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Geospatial Mapping of Malaria in the Lowland Forest Ecological Zone of Ondo State, Nigeria

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Abstract

Purpose: This study analyzed the spatial and temporal patterns of malaria occurrence in Ondo state, Nigeria, and to identify the major factors influencing the disease transmission and control.

Methodology: The research collects primary data from questionnaires administered to hospital staff and workers in areas with high malaria cases while secondary data were sourced from the State's ministry of health malaria cases gazette. The data was sorted, processed, and analyzed using Microsoft Excel and ArcGIS 10.2 software to produce maps and graphs showing the malaria occurrence and trends in the study area.

Findings: The study analyzed the malaria occurrence and trends in Ondo State, Nigeria, from 2011 to 2018, using questionnaires and secondary data. The result revealed that mosquito, blood group, poverty, and communicability were significant factors for malaria incidence ($p < 0.001$), while seasonality, time of day, and immunity status were non-significant ($p > 0.05$). Result shows that malaria could be transmitted from mother to child during childbirth ($p=0.008$), but mortality was non-significant in the three Local Government Areas (LGAs) studied ($p = 0.166$). In addition, malaria cases and attack rate declined significantly from 2015 to 2018, due to the improved health facilities and preventive measures implemented by the State government and health authorities

Unique contributor to theory, policy and practice: The study contributes to the existing knowledge and literature on malaria epidemiology and control in Nigeria, by providing a comprehensive and updated spatial and temporal analysis of the disease occurrence and factors in Ondo state. The study also provides useful recommendations for the state ministry of health and government to conduct further studies and develop strategies to interrupt malaria transmission in low susceptible settings, and to achieve the goal of malaria elimination in the state in line with global setting.

Keyword: *Malaria; Urbanization; ANOVA; Geospatial; World Health Organization*

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1.0 Introduction

Malaria, an unrelenting and widespread vector-borne ailment, poses an enduring health challenges in numerous tropical regions around the globe (W.H.O, 2020). Current research has highlighted the intricate interplay between pathogens, hosts, and the environment as a pivotal factor influencing the emergence or resurgence of various diseases. Additionally, changes in population demographics and social structures, including factors such as population growth, urbanization, globalization, the interconnectedness of trade, frequent travel, and close proximity to livestock, have been firmly connected to the resurgence of diseases transmitted by vectors (Chala and Hamde, 2021). Nestled within Nigeria's tropical ecosystem, Ondo State epitomizes this global health challenges. Its abundant biodiversity and favorable climate create an ideal habitat for the propagation of malaria-carrying mosquitoes, notably the Anopheles species (Olusi *et al*., 2021). Consequently, gaining insights into the spatial distribution of malaria within Ondo State becomes of utmost importance for effective disease management and the implementation of targeted public health interventions.

Some identified challenges of malaria in tropical ecological zone of Ondo state include: (i) The lack of spatial information on the breeding sites of mosquitoes which may worsen the incidence of the disease. (ii) An estimated 65% of Nigeria's population are experiencing poverty and this is a major factor in malaria prevention and treatment. (iii) There have always been reported cases of malaria especially during the rainy season in local government areas within the lowland forest ecological zone such as Akure, Idanre, Ifedore and Ondo town from various medical authorities. (iv) There is no map showing the cases of malaria occurrence in all local government areas in Ondo state.

The aim of this research is to showcase how geospatial techniques can be applied to map malaria in Ondo state with a view of reducing its occurrence if not totally eradicated. The following research questions provide the impetus that enables the research aims to be achieved: (i) Why is the need to produce malaria incidence maps of local government areas in Ondo state? (ii) What are the major factors responsible for malaria in local government areas in Ondo state? (iii) How can malaria be controlled in the selected local government areas of the state? Thus, geoinformatics technology can obviously fill gaps of knowledge about the effects of urbanization and malaria (Tatem *et al*., 2004).

1.1. Background Background

Malaria poses serious economic, social and health burdens in tropical and subtropical countries where it is widely acknowledged that the malaria transmission dynamics are closely related to socioeconomic, climatic and environmental factors; the latter including altitude, precipitation, temperature and land use and land cover. Malaria has, therefore, been defined as an environmental disease (Hay *et al.,* 2000). About 70-90% of the risk of malaria is considered due to environmental factors which in turn influence the abundance and survival of the vectors (Bousema *et al.,* 2010).

Hence, a deeper knowledge of environmental variables, conducive to mosquito vector life cycle, is important to target control interventions. Modelling environmental variables are very valuable in defining foci of malaria transmission. The development of spatial analytical techniques has created an avenue to evaluate environmental variables that are generated by remote sensing satellite sensors and captured by Geographic Information Systems (GIS) for spatial and temporal environmental analysis (Tatem *et al*., 2004).

