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A Study of Malaria Epidemic Using Geospatial Information Systems (GIS)

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Abstract: ***Malaria has become a major global health problem militating the lives of many people especially pregnant women and children less than five years. It affects 3.5 to 5.0 billion people worldwide with environmental factors contributing enormously to the disease risk. The objective of this research was to create malaria risk maps for the Sekondi-Takoradi Metropolitan Assembly for focused intervention by Stakeholders. The results showed an average decrease of 6% from 2012 to 2013 and a decrease of 24.5 % between 2013 and 2014. The disease was seen to be very high at the forested areas and areas close to water bodies compared to the plains and the non-forested areas. Nonetheless, it was observed that though malaria incidences increases during rainy seasons, continual heavy rainfall patterns decreased malaria incidences in some areas as the eggs are washed away.***

Key words: STMA, Malaria, Anopheles Mosquito

1. Introduction

Malaria is a tropical disease caused by a parasite genus Plasmodium. In Africa, the predominant species of the disease-causing parasite is Plasmodium *falciparum*. Infection of the human host occurs when a person is bitten by a female Anopheles mosquito that has previously become infected [1, 2].

According to [3], the parasites multiply in the liver and re-invade the blood via Red blood cells. The disease is bound to conditions which favour the survival of the anopheles mosquito in terms of habitat and breeding sites [4-7]. Malaria has always been the most significant public health threat to communities in Ghana and Africa largely [7]. It remains the leading cause of death in children under five years in Africa [8]. Malaria is one of the killer diseases in tropical and subtropical countries. It therefore poses a serious health problem to these countries including Ghana [9]. The disease can be considered to be a disease of the poor because its prevalent rate is very high in poor tropical countries [10, 11].

In recent times, malaria cases have aggravated militating the lives of many Ghanaians especially the aged (seventy and above years) and children under five years as well as pregnant women [2, 3, 7].

It is been estimated that economic growth per year of countries with intensive malaria was 1.3% lower than that of countries without or with less malaria incidences [12]. In Ghana, the peak period of malaria transmission occurs during the rainy season and often coincides with the peak period of agricultural activities such as planting and harvesting, thus, hindering the economic development of the affected [8, 9]. According to the National Malaria Control Program (NMCP) [13], Ghana in 2013 recorded about 11.3 million malaria cases at Outpatient Departments (OPD). On average 30 300 of such cases were attended to each day in the country's health facilities [1, 3].

A lot of resources including time, money, man-hours just to mention but a few have gone down the drain in the course of treating malaria. The Government of Ghana spends so many resources in controlling and curbing malaria incidence through mass chemical spraying, distribution of mosquito treated bed nets, subsidised treatments and many others [7, 14].

According to the World Health Organisation Malaria report [1, 13, 15], between 23 000 and 37 000 people die of malaria in a year worldwide with Africa totalling 90% and 10% for all the other continents. This results in reduction in economic productivity of the individuals because of malaria infections. Based on these circumstances, spatio-temporal information and trends of the transmission are required for effective forecasting of likely malaria prone areas [16-18].

A lot of research has been done relating to modelling and prediction of malaria episodes [3, 16, 17, 19]. For instance, [20] combined field data, satellite images analysis and GIS modelling to develop high resolution maps of malaria entomological inoculation rates in The Gambia, West Africa when designing vaccination trials. The analyses were based on variations in exposure to malaria parasite experienced in 48 villages from 1996 and 27 villages in 1997. The entomological inoculation rate varied from 0 to 166 infective bites per person per rainy season. It was concluded that the model developed predicted the trends in the severity of the disease and the spatial maps created also helped in locating places that needed critical attention in terms of drugs thereby saving time and resources.

Furthermore, environmental factors such as elevation, slope and distance to streams as well as topography and rainfall that make the condition suitable for breeding, outbreak incidence, maturity and development of the plasmodium parasite were combined to produce Malaria Risk Maps of areas (Districts) in Ethiopia using Multi-Criteria Evaluation [21].

