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The influence of environmental factors on the prevalence of malaria in Akure metropolis using Geographical information System (GIS)

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Abstract: Billions of dollars have been invested in the development of malaria control measures, but it is still killing hundreds of thousands of people per year in developing countries. In Nigeria, malaria is a major public health problem, it accounts for more cases and deaths than any other country in the world and 97% of Nigeria's population is at risk. This study therefore aimed at studying the influence of environmental factors on the prevalence of malaria in Akure metropolis. The environmental and other factors used in this study were temperature, rainfall, land use/land cover, topography, watershed, age group and settlement patterns, data were collected from Survey and Mapping Division Ondo State, Nigeria. Etrex Hand Held GPS was used to obtain the spatial coordinates. The population data and malaria case data from July 2014 to June 2015 were used in this study. ArcMap 10.3.1 was used to construct the malaria risk map. Prevalence of malaria in the study area is influenced by land use types, watershed, settlement patterns, age group and amount of rainfall. These factors have effects on *Anopheles* mosquito habitats (breeding and resting sites). The hot spot for malaria risk in the study area are Orita-Obele, Araromi, Oshinle and Ondo road. Therefore the output of this study will help to effectively control malaria in the study area and there should be focus on the people around the hot spot area.

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Key words: malaria, prevalence, environmental factors, risk map, hot spot

Introduction

About 90% of all malaria deaths in the world today occur in Africa south of the Sahara. This is because the majority of infections in Africa are caused by *Plasmodium falciparum*, the most dangerous of the four human malaria parasites. In Nigeria, malaria is a major public health problem, it accounts for more cases and deaths than any other country in the world and 97% of Nigeria's population is at risk. The remaining 3% of the population live in the malaria free highlands. It is also because the most effective malaria vector, the mosquito *Anopheles gambiae* is the most widespread in Africa and the most difficult to control (WHO, 2013).

Many studies about malaria were done in different parts of the World. Most of them tried to investigate the ecology of the vector (Smith *et al.,* 2013), efficiency of control measures (Karema *et al.,* 2012; Mackinnon, 2005) and the spatial disease modeling (Hay *et al.,* 2006; Machault *et al.,* 2011). Most of researches described the interplay of biophysical/environmental, social and economic susceptibilities that define malaria risk (Stratton *et al.,* 2008; WHO, 2008). Land-use patterns and agricultural practices combined with the climate and economic driven ecosystems change, are human actions that have favoured the breeding of malaria vectors, exposed populations to infection and facilitated the movement of malaria parasites (Packard, 2007). Indeed, the combination of different factors has favoured the life cycle of the vector and its contact with the host (Stratton *et al.,* 2008).

The biophysical/environmental (climatic and topographic) variables that can determine the regions with high endemicity have been object of different researches (Sipe and Dale, 2003; Zayeri *et al.,* 2011). Anopheles mosquito proliferation depends on environmental factors like temperature, rainfall and humidity in association with vegetation cover and hydrology, especially water bodies (Sipe and Dale, 2003). Altitude is also an important factor and Anopheles mosquito prefers low altitude areas not only because they are characterized by high temperature and humidity especially in tropical regions but also because of their ability to retain water during and after rainy seasons (Fanello *et al.,* 2007).

Geographical information system (GIS) can be described as general purpose computer based technology for handling geographical data in digital form in order to capture, store, manipulate, analyse and display diverse sets of spatial or geo-reference data. It aid in visualization of differences, clustering, heterogeneity or homogeneity within data. The link between climate and medical data has not been well defined, and health information systems have been weak due to the lack of case detection, irregularity in reporting, under reporting and poor coordination. There is need for risk map to draw attention to hot spots and areas where intervention measures can be tailored to improve the monitoring of the occurrence, distribution and control of malaria in the study area (Machault *et al.,* 2011; Hassan *et al.,* 2013).

Materials and methods

Study area

Akure is the largest city and capital of Ondo State, located in south-west Nigeria. Akure lies about 70°15 North of the equator and 50°15 East Meridian. The city has a population of 588,000 which is 0.305% of Nigeria population based on 2006 population census, the people are of Yoruba ethnic group and are situated in the tropic rainforest. The city is a trade center for farmers where cocoa, bananas, palm oil, yams, cassava, corn, cotton and tobacco are mostly cultivated, the residents also engaged in various economic activities such as trading, transportation business, civil service and education.