2.0 Literature Review

Many scientists are dwell to shape out the predominant factors causing malaria and hence prone area vulnerable to risk and hazard in our surrounding environment but have faced challenges in many faces with one issue or the other in other to verify if their research is on the right face. Here are a few scientists who carried out few research on malaria outbreak:

Shirayama (2009), explore the impact of the intervention coverage and people's adherence to the intervention on malaria health outcome among targeted villages in various geographic locations, Geographic information system (GIS) maps were developed using the data collected in an active case detection survey in Khammouane province, Laos. The survey used a rapid diagnostic test (RDTs) and a structured questionnaire at 23 sites in the province from June to July, the rainy season, in 2005. A total of 1,711 villagers from 403 households participated in the survey. As indicated on the GIS maps, villages with malaria cases, lower intervention coverage, and lower adherence were identified. Although no malaria case was detected in most villages with the best access to the district center, several cases were detected in the distal villages, where the intervention coverage and adherence to the intervention remained relatively lower. Based on the data and maps, they demonstrated that malaria remained unevenly distributed within districts balancing the intervention coverage in the distal villages with the overall coverage and continued promotion of the proper use of ITNs are necessary for a further reduction of malaria cases in the province.

Ahmed (2015), work on integrating malaria data into decision support system (DSS) using GIS and remote sensing tools. His study attempted to asses and produce maps of malaria prone areas including the most important natural factors. The input data were based on the geospatial factors including climatic, social and Topographic aspects from secondary data. The objective of his study was to prepare malaria hazard, vulnerability, and element at risk map which give the final output, malaria risk map. The malaria hazard analyses were computed using multi criteria evaluation (MCE) using environmental factors such as topographic factors (elevation, slope and flow distance to stream), land use/ land cover and Breeding site were developed and weighted, then weighted overlay technique were computed in ArcGIS software to generate malaria hazard map.

Abdulkareem *et al.,* (2017) exploits the integrated approach of Remote Sensing and GIS in Epidemiology with the aim of generating malaria risk map of Akure with a view to determining

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the degree of vulnerability of the study area and reducing the malaria incidence through appropriate medical intervention. Their objectives are to generate a mean malaria incidence map of Akure, Analyse the factors responsible for the mean malaria distribution (i.e. Hazard map) of Akure and finally to generate Malaria Risks Map. The mean monthly malaria data across the 23 electoral ward was interpolated using the Inverse Distance Weighted (IDW) techniques. The Hazard map was generated using the multi criteria evaluation. Their study recommends the establishment of health centers should be made at high and very high-risk areas at reasonable distance away from the existing health facilities so that people at a distance can easily access the service.

Li *et al*. (2008) mapped the distribution and abundance of mosquito vectors in the highlands of West Kenya using spatial modelling methods; in their study, three environmental variables namely, wetness index, distance to high-order streams, and distance to low-order streams were used to describe the density and abundance of mosquitoes. They used spatial lag model confirmed that houses situated close to high-order streams were identified as an effective predictor for the distribution of adult mosquitoes. GPS was also used to collect points where mosquito larva was sampled, and the field data were integrated with remote sensing data in ArcGIS (ESRI, Redlands, CA, USA). Bivariate and multivariate logistic regression models were used to identify the characteristics of a breeding site which is associated with increased risk of larvae presence. The study findings revealed that most positive sites were associated with temporary standing water around channel edges of the main Nile River. Close to the Nile channel, a distinct seasonal pattern in larval populations was evident and appeared to be linked to changes in water level.

Abellana *et al*. (2008) studied the seasonal effect on the spatial distribution of malaria incidence in a group of children less than 10 years old living in Manhica district in Mozambique; they used poisson regression analysis to assess the relationship between malaria incidence and the covariates: sex, age groups, and climate season. Their results revealed that there is a clear spatial pattern, with a higher incidence in the neighborhoods situated in the north and northeast of the Manhica district. Also, malaria transmission decreased with age and was highest during the wet season, but the spatial pattern of malaria did not differ from that observed during the dry season

Robert *et al* (2019) employed Model-based geostatistical methods to analyze, predict and map malaria prevalence. Their result shows that there is a significant association of malaria prevalence with area of residence (rural/urban), age, indoor residual spray use, social economic status and mother's education level. Overall, parasitaemia prevalence among children under 5 years old for the year 2016 is low albeit characterized by "hotspots" in specific areas. Also, their risk maps indicate the spatial heterogeneity of malaria prevalence. They recommended that high resolution maps can serve as an effective tool in the identification of locations that require targeted interventions by programme implementers.

Yeshiwondim *et al*., (2009) mapped malaria incidence at village level in an area with unstable malaria transmission in central part of Ethiopia. These authors developed a structured village global positioning system (GPS) survey questionnaire that was used to record the location information and other relevant demographic data. After calculating a malaria incidence density of 1000 people per year for each geo-referenced village, a spatial clustering method was used to map malaria incidence. Mapping malaria incidence and/or prevalence have led to growing interest in modelling the association between malaria incidence and/or prevalence and other potential related variables.