Moreover, Poisson and Negative Binomial Regression and other known statistical models were used to assess malaria episodes in Obuasi, Ghana between children, adults and the aged (both male and female) on quarterly basis [3]. It was concluded that the model fits best when the Negative

Binomial was used. It was also established that the malaria episodes were most predominant among children especially those under five years and the pregnant women between the months of January and March [3].

Research has shown that there is the need to monitor closely the trend in malaria cases. Hence, adopting concise methods capable of predicting the trends and produce maps of risk areas of malaria disease could save the country and the individual appreciable resources [22]. This research seeks to predict trends of malaria episodes and show endemic areas in the Sekondi Takoradi Metropolitan Assembly (STMA).

The objective of this research is therefore to determine risk areas in STMA also to predict the trends of malaria incidences in the study area.

2. Materials and Methods

2.1. Study Area

STMA lies between 04° 55' N and 01° 46' W. The Metropolis is located on the South-western part of Ghana, about 242 km west of Accra, the capital of Ghana. It is also approximately 280 km from Cote D'Ivoire border in the west [23, 24]. It is bordered by Ahanta West District to the west, Shama District to the east, Mpohor Wassa East District to the north and the Gulf of Guinea (the Atlantic Ocean) to its southern border. It has a total land area of 385 sq. km The Metropolis is a tropical rainforest area with an estimated population of 559 548 [25]. Agriculture such as fishing and growing of perishable crops is on minor scale. However, majority of the citizens engage actively in industrial work such as Cocoa Processing, Crude oil, Hospitality Industry and many others. hwindo and Pra rivers and their tributaries drain the Metropolis [26] (Figure 1).

2.2. Data Acquisition

Data for the study include; a five-year malaria recorded cases from Sekondi-Takoradi Metropolitan Information Health Unit (IHU), Population and Housing Census Data of individual towns, Rainfall and Temperature data from 2012 to 2016 and the coordinates of individual towns were obtained using GPS receiver.

2.3. Method Used

Malaria prone areas in the study area were delineated using risk maps. The procedure adopted to achieve this objective is summarised as follows.

2.3.1. Data Validation

Data validation was undertaken to ascertain the accuracy and reliability of the primary data obtained. The GPS receiver was used to pick coordinates of the hospitals and the towns.

These were plotted on the base map to check their corresponding locations on the map. Points representing the location of the hospitals and the towns were analysed to ensure they fall within acceptable accuracies.

2.3.2. Data Processing

Recorded malaria cases for the year 2012 to 2016 in the various health facilities in the Metropolis were reduced into major disease occurring in the various towns in the Metropolis. The ten semi-annual data (five-year data) were merged to create a single database for further analysis. The locations of the towns were linked with the health records which were later used for analysis in ArcGIS 10.1 environment.

2.3.3. Risk Map Creation

Maps showing the extent of the spread of the disease were created by using ArcMap 10.1. The digital map of STMA was exported from the topographic map database. The river/stream, the towns (their coordinates) were in the War Office coordinate system which lies in zone 30 N and clipped to fit the study area. This creates a raster dataset. The vector data (shapefiles) for towns were then created to show the individual boundaries (imaginary).

The raster dataset and the malaria recorded cases obtained from the IHU were categorised into towns and then overlaid in a GIS environment. A buffer of 500 m radius was created around them. The malaria datasets were then categorised and classified into ten (10) classes for easy analysis.

2.3.4. Trends of Malaria

The trends of malaria of the towns in the study area were obtained by calculating the rate of prevalence of the disease per hundred (100) persons, thus;

Rate of Prevalence =

$$\frac{Total\ Malaria\ cases}{Total\ Population} \times 100\ individuals.\ [17]$$

