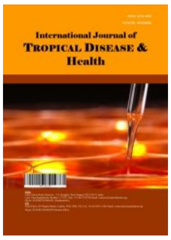

International Journal of TROPICAL DISEASE & Health

43(10): 10-18, 2022; Article no.IJTDH.86635
ISSN: 2278–1005, NLM ID: 101632866

Mapping Malaria Prevalence Using Geographic Information Systems (GIS) in Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJTDH/2022/v43i1030617

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/86635

Original Research Article

Received 20 February 2022
Accepted 29 April 2022
Published 13 May 2022

ABSTRACT

Background: Nigeria aspires to eradicate malaria, and the significance of mapping in this endeavour has grown. The prevalence and spatial distribution of malaria in Rivers State were studied using data from Primary Healthcare Centres (PHCs).
Methodology: PHCs in Rivers State were geo-referenced using the global positioning system (GPS) and 74 were selected across 21 local government areas using Systematic GridPoint Sampling Technique. Blood samples were obtained from 2340 consented individuals whose demographic data were obtained with structured questionnaires. Blood films were examined for *Plasmodium spp*. using standard parasitological techniques. An overall prevalence of 56.3% was recorded identifying only *P.falciparum*. Coordinates of PHCs sampled and the prevalence data for malaria were inputted into a spread sheet and imported into ArcGIS 10.7. This was used to generate prevalence maps of malaria infection in the State.
Results: Ogu-Bolo, Omumma, Abua-Odual LGAs recorded very high LGA prevalence whereas Ikwerre, Abua-Odual, Ahoada West, Oyigbo and Ogba/Egbema/Ndoni LGAs recorded very high state-level prevalence. Eleme and Port Harcourt City LGAs had the least prevalence.
Conclusion: The observed spatial variation could be attributed to land use land cover (LULC) patterns and further research to evaluate the impact of LULC patterns on the spatial distribution of malaria is recommended. This study provides malaria maps which will serve as a valuable resource to policy makers for targeted interventions in the State.

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Keywords: Malaria prevalence; distribution; primary healthcare centre; geographic information systems; maps.

1. INTRODUCTION

Malaria remains a public health concern in the world's poorest countries incluing Nigeria, [1]. The disease is one of the most common causes of death and illness in children and adults in tropical settings [2,3] and is a major cause of morbidity and mortality especially, in Sub-Sahara-Africa, where significant deaths occur annually [4]. The WHO African Region still bears the largest burden of malaria morbidity and mortality, with an estimated 215 million malaria cases and 384,000 malaria deaths accounting for about 94% of cases and deaths in 2019 [5]. Malaria is caused by single-celled obligate protozoan parasites of the genus; *Plasmodium* [6,7] that are naturally transmitted to man through the bites of infected female mosquitoes of the genus; *Anopheles* [4,8].

Malaria parasite and clinical transmission of infection are marked by significant microgeographic variations that frequently occur among neighbouring villages, households, or families [9]. A variety of variables, including human-based factors [10], environmental factors [11] and others, contribute to the variability in local malaria transmission. The local environment that houses human and vector hosts mediates their interactions and determines malaria endemicity [12]. As a consequence of this environmental reliance, complex patterns of regional differences in malaria transmission exist at practically every scale [12]. Once these variations in malaria distribution and the variables that contribute to them are known, solutions may be created to help manage and perhaps eliminate the disease [13].

A decline in malaria prevalence [14] and malaria mortality [15] and renewed interest in malaria eradication [16] have all underlined the need for improved malaria control in Sub-Saharan Africa SSA [17]. The Global Technical Strategy for Malaria 2016–2030 argues for a more targeted resource distribution and malaria control strategy [18]. Malaria elimination requires finer scale malaria risk maps to identify hotspots for performing surveillance–response actions, allocating resources, and constructing health facilities depending on local requirements [19]. Tools to map, plan, and monitor life-saving actions in low-resource locations are vital [20]. Geograpic Information System (GIS) is a computer software used to capture, map, retrieve, analyze, and compare the distribution of numerous phenomena, such as communicable and non-communicable illnesses, globally and across time [21]. GIS is helping to eliminate residual malaria epicenters [20,22]. GIS has been used to visualise and identify trends and patterns in the distribution of malaria over defined geographical areas [14].

