping under insecticide treated mosquito nets, spraying of insecticides and access to good and affordable medical services. These findings might be used in establishing good immunization system for the vulnerable children and other age groups so as to curb the spread of the disease.

***Keywords*:** Malaria; Mosquito; Rainfall; Temperature; Ekiti State; Ado – Ekiti; Population; Plasmodium

1. INTRODUCTION

The effects of weather patterns on malaria prevalence have been of major interest because the disease is a public health burden and its transmission is sensitive to changing atmospheric conditions. The malaria is a parasitic disease caused by the single celled organism called Plasmodium that affects the human liver and red blood cells. It is responsible for many human deaths in the tropical regions despite the successes achieved through research and the discovery of new drugs [1]. For instance, 80% of about 300-500 million annual global clinical cases of malaria are from Africa where there are suitable environmental conditions for the spread of the disease [2]. Research has shown that P. falciparum is the Plasmodium which is responsible for most of the severe malaria with the highest mortality in human being when compared to others like P. vivax, P. malariae and P. ovale [3-5]. Unlike these less dangerous species that dominate in many countries, the P. falciparum is responsible for most deaths caused by malaria disease and it is also blamed for over 75% of such deaths in sub-Saharan Africa [6]. The intermittent fevers of malaria, initiated by a bite from an infected female Anopheles mosquito and the pouring of plasmodium from a sufferer's blood into the circulatory system of a new host [7], are due to repeated cycles of the parasite replication in the red blood cells. This will lead to rupture of the affected cells, causing the invasion of healthy cells by the emitted parasites [8]. However, this could be prevented if appropriate treatments or drugs are used before the appearance of the malaria symptoms like frequent chills, fevers, severe joint pain, back pain, headache, sweating, dry cough, spleen enlargement, vomiting and diarrhoea [9,10]. Such treatments for complicated infections include a well-monitored 7 days of "Artemisinin-based Combination Therapies (ACTs)" while similar period of quinine plus clindamycin is recommended for pregnant women or artesunate plus clindamycin if the former failed [11].

There is predictable climate induced seasonal transmission of the disease with between year variability caused by fluctuations in rainfall pattern in areas suitable for mosquito breeding. These changes in the seasonal patterns represent important information for the timing to control the vector's larval stage. For example, the sustained transmission of the malaria depends on favourable environmental conditions for the vectors and the parasite; however, the duration of the development of the parasite in the female Anopheles (sporogony) is affected such that the survival of the vectors is not possible at extremely high temperature [12]. Though many social factors like the level of economic development, health facilities and living conditions may also affect the occurrences of malaria [13], but changes in climate are the important factors that could alter the distribution of the vectors and the spread of the disease into new areas [14]. The disease is prevalence in the tropical and subtropical regions where suitable temperature of about 20 °C to 30 °C is available [15] with consistently high rainfall and humidity along with presence of stagnant waters in which mosquito larvae could develop [16]. However, the true relationships between climate, seasonal parasite transmission and the disease outcomes are not very clear.

For instance, 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 [17]. However, there are growing concerns about the direction of the malaria trend under the future climate change. Insufficient knowledge of the seasonal changes in malaria spread may be an obstacle to the right information needed for controlling the vector's larva [18] while it may also lead to poorly designed immunization for children and other age groups in the society. Even though not all malaria cases are brought to the hospital, especially in rural areas with limited access to health services, many studies still revealed that malaria is the main public health problem causing lots of deaths and absenteeism at work [1,7,10]. Since rainfall plays an important role in the breeding of the malaria vectors, this study will investigate the impacts of variations in rainfall on the regional changes in malaria patterns in Ekiti State which is part of rain forest with high intensity of precipitation in Nigeria.