Noor *et al*. (2008) produced a continuous map of malaria prevalence across Somalia based on a dataset obtained from a national malaria cluster sample survey in 2005 and routine cluster survey in 2007. The map revealed that malaria transmission in Somalia varied from hypo- to meso-endemic. The map explicitly illustrated that malaria prevalence in Somalia was primarily located near Juba and Shabella rivers.

In Mali, Sogoba *et al*. (2007) conducted a study to identify environmental determinants for the spatial and temporal relative frequency of *A. gambiae s.s.* and *A. arabiensis* mosquitoes with the principal objective to produce spatio-temporal distribution maps. The relative frequency of these mosquito species was computed from the collated larvae in the study area. Ecological variables such as temperature, rainfall, and soil water index at 5 x 5 km spatial resolution, land use and land cover at 1 x 1 km spatial resolution, and the normalized difference vegetation index (NDVI) at 8 x 8 km spatial resolution were extracted for the study area from existing continental datasets. Logistic regression was applied to identify the environmental variable which determines the relative frequency of *A. gambiae s.s.* and *A. arabiensis* mosquitoes. Soil water index, and minimum and maxima temperatures were significantly associated with the relative frequency of *A. gambiae* and *A. arabiensis*. Finally, a Bayesian geo-statistical model was used to produce maps of the spatial distribution of these species.

Therefore, the review of literature confirmed that remote sensing methods and Geographical Information System (GIS) can be used for mapping malaria with respect to reducing its occurrence in the environment. However, there have not been any major research on malaria in the study area using geospatial techniques; this is the gap this study wishes to fill.

3.0 Materials & Methods

3.1 Study Area

The study area (Figure 1) is Ondo State, a coastal state in southwestern Nigeria with a total of 15,500km^2

(6000sq ml). The state comprises of eighteen (18) Local Government Areas and has a projected population of 4,011,407 as of 2023. The capital and the largest city of the state is Akure, while other major cities include Ondo town, Owo, Ore, and Ikare Akoko. The state lies on coordinates between latitude 6˚ 0' 0" and 7˚ 30 ' 0 " North of the Equator and longitude 4˚ 30 ' 0 " and 6˚ 0 ' 0 " East of the Greenwich Meridian. It has a tropical climate with an annual rainfall of about 1524mm and a temperature range of 28˚C and 31˚C. The state has a lowland relief along the coast and a highland relief in the interior, with the highest point being Idanre Hill at 900m above the sea level. The main occupation and source of income of the people of Ondo State is agriculture, as the state produces various crops such as cocoa, oil palm, rubber, cassava, rice, maize, yam, plantain, and cashew. The state also has abundant mineral resources such as oil and gas, bitumen, limestone, kaolin, coal, and granite, which contribute to its industrial and economic development. It also has a rich cultural and natural heritage, with attraction such as natural parks, waterfalls, caves, festivals and historical sites.

