ABSTRACT

Degraded environments have been observed to have negative effects on health outcomes. The right actions on environmental health can reduce the burden of the disease as curative measures are usually costlier and complicated, when compared to preventive measures. The key objective of the study is to identify areas of high malaria burden and policy which provide a framework to curb the malaria disease burden, especially among expectant mothers. This study employed Inverse Distance Weighting (IDW) interpolation which is a spatial analysis method whereby values at a particular location are determined by giving more importance to the values of nearby points. This was used to identify, visualize, and map out areas of high malaria incidence amongst expectant mothers in Edo South Senatorial District in Southern Nigeria based on temperature and rainfall data from 2013 - 2020. The study found three of seven Local Government Areas (LGAs): Egor, Ovia South West and Oredo, to have the highest record of malaria confirmed in expectant mothers, which were tied to environmental conditions, as slight increases in temperature overtime were observed to have a relationship with malaria outcomes in expectant mothers. Consequently, curbing extreme temperatures ranges was found to be crucial not only to addressing climate change concerns but combating the development and spread of the mosquito vector. Based on the findings, the study recommends the need for a standard maintenance of the immediate surroundings of households in order to minimize malaria incidence. Experts and policy makers can mobilize public support by involving Local communities and other stakeholders in the fight against malaria eradication, especially amongst vulnerable groups such as expectant mothers.

Keywords: Climate, Environment, Expectant mothers, Malaria Outcomes
INTRODUCTION
Malaria has been reported to be present in over one hundred countries and is accountable for over 100 million medical cases with about one to two million deaths annually, although this is more felt in poor developing countries such as Nigeria (WHO, 2003). This high frequency in malaria occurrence in the general populace and especially in expectant mothers creates a big economic burden on families and the community as a whole, especially among susceptible groups such as children, expectant mothers and the elderly (Sachs and Malaney, 2002).

In recent times, the impact of the environment on malaria incidence has gained the attention of environmentalists, geographers and policy makers. The relationship between climatic factors and malaria distribution has for long been recognized, as the diffusion of the malaria parasite appears highly dependent on conducive environmental settings for both the vector and the parasite (Tanser et al., 2003). Furthermore, expectant mothers are at a higher risk of malaria, as can be seen from a study carried out by Duffy and Fried (2005), where it was observed that expectant mothers were more susceptible to malaria as a result of the changes in their body and the drop in immunity, which increases the risk of the malaria disease both for the mother and the child. Expectant mothers, therefore, fall within the highly vulnerable malaria mortality groups.

As Environmental health practitioners, there is the need for more comprehensive understanding of the spatial pattern of the spread of disease, in order to appreciate some of the remote causes and provide the right solutions. In fact, the covid-19 pandemic which was been observed to be highly transmissible geographically, demonstrates the need to understand the spatial patterns of the spread of diseases in order to forestall their spread.

According to Beck-Johnson et al. (2013), malaria transmission is highly dependent on the female Anopheles mosquito and the development and survival rates of the female Anopheles mosquito and the plasmodium parasite which causes malaria transmission, depends to a large extent on temperature; thus making temperature a key driver of mosquito population dynamics and its transmission. According to their study, malaria abundance and transmission peaks at temperatures in the mid-20s, which is 25°/26° Celsius and was at its peak at 28°C. Rainfall on the other hand, also has an impact in mosquito abundance, by providing wet and moist conditions that favours’ the breeding of the anopheles mosquito (Castro, 2017). The aim of this research, therefore, is to ascertain the impact of temperature and rainfall on malaria outcomes in expectant mothers in the southern part of Edo State, Nigeria by exploring malaria, incidence, rainfall and temperature trends overtime, in order to map out specific hotspot areas of malaria occurrence amongst expectant mothers, and establish patterns of malaria prevalence, which might be useful to public policy.

MATERIALS AND METHODS

Study area
The study is on Edo South Senatorial District as can be seen from Figure 1, one of the three senatorial districts making up Edo State. The District has 57.54 percent of the total population of the State (Edo SEEFOR, 2017). Edo South is located within latitude 5°44N and 6°87N and longitude 5°00 E and 6°43E of the Equator. It shares a boundary with Ondo State in the West, and is bounded in the North East by Owan West, Esan West and Igueben Local Government Areas; and in the South by Delta State. It has a total land area of 8,778.921km. The population of Edo South has been increasing gradually. The total population of Edo South Senatorial District is 1,686,041 (NPC, 2019), with a population density of 163.1 persons per square kilometer.
The research adopted convenience sampling research design which is a non-probability sampling method that involves samples being drawn from that part of the population that is closest at hand. The advantage of this method is that it is efficient and easy to implement (Yomere and Agbonifoh, 1999). Rainfall and temperature data were retrieved from the Centre for Hydro-meteorology and Remote Sensing (CHRS) data portal and the National Centre for Atmospheric Research (NCAR) website respectively from 2013-2020. Secondary data were retrieved from the Edo State Ministry of Health from 2017-2020 after obtaining ethical approval from the Edo State Ministry of Health to authorize the collection and use of medical records from the Ministry. Medical data were compiled from the Edo State Ministry of Health on annual reported malaria cases from Primary Health Care Centre’s from each of the Local Government Areas.