2. THE STUDY AREA AND THE METHODOLOGY

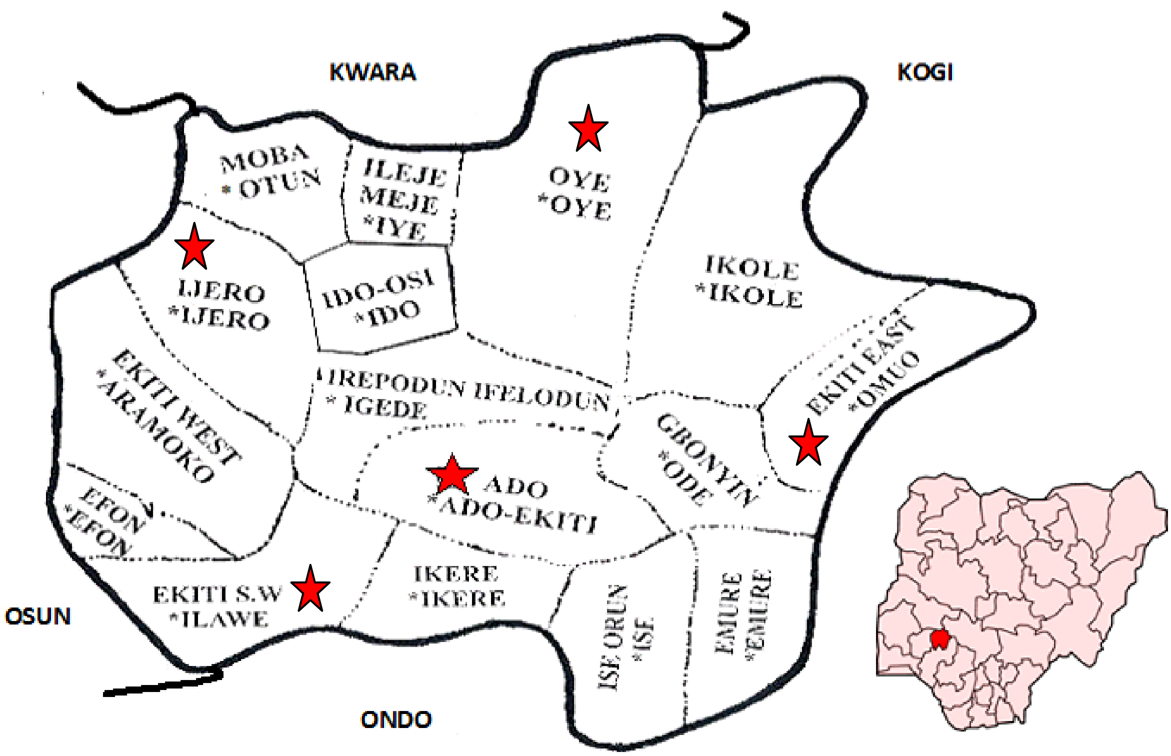


Figure 1. The map of Ekiti State showing the Local Government Areas (LGAs) with their headquarters marked with stars (*) while the study areas and the state capital (Ado – Ekiti) are shown with the red stars (adapted from nigerianmuse.com, [21]). Inserted is the map of Nigeria with location of Ekiti State in red (source: www.ngex.com/nigeria, [22]).

The study regions are in Ekiti State, Nigeria, West Africa. The state is located in the south western part of Nigeria between latitude 7.667° N and longitude 5.250° E [19] 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 [20]. The region lies at about 250 m above sea level and it is characterised by tropical type of climate with the dry season between November and March while the wet season is within March-October of each year [20]. 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 compared to the cooler and wetter south where a more tropical rain forest is found [20]. It is a landlocked state with no coastal boundary, but it is blessed with water resources which include rivers like Ero, Osun, Ose and Ogbese [19] while cocoa is the main cash crop and yam, cassava and grains like rice and maize stands for the food crops [20]. Besides farming, the inhabitants of the state are artisans, traders, civil and public servants.

The local government areas (LGA) used in this study are selected from the different parts of the state based on the available data to represent the northern, southern, western, eastern and central parts of the state. These consist of Ekiti East LGA with headquarter in Omuo - Ekiti which represent the eastern part of the state, Oye LGA that has the head office in Oye – Ekiti stands for the north, Ijero is the seat of Ijero LGA which is selected for the western part of the state. These LGAs, along with Ekiti South West that stands for the south with its headquarter in Ilawe - Ekiti, are compared with the published data from Ado LGA [10] which belong to Ekiti Central where the state capital (Ado – Ekiti) is located. As the seat of the state capital, Ado LGA has many federal and state offices while there are two Universities and a Federal Polytechnic, thus making it the most populous among the sixteen LGAs in the state. The 2006 population census put Ado LGA at about 308,621 people, that of Ijero LGA was about 221,405 inhabitants while the population figures from Ekiti East, Ekiti South West and Oye LGAs were approximately 137,955, 165,277 and 134,210 respectively [20]. The 2002-2011 data used in this study is obtained from the Federal Ministry of Agriculture in Ado-Ekiti. The analysed data include the observed rainfall, the reported cases of malaria among the youths, adult males and adult females together with the corresponding average (mean) temperature. The plots of the malaria cases are compared with those of rainfall and the mean temperature from the study areas and compared with those from Ado LGA; the aim is to understand the impacts of variations in the rainfall on the malaria distribution within the states. However, a comprehensive study of the impacts of climate on malaria distribution in the state is envisaged as data become available from all the LGAs.

