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An assesement of the spatial pattern of malaria infection in Nigeria

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Malaria transmitted by female anopheles mosquitoes is a major cause of death in many developing countries of the world. In Nigeria, malaria prevalence is as high as 80 to 85% and is the most common cause of outpatient visits to health facilities. The malaria situation in Nigeria is very burdensome and it impedes human development. The degree of malaria infestation varies from region to region in Nigeria. This spatial attribute of malaria infestation across regions necessitate the needs for malaria mapping among researchers. Also, the rate of malaria infection across space depends on dynamic processes involving complex climatic, environmental, physical, and social variables operating differently in space. This complexity makes the analysis of the spatial pattern of malaria infection in Nigeria important. Such analysis can explain the variations, providing a basis for policy intervention. It is against this background that this paper examines the spatial patterns of malaria infestation in Nigeria. Malaria data for fifteen years (1993 to 2007) were collected from the World Health Organisation (WHO) Data Bank, Roll Back Malaria/Epidemiological Unit of both the Federal and State Ministries of Health for twenty-three states in Nigeria. The pattern of spatial variation in the rate of malaria infection was analyzed using principal component analysis (PCA). The results indicate that seasonal variations play significant roles in malaria infection in Nigeria. It also shows high concentration of malaria infections in some few states. This paper therefore recommends that deliberate effort should be made to increase the distribution of treated mosquito nets and drugs in the affected states and an increment in the financial allocation to the affected states by the Federal Ministry of Health with a few to reducing the effect of the disease in the affected states.

Keywords: Assessment, spatial, patterns, malaria, infection, Nigeria.

INTRODUCTION

Malaria is a parasitic disease transmitted by female anopheles mosquitoes. Malaria affects 3.3 billion people, or half of the world's population, in 106 countries and territories. World Health Organisation (WHO) estimated 216 million cases of malaria in 2010, 81% in the African region. WHO estimated that there were 655,000 malaria deaths in 2010, 91% in the African region, and 86% were children under 5 years of age. Malaria is the third leading cause of death for children under five years worldwide, after pneumonia and diarrheal disease. Malaria is a major public health problem in Nigeria where it accounts for more cases and deaths than any other country in the world. Malaria is a risk for 97% of Nigeria's population. The remaining 3% of the population live in the malaria free highlands. There are an estimated 100 million malaria cases with over 300,000 deaths per year in Nigeria. This compares with 215,000 deaths per year in Nigeria from HIV/AIDS. Malaria contributes to an estimated 11% of maternal mortality (Akpan, 1996; Thompson, 2004; US Embassy Nigeria, 2011; United States.

Agency for International Development [USAID], 2011; National Population Commission (NPC) [Nigeria], National Malaria Control Programme (NMCP) [Nigeria], and ICF International, 2012).

The malaria situation in Nigeria is very burdensome and it impedes human development. It is both a cause and consequence of underdevelopment (Department for International Development [DFID], 2008). The degree of malaria infestation varies from region to region in Nigeria. This spatial attribute of malaria infestation across regions necessitate the needs for malaria mapping among researchers. The mapping of patterns in the spatial distribution of features has been of great significance in virtually all fields. The primary aim in the mapping process is to bring out hidden relationships among variables (Oluwafemi et al., 2013). Detailed mapping of malaria in Africa using actual malaria data have been very difficult due to paucity of data, thus the use of climatic models, which can predict fairly accurately, the real situation, is normally used. In addition, most of the researches on malaria mapping in sub-Saharan Africa have been concentrated in East and Southern Africa, Craig et al. (1999) in Kenya, Hay et al., (2002) in East African Highlands, Lindsay and Birley (1996) in Tanzania, Lindsay and Martens (1998) in Zimbabwe, Votava et al. (2000) in Burundi and Malawi. Little or nothing have been done in West Africa especially Nigeria. Though, malaria mapping/modelling using climatic variables tends to explain the malaria situation in a fairly accurate way, these models are mostly theoretical and they are normally based on available long-term climatic data (Martens et al., 1995; Shanks et al., 2002). But weather conditions and therefore malaria transmissions, vary substantially from one year to the next and from region to region. This makes the inclusion of actual malaria data from the field very fundamental in malaria mapping studies, as they are useful for understanding trends in the relative burden of malaria in the public health sector (WHO Malaria Country Report, 2005; Idowu et al., 2009).