Results from the study are presented below using descriptive statistics such as maps and graphs in order to analyse the impact of environmental/climatic factors such as “rainfall and temperature” overtime on malaria occurrence in “expectant mothers”. The Inverse Distance Weighting (IDW) interpolation and Choropleth mapping technique was utilized to easily visualize, and map out areas with high malaria incidence amongst expectant mothers in the seven Local Government Areas of Edo South Senatorial District.

**Figure 1:** Edo South Senatorial district (Study Area)
Source: Edo State ministry of Lands and Survey

**RESULTS AND DISCUSSION**

Figures 2 to 4 show that malaria occurrence peaked in expectant mothers at 26°C, especially in urban-based Local government areas of Edo South Senatorial District. This accord’s with the study carried out by Shapiro *et al.* (2017), which also affirmed that mosquito abundance peaked at about 25°C. Overall, the tropical and humid climate of the study area also promotes unbearable temperature increase, which lures residents to sit outside their homes in the evenings to take in fresh air, because of the irregular supply of electricity. This further increases the exposure of
residents to mosquito bites, as mosquitoes are known to be more active in the evenings. Again, though rainfall according to Craig et al. (1999) seems to be critical in providing suitable habitats for mosquitoes to breed, nevertheless, temperature seems to be a major key driver affecting the life cycle of the mosquito by determining the development, biting and survival rates of mosquito vectors, which all combine to determine malaria transmission intensity (Mordecai et al., 2013).

Figure 2: Temperature variation for Edo South (2013-2020)

The mean recorded rainfall figure for the period under review was observed to portray a relatively slight increase from 2017 to 2020 as can be seen in Figure 3. High malaria outcomes in expectant mothers were observed to peak in some urban-based Local Government such as Oredo in 2019, with an equally high recorded rainfall figure. This may be attributed to the presence of a good number of open drainages which have become blocked with dirt and stagnant water as a consequence of various road developments in the urban area. Surprisingly, in some other Local Government Areas such as Ikpoba-Okha and Orhionmwon in 2019, there was an inverse relationship. As rainfall increased, malaria dropped. This may be attributed to the fact that rural areas have better coping abilities, perhaps through the intake of regular herbal medicines as revealed in the course of a focus group discussion. However, there may be need for more research to be done on the relationship between rainfall and malaria, in order to uncover other factors that may be responsible for the inverse relationship observed between rainfall and malaria in some Local Government Areas.
Figure 3: Rainfall variation in Edo South (2013-2020)
Source: Centre for Hydro-meteorology and Remote Sensing (https://chrsdata.eng.uci.edu/)

Figure 4 shows the clinical malaria report amongst expectant mothers from 2017 to 2020 in the 7 Local Government Areas of Edo South Senatorial District. In 2017, Oredo was seen to have the highest record of clinical malaria, given as 0.88 per 1000 (699 cases), while Ikpoba-Okha had the least record. In 2018, Oredo again recorded 0.95 per 1000 (756 cases) of malaria amongst expectant mothers with Ikpoba-Okha having the lowest record for that year. In 2019, Oredo had the highest record for the time period with 1.23 per 1000 (979) of clinical malaria amongst expectant mothers, and Ikpoba-Okha had the lowest record, followed by Orhionmwon and Ovia north east.

From close observation, there appears to be some relationship between urbanity/rurality and malaria outcome, as Oredo which is largely an urban area was observed to have the highest malaria record compared to other rural-based LGAs in Edo South. This seems to be in line with a similar study carried out by Wilke et al. (2019), which revealed that urban processes such as gardening, use of flower pots in and around the house, etc., tend to create favorable habitats that promote mosquito breeding grounds. Results from that study revealed that mosquito abundance were more in urban areas compared to rural areas. Another study carried out in Slovakia by Cabanova et al. (2018) also revealed an increase in mosquito-borne infections being associated with urban environments.
In 2020, malaria mortality cases amongst expectant mothers generally dropped. Oredo had a record of 559 cases (0.70 per 1000), followed by Egor with 500. Ovia North-East, Orhionmwon and Ikpoba-Okha had the lowest record of clinical malaria amongst expectant mothers. The general drop in malaria may perhaps be attributed to the lockdown period in that year, where everyone was advised to stay indoors as a result of the corona virus pandemic. Again, Oredo was observed to constantly record a higher malaria morbidity rate amongst expectant mothers. There is therefore need for further investigation and study in order to ascertain why Oredo seems to have a recurrent high malaria morbidity rate amongst expectant mothers. From Figure 4.2, Egor was observed to have the highest level of malaria confirmed in pregnant women, followed by Ovia South-West and Oredo. Ovia North East was followed by Ikpoba-Okha and Uhunmwonde which recorded the lowest figure for malaria in pregnant women.