Questions about geographical distribution of malaria infection have remained a daunting challenge both to policy makers and researchers at micro levels in Nigeria largely because of dearth of data and poor quality of data. Hence, this study is aimed at mapping malaria prevalence in Rivers State, South-South Nigeria.

2. DATA AND METHODS

2.1 Study Area

Rivers State is one of the 36 states of Nigeria and is located within latitude 4°18^{1}58.294”N-5°43^{1}51.652”N and longitude 6°24’7.883”E - 7°35’58.683”E and occupies an area of about 10,363.98 km^{2}. Its capital, Port Harcourt is the largest city and is economically significant as the centre of Nigeria’s oil industry. Rivers State occupies an area of about 10,363.98km^{2}. It is bordered on the North, South, East and West by Imo and Abia States; Atlantic Ocean; Akwa Ibom and Bayelsa States and Delta State respectively with its shores forming part of the West African Coastline. Water occupies over one-third of the state. The low land areas stretch from Ndoni to Bonny in the Northern and Southern parts of the State respectively, with a network of creeks stretching through Bonny into the Atlantic Ocean. Andoni, Asari Toru, Akuku Toru, Bonny, Degema, Ogu-Bolo, Okrika, Opobo-Nkoro LGAs constitute the core riverine areas whereas, Eleme, Emohua, Etche, Gokana, Ikwerre, Khana, Obio-Akpor, Omuma, Oyibo, Port Harcourt City and Tai LGAs constitute the upland LGAs. Abua–Odual, Ahoada East, Ahoada West and Ogba–Egbema-Ndoni are made up of mixed terrains. It is worthy to note that hand-pulled canoes and small motorized boats can only be used to assess some communities in Emohua Gokana, Khana, Omuma. Population and Economy. From the 2006 National Population Commission figure, the state has a population of 5,522,575.

2.2 Sampling

Three hundred and fifty one (351) PHCs in Rivers State were geo-referenced using a handheld Garmin eTrex 30X Global Positioning System (GPS) and mapped. Systematic grid-point sampling method was used to select study sites [23]. This was done by placing a 10 km by 10 km grid on the map of PHCs in Rivers State and geo-referencing the centres of the grids. The ArcGIS version 10.7. Software was used to extract the geographical coordinates of the PHCs and the closest PHC to the centroid of each grid was selected for the study. A total of 74 PHCs were selected and blood samples were obtained from 2340 consented persons from the PHCs across the 21 LGAs and analysed.

2.3 Laboratory Analysis

Malaria diagnosis was conducted by making thick and thin blood smears on clean, grease-free microscope slides, stained with Giemsa's stain. *Plasmodium* species were identified by distinctive morphological characteristics using standard *Plasmodium* spp., diagnostic keys outlined by [24].

2.4 Spatial Analysis

Geographic coordinates of study sites (PHCs) and malaria prevalence data were entered using Microsoft Excel 2007 and imported into the GIS database. Spatial queries were performed using Boolean Operation in ArcGIS environment. ArcGIS 10.7 software was used to compute the spatial and aspatial datasets to further display, analyse, query and model factual information. Thematic maps of the study area were produced.