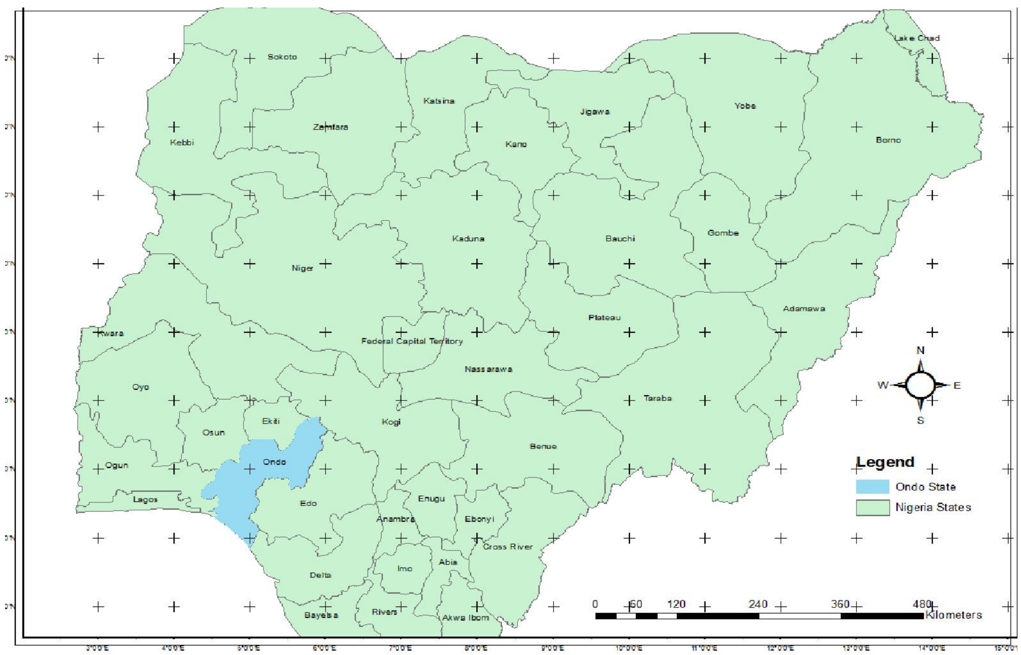

Figure 1: Map of Nigeria showing Ondo State

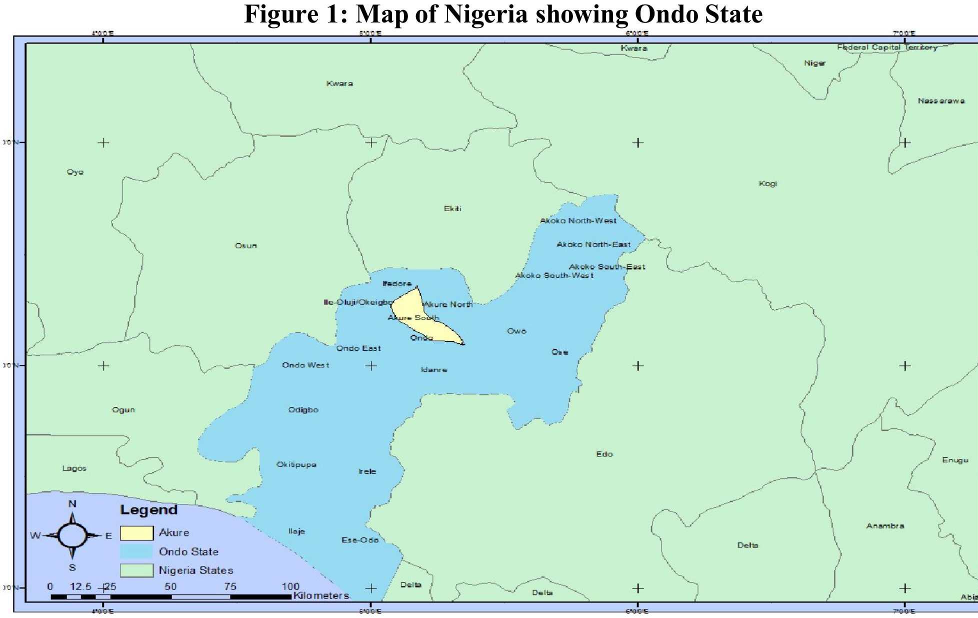

Figure 2: Map of Ondo State showing Akure city

Materials used

A digitalized boundary map of the district (Akure; at scale 1:250,000). Topographic maps (Sheet 0602C1, C3, 0602D2 and D4 at scale of 1:50,000) showing location of settlements of Akure were obtained from Survey and Mapping Division Ondo State, Nigeria. Etrex Hand Held GPS was used to obtain the spatial coordinates. The population data from July 2014 to June 2015 was used in this study.
The Minitab statistical software was used for the graph of relationship between malaria prevalence and temperature/rainfall, Microsoft Excel and GIS software were used.