In addition, the rationale behind malaria mapping is centred on the fact that malaria vector is distributed unevenly both within and between places, that is, it exhibits spatial variation. The rate of malaria infection across space depends on dynamic processes involving complex climatic, environmental, physical, and social variables operating differently in space. This complexity makes the analysis of the spatial pattern of malaria infection in Nigeria important. Such analysis can explain the variations, providing a basis for policy intervention. It is against this background that this paper examines the spatial patterns of malaria infestation in Nigeria.

MATERIALS AND METHODS

Malaria data for fifteen years (1993 to 2007) were collected from the WHO Data Bank, Roll Back Malaria/Epidemiological Unit of both the Federal and State Ministries of Health for twenty-three states in Nigeria. The year 1993 to 2007 was used due to the availability of data in the period. Total malaria infections for each month for the fifteen year period were added up and the aggregated values for January to December for the fifteen year period represent the variables of the study. Consequently, there are twelve variables (January to December). The pattern of spatial variation in the rate of malaria infection was analyzed using principal component analysis (PCA). PCA is a branch of factor analysis used to reduce many related variables into a few underlying constructs without losing their statistical validity. PCA has 3 principal objectives namely: (a) to reduce large set of data to a manageable size; (b) to identify presumed factors that underlie a large set of factors; and (c) to test hypothesis about the relationship among variables (Dillion and Goldstein, 1984).

The first step in PCA is the standardization of all the variables to produce a matrix structure. In this study, the data were standardized using the Z-score transformation technique. The second step involves correlation analysis. In this context, a multiple correlation analysis was computed from the standardized data matrix. The correlation matrix indicates the degree of inter-correlation among the variables, with elements along the diagonals indicating the total variations in the population represented. The output of the correlation shows that some of the variables were highly correlated with each other. In the light of this correlation observed, the principal component was computed using varimax rotation.

FINDINGS

Of the total twelve variables that were used for the analysis, three critical components that had greater than one eigenvalue were identified. These three components represent three structural patterns in malaria infestation during the period under investigation. It explains the spatial variation in the pattern of malaria infestation across the 23 states used for the study. Table 1 shows the eigenvalue table. The eigenvalue table shows the number of components retained from the varimax rotation.

Table 1 shows that the three components combined accounts for approximately 77% of the total variance (this value can be observed at last column with the heading label cumulative percentage). The major criteria used in retaining the ten components are the eigenvalue greater than one, the screen plot technique and the percentage variance accounted for criterion. The first three components retained have their eigenvalue greater than one. The first component accounted for the highest percentage (39.76%) of the total variance explained by the total variables. Component two accounted for 27.28%, while component three accounted for 9.97%. Also, the first component accounted for the highest eigenvalue. It accounted for 4.77 eigenvalue. Component two accounted for 3.27 eigenvalue, while component three accounted for 1.19 eigenvalue. The fourth component down to the twelfth components has an eigenvalue less than one and hence they were not used for interpretation of the result.

So far, the results from the eigenvalue-one criterion, the variance accounted for criterion, and the screen plot converged in suggesting that a three-component solution is appropriate. It is now time to review the rotated component

Table 1. Eigenvalue.

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
1	4.772	39.763	39.763	4.772	39.763	39.763	4.654	38.785	38.785
2	3.273	27.277	67.039	3.273	27.277	67.039	3.254	27.117	65.902
3	1.196	9.968	77.008	1.196	9.968	77.008	1.333	11.105	77.008
4	0.668	5.566	82.573	-	-	-	-	-	-
5	0.629	5.241	87.815	-	-	-	-	-	-
6	0.496	4.135	91.949	-	-	-	-	-	-
7	0.322	2.687	94.636	-	-	-	-	-	-
8	0.251	2.090	96.726	-	-	-	-	-	-
9	0.189	1.575	98.302	-	-	-	-	-	-
10	0.123	1.025	99.326	-	-	-	-	-	-
11	4.245E-02	0.354	99.680	-	-	-	-	-	-
12	3.840E-02	0.320	100.000	-	-	-	-	-	-

Extraction method: Principal component analysis.
Source: Author's Compilation (2012).