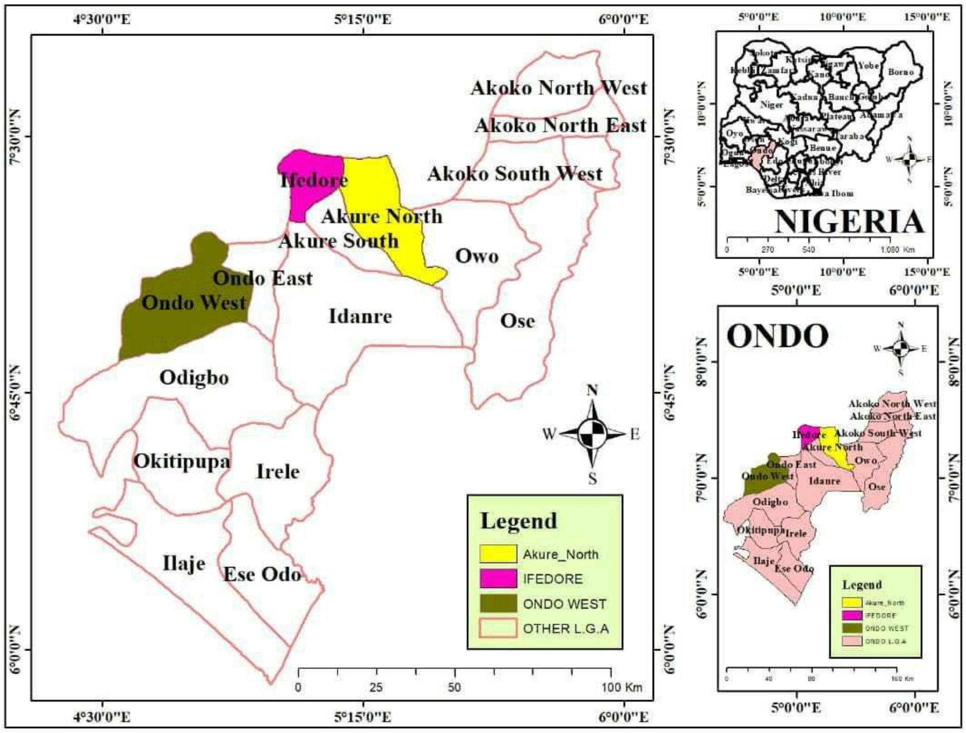

Figure 1: Map of Ondo State

3.2 Data Collection and Processing

Data and materials adopted for this research were classified into two categorical classes viz: primary and secondary. The primary data for the project was obtained through questionnaires distributed to staffs and other workers in hospitals in areas that have high reported malaria cases, i.e. Igabara-oke in Ifedore local government area, Oba-Ile in Akure-North local government area and Ondo West local government area with each area located within the lowland forest ecological zone in the state. A total of 300 questionnaires were distributed to the respondents living in areas close to hospitals; 100 questionnaires per local government area, which was complemented by personal interviews especially at the initial stage of the data collection. 283 questionnaires were retrieved and processed. The selected local government area were purposively selected based on proximity to the state capital, easy access to malaria case files/data and the presence of health center that were in the same category and the respondents were selected randomly. Their demographic information was assessed and information on malaria incidence from 2011- 2018 such as, different cases of malaria, its effect and when and where it occurs the most were acquired from respondents. The interviews allowed explanation of issues in the questionnaire in areas where some respondents may not be fully knowledgeable. While secondary data which was used for map production was obtained from Ondo state ministry of health malaria cases gazette from 2011 – 2018. The map were scanned, imported into ERDAS IMAGINE and georeferenced using points with known geographical co-ordinates. The scanned map was captured and digitized. And the average annual rate of malaria cases was linked into spatial database. ArcMap Software was used for preparing the thematic map.

The pre-processing stages was carried out on Microsoft excel software with database creation, specifically, the malaria data obtained from the Ministry of Health were inputted into Microsoft Excel (2013) applications and saved as "Malaria cases" format in other to create a simple database, the malaria cases were entered according to number of reported cases in the selected Local Government Areas in Ondo State (Igbara-oke; Oba ile; and Ondo west) from 2011-2018 in excel in line with Ayele *et al.,* (2013). Query was generated in other to retrieve information stored in the database. This operation was basically carried out to check if all the local government areas have malaria case between 2011 and 2018 and thereafter the map production was carried out on ArcGIS 10.2 software in line with Bousema *et al.,* (2010).

4.0 Presentation and Analysis of Results

4.1 Presentation of Results

This section explains fully how the processed result was analyzed. The analyses were done in segment as follows: Malaria incidence in all Local Government Areas, trend of malaria cases in the study area and factors responsible for occurrence of malaria in the three LGAs

4.1.1 Malaria Incidence in All Local Government Areas

Meades, *et al.,* (1988), observed that the disease experience by any community is not static but dynamic. Hence, the malaria profile of the studied area has shown remarkable temporal variations. Geographical information system was used in studying in details the pattern of malaria from 2011 to 2018 in all the Local Government Areas of Ondo State. Thematic maps prepared indicate number of malaria affected people in the study area. This determines the geographical distribution of the malaria cases and their prevalence using different colors to depict the numbers with their respective places as shown in figures 2 and 3. The maps produced can help epidemiologist with real time mapping of malaria, malaria progression, specific environmental conditions, the prediction of vulnerable populations and support for decision-making with rapid and effective communication for rapid planning (UNC, 2013).

Essentially, Table I accompanied by (Figure 4) summarizes the total number of malaria cases from 20112018. The highest occurrence of malaria was reported in 2013 (179376 cases) followed by 2012 (171419 cases), 2011(164882 cases) while least occurrence was reported in 2016 (26666 cases). Akure-south is the LGA with highest occurrence of malaria cases in the state (185067

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cases), followed by Ondo West (162729 cases) while Ese-Odo LGA has the least occurrence with only 5737 cases. These findings highlight the need for proactive measures, given the substantial negative impacts of malaria on health, economy, society, ecology, and the environment in Ondo State. Likely causes include dynamic disease patterns. Effects encompass health issues, economic strain, and hindered development. Mitigation requires evidence-based interventions, intersectoral coordination, and sustainable approaches to address multifaceted challenges posed by malaria.