Malaria prevalence rate

The malaria cases data were obtained from the basic health centres in Akure (Orita-Obele, Araromi, Ounrinboye hospital, Danjuma, Abioye hospital, Ijoka, Don bosco, Odo-Ikoyi), malaria prevalence per hundred (100) people of the population was calculated;
Prevalence = (number of cases / population) x 100

Buffer/overlay operations

The spatial data analysis in GIS was executed using ArcGIS 9.2. The digital map of the district was exported from the Akure topographic map database. A buffer distance of 500m, 1000m, 1500m and 2000m was generated because 2000m is the average flight distance of mosquito (Wim *et al.,* 2003). The combinations of the factors (elevation, rivers/streams and forest cover) were overlaid with the disease rates to investigate the combined influence of multiple factors on malaria prevalence. Assigned weights of 1, 3 and 5 generated the combined risk map using elevation, forest and rivers respectively according to their level of influence on malaria.

Results

Figure 3 revealed the land use/land cover of the study area, the map showed that more of the land area are built up areas and are at the center while the bare surface are scattered, the vegetation covered mostly the extreme end of the study areas and are also scattered within the built up areas.

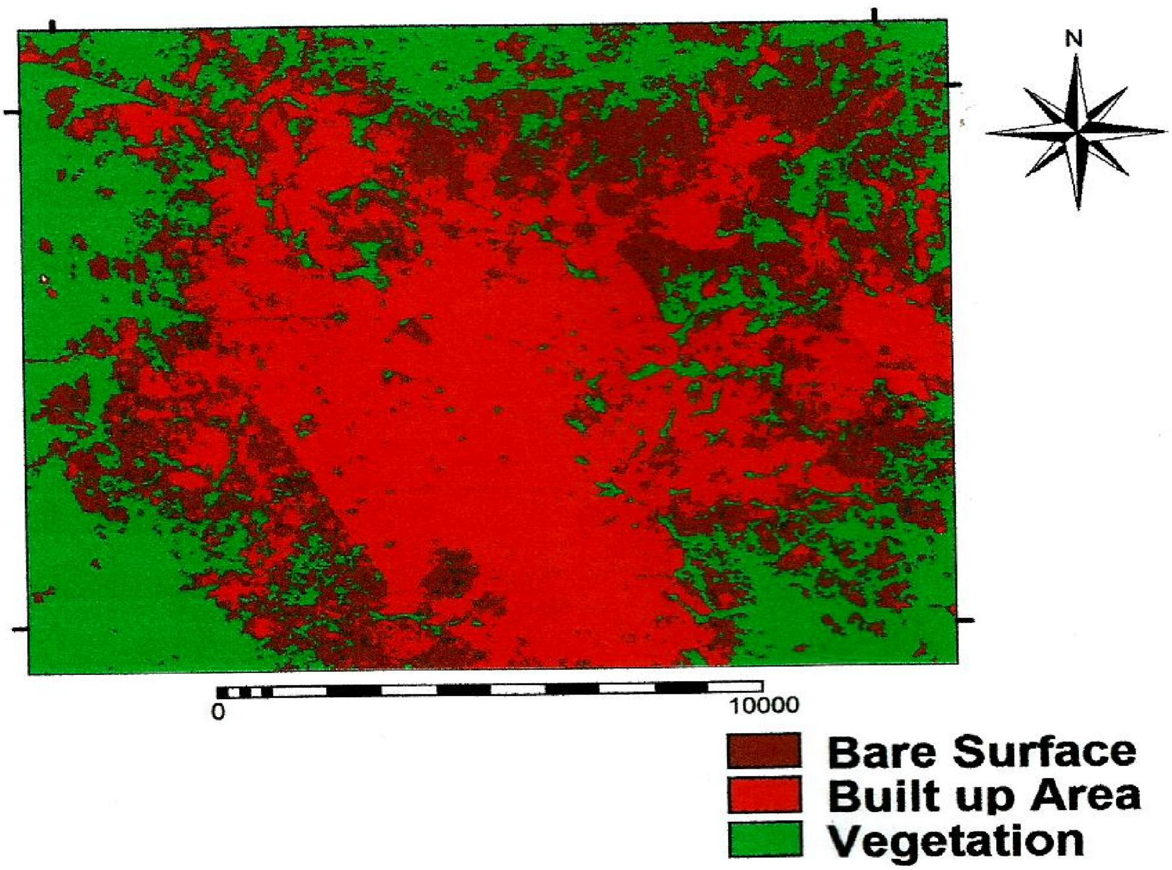

Figure 3: Map showing the land use/land cover of Akure

The result of watershed (rivers and streams) is shown in Figure 4, the map revealed that rivers/streams moved across the built up area, bare surface and vegetation in the study area, however Figure 5 showed the topography of the study area. It was observed that the study area the topography of the study area ranged from 305m to 400m above the sea level, there was high elevation in the North-East, North, West, South-West and at the Southern part of the study area. Figure 6 revealed the settlements pattern of Akure metropolis. The map showed that the settlements are mostly (Oyemekun, Araromi, Oke-Ijebu, Arakale, Alagbaka, Ijapo and Shagarri) located towards the centre of Akure metropolis.