Table 2. Rotated component matrix of malaria infection in some selected states in Nigeria.

Month	Component 1	Component 2	Component 3
January	0.893*	0.167	0.111
February	0.877*	5.196E-02	0.157
November	0.869*	-0.152	1.977E-02
March	0.843*	0.197	6.498E-02
October	0.791*	-0.171	0.117
December	0.763*	-0.157	2.714E-02
May	-6.849E-02	0.921*	-0.113
June	-0.291	0.880*	-0.111
July	-9.124E-03	0.825*	0.352
April	0.431	0.671*	-0.132
August	0.146	0.594*	0.487
September	0.152	-3.539E-02	0.935*

Extraction method: Principal component analysis. Rotation method: Varimax with Kaiser normalization. a Rotation converged in 4 iterations.
Source: Author's Compilation (2012).

component matrix pattern to see if such a solution is interpretable. This matrix is presented in Table 2. The entries in the table are the factor loadings. They represent clusters of inter-related variables, which delineate general patterns of covariations within the data set. Each of the variables is weighted according to its degree of importance in defining the principal components. The second line of column two is the factor loading of 0.893 for the variable "January" on component one. In the third column of the same row is a factor loading of 0.167 for the variable "February" for component two. Thus, each of the variables loaded on the three retained components.

In Table 2, six variables have their highest loadings on component one. They are January, February, March, October, November and December. Five variables have their highest loadings on component 2. They are April, May, June, July and August. The last component has one variable loaded on it and that is September. The three components retained represent three different patterns or clusters of malaria infestation in Nigeria. The variables in the first component contribute more to the spatial variations in malaria infestation in Nigeria and component two contributes more than component three. From the pattern of the loadings on the three components, it reveals that variables in the first component are all within the dry season period, while the component two variables are the rainy season period. However, the third component represents a transition period between the rainy

Table 3. Components, variables and their labels.

Component	Variable	Label
1	January, February, March, October, November and December	Dry season component
2	April, May, June, July and August.	Rainy Season component
3	September.	Transition season component

Source: Author's Compilation (2012).

Table 4. Component scores of malaria infection in some selected states in Nigeria.

State	Component 1	Component 2	Component 3
Lagos	1.222	0.096	-0.333
Edo	0.936	-0.649	-0.561
Ondo	1.059	-0.898	-0.293
Rivers	0.965	-0.871	-0.331
Enugu	-0.226	-1.414	0.050
Delta	1.099	0.676	-0.347
Imo	0.176	-1.146	-0.120
Cross rivers	0.470	-0.356	-0.706
Oyo	0.980	0.694	-0.274
Katsina	-0.612	0.849	-0.509
Kano	-0.931	1.942	-0.203
Borno	-1.162	1.115	0.362
Sokoto	-0.885	0.481	0.194
Bauchi	-1.045	-0.900	-0.240
Kaduna	-0.721	-0.046	-0.4731
Adamawa	-1.256	-1.717	-0.415
Plateau	-1.164	-1.875	-0.282
Benue	1.616	1.424	0.027
Kwara	-0.365	1.245	-0.814
Kogi	0.262	0.948	0.811
Zamfara	-0.714	0.398	0.258
Yobe	-1.277	0.110	3.979
Niger	1.12	0.340	0.507

Source: Author's Compilation (2012).

Labelling the components

For the purpose of identification, there is the need to identify the various components using appropriate labels. This is important because the derived components have no names. Consequently, each of the three components was labelled as shown in Table 3. The table also indicates the variables that make up each of the components.

Table 3 shows the labels of the three components. Component one with six loadings is label dry season component; component two with five loadings is label rainy season component, while the third component with a single loading is labelled the transition season component. The three components constitute the underlying factors that explain the spatial pattern of malaria infestation in Nigeria. While the aforementioned analysis has determined the relative contribution of the various variables across the three components, their spatial distributions across the twenty-three states which the study covers is yet to be determined. This is achieved by the determination of the component scores of each state for the three retained components. The determination of the component scores permits inter-state comparison of the level of contribution of each of the three components to the twenty-three states. The component scores were obtained by summing the products of the standardized scores and the loading under each component score co-efficient matrix (Table 4).