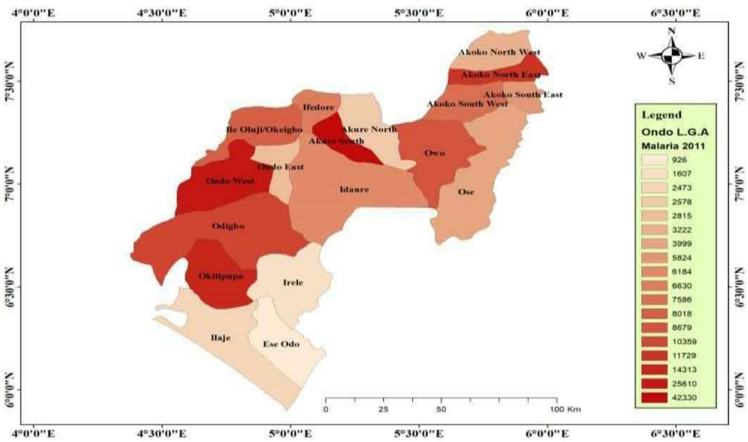

Figure 2: Incidence of Malaria in Ondo State In 2011

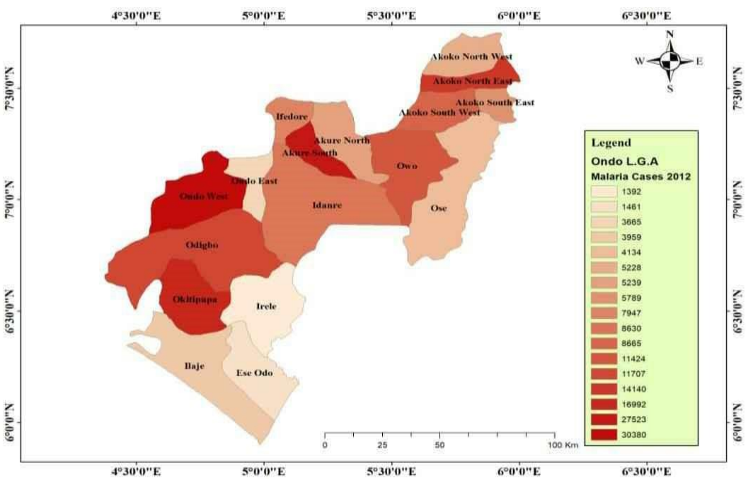

Figure 3: Incidence of Malaria in Ondo State In 2012

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Table I: Malaria Incidence in All the Local Government Area from 2011- 2018

LOCAL 'ERNMENT AREAS	2011	2012	2013	2014	2015	2016	2017	2018	TOTAL
AKOKO NORTH E	11729	14140	13016	10297	2211	1825	8676	5332	67226
AKOKO NORTH WEST	3222	5228	3706	2181	267	370	2317	1818	19109
AKOKO SOUTH EAST	5824	5789	3017	5343	556	189	1354	314	22386
AKOKO SOUTH WEST	7586	8665	5944	5021	796	670	1971	1997	32650
AKURE NORTH	2578	5239	4305	1354	617	273	794	780	15940
AKURE SOUTH	42330	27523	41970	27223	8176	5669	18618	13558	185067
ESE ODO	926	1461	985	864	289	221	805	186	5737
IDANRE	6184	8630	7992	6153	1443	746	2752	2048	35948
IFEDORE	6630	7947	6462	1584	534	348	1444	929	25878
ILAJE	2473	3959	3828	3010	1256	886	992	1569	17973
ILE OLUJI/OKEIGO	8018	3144	7846	6783	766	508	2542	1582	31189
IRELE LGA	1607	1392	1106	1408	144	174	1201	452	7484
ODIGBO	10359	11707	10234	8696	1975	1376	3969	6817	55133
OKITIPUPA	14313	16992	15434	8644	3348	2008	5178	4457	70374
ONDO EAST	2815	3665	3057	2087	277	227	1560	371	14059
ONDO WEST	25610	30380	35206	21035	12906	9409	19399	8784	162729
OSE	3999	4134	3819	2028	345	204	634	440	15603
OWO	8679	11424	11449	3368	1723	1563	4158	2101	44465
TOTAL	164882	171419	179376	117079	37629	26666	78364	53535	