This was done for malaria recorded cases from 2012 to 2016 in STMA. In order to

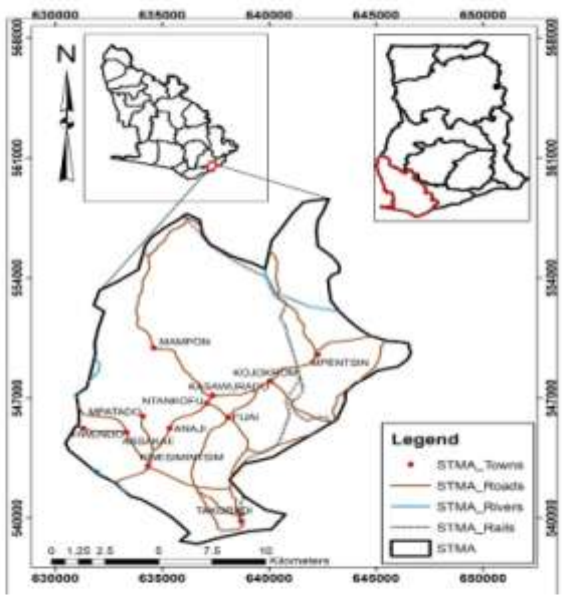

Figure 1: Map of STMA

3. Results and Discussions

The risk map created highlights the areas of high risk that need to be identified so as to tailor major interventions and monitoring activities. After analysing the data obtained, the location coordinates of the towns and the reported malaria cases were plotted on STMA map. The reported malaria cases in the various health centres within the Metropolis that constituted major disease from the various towns were displayed on the STMA map for each of the health centres considered. The risk maps of malaria in the study area are shown from Figure 2 to Figure 6. A drastic rise of the disease was observed in 2013. There was an average risk of the disease in communities further away from the Metropolitan capital.