The scores ranged from 1.61652 for Benue state to –1.27737 for Yobe state. States that display high component scores for component one labelled dry season component include state in the southern part of Nigeria and the middle belt, while states that display low component scores include states in the northern part of Nigeria. For a clearer observation and analysis of the spatial pattern of the dry season component scores, the states were grouped into three categories namely, high level malaria infestation, medium level malaria infestation and low level malaria infestation.

Table 5 shows that three states are located in the high-level malaria infestation in the first group. They are Lagos, Ondo, Delta, Benue and Niger state. The second group labelled medium level infestation is made up of five states including Edo, Rivers, Imo, Cross Rivers and Oyo state, while the last group labelled low level infestation has twelve states including Enugu, Katsina, Kano, Borno, Sokoto, Bauchi, Kaduna, Adamawa, Plateau, Kwara, Zamfara, and Yobe state. The different levels of infesta-tion as identified earlier are reflection of the spatial varia-tions in malaria infestation in Nigeria. The pattern reveals from Table 5 shows that the southern states and middle belt states with higher humidity during the dry season records higher malaria infestation in the first component while the northern states with lower humidity during the dry season records lower infestation in the first component.

The third column in Table 4 shows the second component scores labelled rainy season component for each of the twenty-three states. The scores range from1.94245 for Kano state to –1.8753 for Plateau state. States that display high component scores for component two labelled rainy season component include state in the northern part of Nigeria and the middle belt, while states

Table 5. Level of infestation: dry season component .

Group	Range of score	State	Level of malaria infestation
1	>1.00	Lagos, Ondo, Delta, Benue, Niger	High level infestation
2	1.00-0.01	Edo, Rivers, Imo, Cross Rivers, Oyo and Kogi	Medium level infestation
3	<0.01	Enugu, Katsina, Kano, Borno, Sokoto, Bauchi, Kaduna, Adamawa, Plateau, Kwara, Zamfara, Yobe	Low level infestation

Source: Author's Compilation (2012).

Table 6. Level of infestation: rainy season component (Author's Compilation, 2012).

Group	Range of score	State	Level of malaria infestation
1	>1.00	Kano, Borno, Benue, Kwara	High level infestation
2	1.00-0.01	Niger, Yobe, Zamfara, Kogi, Sokoto, Katsina, Oyo, Delta	Medium level infestation
3	<0.01	Lagos, Edo, Ondo, Rivers, Enugu, Imo, Cross Rivers, Bauchi, Kaduna, Adamawa, plateau	Low level infestation

Source: Author's Compilation (2012).

Table 7. Level of infestation: rainy season component (Author's Compilation, 2012).

Group	Range of score	State	Level of malaria infestation
1	>1.00	Yobe	High level infestation
2	1.00-0.01	Niger, Zamfara, Kogi, Sokoto, Borno	Medium level infestation
3	<0.01	Lagos, Edo, Ondo, Rivers, Enugu, Imo, Cross Rivers, Oyo, Katsina, Kano, Bauchi, Kaduna, Delta, Adamawa, Plateau, Kwara, Benue	Low level infestation

Source: Author's Compilation (2012).

that display low component scores include states in the southern part of Nigeria. Again, for a clearer observation and analysis of the spatial pattern of the rainy season component scores, the states were grouped into three as shown in Table 6.

