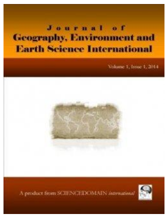

Journal of Geography, Environment and Earth Science International

15(1): 1-10, 2018; Article no.JGEESI.40515
ISSN: 2454-7352

Spatial Pattern of Insanitary Toilet Facility in Nigerian States and Federal Capital Territory Using GIS Pattern Analysis

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Authors' contributions

This work was carried out in collaboration between all authors. Author MR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author GAEG managed the analyses of the study. Author MAS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JGEESI/2018/40515
Editor(s):
(1) Anthony R. Lupo, Professor, Department of Soil, Environmental and Atmospheric Science, University of Missouri, Columbia, USA.
Reviewers:
(1) Fosu Brempong, Global Support Foundation & Research Institute, Ghana.
(2) Asmaa Mahmoud Mohammed El-Hefni, National Authority for Remote Sensing and Space Sciences, Egypt.
Complete Peer review History: http://www.sciencedomain.org/review-history/24377

Original Research Article

Received 21st January 2018
Accepted 2nd April 2018
Published 28th April 2018

ABSTRACT

There are studies on spatial demography that tackled issues related to households livelihood, however little is known regarding toilet facility despite the fact that it is a significant element in household livelihood. Its spatial variability, type, methods, and adequacy are sensitive issues of pressing health concern in rural developing countries like Nigeria. Our objectives are to determine if spatial clustering of Insanitary Toilet Facility exists among Nigerian states and to calculate Z-Sores and p-values to determine statistically significant hot spot states. We used data from Nigerian population and housing census. A GIS Pattern analysis method was employed for both Analyzing pattern and Mapping cluster analysis. Analyzing pattern revealed the presence of spatial clustering of variables with Z-Score value of 2.76 for Nearby bush beach and field, Public toilet 4.64 and

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Other 2.11. The p-values are statistically significant at p<0.01, p<0.01 and p<0.05 respectively, the observed pattern could not have been the result of random chance. Mapping cluster analysis shows Hot spot states for Nearby Bush Beach and Field to include Ekiti, Kwara, Lagos, Ogun, Osun and Oyo, Public toilets Abia, Akwa Ibom, Anambra, Bayelsa, Delta, Imo and Rivers, states, Other type include Abia, Anambra, Bayelsa, Delta, Imo and Rivers states. This study has implication in pre-disaster management phase, environmental sanitation and control and the budgetary provision by authorities. We limit to spatial pattern hence recommend further study to examine predictor factors to predict future vulnerable households. We recommend adapting water closet and well planned pit latrine.

Keywords: Geographic information system; toilet facility; pattern analysis; spatial demography.

1. INTRODUCTION

Toilet facilities are a significant element in household livelihood. Their spatial variability, type, methods, and their adequacy are sensitive issues of pressing health concern in rural developing countries like Nigeria. The quality of toilet facility depended on household's socio-economic status, government legislation and the spatial environment. Geographic Information Science pattern analysis enabled spatial demographic studies to pave spatial analysis of toilet spatial variability in an attempt to improve household health care quality. These will further bridge some of the unresolved issues in geo-demographic studies such as the need for detailed and comprehensive demographic studies for Africa, the methods of raising the productivity of manpower in developing countries through better education, training, and health and sanitation services, the studies of population patterns and dynamics in relation to patterns and rates of development, and the studies of social and cultural traditions in harmony with population and demographic policies.

This study attempts the application of Geographic Information Science in spatial demographic study. Spatial demography is looked as a usual demographic study of demographic attributes aggregated to certain measure within a geographic area [1]. The study hence reduced to Toilet facilit0y that is linked with socio-economic activities and has its values considered as demographic attributes and aggregated within 36 states and federal capital territory of Nigeria (Geographic area), this is a clear manifestation of spatial pattern and examination of spatial pattern separates geography from all other field of study [2], with the fact that nearer phenomenon are more related than those far away [3]. It is apparent that in Nigeria, access to sanitary toilet facility such as water closet (WC) is awkward. Majority, especially in rural societies, manage to look for an alternative, for instance defecating in nearby bushes, beaches and fields and other insanitary places, these contribute to over 1billoin poorest people on earth who defecate on open space [4]. This has great health implications; in 1991 for example the world deaths as a result of cholera were 14,400 out of which half occurred in Nigeria [5]. Cholera is believed to happen largely due to drinking of water contaminated through defecated materials. According to Commission [6] out of total distribution of regular households by toilet facility in Nigeria, only 15.22% used (WC) facility, households who visited nearby bush, beach, and field amount to 19.79% and those who managed the few available public toilets and other unidentified toilet facilities are 9.58%.