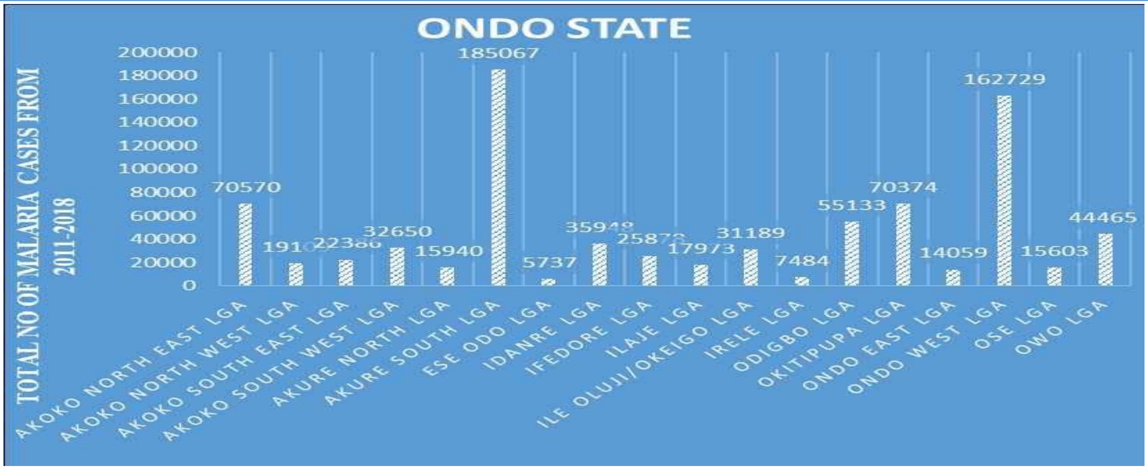

Fig. 4: Total number of malaria cases from 2011-2018**.**

4.1.2 Trend of Malaria Cases in the Study Area

The rate of malaria attack in each local Government areas during the period 2011-2018 was studied. More emphasis was laid on three local government areas which are Ifedore LGA, Akure North LGA and Ondo West LGA. According to Figure 5 it was observed that malaria cases in Akure North LGA were relatively small in 2011 before a sharp increase in 2012 and decrease in all other years. The table shows the highest case in 2012 while the lowest was in 2016. Notable too was Figure 6 which shows a synonymous case as that of figure 5 for Ifedore LGA while figure 7(Ondo west LGA) revealed that the highest case was in 2013 and the lowest to be in 2017. Generally, it was noticed that there is a massive decrease in the malaria cases from 2015-2018 which could be attributed to improved health facilities and preventive measures in the state. The malaria attack rate declined progressively since 2016. This observed trend aligns with a complex interplay of factors influencing malaria transmission and control state in (Malaria-Consortium, 2021) Likely causes include environmental, socio-economic, and biological factors, contributing to the fluctuating incidence. The effects of malaria, encompassing severe morbidity and mortality, economic and social consequences, and environmental impacts, underscore the multifaceted challenges posed by the diseases. Mitigation strategies, such as integrated vector management (IVM) and behavior change communication (BCC), have played a pivotal role in reducing malaria cases (Dada, 2023; Malaria-Consortium, 2021). IVM involves methods like insecticide-treated nets and environmental management, while BCC employs various media to raise awareness and influence community attitudes. The substantial decrease in malaria cases from 2015-2018 suggests progress in health facilities and preventive measures in the state, with the malaria attack rate progressively declining since 2016