3. THE RESULTS

A. Regional Distribution of Malaria among the Youth, Male and Female Adults

The variations in the reported malaria cases within the youth population from the study regions are shown in Figure 2 where the malaria cases from Ado LGA are placed in the secondary scale with higher magnitudes than the values from the other locations. According to the results, there is a general reduction in the reported cases of malaria in 2003 which is slightly repeated in 2005 after an overall increase in 2004. This is followed by a consistent rise in the malaria infections through 2006 to 2008 with the exception of Ijero LGA where a small reduction is seen in 2006. The infections among the youths in Ado LGA plunged to the minimum level in 2009 while slight reductions are seen in other cases with the exception of a small increase in Ekiti East LGA. The ailments rise to the peak in Ado and South West LGAs; but this is delayed till 2011 in Ekiti East, Ijero and Oye LGAs during which a small decrease is seen in Ekiti South West LGA and in Ado LGA (Fig. 2).

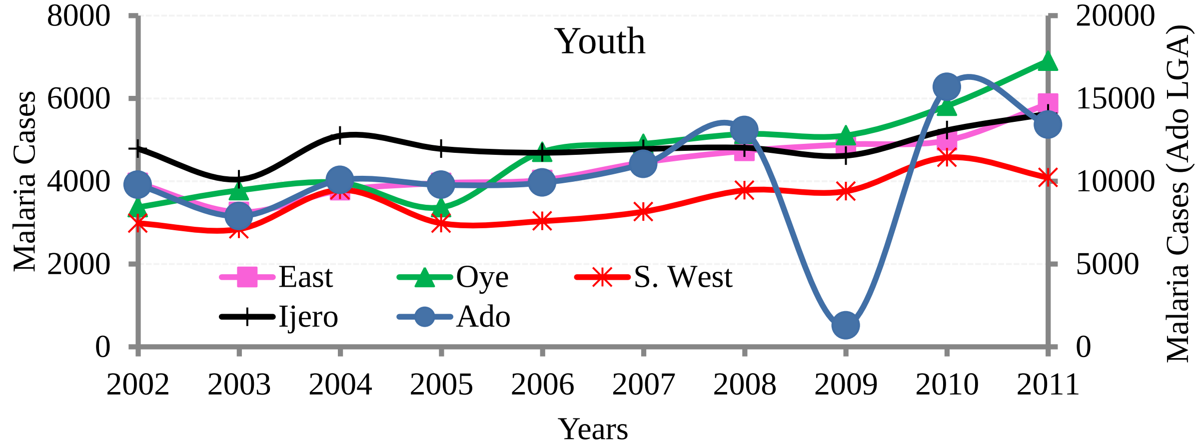


Figure 2. The region variations in the malaria disease among the youth population from the five LGAs in Ekiti State. Note that Ekiti South West LGA is shown in the figure as S. West.

The investigation reveals an overall increase in the malaria disease among the youths over the study period in all the LGAs while the magnitude is highest in Ado LGA when compared with other LGAs considered. On the regional basis, the lowest level of the infections is seen in Ekiti South West, it is average in Ekiti East whereas the highest magnitude is obtained in Ado LGA, followed by Ijero LGA where it was overtaken in 2006 by Oye LGA during which the disease maintains the secondary peak till 2011 (Fig. 2). In all the LGAs, the least magnitude of 1,278 cases is recorded in Ado LGA in 2009 while the highest value of 15,690 also occurred there in 2010 among the youth. The strong malaria cases in Ado LGA might be associated with the highest population in the region compared to other LGAs, creating the tendency for more infections to be feasible while the weather conditions also affect the general patterns observed in all the LGAs. The least infections occurred in 2003 in most of the other LGAs with magnitude of 3254, 2846 and 4045 in Ekiti East, Ekiti South West and Ijero LGA respectively while 3372 cases in 2005 is the minimum in Oye LGA. Except that of Ekiti South West with the highest cases of 4576 in 2010, the respective peak occurred in 2011 with magnitude of 5873, 6909 and 5631 in Ekiti East, Oye and Ijero LGA.

The Male and Female reported malaria cases are shown in Figure 3(a, b). It should be noted that the scales are smaller when compared with those used for the youth cases and the magnitudes of the infections are lower in the four LGAs than the values from Ado LGA which is shown on the secondary scale of Figure 3(a, b). In close agreement with the youth patterns, the periods of reduced infections which are mostly alternated with times of strong malaria are more pronounced in 2003 in the male cases (Fig. 3a). These periods of low malaria are weakly observed in 2005 and almost in non-existence in 2007 with the exception of Ekiti East, later it becomes clearly visible in 2009 and 2011 in most of the LGAs. This is not the case in Ijero LGA where the infections rise through 2006 to 2011. Similarly, the malaria trend reveals an overall increase from 2002-2011 in all the study regions; the highest magnitude is seen in Ado LGA while the levels of the infections are low in Ekiti East LGA and Ekiti South West LGA where the infection is generally at the lowest level. The respective minimum cases of 3784, 1207, 875, 1563 that occurred in 2003 within Ado, Oye, Ekiti South

West and Ijero LGAs shifted to 2007 in Ekiti East with values of 893 while the malaria cases peaked in 2010 almost all the LGAs.