Historically, spatial data for spatial analysis received intriguing attention in the late 80^{th}. Anselin [7] sees spatial data as always playing a principal position in the quantitative scientific tradition in geography. Anselin’s assertion was preceded by studies in spatial autocorrelation [8,9]. There was also a concrete review of point pattern analysis [10]. The development of today’s Geographic Information System (GIS) would not have been possible without spatial data analysis [8,11]. Since then there have been greater achievements in spatial technology that makes it more possible for different disciplines in Health, Management, Natural sciences, Humanities and social sciences etc to join the race and benefit from the wider opportunities offered by spatial data.

The spatial analysis of toilet facility presume using a spatial data that ensures link between spatial data analysis (SDA) and Geographic Information Systems (GIS) to forge ahead from the human perspective rather than traditional physical geography [12]. Most shortfalls of toilet facility and its associated resultant upshots are pervasively in developing countries such as in sub-Saharan Africa, a good example is a study that revealed a high prevalence of diarrhoea rooted to unhygienic toilet facilities in Nigeria, the high prevalence was observed in Northern and Eastern states using spatial factors and their attributes [13]. The global concern for human right phenomena especially for people with special needs persuaded a study in Ireland to examine if those categories of individuals have adequate provision of accessible public toilets. This study revealed a weak planning legislation is weak and often not enforced. Accessible public toilets are few and far apart, those that exist are mostly poorly designed, this has severely delimits the daily spatial behaviour of disabled people [14].

In general term, pattern analysis has different applications, the standard methods for analyzing the spatial distribution and structure of plant species for example, are nearest neighbour and Ripley's k-function [15]. Other types of spatial data such as industrial firm were analyzed using K-function. Hot spot analysis has also been used in crime location analysis and mapping [16]. In the analysis of public health data, pattern analysis has also been found vital [17] Geographical epidemiology [18], in pest management [19]. It has been useful however in housing price [20].

Spatial autocorrelation measures the relationship among values of a variable according to spatial arrangement of the values [21]. Similarly, Spatial autocorrelation is a concept that helps to define the field of spatial analysis [22]. Further more it helps researchers to build representations, however frustrate their efforts to predict [23]. It has also been found useful for analyzing temporal changes of spatial distribution [24,25]. It has been a tool for spatial dependency over distance classes quantification [26], the standard statistical test can also be validated using spatial autocorrelation [27]. In a situation where a data exhibit significant spatial autocorrelation, a spatial dependency can be in-cooperated in to the analysis [28]. However, Spatial autocorrelation in non demographic data can inflate Type i errors in statistical analyses [29]. The inferences about spatial structure in European populations, based on spatial autocorrelation analysis, suggest a pattern dominated by migration, followed by expansion and admixture rather than selection or chance fluctuations [30]. This study therefore, joins the spatial race for analyzing spatial arrangements of toilet facility in sub-Saharan Africa.

2. MATERIALS AND METHODS

2.1 Study Area Location

The Federal Republic of Nigeria (Study Area) is in the West African sub region which has an area of 923,768 square kilometres which is the fourth largest in Africa and is situated between 3^0 and 14^0 East longitude and 4^0 and 14^0 North latitude. The longest distance from East to West is about 767 kilometres, and from North to South 1,605 kilometres. Nigeria is bordered on the North by the Republic of Niger, on the South a coastal border by Gulf of Guinea that is approximately 800 kilometres of the Atlantic ocean, stretching from Badagry in the South-West to the Rio del Rey in the South-East, on the East by the Republic of Cameroon, on the West by the Republic of Benin, on the North-East by Chad Republic, on the South-East by the Republic of Cameroon, and on the South-West by the Niger Republic. Fig. 1A below shows the map of the study area.