3. RESULT AND DISCUSSION

3.1 Prevalence of Malaria at the LGAs during the Study Period

An overall prevalence of 56.3% was recorded in the study. Table 1 represents the prevalence of malaria across the 21 LGAs in Rivers State during the study period. A total of 2340 persons were examined out of which 1317 were infected. Data showed that Ahoada West had the highest number of respondents (256), followed by Ikwerre (214) and Abua-Odual (162) LGAs. Ogu-Bolo and Omumma recorded very high prevalence of 95.23% and 95.16% respectively whereas Obio-Akpor had the least prevalence of 33.33%. Ikwerre LGA recorded the highest state-level prevalence of 10.71%, followed by Abua-Odual with 10.17%. Eleme and Port Harcourt City LGAs recorded the least state-level prevalence of 0.91%. The differences in the malaria distribution across the LGAs was tested and was found to be statistically significant ($p<0.05$).

3.2 Spatial Distribution of Malaria Prevalence in Rivers State during the Study Period

Fig. 1 represents the thematic map of malaria prevalence in the various LGAs whereas Fig. 2 represents the thematic map of state-level malaria prevalence in Rivers State during the study period. Amongst the various LGAs, Ogu-Bolo, Omumma and Abua-Odual recorded very high prevalence whereas, Obio-Akpor had the least. With respect to state-level prevalence, Ikwerre, Ahoada West and Abua-Odual LGAs had the highest prevalence, followed by Oyigbo, Ogba-Egbema-Ndoni, Khana, Etche and Andoni LGAs. Eleme and Port Harcourt LGAs recorded the least.

The primary goal of the GIS in this study is to create the maps of the prevalence of malaria across the study area. Result from the study shows variation in the spatial distribution of malaria in Rivers State. The observed variation is in line with the findings of [25,26] and [27] who conducted malaria mapping research in other to ascertain malaria's epidemiological stratification. LGA and overall prevalence of malaria in the state is shown in (Table 1). Out of the 21 LGAs, 15 recorded malaria prevalence above 50%. This signifies high malaria disease burden in the State (Fig. 1). However, there was variation amongst the LGAs. Ogu-Bolo and Omumma recorded very high LGA-based prevalence whereas Obio-Akpor had the least prevalence (Table 1). The state-level prevalence is shown in Fig. 2. Ikwerre LGA recorded the highest state-level prevalence followed by Abua-Odual, Ahoada-West, Ogba-Egba-Ndoni and Oyigbo. These LGAs with high malaria prevalence have a homogenous, indigenous rural population, rigid in their cultural values and predominantly farmers who are highly exposed to the natural environment thereby making them vulnerable to the bites of malaria vectors. It is worthy to note that the majority of the land mass of Ikwerre and Abua-Odual LGA is covered by vegetation which plays a significant role in malaria transmission dynamics by favouring vector binomics. This is similar to the findings of [28] and [29] who recorded higher malaria prevalence in areas with vegetation.

Table 1. Prevalence of malaria across the LGAs during the study period

S/No	LGA	No. Examined	No. infected (%)	State-level Prevalence (%)	x^2	P
1	Abua/Odual	162	134 (82.7)	10.17		
2	Ahoada East	92	57 (61.96)	4.33		
3	Ahoada West	256	126 (49.21)	9.57		
4	Akuku Toru	97	35 (36.08)	2.66		
5	Andoni	148	73 (49.32)	5.54		
6	Asari Toru	66	35 (53.03)	2.66		
7	Bonny	106	45 (42.45)	3.42		
8	Degema	61	38 (62.29)	2.89		
9	Eleme	23	12 (52.17)	0.91		
10	Emohua	105	65 (61.9)	4.94		
11	Etche	162	81 (50)	6.15		
12	Gokhana	40	22 (55)	1.67		
13	Ikwerre	214	141 (65.89)	10.71		
14	Khana	176	91 (51.7)	6.91		
15	Obio-Akpor	78	26 (33.33)	1.97		
16	Ogba/Egbema/Ndoni	174	93 (53.45)	7.06		
17	Ogu-Bolo	21	20 (95.23)	1.52		
18	Omuma	62	59 (95.16)	4.48		
19	Oyigbo	190	108 (56.84)	8.20		
20	Port Harcourt City	28	12 (42.86)	0.91		
21	Tai	79	44 (55.69)	3.34		
	TOTAL(%)	**2340**	**1317 ()**		**164.862**	**0.000**