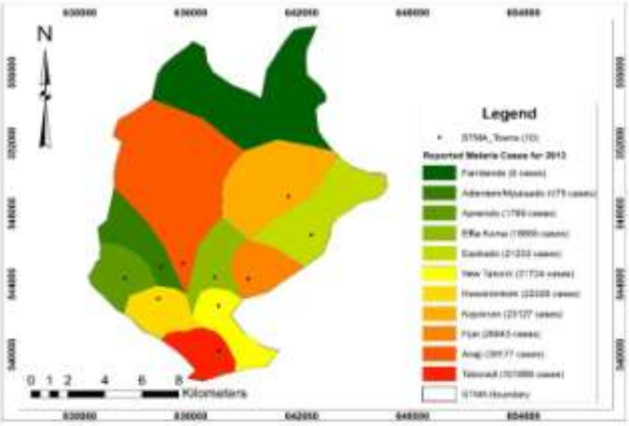

Figure 2: Reported Malaria Risk Map for 2012

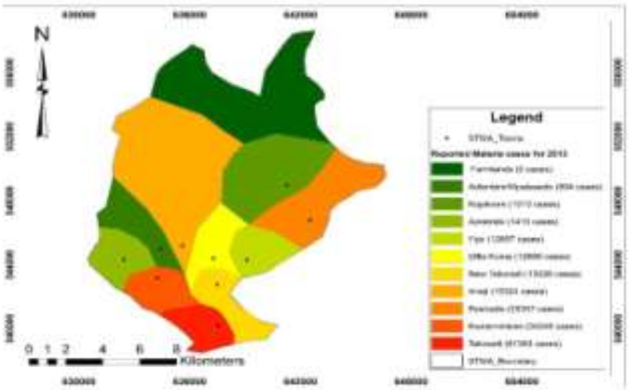

Figure 3: Reported Malaria Risk Map for 2013

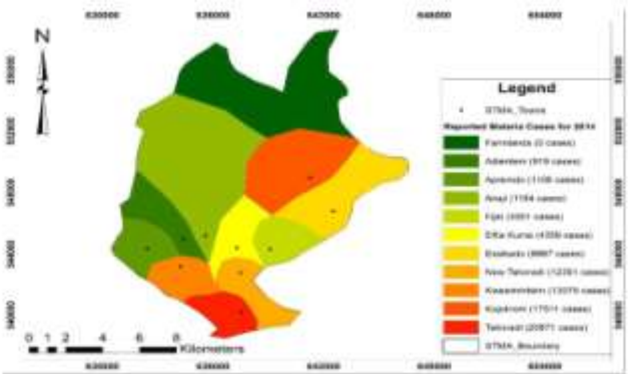

Figure 4: Reported Malaria Risk Map for 2014

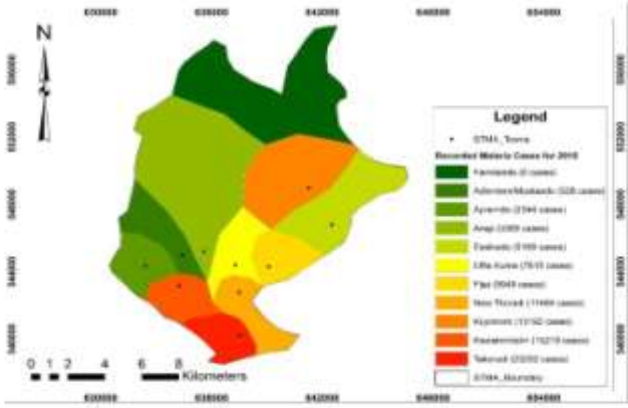

Figure 5: Reported Malaria Risk Map for 2015

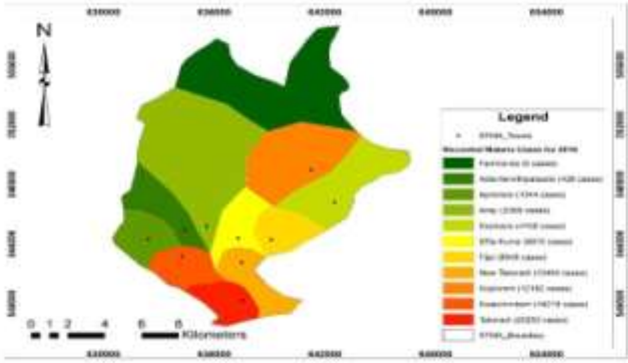

Figure 6: Reported Malaria Risk Map for 2016

3.1. Trends of the Disease

The trend of the disease was determined by using the Rate of Prevalence thus finding how fast the disease is spreading among hundred (100) people out of the total population. The following results were obtained from Figure 7 to Figure 14.

There were high incidences recorded in some areas especially New Takoradi, Takoradi, Kojokrom and Fijai as well as Kwesimintsim. The results also showed that some areas such as Apremdo, Essikado and Adiemtem had nearly stagnant reported cases.

There was generally a fair decrease in the malaria risk from the year 2012 to 2013. Malaria cases reduced averagely by 5.97 % (approximately 6 %) from 2012 to 2013 and by 24.5 % during the period 2013 to 2014. There were many areas reporting low risk in the recurring years.

The disease was very high at forested areas and areas close to the sea [7, 27] such as New Takoradi, Kojokrom, Fijai and Takoradi compared to the plains and non-forested areas within 1 km to 3 km. These areas serve as the major breeding grounds for the vector anopheles mosquito thereby increasing the disease prevalence. According to [7], mosquitoes that live in forested zones tend to live longer and healthier than those that live in deforested zones (highlands) in both rainy and dry seasons. They have shorter life cycle thereby producing more eggs and reproducing very fast. It is not surprising that the areas closer to the forest zones and the sea (mangrove areas) recorded the most incidence of the disease.

Moreover, the prevalence of the disease is always necessitated by factors such as rainfall and temperature. The results showed that rainfall had decreasing effects on the disease prevalence. This is because there were a major increase in the mean rainfall recorded between 2012 and 2016 which resulted in a decrease in the recorded cases since too much rainfall does not promote the survival of eggs of the mosquito rather it washes them away [7]. However, the results of effects of temperature on malaria prevalence did not show any pattern of the disease.