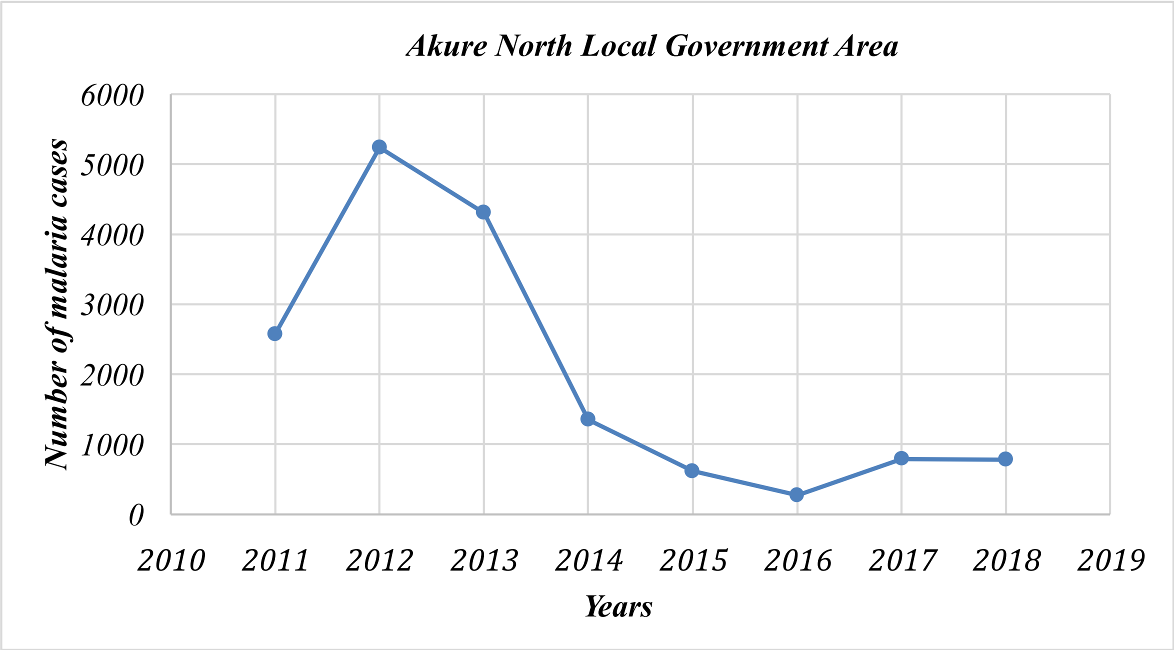

Figure 5: Trend of malaria Cases in Akure North LGA 2011 to 2018

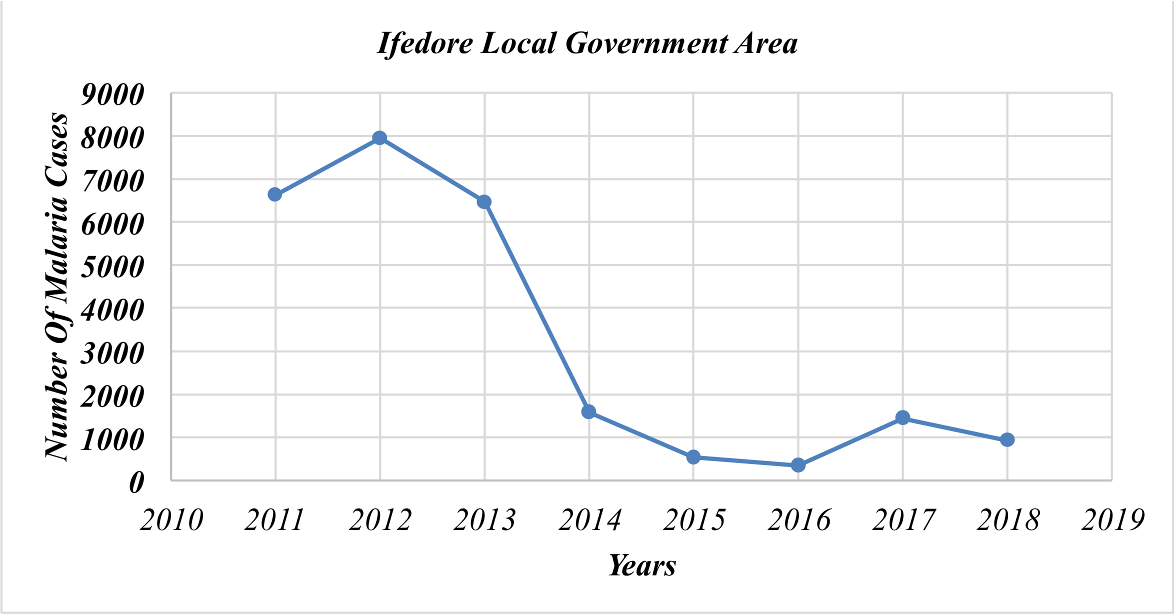

Figure 6*:* Trend of malaria Cases in Ifedore LGA from 2011 to 2018.

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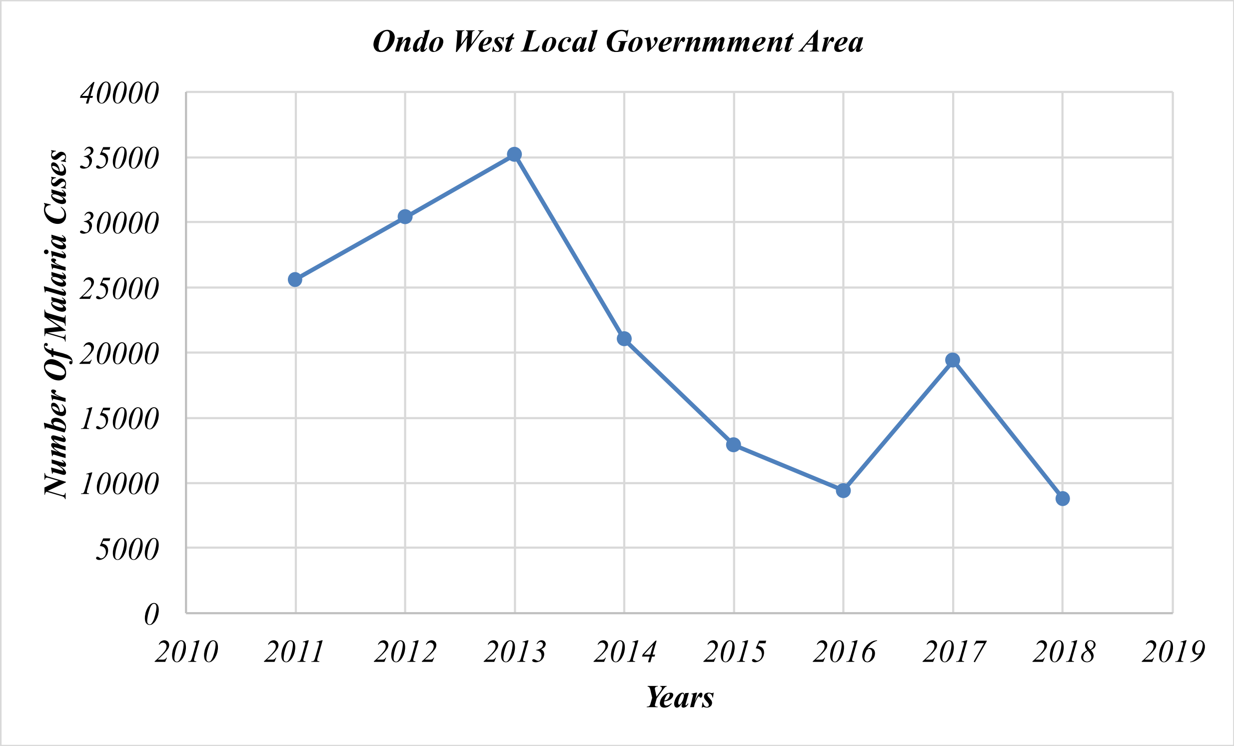

Figure 7: Trend of malaria Cases in Ondo West LGA from 2011 to 2018.