x^2= 164.862, p=0.00

Obio-Akpor recorded the least LGA prevalence of 33% while the lowest overall prevalence was recorded in PHC and Eleme LGAs which are metropolitan. Obio-Akpor and Port Harcourt City LGAs are metropolitan heterogeneous communities devoid of natural un-disturbed vegetation. They are characterized by presence of improved infrastructure, enlightened population who are aware of epidemiology and extant malaria control strategies and interventions in the country. These people live in modern houses with barriers (like screened doors and windows) against malaria vectors. These prevailing environmental conditions are un-conducive for malaria transmission. Eleme LGA is noted for the presence of Eleme Petrochemical Company which is an Olefin-based multi-petrochemicals complex with liquid gas as its main feedstock and discharges its effluents into the creeks thereby impacts negatively on aquatic ecosystem [30]. Effluent discharge is point-source pollution [31]. Pollution is one of the biggest threats to global health and is capable of destroying the soil, contaminate air and water [32]. They disturb natural ecosystems and may render the environment un-conducive for vector breeding. This therefore could be the reason for the low prevalence recorded in Eleme LGA.

Many nations' control and elimination programmes rely on mapping malaria transmission intensity and case distribution to target and execute interventions [14]. Maps have long been utilized to delineate areas where malaria prevalence is high so as to implement effective interventions [33] and have also been used by national stakeholders to define policy goals, strategies and actions [34]. Ogu-Bolo, Omumma, Abua-Odual LGAs recorded very high LGA prevalence whereas Ikwerre, Abua-Odual, Ahoada West, Oyigbo and Ogba/Egbema/Ndoni LGAs recorded very high state-level prevalence. Due to the relatively higher prevalence recorded in these locations, they could be interpreted as hotspots of malaria transmission in the State. These findings from this study would be of interest to Disease Control Programme Managers and Policy Makers in Rivers State with significant potential towards achieving a more targeted control of malaria in the State. The future success of malaria control in Africa depends on the intelligent use of epidemiological evidence, moving away from the dogma that one size fits all [35]. This study therefore, provides malaria prevalence maps to Rivers State government which will aid malaria control by providing genuine epidemiological data to guide the distribution of intervention resources across the State.