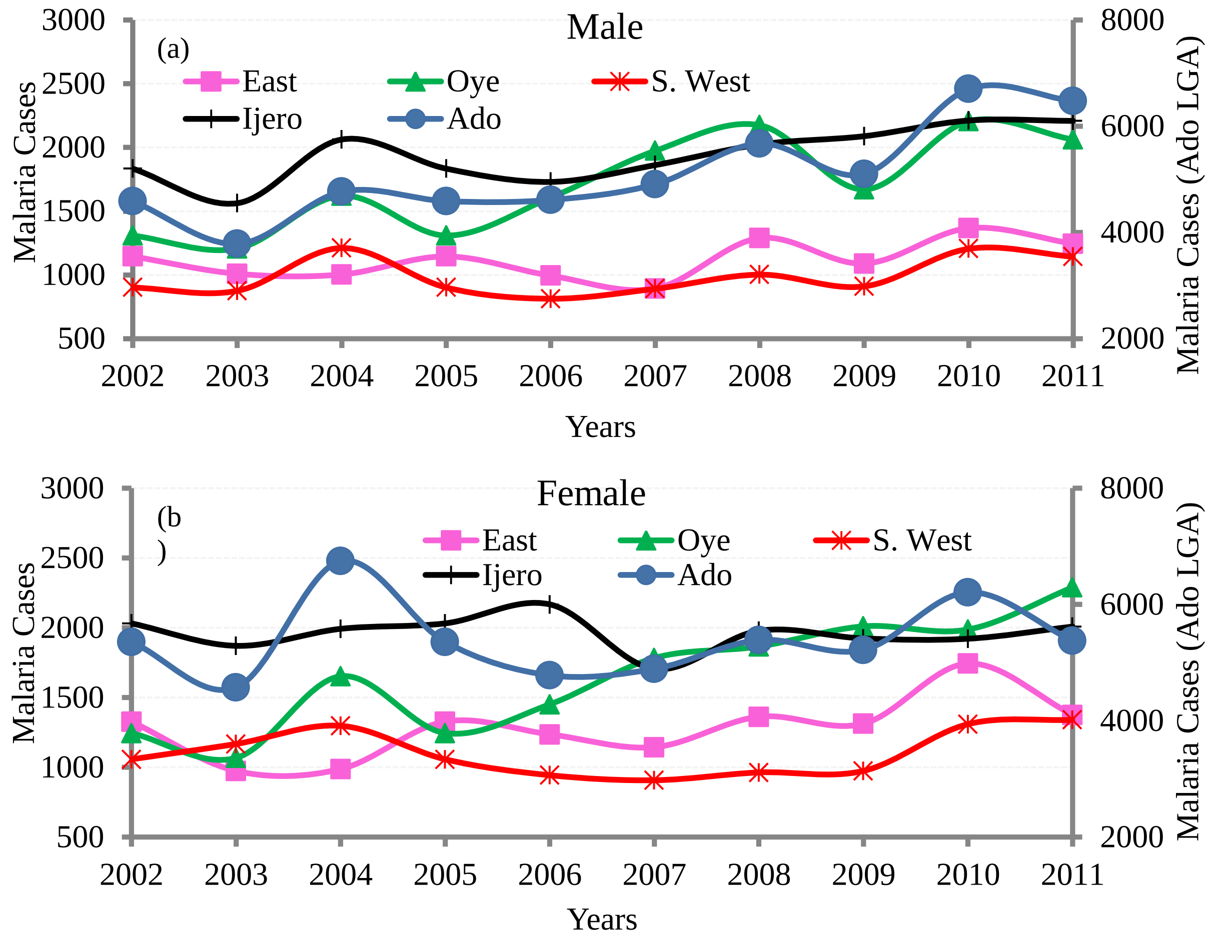
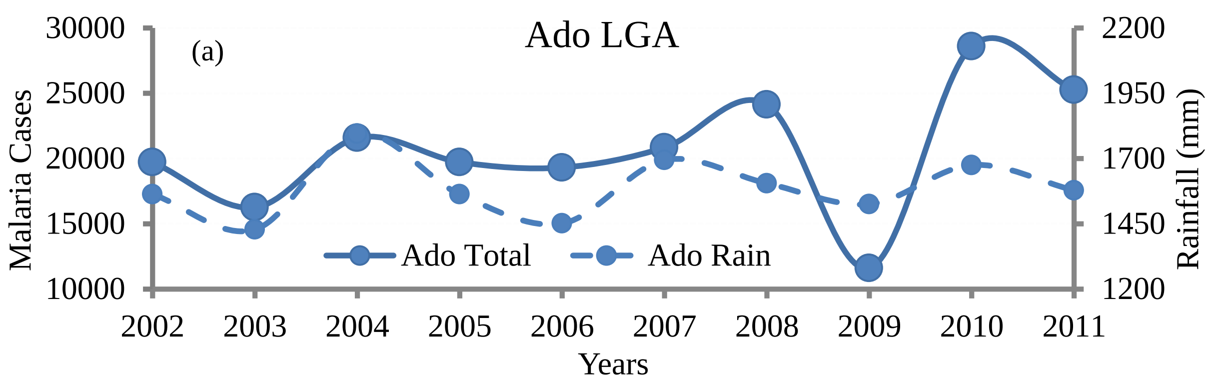