2.2 Data Source

The demographic data in the Nigerian population and housing census for the distribution of regular households by toilet facility were used. Two types of toilet facility used for the purpose of this study are categorized as Insanitary Toilet Facilities. These are classified as "Type A Insanitary Toilet Facilities" TAITF (They include Nearby bush, field and beach, Public toilets and Other) and "Type B Insanitary Toilet Facilities" TBITF (encompasses Pit latrine, Bucket/pan, and Toilet facility in different dwelling). The data used contained a total of 28,197,085 households across Nigerian states and Federal Capital Territory (FCT), only 4,292,654 household uses water closet which is considered as "Complete Sanitary Toilet Facility" (CSTF) representing only 15.22%. The (TAITF) constitutes 29.38% of the total households while (TBITF) composed of 55.40% of the total households. The decision to use (TAITF) was intrigued for its likelihood to put households at risk of health disaster for the existence of interdependence with water facility. Water for domestic use can easily be contaminated in the process of utilizing (TAITF) leading to spread of water-borne diseases.

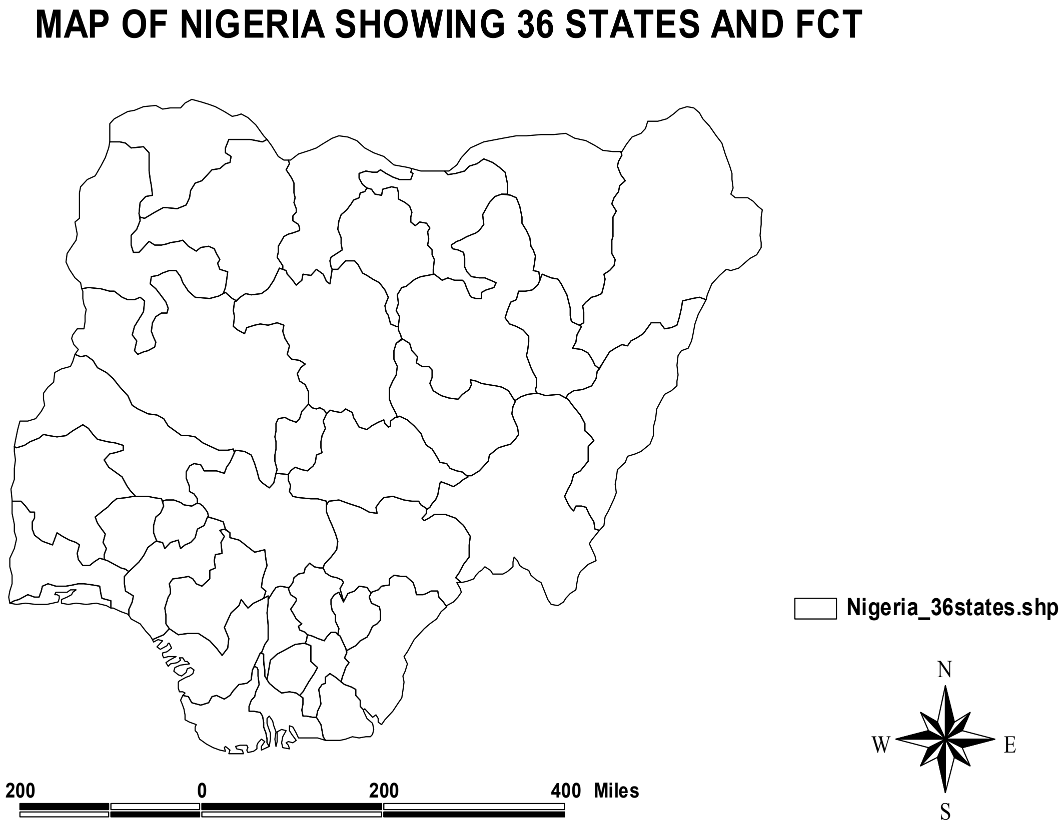

Fig. 1A. Map of the Study Area

2.3 Methods

2.3.1 GIS pattern analysis

i. Analyzing Pattern (Global Moran's I Spatial Autocorrelation)

This analysis is to observe the presence of spatial clustering of (TAITF) at global scale across Nigerian states and the FCT using ArcGIS 10.1 software. It provides statistics that quantify the spatial patterns that tells if the features in the dataset (TAITF) spatially clustered and if the clustering is becoming more or less intense over time. It is an inferential statistics with the null hypothesis that this features exhibit a spatially random pattern. Spatial autocorrelation is given in the equation 1 viz;

$$I = \frac{\sum_{i-1}^{n}\sum_{j-1}^{m} wij(xi-\dot{x})(xj-\dot{x})}{s2\sum_{i=1}^{n}\ \sum_{j=1}^{m} wij} \qquad (1)$$