4.1.3 Factors Responsible for Occurrence of Malaria in the three LGAs

Considering the questionnaires administered throughout the three LGAs after the comparison based on the question asked from the field survey as shown in Table II, it was discovered that malaria is not a deadly disease after all, that is, the death toll recorded in the three-LGAs area was not significant when compared to the value obtained from the ANOVA performed to be 0.166 which is more than alpha (α) =0.05. Similarly, when the major causes of malaria in Ondo state was considered, the ANOVA conducted indicates that mosquito is a highly significant factor which contribute to malaria incidence by returning 0.000 which was not up to (α) =0.05. In addition, looking at a process whereby maybe malaria can be contacted through individual or not? that is, testing the possibility of passing malaria during child birth from mother to child shows that its relatively possible giving the ANOVA value as 0.008.

Moreover, 0.539, 0.001 and 0.097 were the ANOVA values obtained against (α) =0.05 indicating a non-significant outcome when testing: (i) maybe malaria in Ondo state increases during rainy season or not? (ii) Weather malaria transmission occurs at night or not? and (iii) checking how likely will the side effect of lack of immunity leading to the death of women and young children in the study area respectively? The ANOVA also revealed a 'significant' outcomes of 0.000 when compared with (α) =0.05 for the following probes the three LGAs: (i) malaria being more likely to occur among those with non-O blood groups? (ii) People who are poor are likely more affected by malaria? and (iii) if malaria is a communicable disease or not?.

Table 2 ANOVA result of the awareness of malaria from Questionnaire analysis

		Sum of Squares	Df	Mean Square	F	Sig.
AOM 1	Between Groups	1.890	3	.630	1.718	.166
AOM 2	Within Groups	53.550	146	.367		
AOM 3	Total	55.440	149			
AOM 4	Between Groups	11.760	3	3.920	12.229	.000
AOM 5	Within Groups	46.800	146	.321		
	Total	58.560	149			
AOM 6	Between Groups	14.865	3	4.955	4.060	.008
AOM 7	Within Groups	178.175	146	1.220		
AOM 8	Total	193.040	149			
	Between Groups	1.171	3	.390	.724	.539
	Within Groups	78.722	146	.539		
	Total	79.893	149			
	Between Groups	13.450	3	4.483	6.143	.001
	Within Groups	106.550	146	.730		
	Total	120.000	149			
	Between Groups	4.702	3	1.567	2.144	.097
	Within Groups	106.738	146	.731		
	Total	111.440	149			
	Between Groups	13.371	3	4.457	8.245	.000
	Within Groups	78.922	146	.541		
	Total	92.293	149			
	Between Groups	25.963	3	8.654	16.781	.000
	Within Groups	75.297	146	.516		
	Total	101.260	149			
AOM 9	Between Groups	27.626	3	9.209	8.688	.000
	Within Groups	154.747	146	1.060		
	Total	182.373	149			

5.0 Conclusion

This research confirms that occurrence of malaria cases varies over space, and that certain environmental and behavioral factors make people vulnerable to malaria. The findings of this study compared favorably with the findings of Ifatimilehin *et al*., (2006) where appreciable environmental differences and population reflected huge number of malaria cases around Akure south and Ondo West. It is hereby brought into conclusion that the main causes of malaria in Ondo state is through mosquito and it occurs at a very high rate in the evening. In view of this discovery, any citizen residing in any part of Ondo state and specifically, in the three selected LGAs should take note before taking rest for the night. It was also induced that high poverty rate contribute greatly to the trend of malaria in the State. Malaria can be prevented and controlled within the vicinity of the study areas through distribution of mosquito net as well as sensitization of inhabitant of the said area on the effect of mosquito bites.

6.0 Recommendation

Recommendations arising from this research encompass a range of strategies to combat malaria in Ondo State. Firstly, further investigations are urged to delve into the specifics of malaria transmission during high-risk seasons. This in-depth understanding would inform targeted interventions. Secondly, there's a pressing need to improve spatial data regarding mosquito breeding sites, a pivotal element in malaria control. Poverty alleviation initiatives should take precedence, recognizing its significant role in malaria prevention and treatment. The state should maintain vigilant surveillance of malaria cases, promptly responding to any resurgences or outbreaks. Public health campaigns, particularly emphasizing the use of mosquito nets among vulnerable groups, are recommended. Concurrently, healthcare infrastructure enhancements are vital, ensuring timely and effective treatment. Continued investment in vector control measures, such as insecticide-treated bed nets and indoor spraying, is essential. Public education and sensitization programs should enlighten residents on prevention and the importance of prompt medical care. Environmental management strategies, like improved waste disposal and drainage, can minimize mosquito breeding sites. Lastly, fostering research collaborations with local and international partners will facilitate the implementation of cutting-edge malaria prevention and control methods in the region. These measures collectively aim to reduce the malaria burden and enhance the well-being of Ondo State's populace.

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