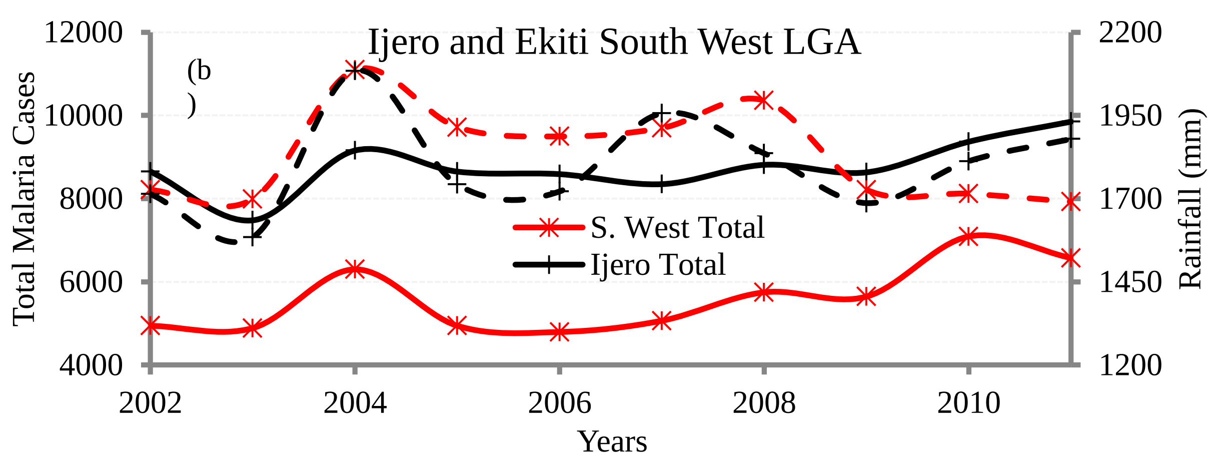
Figure 3. The variations in the regional malaria infections among the (a) Male and (b) Female populations from the five LGAs of Ekiti State. Colour codes and symbols as in Figure 2 – both are similar for the same LGA in all cases.

Furthermore, the malaria cycles that involve the alternations between the maximum and minimum infections within the study period are not prominently seen in the female cases (Fig. 3b). The exception to this is seen in Ado LGA where the cycle is clearly observed and it is mainly absent in the pattern from Ijero LGA, Ekiti South West LGA while it is poorly represented in Oye LGA and in Ekiti East LGAs. Also, there are no clear trends in the reported cases of the malaria disease in Ijero, Ado and Ekiti South West LGAs where the levels of the infections are virtually the same throughout the study period. However, the positive trend recorded in Ekiti East LGA is lower than that seen in Oye LGA where the infections increase strongly through the years from 2005 to 2011 (Fig. 3b). The overall result shows that the malaria is very low in Ekiti South West LGA while the highest magnitude is seen in Ado LGA. In comparison with the male cases, the malaria disease is generally low in Ekiti East LGA and in Ekiti South West LGA where the smallest amounts of infections are recorded in both male and female groups while the highest magnitude reported in the highly populated Ado LGA is far more than the high value from Ijero LGA (Fig. 3a, b). The lowest values from the male and female populations are 813 and 907 respectively; both occurred in 2006 from Ekiti South West LGA while the overall highest cases from male and female are respectively 6701 and 6209 in 2010 from Ado LGA.

B. The Relationship between the Malaria Infections and Rainfall Patterns

The total malaria cases (obtained by adding the reported cases from youth, male and female infections) are compared with the observed rainfall patterns from the study areas so as to understand the impacts of rainfall distribution on the spread of the disease in each LGA (Figs. 4a, b, c). The outcome in Ado LGA shows good agreement between the rainfall intensity and the total malaria which is shaped by the high magnitude of the infections observed among the youth population in the LGA (Fig. 4a). Also, such close agreement is seen in Ijero LGA while the early good phase relationships observed in Ekiti South West LGA (Fig. 4b) and Oye LGA (Fig. 4c) are later reversed and ended in 2011 with opposite trends between the malaria infections and the precipitation. On the other hand, Ekiti East LGA revealed an initial out of phase relationship between the observed malaria and the rainfall which later matches slightly (Fig. 4c). The overall results suggest that an increase in the intensity of the rainfall will lead to more malaria infections in almost all the LGAs.