Table 6 shows that four states are located in the high-level malaria infestation in the first group in the second component labelled rainy season component. They are Kano, Borno, Benue, and Kwara state. The second group labelled medium level infestation is made up of eight states including Niger, Yobe, Zamfara, Kogi, Sokoto, Katsina, Oyo, and Delta state, while the last group labelled low level infestation has eleven states including Lagos, Edo, Ondo, Rivers, Enugu, Imo, Cross Rivers, Bauchi, Kaduna, Adamawa, and Plateau state. The second component shows a mixed pattern among the states contributing to the spatial variation in malaria infestation. There is no clear distinction among the southern and northern states in this component. The seasonal variations have less influence in the rate of ma-laria infestation in component two. This partially explains the mixed pattern among the states as observed earlier. This also explains while component two explains only 27.28% of the total variance in malaria infestation as against 39.76 of the first component. The fourth column in Table 4 shows the third component scores labelled transition season component for each of the twenty-three states. The component scores range from 3.97962 for Yobe state to –0.8147 for Kwara state. Also, for a clearer observation and analysis of the spatial pattern of the rainy season component scores, the states are grouped into three as shown in Table 7.

Table 7 shows that one state is located in the high-level malaria infestation in the first group in the third component labelled transition season component and that is Yobe state. The second group labelled medium level infestation is made up of five states including Niger, Zamfara, Kogi, Sokoto, and Borno, state, while the last group labelled low level infestation has seventeen states including Lagos, Edo, Ondo, Rivers, Enugu, Imo, Cross Rivers, Oyo, Katsina, Kano, Bauchi, Kaduna, Adamawa, Plateau, Kwara, Benue, and Delta state. The third component also shows a mixed pattern among the states contributing to the spatial variation in malaria infestation. There is no clear distinction among the southern and northern states. The climatic factors of rainfall and humidity have lesser influence in the rate of malaria infestation among the twenty-three states in component three. This also explains why component three explains only 9.97% of the total variance in malaria infestation among the twenty-three states. To show the total variations in malaria infestation, the component scores for each of the state for each of the state from component one to three (Table 4) was added up. This was transformed to z-scores (Table 8). The results show that the z-scores range from1.79 for Benue to -1.99 for Adamawa state. Figure 1

Table 8. Standardized component scores of malaria infection in some selected states in Nigeria.

State	Component 1	Component 2	Component 3	Total	Z-score
Lagos	1.222	0.096	-0.333	0.985	0.57
Edo	0.936	-0.649	-0.561	-0.274	-0.16
Ondo	1.059	-0.898	-0.293	-0.132	-0.08
Rivers	0.965	-0.871	-0.331	-0.237	-0.15
Enugu	-0.226	-1.414	0.050	-0.1.59	-0.94
Delta	1.099	0.676	-0.347	1.428	0.83
Imo	0.176	-1.146	-0.120	-1.09	-0.65
Cross rivers	0.470	-0.356	-0.706	-0.592	-0.35
Oyo	0.980	0.694	-0.274	1.40	0.82
Katsina	-0.612	0.849	-0.509	-0.272	-0.17
Kano	-0.931	1.942	-0.203	0.808	0.47
Borno	-1.162	1.115	0.362	0.315	0.18
Sokoto	-0.885	0.481	0.194	-0.21	-0.13
Bauchi	-1.045	-0.900	-0.240	-2.185	-1.29
Kaduna	-0.721	-0.046	-0.4731	-1.240	-0.73
Adamawa	-1.256	-1.717	-0.415	-3.388	-1.99
Plateau	-1.164	-1.875	-0.282	-3.321	-1.95
Benue	1.616	1.424	0.027	3.067	1.79
Kwara	-0.365	1.245	-0.814	0.066	0.03
Kogi	0.262	0.948	0.811	2.021	1.18
Zamfara	-0.714	0.398	0.258	-0.058	-0.04
Yobe	-1.277	0.110	3.979	2.812	1.65
Niger	1.12	0.340	0.507	1.967	1.15

Source: Author's Compilation (2012).