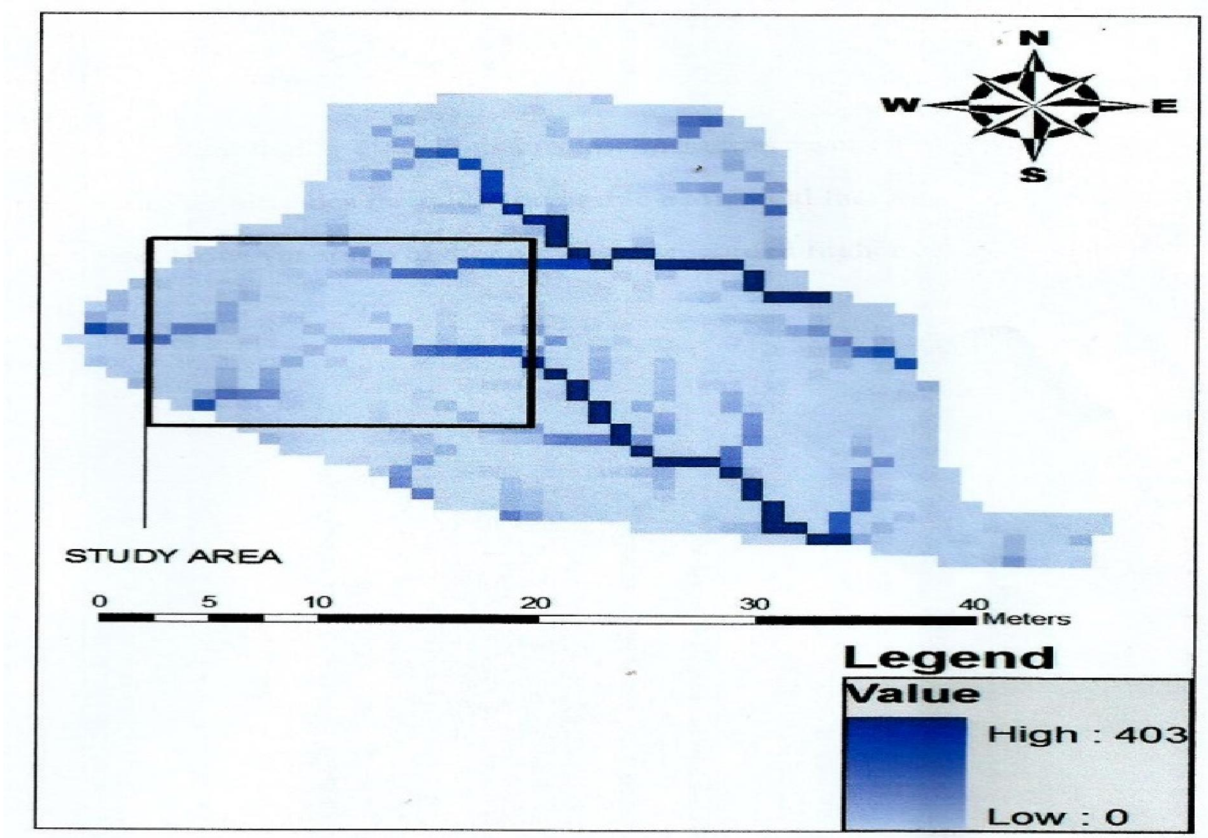

Figure 4: Map showing the watershed area of Akure

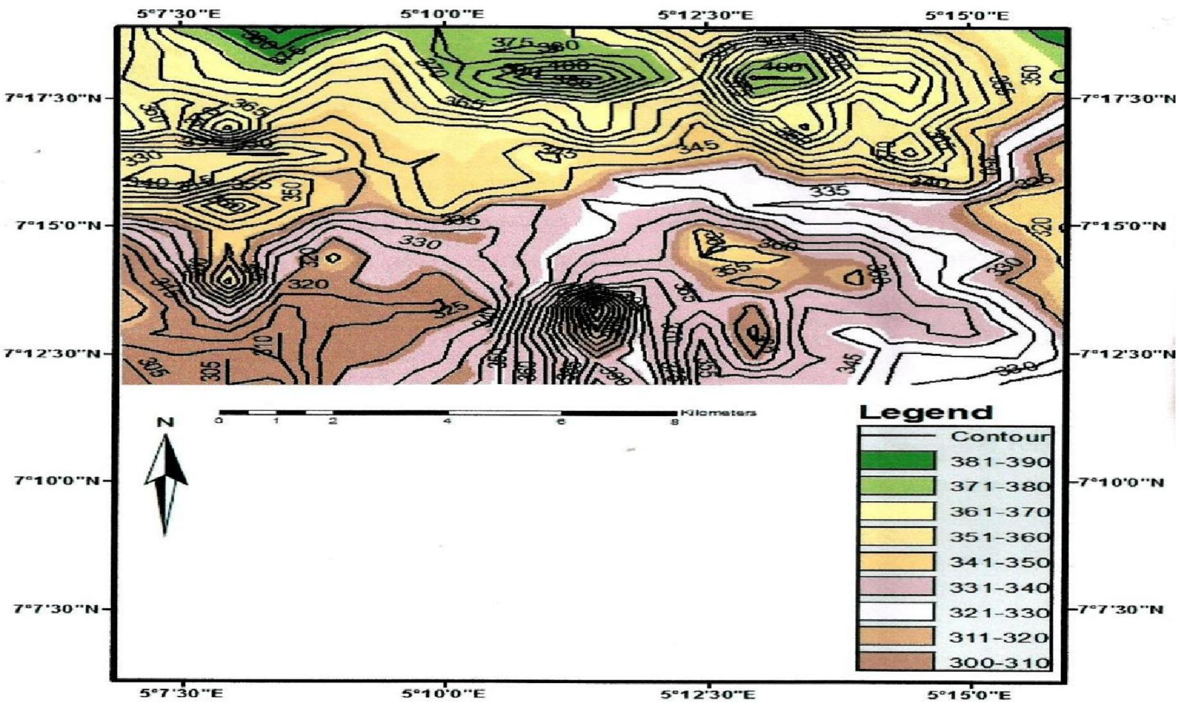

Figure 5: Map showing the topography of Akure

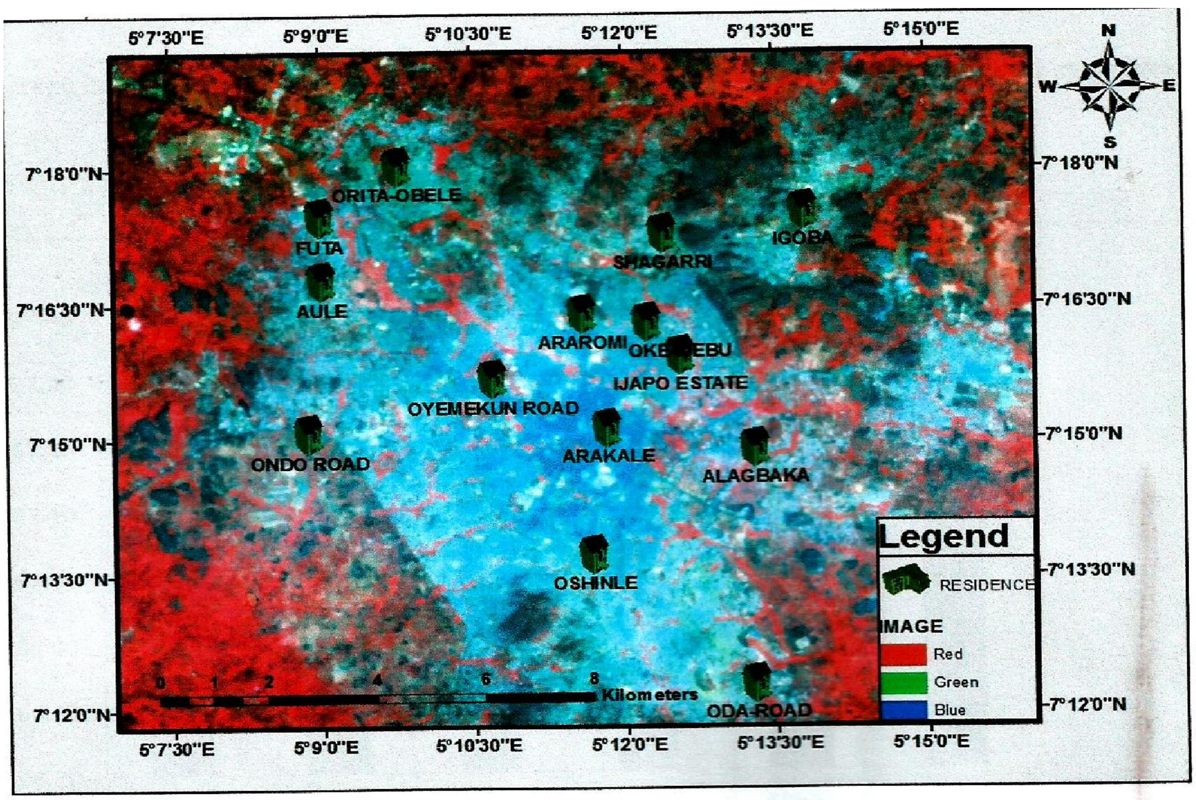

Figure 6: Map of Akure showing the settlements

Malaria prevalence in Akure metropolis risk map is shown in Figure 7, it was observed that the overall prevalence of malaria is very high among the age group 18 – 45 years. Generally, the highest malaria prevalence was observed in Orita-Obele followed by Araromi then Oshinle and Ondo road areas (Orita-Obele > Araromi > Oshinle > Ondo road). Rainfall and malaria prevalence in Akure is shown in Figure 8. The result showed the relationship between the rainfall and malaria prevalence, it was observed that the malaria prevalence gradually increased with increase in the amount of rainfall. Also, the relationship between temperature and malaria prevalence is shown in Figure 9, it was noted that the rise in temperature did not give a corresponding increase in the malaria prevalence.