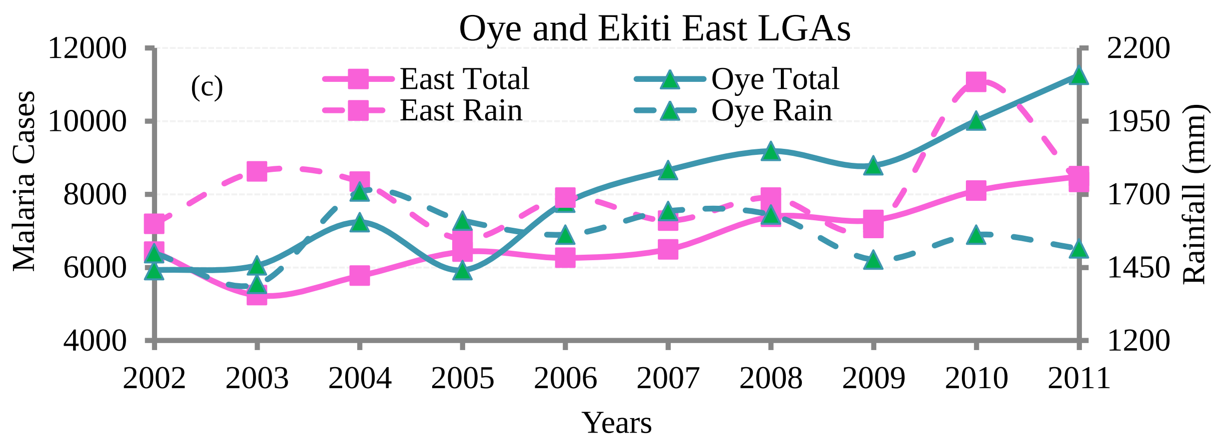


Figure 4. Comparisons between the total malaria cases and rainfall patterns from (a) Ado LGA, (b) Ijero and Ekiti South West LGAs and (c) Oye and Ekiti East LGAs of Ekiti State. Note that the high magnitudes of malaria from Ado LGA are plotted on different primary scale. Also, the full lines and their symbols represent the total malaria cases (as used in Figures 2 and 3) while the broken lines stand for the rainfall.

The disease will tend to rise during rainy season due to more mosquito bites since many inhabitants of Ekiti are farmers who engaged in various farming activities that sometimes involve working in villages surrounded by mosquito infested bushes, shrubs and water-logged areas. However, there might be contributions from other factors like presence or absence of health facilities, availability or non-availability of malaria drugs, changes in levels of awareness about how to control the disease, changes in temperature pattern, population, personal sanitation and lots more. Investigation into the impacts of temperature on the malaria show that the average temperatures are initially out of phase with the rainfall and with the overall malaria patterns in four LGAs with exception of Ekiti East; however, the curves are afterward inconsistent with the changes in the temperatures which are generally high between 2009 to 2011 (not shown).

C. The Correlation Coefficients

The correlation coefficient is examined to further establish the relationships between the average temperature, rainfall and the malaria occurrences. In favour of the inconsistency observed in the temperature patterns (not shown), the positive and negative correlation coefficients obtained between the average temperature and the malaria (youth, male, female) across the LGAs are generally poor with few exceptions. The finding suggests that the malaria prevalence is not strongly influenced by the temperature distribution in the study area. It however indicates that the disease will be reduced as temperature rises above a threshold value below which the malaria disease will spread more. This is expected since temperature is lowered under the cloudy sky that accompanies a rainfall event while increase in the breeding of mosquito that comes with intense precipitation will be reversed under a dry condition and also impossible at extremely low temperature.

On the other hand, the correlation coefficients between the malaria and the rainfall generally revealed positive values in most cases (youth, male, female); the correlations are strong in some of the LGAs, thus suggesting that the malaria will rise with increased rainfall. The few exceptions to this observation is prominent in Ekiti South West LGA (see Fig. 4b) where the observed correlations are generally poor and negative. For instance, the correlation coefficient obtained between the total (or average) malaria cases from each LGA is 0.51 (Ado), 0.56 (Ijero), 0.33 (Ekiti East), 0.11 (Oye) and -0.09 (Ekiti South West). These results are in agreement with the rainfall patterns shown in Fig. 4(b, c) where the matches between the rainfall and malaria cases are poor in Oye and Ekiti South West LGAs when compared with other LGAs. These observed cases with low or negative correlation coefficients might be associated with reduction in the breeding of mosquitoes under an intense rainfall and the resulting fast moving water bodies that tend to wash the mosquitoes away. Similarly, the above correlation coefficients suggest that more factors (beside rainfall intensity) are contributing to the malaria spread. Also, the values of the correlation coefficients obtained between the malaria and rainfall are higher than the very low magnitudes involving the malaria and the average temperature, thus suggesting that rainfall has more impacts on the spread of the malaria in the regions than temperature.