Where x_i is the value of polygon i, x_j is the value of polygon i's neighbour j, wij is the coefficient, n is the number of polygons and S^2 is the variance of x values with a mean of x.

ii. Mapping Cluster (Getis-Ord Gi* Hot spot Analysis)

This analysis is to perform cluster analysis to identify the locations of statistically significant hot spots and cold spots for the feature (TAITF) across Nigerian states and the FCT using ArcGIS 10.1 software. Moran's I earlier used only to detect the presence of clustering of similar values, this analysis hence is able to separate clusters of high values from clusters of low values [20]. This method is described in the equation 2 below;

$$G(d) = \frac{\sum\sum\ wij(d)\,xi\,xj\,)}{\sum\sum\ xi\,xj}, \text{ i} \neq \text{j} \qquad (2)$$

Where xi is the value at location i, xj is the value at location j if j is within d of i, and $wij(d)$ is the spatial weight.

3. RESULTS AND DISCUSSION

3.1 Analyzing Pattern (Global Moran's I Spatial Autocorrelation)

The result of Moran's I spatial autocorrelation shows presence of spatial clustering of (TAITF) values for all the three toilet facilities. The Z-Score value of 2.76 in Table 1 for Nearby bush beach and field is statistically significant p<0.01, there is therefore less than 1% likelihood that this observed clustered pattern could be the result of random probability as contained in Fig. 1B.

Similarly, the Z-score value of 4.64 from Table 1 maintains a good spatial clustering of Public toilet. The result moreover reveals a statistical significance at p<0.01 that the observed pattern is not among many possible versions of complete spatial randomness as portrays in Fig. 2.

The analyzing pattern result for Other further exhibit spatial clustering. The calculated Z-Score of 2.11 is statistically significant at p<0.05, this means that there is 95% confidence that the observed pattern could not have been the result of random chance. This scenario is explained in Fig. 3.