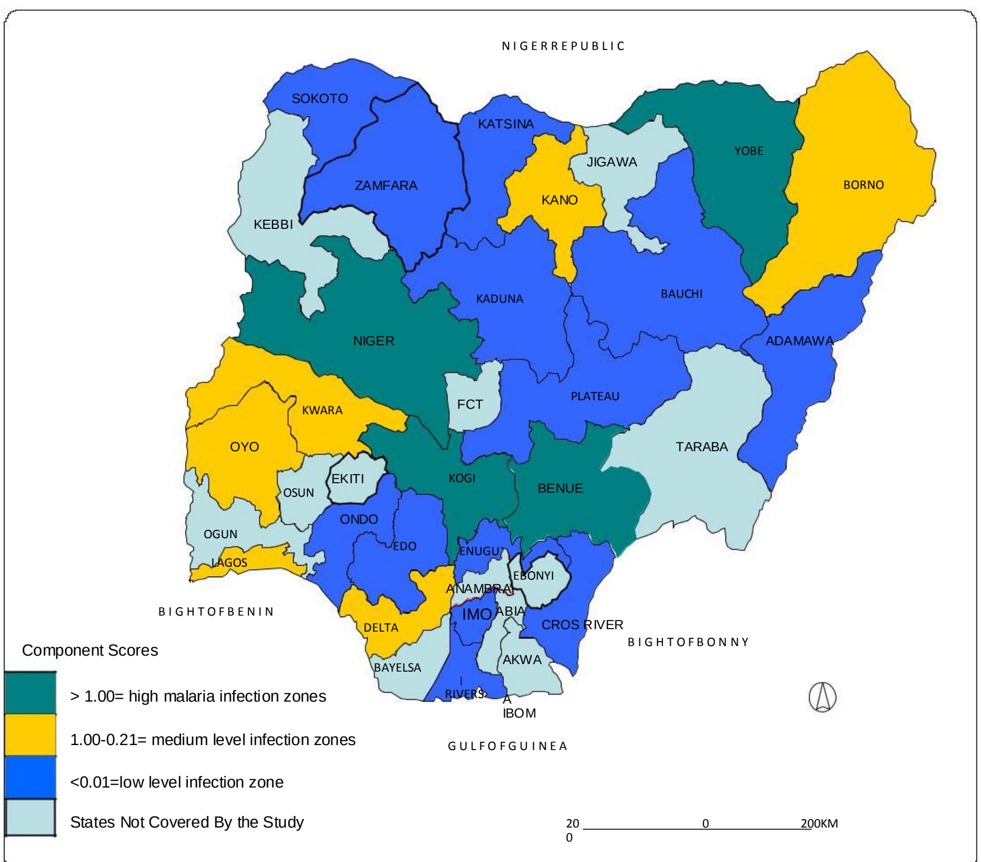

Figure 1. Spatial variations in malaria infestation in Nigeria.

shows the spatial variations in the distribution of malaria infection in Nigeria.

For a clearer observation and analysis of the spatial pattern of malaria infestation in Nigeria, the states were grouped into three categories, namely, high level malaria infestation (>1.00), medium level malaria infestation (1.00 to 0.021) and low level malaria infestation (<0.01). Figure 1 shows the spatial distribution of malaria infections in Nigeria. From Figure 1, four states occupy the high malaria infection zones. They are Kogi, Niger, Yobe and Benue states. Also, six states occupy the medium level malaria infection zones. They are Oyo, Lagos, Kwara, Delta, Kano and Bornu states. In addition, thirteen states occupy the low level malaria infection zones. They are Sokoto, Zamfara, Katsina, Kaduna, Bauchi, Plateau, Adamawa, Ondo, Edo, Enugu, Imo, Cross River and River states.

Conclusion

Seasonal variations play significant roles in malaria infection in Nigeria. Surprisingly, as indicated by the analysis, there are high levels of malaria infestation during the dry season than the rainy season. The paper also indicates that Kogi, Niger, Benue and Yobe states in Nigeria occupies the zones of high malaria infection. States like Oyo, Lagos, Kwara, Delta, Kano and Bornu occupy the medium level malaria infection zones, while states like Sokoto, Zamfara, Katsina, Kaduna, Bauchi, Plateau, Adamawa, Ondo, Edo, Enugu, Imo, Cross River and River occupy the low level malaria infection zones. The concentration of malaria in a few states has specific implications for the health of the people. One consequence of the concentration is loss of income and man hour on the part of infected people, while huge governmental resources are wasted in procuring the required drugs. Deliberate efforts should be made to increase the distribution of mosquito treated nets and drugs in the affected states. Measures should be introduced to increase the financial allocation to the affected states by the federal ministry of health with a few to reducing the effect of malaria infection in the states located in the high infection zones.

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