4. SUMMARY AND CONCLUSIONS

This study investigates the regional variations in malaria distribution from the Central, Eastern, Northern, Western and Southern parts of Ekiti State as represented by Ado, Ekiti East, Oye, Ekiti South West and Ijero LGAs respectively. Since data covering the whole state is not available at the time of this research, the selected LGAs are thus used as representatives of the above regions based on the available data. The overall results indicate that the total number of malaria cases between 2001-2011 in Ado, Ekiti East, Oye, Ekiti South West and Ijero LGAs is 207033, 67890, 80827, 55986 and 87521 respectively. The results further show that the malaria disease is most rampant among the youths in all the LGAs while the observed cases within the female populations are slightly higher than the mean infections recorded in the male group from the LGAs (Fig. 5). These results indicate that children are the most vulnerable when compared to the adults with well-developed immunity.

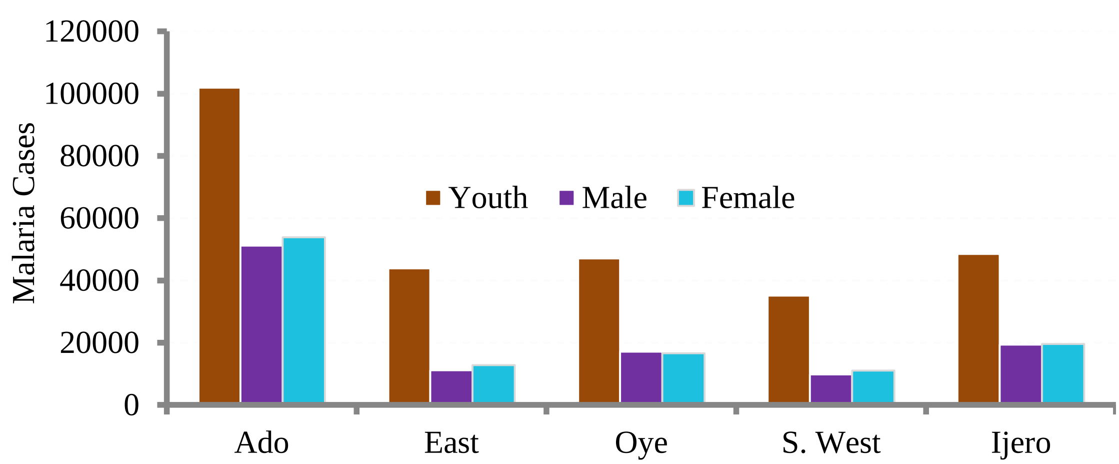


Figure 5. The mean malaria cases among the different age groups in all the LGAs.

The results compared well with other studies where it has been established that children under five years have the highest risk of getting the malaria disease [7,10,23]. Also, the higher cases among female adults than in male adults could be attributed to more visit of the women to the hospital, especially the pregnant women who are at risk because of reduced immunity while self-medication which is mostly practiced by male adults might also be an additional reason [10]. Furthermore, the overall results show a rise in the rainfall intensity will increase the incidents of the malaria disease; this is supported by the positive correlation coefficients between the mean rainfall and the total (or average) malaria from the LGAs. Also, the findings suggest that the spread of the disease depends on the population of an area with the highest seen in the highly populated Ado LGA (Fig. 5). This is followed by the next densely populated Ijero LGA; it is low in Ekiti East LGA while the least is seen in Ekiti South West LGA. The current increase in the malaria disease in Oye LGA might be connected with possible rise in the population associated with a currently established university in the region. Thus the high infections among the youths could be due to the greater probability of occurrence in that age group which has the highest population in all the groups.

The malaria disease could be reduced through improved personal hygiene, better sanitation, sleeping under insecticide treated mosquito nets, spraying of suitable insecticides, access to good and affordable medical treatments and lots more. Applications of these guidelines might be part of the reasons for the reduction in the malaria cases in Ekiti South West LGA. In addition, the use of prescribed drugs to prevent malaria is very important while good drainage system will help in reducing the breeding places for mosquitoes which will consequently lower the amount of mosquito bites and the resulting infections. Though some inconsistencies in the results could be due to errors in the recorded data, the ideal total numbers of malaria cases in each age group could be above the observed values used in this work. This might be due to unreported cases caused by self medication and other reasons while the high records in urban areas like Ado LGA may possibly be due to more visits to health centres unlike remote areas that lack good health facilities. In general, a well–designed immunization system for children and other age groups based on our current understanding of rainfall and climate induced changes in malaria spread will be a good way of curbing the disease. However, there are ongoing efforts to have good understanding of the impacts of climate on the malaria distribution across the whole Ekiti State by extending the analysis to every LGA as long data becomes available.