High malaria morbidity levels observed in Egor and Oredo could be attributed to the fact that they are located in urbanized areas, and these areas usually have open drains which are seldom cleaned out, or worse still, form points for indiscriminate waste disposal which favour the proliferation of mosquito development and spread. On the other hand, Ikpoba Okha which is a largely sub-urban area also has a high level of malaria record after Egor and Oredo, which could be attributed to the presence of open drainages. These drains become are blocked and in no time become stagnant pools which can promote the proliferation of the mosquito lava.

Again the use of Insecticide Treated Nets is very key in malaria prevention as a study carried out by Utzinger and Singer (2001) suggests that malaria spread can be drastically reduced by control interventions involving environmental management and the regular use of treated bed nets (as cited in Nkuo-Akenji, et al., 2006).

Figure 4: Expectant mothers with clinical malaria in Edo South (2017-2020)
Source: Edo State Ministry of Health
Figure 5 shows a summary of malaria morbidity levels amongst expectant mothers in each Local Government Area from 2017 to 2020. It clearly reveals that malaria is higher in Egor Local Government Area. Egor has a record of 5 persons per 1000 cases from 2017 to 2020, while Oredo has 3 persons per 1000 cases. Ovia South-West has 10 persons per 1000 cases, followed by Uhunmwonde and Egor which had 3 persons per 1000 cases respectively. Ikpoba-Okha and Ovia North-East had only 1 person each. Though these morbidity figures may appear small and insignificant, nevertheless, consideration must also be given to the fact that malaria is hardly reported in hospitals and is more often than not treated at home through self-medication. Hence the actual number of reported malaria cases might seem apparently insignificant whereas in reality there is a high malaria morbidity/mortality being experienced but not reported or recorded. Ovia South West, just like Ikpoba-Okha, also has a high malaria record which can be attributed to the high temperature record in the area.

CONCLUSION AND RECOMMENDATIONS

The study was designed to show environmental impact of rainfall and temperature variation on malaria prevalence in expectant mothers in Southern Edo State. Urban-based LGAs such as Oredo was also observed to record the highest malaria outcome amongst expectant mothers in Edo South. This coincided with some past studies carried out in other regions which revealed an association between mosquito abundance and urban areas, which may be the result of urban processes such as gardening, the use of flower pots, etc., most of which are breeding sites for mosquitoes.

It was observed from the study that areas with slight increases in temperature coincided with areas with high malaria outcomes. This therefore means that temperature is a key determinant of malaria outcomes, and as such, has to be kept as low as possible by preventing human activities that can trigger global warming conditions which favor the development and proliferation of the mosquito vector. For this to be achieved there is need for a better awareness and sensitization on the positive relationship between slight increases in temperature and malaria outcomes.
Burning of fossil fuels has to be reduced to a minimum in order to curb global warming conditions. Environmental friendly methods should be embraced, such as the use of bio-gas, etc., rather than firewood, bush burning should also be discouraged. Maps have also helped to identify areas with high malaria incidence, and provide directions for policy in tackling the menace of mosquitoes. Malaria is a very serious disease with a high morbidity/mortality rate. It is also a very common disease; hence there is need for the government to help to subsidize the cost of purchasing reliable and quality drugs for malaria treatment in order to reduce the malaria burden on families.

Areas with high malaria morbidity and mortality should be visited and observed closely in order to ascertain the reasons for high malaria morbidity/mortality levels and provide relevant solutions. Insecticide treated nets (ITNs) can also be distributed on a more regular basis amongst expectant mothers when they go for prenatal follow up in the primary health care centres and hospitals in order to help combat malaria morbidity and mortality.

Mild chemicals can be used in treating mosquito nets in order to encourage the use of ITNs, as some people sometimes complain that they had respiratory and skin reactions triggered off by the harsh chemicals used to treat the nets. The economic situation of the country has also not made things any better. Government needs to win the trust of the people so as to encourage them to take up suggestions on malaria prevention proffered by the authorities; and there may be the need for the government to provide regularly electricity in order to reduce residents’ exposure to mosquito bites when they are driven outside their houses in the evenings in order to seek relief from indoor heat.

**COMPETING INTERESTS**

The authors declare that there are no competing interests.

**REFERENCES**


**ETHICAL CLEARANCE**