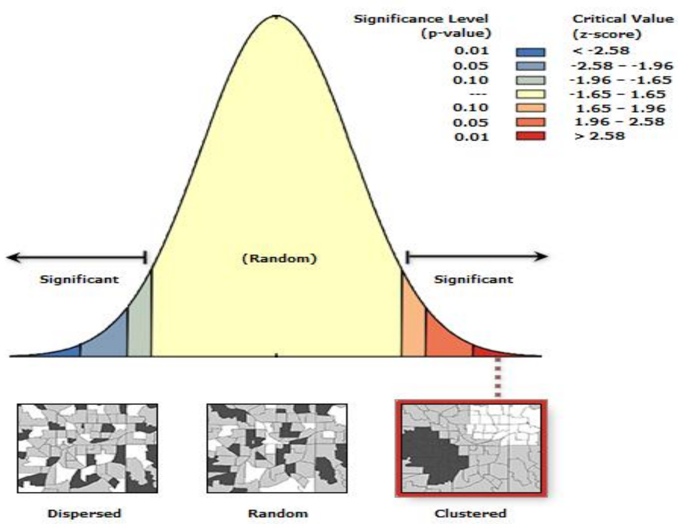

Fig. 1B. Analyzing Pattern for nearby bush, beach and field

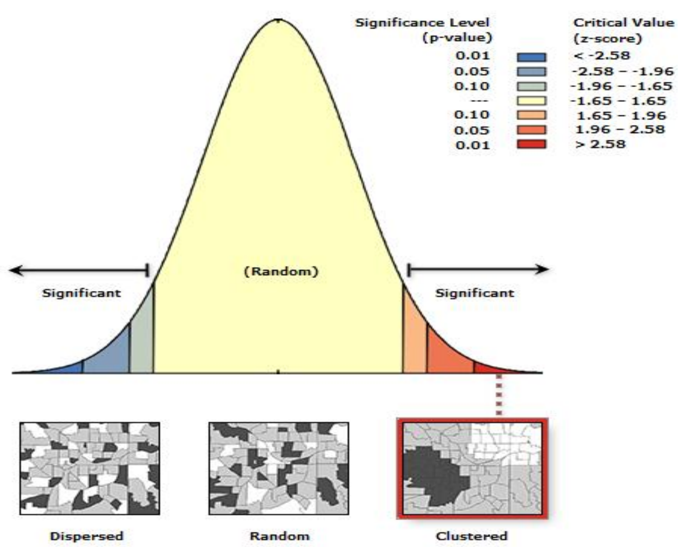

Fig. 2. Analyzing pattern for public toilet

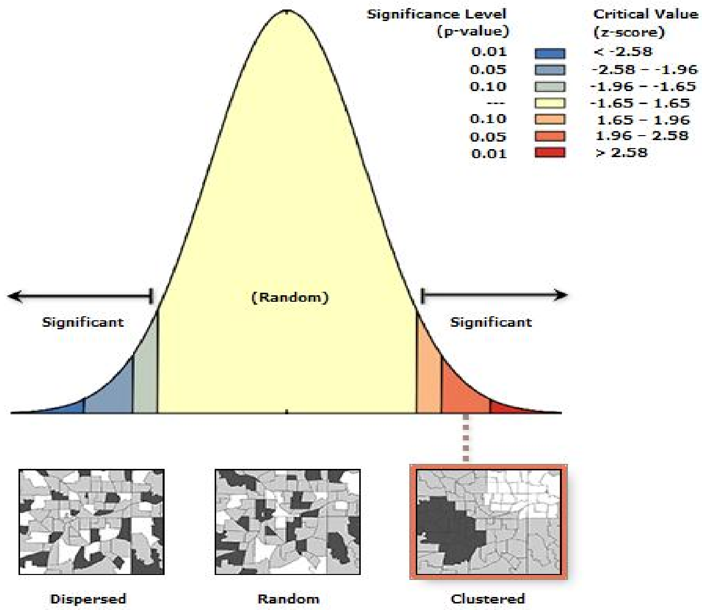

Fig. 3. Analyzing pattern for other

The results of analyzing pattern in this research so far identified geographic patterns, this perception of observed patterns is important for understanding how geographic phenomena behave. These results only give a sense of the overall pattern of (TAITF) at global scale. This makes it easier to compare patterns for the distributions of the three toilet facility types in (TAITF), it is a starting point for more in-depth analyses, and the preceded hot spot analysis ensures mapping of areas with high values as well low values. The aforementioned null hypothesis that, the features (TAITF) exhibit a spatially random pattern is therefore rejected, there is observed clustered pattern for all the three toilet facility types in (TAITF).

The calculated probability (p-values) from Table 1 gave a high level of confidence especially for Nearby bush, beach and field and Public toilet. This analysis provides statistics that quantify broad spatial patterns that takes care of spatial clustering questions.

3.2 Mapping Cluster (Getis-Ord Gi* Hot Spot Analysis)

The mapping cluster analysis identifies the locations of statistically significant hot spots. It shows states that demand action based on its hot spots in visual form. The hot spot states are deemed states with high clustering of Type A Insanitary Toilet Facilities (TAITF), they are hence, states whose households are vulnerable to incursion by communicable diseases. They therefore needed a pressing action.

i) Nearby Bush Beach and Field:- The states with high number of households that uses Nearby Bush Beach and Field are Ekiti, Kwara, Lagos, Ogun, Osun and Oyo. They have high Z-Score values >1.46 <3.21 as in Fig. 4. These spatial pattern manifest an incessant utilization of a toilet facility that is insanitary, there is therefore need for radical overhaul of this traditional method of toilet facility. This will ensure healthier households free from infectious diseases.

Table 1. Morans I spatial autocorrelation analysis for (TAITF)

Type of toilet facility	Z-Score values	p-values
1- Neraby Bush, Beach and Field	2.75791	0.005817
2- Public Toilet	4.63905	0.000004
3- Other	2.11226	0.034664