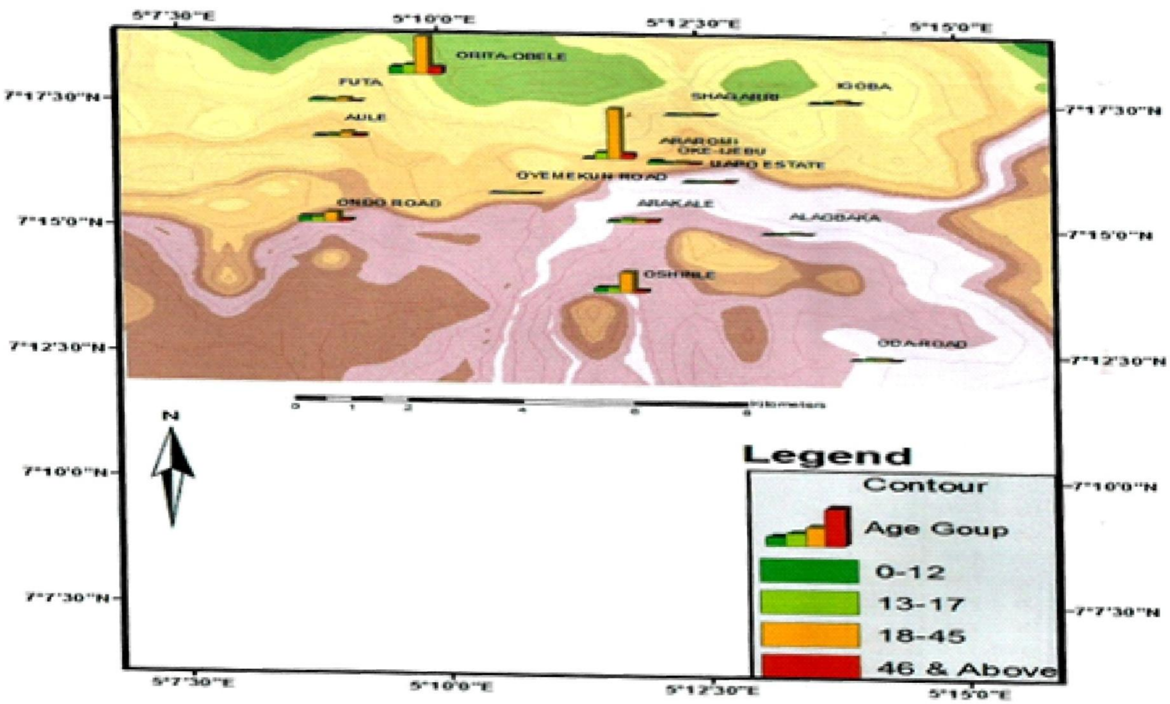

Figure 7: Map of malaria prevalence in Akure metropolis

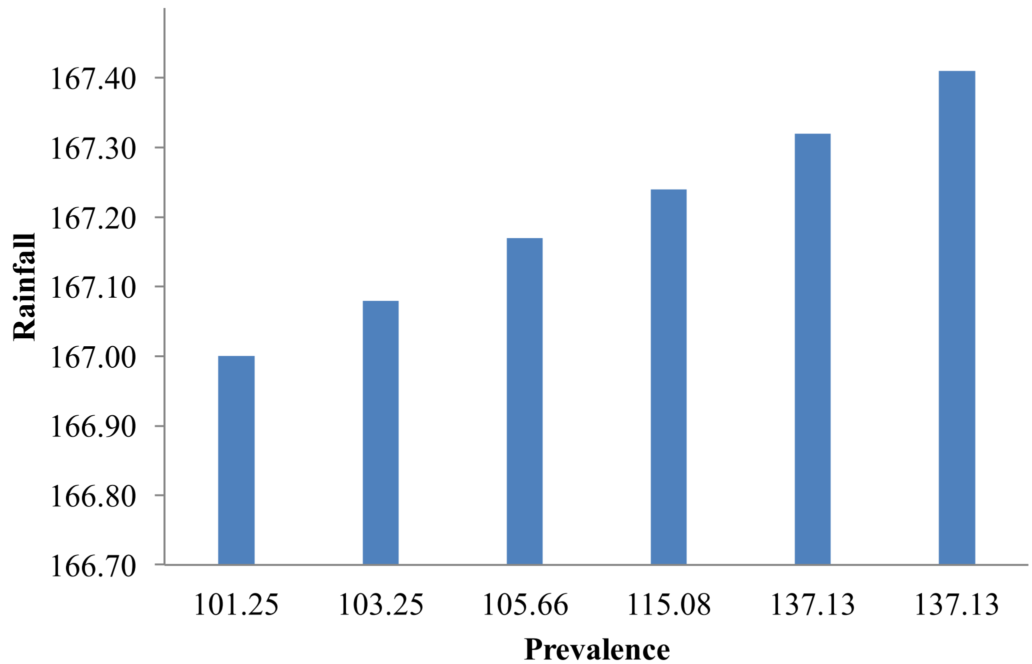

Figure 8: Malaria Prevalence in Akure and Rainfall

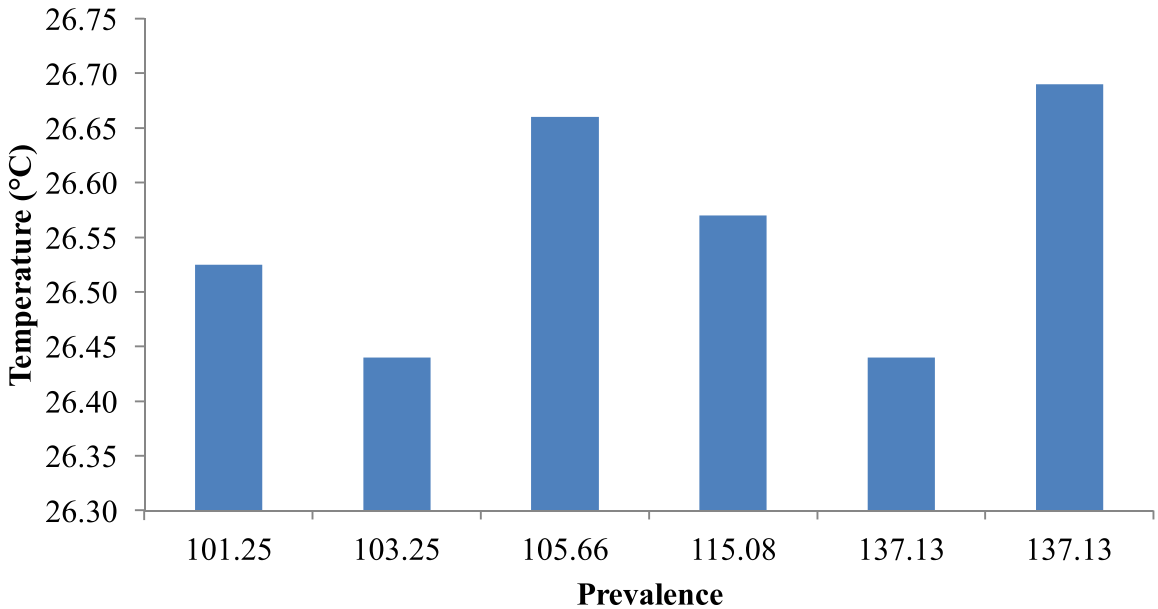

Figure 9: Malaria Prevalence in Akure and Temperature

Discussion

In nature, diseases are not evenly distributed. Malaria is characterized by areas with high prevalence known as hot spots and areas of low prevalence known as cold spots. In this study, land use/land cover showed that there were no malaria case in the area that are well covered with vegetation (outskirt of the study area) compared with built up areas. This may be because the malaria vector (*Anopheles* mosquito) did not have access to man thereby limiting the malaria transmission in the areas that are well covered with vegetation and this corroborate with the report of WHO, 2013; the rate of Malaria transmission is higher in areas where the mosquito lifespan is longer and where it prefers to feed on humans rather than other animals.

This study also showed that within 2.0 km away from the water source (streams/rivers), high prevalence of malaria was observed except for Igoba, Oke-Ijebu, Ijapo and Alagbaka. The high prevalence of malaria within 2.0 km away from the water is due to the fact that mosquito breeds in water and other human activities such as irrigation farming which increases nutrients and temperature which are favorable for the mosquito breeding and larvae survival (Munga *et al.,* 2006; Wielgosz *et al.,* 2012; WHO, 2013) and the low prevalence in Igoba, Oke-Ijebu, Ijapo and Alagbaka despite closeness to water might be due to other factors such as malaria control strategy, level of income, immunity, quality of house material, literacy, life style and so on (Yamamoto *et al.,* 2010; Hassan *et al.