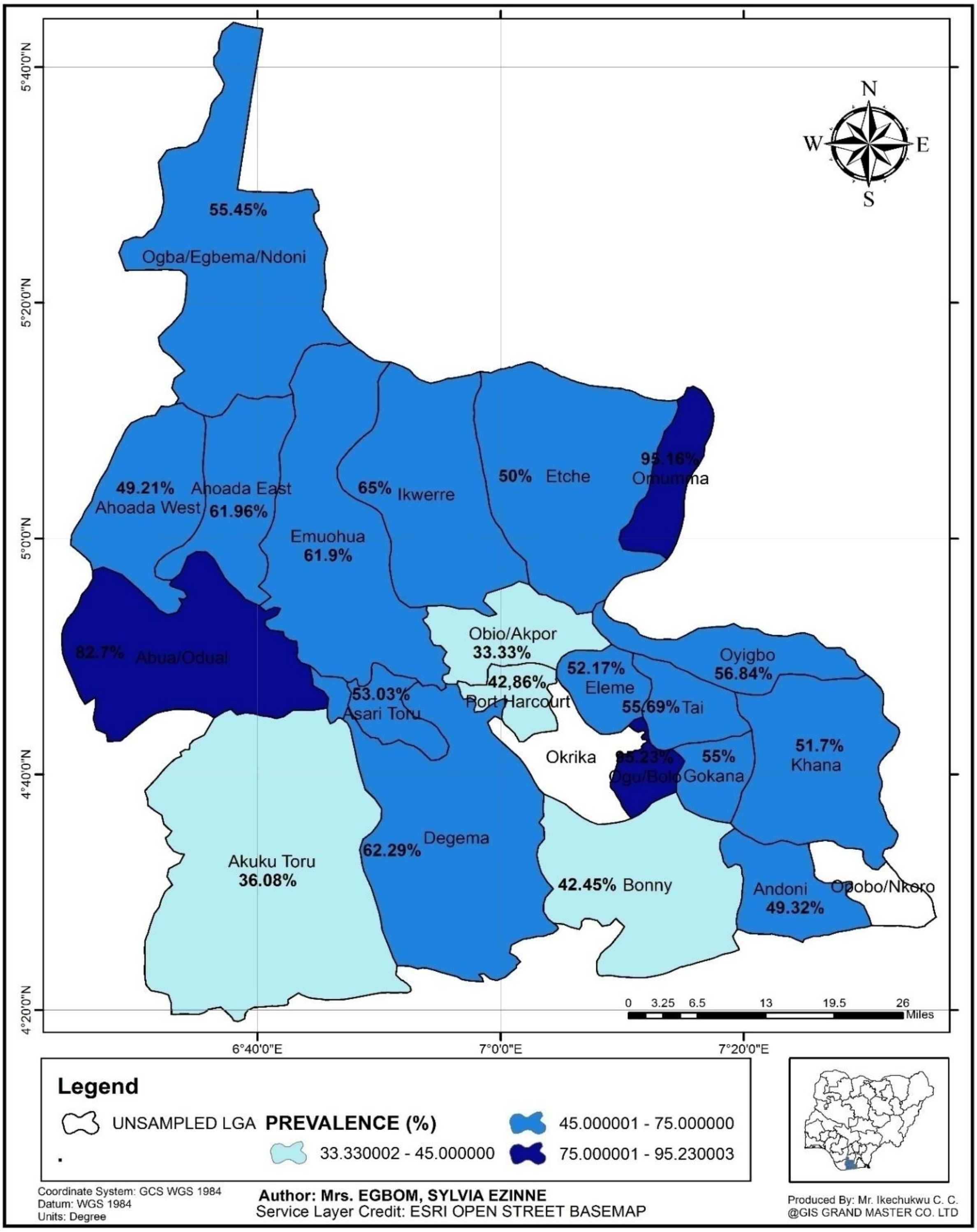

Fig. 1. Thematic map of malaria prevalence in the various LGAs

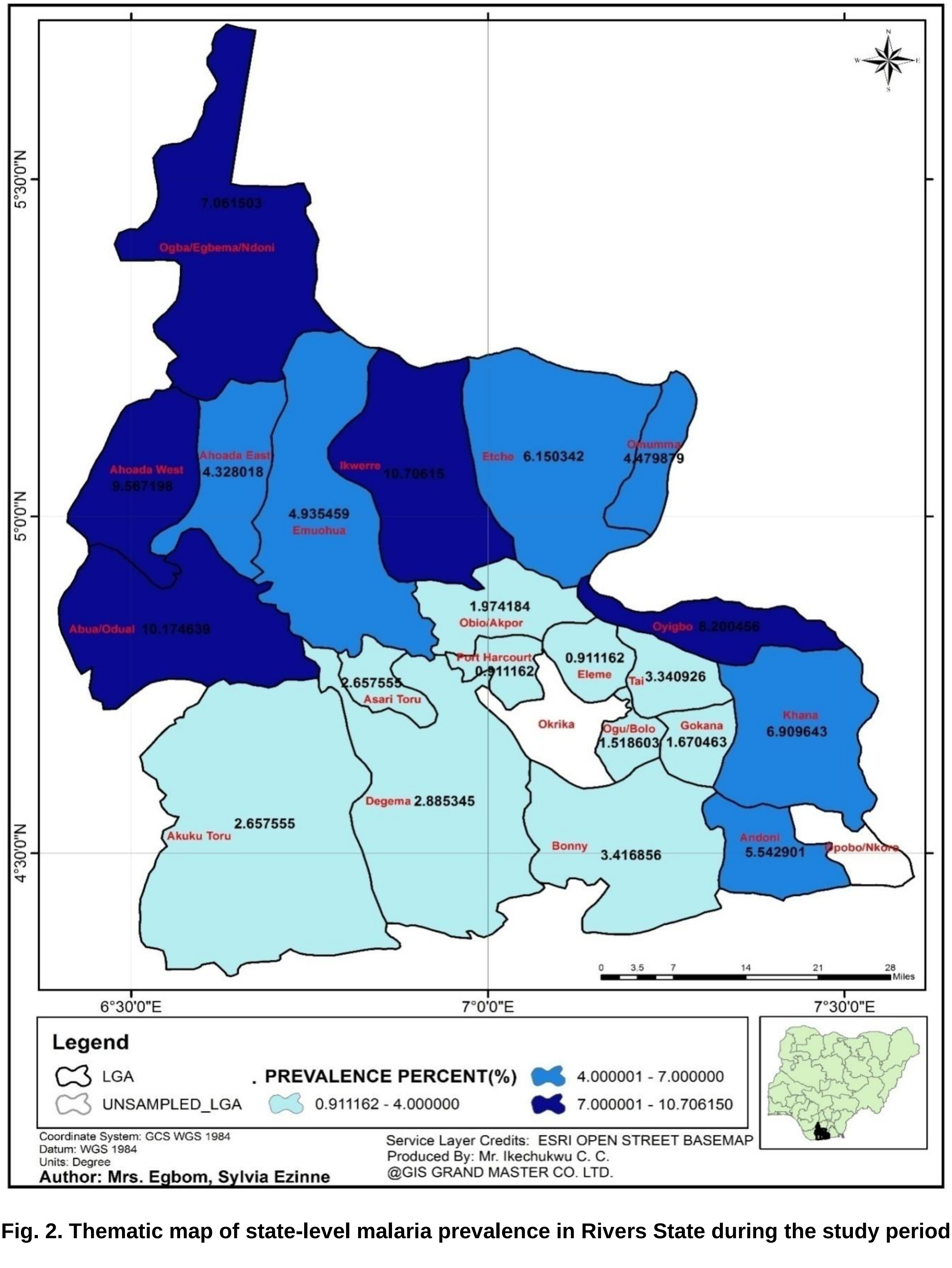

Fig. 2. Thematic map of state-level malaria prevalence in Rivers State during the study period

4. CONCLUSION AND RECOMMENDATIONS

The study shows that malaria is highly prevalent in Rivers State with Ogu-Bolo and Ikwerre LGAs recording the highest LGA and State-Level prevalence respectively. This spatial variation in the distribution of malaria could be hinged on numerous geographic factors including LULC patterns. It is therefore recommended that further studies be carried out in the study area to evaluate the impact of land use/land cover patterns on the observed geographic variations in malaria distribution.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

ETHICAL APPROVAL AND CONSENT

Ethical clearance to undertake this research was obtained from the University of Port Harcourt Health Research Ethics committee (UPH/CEREMAD/REC/MM77/020) and Rivers State Ministry of Health (MH/PRS/391/VOL.2/438). Written consent was obtained from the subjects who enrolled for the study.

STRENGTH AND LIMITATIONS OF THE STUDY

This work represents the first state-wide mapping of malaria prevalence in Rivers State and thus, provides baseline prevalence data on malaria. It is, however, a cross-sectional study that only collected information at one point in time.

ACKNOWLEDGEMENT

We hereby appreciate Rivers State Ministry of Health and particularly, Rivers State Primary Health Care Management Board for granting us access to the PHCs that served as our sampling units.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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