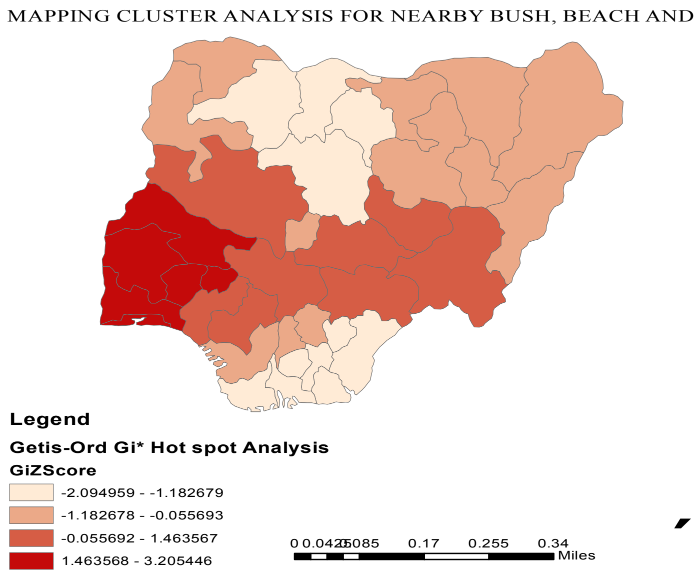

Fig. 4. Mapping cluster (hot spot analysis) nearby beach, bush and field

ii) Public Toilet:- The utilization of public toilets is prevalent in the south-south and south-eastern states of Nigeria. They are made available for use by authorities and happen to be insufficient to take care of teaming citizens. They are run in an unhygienic condition due to intense pressure and render households vulnerable to infectious diseases. The unexpectedly outbreak of communicable diseases according to the hot spot analysis from Fig. 5 may crop up at Abia, Akwa Ibom, Anambra, Bayelsa, Delta, Imo and Rivers, states.