*, 2013). High prevalence up to 2.0 km away from water may also be that the mosquitos in the study area have high flight distance. Verdonschot and Besse-Lototskaya (2013) stated that *Anopheles* mosquito average flight distance is around1000 m. However, the flight distance depends on the habits of the species and some species have a stronger dispersal capacity than others.

Altitude plays an important role in the prevalence of malaria because mosquito breed well at low altitude however other environmental factors are needful. The result of the topography showed in this study that the study area has different elevation and however generally has very low distance above the sea level. The highest malaria prevalence was noted at Araromi (345m above sea level), Orita-Obele (370m above sea level), Oshile (365m above sea level) and Ondo road (340m above sea level). Other area with high and low elevation has low prevalence of malaria. Therefore topography might not responsible for the high prevalence of malaria in the study area but may be other factors (temperature, rainfall and humidity in association with vegetation cover and hydrology, especially water bodies (Sipe and Dale, 2003).

This study also revealed that the prevalence of malaria is concentrated towards the centre of the study area, this may have been because the settlements are majorly located at the centre thereby favouring the population density and proximity of uninfected to infected people, according to Bizimana *et al.* (2009), the high risk of malaria is related to the combination of environmental conditions and high population density with poor living conditions. This study also showed that the prevalence of malaria was high in the age group 18-45 years in the study area, high malaria infection noticed in this age group could be attributed to the nature of their job which exposed them to bites of the vectors of malaria and people of this group visit the hospital mostly than other age groups. Daily hustle and bustle involved in commercial activities might cause fatigue resulting in deep-sleep at night which favours the uninterrupted blood sucking tendency of vectors of malaria (Kalu *et al.,* 2012).

The relationship between rainfall, temperature and prevalence of malaria in Akure revealed that rainfall has a direct influence on the prevalence of malaria, that is the higher the amount of rainfall the higher the prevalence of malaria, rainfall make more water available for the breeding sites of *Anopheles* mosquito (Munga *et al.,* 2006; Wielgosz *et al.,* 2012; WHO, 2013). The risk of being infected with malaria will increase as the amount of rainfall increases.

Conclusion

Malaria prevalence in the study area is influenced by combinations of malaria causing factors; prevalence is influenced by those land use types, watershed, settlement patterns, age group and amount of rainfall. These factors have effects on *Anopheles* mosquito habitats (breeding and resting sites). The hot spot for malaria risk in the study area Orita-Obele, Araromi, Oshinle and Ondo road. Therefore there is need to relate the prevalence of malaria in the study area with other biophysical parameters and the output of this study will help to effectively control malaria in the study area.

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