References

[1] Khan, J.S., Usman, M., Abbass, Y., Hussain, M, & Alli, M., Knowledge, attitude and Practice study on malaria. *Gomal Journal of Medical Sciences* (2010), 8(2), 204-208.

[2] Lucas A. O. and Gilles H. M., Malaria: Short Textbook on Public Health Medicine for the Tropics (2003). India, Arnold Publication.

[3] Rich, S. M.; Leendertz, F. H.; Xu, G. Lebreton, M.; Djoko, C. F.; Aminake, M.N.; Takang, E. E.; Diffo, J. L. D.; Pike, B.L.; Rosenthal, B. M.; Formenty, P.; Boesch, C.; Ayala, F. J.; Wolfe, N. D., The origin of malignant malaria. *Proceedings of the National Academy of Sciences* (2009), 106(35): 14902-14907.

[4] Perkins, D. J.; Were, T.; Davenport, G. C.; Kempaiah, P.; Hittner, J. B.; Ong'Echa, J. M., Severe malarial anemia: Innate immunity and pathogenesis. *International Journal of Biological Sciences* (2011), 7(9): 1427-1442.

[5] Perlmann, P; Troye-Blomberg, M., Malaria blood-stage infection and its control by the immune system. *Folia biologica* (2000), 46 (6): 210-218.

[6] World Malaria Report, WMR, World Health Organisation (2008), p. 10. Retrieved 2009-08-17.

[7] Nmadu P. M., Peter E., Alexander P., Koggie A. Z., Maikenti J. I., The Prevalence of Malaria in Children between the Ages 2-15 Visiting Gwarinpa General Hospital Life-Camp, Abuja, Nigeria, *Journal of Health Science*, Vol. 5 No. 3 (2015) 47-51.

[8] Roberts, Larry S.; Janovy, John, Foundations of Parasitology (7th ed.), McGraw-Hill Education (ISE Editions) (2005), ISBN 0-07-111271-5.

[9] Fairhurst, R. M., and Wellems, T. E., "Chapter 275. Plasmodium species (malaria)". In: Mandell, G. L., Bennett, J. E., and Dolin, R. (eds.), Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases 2 (7th edn). Philadelphia, Pennsylvania: Churchill Livingstone / Elsevier (2010), 3437-3462.

[10] Salau, O. R., Dependence of Malaria Disease on Changes in Rainfall and Temperature in Ado Local Government Area of Ekiti State, Nigeria, *Intern. J. of Res*. (2016), Vol. 3, Issue 9, pp. 378-387.

[11] WHO, Guidelines for the treatment of malaria, second edition, Authors: WHO. Number of pages: 194. Publication date: 2010. Languages: English. ISBN 978-92-4-154792-5.

[12] Gallup J. and Sachs J., The Economic Burden of Malaria. *American Journal of Tropical Medicine and Hygiene* (2001); 64S: 85-96.

[13] Kelly-Hope, L. A.; Alonso, W. J.; Thiem, V. D.; Canh do, G.; Anh, D. D., and Lee, H. (2008). Temporal trends and climatic factors associated with bacterial enteric diseases in Vietnam, 1991-2001. EHP., 116: 7-12.

[14] Ali H, H., Ahmed, S., and Sulaiman, S., Climate change and health in Sudan. Capacity strengthen in the least developed countries for adaptation to climate change (2008).

[15] Patz J. A., Kovats R. B., Hotspots in climate change and human health. *BMJ* (2005); 325: 1094-1098.

[16] Jamieson, A. Toovey, S. and Maurel, M., Malaria: A Traveller's Guide, *Struik* (2006), p. 30.

[17] Sumana, B., Sharma, C., Dhiman, R.C. and Mitra, A.P., Climate Change and Malaria in India. Current Science (2006), 90(3).

[18] WHO, Press Release WHO/48 Fact Sheet 5th July 2000. Geneva W.H.O. publications (2000): 1-18.

[19] Logbaby, Ekiti State, Nigeria (2016). (Overview, History and Summary Information), retrieved on 04/05/16 (link: logbaby.com/encyclopedia/ekiti-state-nigeria-overview-history-and-summary-information_20.html#.VzDjyutw17p).

[20] EKSG (Ekiti State Government), About Ekiti (2016). Retrieved on 04/05/16 (available on: ekitistate.gov.ng/).

[21] NM (Nigerian Muse), Cartoons, Pictures and Maps, Ekiti Kingdoms (2016), retrieved on 30/04/16, www.nigerianmuse.com/cartoons/NigeriaWithStates1.jpg.

[22] NGEX, Nigeria, Ekiti State, Nigeria (2016). Retrieved on 04/05/16 (available on www.ngex.com/nigeria/places/states/ekiti.htm).

[23] Krongstad D.J. (1996). Malaria as a re-emerging disease epidemiology, Rev. 18: 77-89.

(Received 28 August 2016; accepted 14 September 2016)