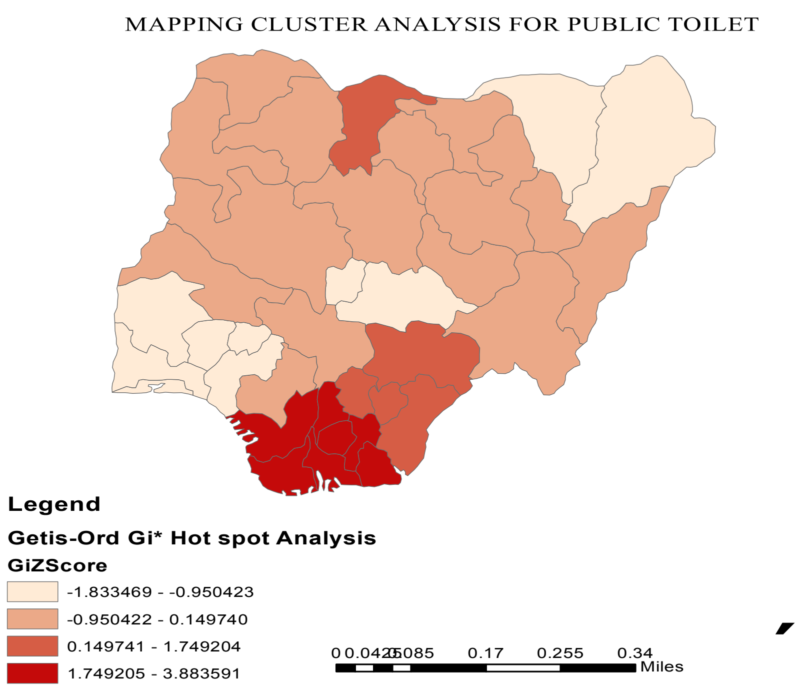

Fig. 5. Mapping Cluster (Hot spot Analysis) Public Toilet

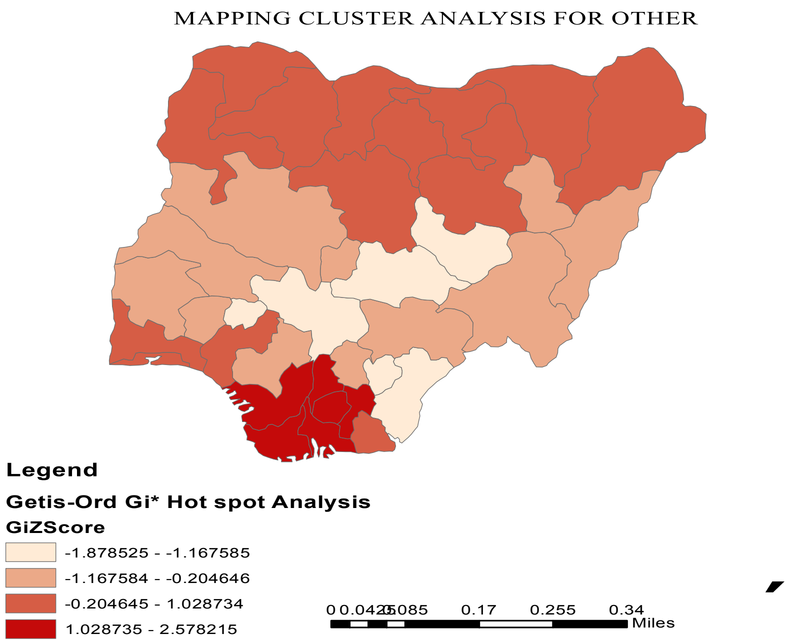

Fig. 6. Mapping cluster (hotspot analysis) other

iii) Other:- These are the rest of toilet facility type beside the listed types. They can foster vulnerability to households since are not categorically merged in the sanitary toilet facilities group. The hot spot states in this type include Abia, Anambra, Bayelsa, Delta, Imo and Rivers states as explained in Fig. 6. The health concern herein is the dread of unexpected infectious diseases that are interdependence with poor toilet facility.

4. CONCLUSION

The major factor that persuaded this study is the interdependence between infectious diseases and toilet facility. There is also an increasing need in spatial demographic studies due to improved spatial technology which ensures interface with spatially referenced data. The flexibility of GIS technology intrigued most spatial demographic researchers to join the race and find solutions to socio-economic and demographic shortfalls more in the developing countries of the world. These consequently bridge some of the unresolved issues in geo-demographic studies such as the need for detailed and comprehensive demographic studies for Africa, the studies of population patterns and dynamics in relation to patterns and rates of development, and the studies of social and cultural traditions in harmony with population and demographic policies. This study hence applied GIS technology in spatial demographic study, it is reduced to Toilet facility that is linked with socio-economic activities and has its values considered as demographic attributes and aggregated within 36 states and federal capital territory of Nigeria (Geographic area), the study looked in to spatial pattern and examination of spatial pattern separates geography from all other field of study. Insanitary toilet facility usually poses health threat; in 1991 for example the world deaths as a result of cholera were 14,400 out of which half occurred in Nigeria. Cholera is believed to happen largely due to drinking of water contaminated through defecated materials. In Nigeria out of total distribution of regular households by toilet facility, only 15.22% used water closet (WC) facility, households who visited nearby bush, beach, and field amount to 19.79% and those who managed the few available public toilets and other unidentified toilet facilities are 9.58%.

The result of Moran's I spatial autocorrelation shows presence of spatial clustering of (TAITF) values for all the three toilet facilities. The analysis revealed Z-Score value of 2.76 for Nearby bush beach and field, value of 4.64 for Public toilet and 2.11 for Other. The p-values are statistically significant $p<0.01$, $p<0.01$ and $p<0.05$ respectively. These indicates a 99%

confidence for the first two toilet facilities and 95% confidence for Other that the observed pattern could not have been the result of random chance.

The hot spot analysis results shows clustering of states with high number of households that uses Nearby Bush Beach and Field toilet facility to include Ekiti, Kwara, Lagos, Ogun, Osun and Oyo with Z-Score values >1.46 <3.21. The analysis for Public toilets shows vulnerable households in Abia, Akwa Ibom, Anambra, Bayelsa, Delta, Imo and Rivers, states, whereas the hot spot states Other type include Abia, Anambra, Bayelsa, Delta, Imo and Rivers states.

This study has implication in the disaster management more in the mitigation measure during pre-disaster phase. It will be useful for environmental sanitation and control, it is also vital in the budgetary provision by authorities. The study will be an essential literature in the academia. This study is limited to the spatial pattern of Insanitary Toilet facility, it doesn't include factors that could influence such observed pattern, we therefore recommend further study that will examine predictor factors that would determine and predict how and where the observed pattern would be. We also recommend authorities to encourage massive utilization of Complete Sanitary Toilet Facilities (CSTF) like water closet (WC) and a well planned pit latrine away from food and water sources if (CSTF) cannot be secured. We further recommend effective legislations to take care of open defecation on bare land and beaches.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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