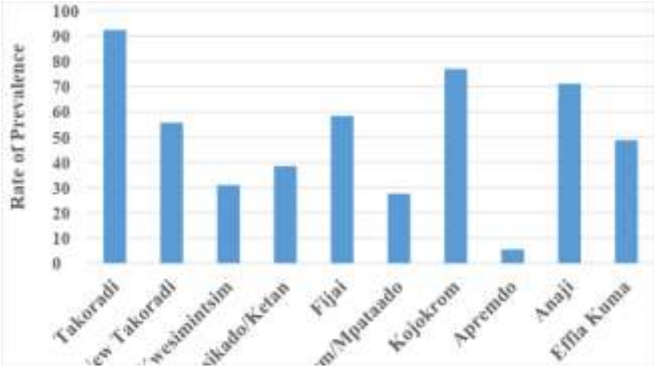

Figure 7: Trend of Malaria in 2012

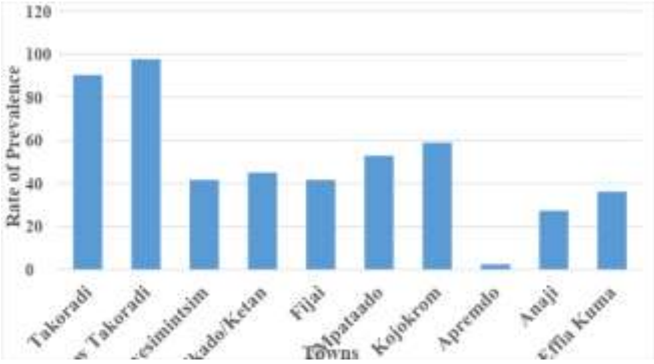

Figure 8: Trend of Malaria in 2013

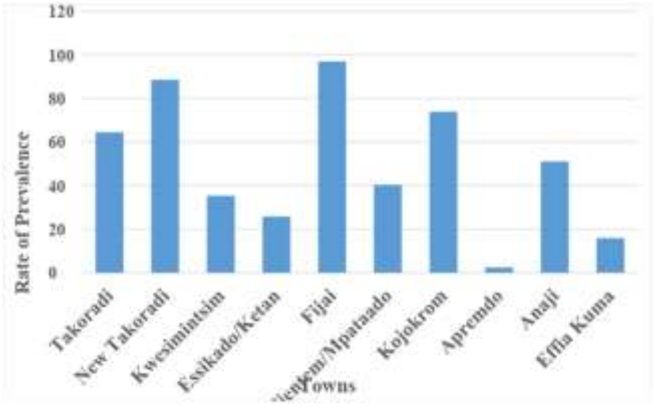

Figure 9: Trend of Malaria in 2014

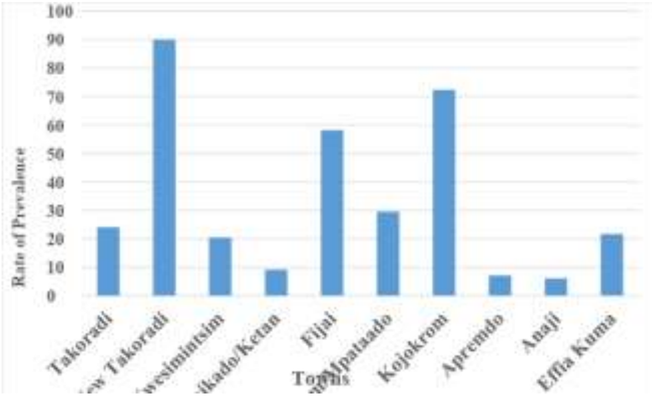

Figure 10: Trend of Malaria in 2015

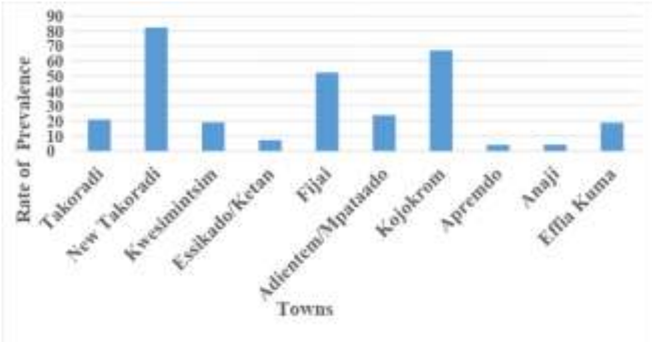

Figure 11: Trend of Malaria in 2016

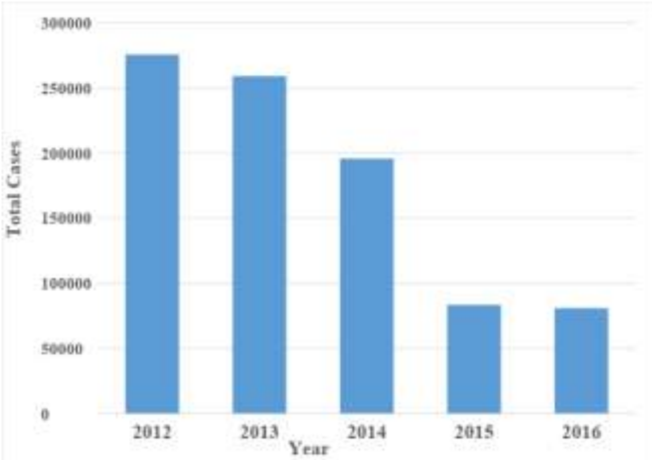

Figure 12: Overall Trend of Malaria in 2012 to 2016

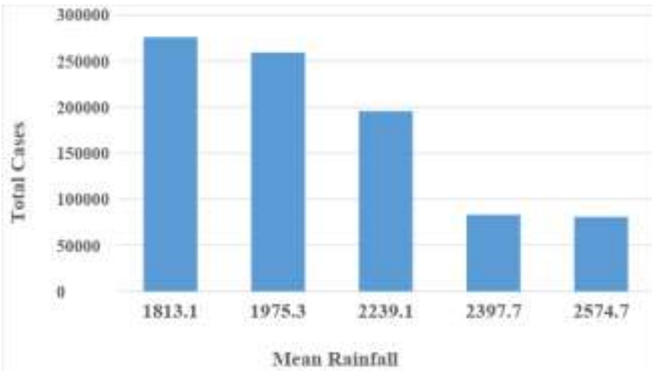

Figure 13: Effects of Rainfall on the Disease

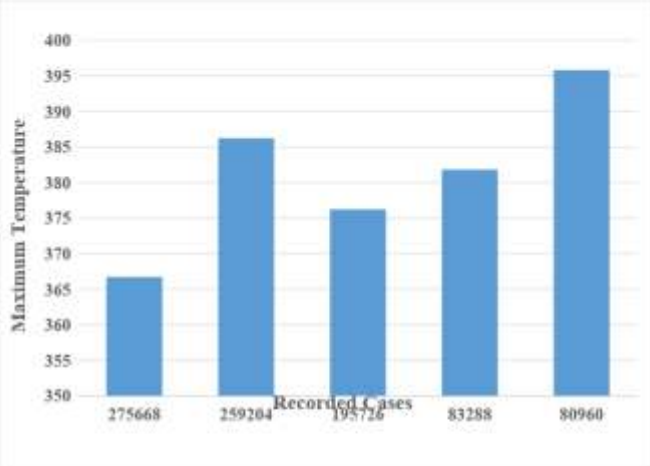

Figure 14: Effects of Maximum Temperature on the Disease

4. Conclusions

The malaria risk maps produced showed that some communities were more at risk especially communities very close to the Metropolitan capital. The results showed an average decrease of 6% from 2012 to 2013 and a decrease of 24.5 % between 2013 and 2014. The disease was seen to be very high at the forested areas and areas close to water bodies compared to the plains and the non-forested areas. Areas nearer to the Gulf of Guinea (the sea) and the forest belt thus 1 km to 3 km away, recorded relatively the highest cases of the disease because they possess all the factors that favour the survival and the breeding of anopheles mosquitoes.

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