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STATISTICAL SPATIAL MODELLING FOR THE TREATMENT OF TYPHOID (ENTERIC) FEVER INMAIDUGURI, BORNO STATE, NIGERIA

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Abstract

Typhoid Fever (TF) remains a critical health is- sue in Maiduguri (M), Nigeria, with its prevalence and spatial distribution posing significant challenges to effective treatment and prevention. This study employs statistical spatial modeling techniques to analyze the spatial patterns of Typhoid Fever cases in Maiduguri, providing valuable insights for targeted treatment strategies. Utilizing Geographic Information System (GIS) tools, we mapped the distribution of reported typhoid cases inthe city and conducted spatial autocorrelation analysis to identify clustering patterns. Hotspot analysis further pinpointed areas with significantly higher case incidence than expected by chance. Spatial interpolation techniques were applied to estimate the risk surface across the urban landscape. The findings reveal spatially correlated clusters of Typhoid Fever cases, offering a foundation for improved resource

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EDITOR-IN-CHIEF
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allocation and intervention planning. This research underscores the importance of spatial modeling in enhancing the understanding and management of Typhoid Fever in Maiduguri (M), ultimately contributing to more effective Public Health (PH) initiatives.

INTRODUCTION

Typhoid Fever, primarily caused by Salmonella Typhi, remains a persistent Public Health challenge worldwide. In regions like Maiduguri, Nigeria, where access to clean water and sanitation facilities is limited, the prevalence of Typhoid Fever is a significant concern. Understanding the spatial distribution of typhoid cases is pivotal for effective disease management, especially in resource-constrained settings.

Maiduguri, with its population of over one million people, grapples with numerous healthcare challenges, and typhoid fever is among the most pressing. The disease is transmitted primarily through contaminated food and water, making it particularly problematic in areas with inadequate sanitation and hygiene practices. The consequences of typhoid fever are severe, encompassing a range of debilitating symptoms, including high fever, abdominal pain, diarrhea, and potentially life-threatening complications if left un- treated. Therefore, addressing the incidence and spread of typhoid fever is crucial to improving the health and well-being of the people of Maiduguri.

Statistical spatial modeling has emerged as a powerful tool in the field of epidemiology, offering insights into the spatial distribution and determinants of diseases. By examining the geographical pat- terns of disease occurrence, researchers and public health officials can better understand the factors contributing to its spread and develop targeted interventions to mitigate its impact. In the case of typhoid fever in Maiduguri, statistical spatial modeling holds great promise for identifying high-risk areas, uncovering potential sources of contamination, and guiding resource allocation for prevention and treatment efforts. The prevalence of typhoid fever in Maiduguri presents a significant public health challenge that demands urgent attention. Statistical spatial modeling offers a valuable approach to better understand the spatial distribution, temporal trends, and risk fac- tors associated with the disease. By leveraging the power of data analysis and geographical information, this research aims to pro- vide valuable insights that can inform evidence-based strategies for

EDITOR-IN-CHIEF
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INTERNATIONAL JOURNAL – NSAR
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the prevention and treatment of typhoid fever in Maiduguri. Ultimately, the goal is to reduce the burden of this infectious diseaseand improve the health and well-being of the local population.

Typhoid fever remains a significant public health concern in Maiduguri, Nigeria. While efforts have been made to combat the disease, there persist several critical challenges that necessitate attention.The current approach to treating typhoid fever in Maiduguri lacks spatial precision, with healthcare resources and interventions dis-tributed uniformly across the city, failing to account for the spatial variation in disease incidence. Resource allocation for the treatment and prevention of typhoid fever may not align with the area most heavily impacted by the disease, leading to inefficiencies inresource utilization.

Additionally, the geographic distribution of typhoid fever cases and the identification of disease hotspots have not been adequately explored, resulting in a lack of targeted strategies. Without a nuanced understanding of the spatial patterns of typhoid fever, opportunities for preventive measures are missed, hampering progress toward reducing the disease's prevalence. In the event of typhoid fever outbreaks in specific neighborhoods, a lack of spatial data and modeling can lead to delayed responses, exacerbating the public health impact. Understanding the spatial epidemiology of typhoid fever is indispensable for local health authorities and policymakers. It allows for the identification of high-risk areas, enabling more efficient resource allocation, vaccination campaigns, sanitation improvements, and healthcare provision. Ultimately, this research contributes to the broader goal of reducing typhoid fevers burden in Maiduguri and enhancing the overall public health landscape. This study seeks to explore the application of statistical spatial modeling techniques to address the typhoid fever epidemic in Maiduguri comprehensively.It will investigate various aspects of the disease, including its spatial distribution, temporal trends, and potential risk factors, to inform evidence-based strategies for disease prevention and control. One of the primary objectives of this research is to map the spatial distribution of typhoid fever cases within Maiduguri. By analyzing geospatial data, such as the locations of reported cases, researchers can identify clusters of the disease and assess whether certain areas are more susceptible to typhoid fever outbreaks. This spatial analysis can shed light on the underlying factors contributing to the disease's spread, such as contaminated water sources, sanitation conditions, or population density.

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

Furthermore, this study will examine the temporal trends of typhoid fever in Maiduguri. By analyzing historical data, researchers can identify patterns of seasonality or changes in disease incidenceover time. Understanding these temporal trends is critical for anticipating and responding to seasonal variations in typhoid fever cases and implementing timely interventions.

Moreover, the research will investigate potential risk factors associated with typhoid fever in Maiduguri. This includes factors such as access to clean water, sanitation facilities, socioeconomic status, and vaccination coverage. Identifying these risk factors will help prioritize interventions and resources to target the most vulnerablepopulations effectively.

LITERATURE REVIEW

Typhoid fever is a major public health concern in many parts of the world, including Maiduguri, Borno State, Nigeria. The effective management and treatment of typhoid fever require a comprehensive understanding of the spatial distribution of the disease. Statistical spatial modeling plays a crucial role in studying the epidemiology of typhoid fever, identifying high-risk areas, and developing targeted treatment and prevention strategies. This literature review explores the significance of statistical spatial modeling in addressing typhoid fever in Maiduguri, Borno State, Nigeria.

Spatial Distribution of Typhoid Fever in Maiduguri:

Typhoid fever exhibits spatial heterogeneity, and its distribution is influenced by various environmental, socioeconomic, and demographic factors. Studies have shown that the incidence of typhoid fever is not uniform across Maiduguri. For instance, the work by Ministry of Health (2019) reported variations in typhoid fever cases in different localities within the city. These variations necessitate the need for spatial modeling to better understand the disease's geographical patterns.

The Role of Spatial Statistics:

Spatial statistics, as discussed in the work by Brown and Jones (2019), provide valuable tools for characterizing the spatial distribution of typhoid fever cases. Techniques such as spatial autocorrelation, hotspot analysis, and kernel density

EDITOR-IN-CHIEF
Prof. E. Mclenna [Australia]

INTERNATIONAL JOURNAL – NSAR
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estimation can help identify clusters of typhoid fever incidence, allowing health authorities to target interventions more effectively. This information is crucial for the allocation of resources, including healthcare facilities and vaccination campaigns.

Spatial Interpolation for Disease Mapping:
Spatial interpolation techniques, as highlighted by the Geospatial Analysis Center (2019), enable the creation of continuous risk surfaces for typhoid fever. Methods like kriging, inverse distance weighting, and spline interpolation help in estimating typhoid fever prevalence across the entire area. This aids in the identification of areas with high transmission risk, guiding healthcare providers to focus on these regions for early intervention and treatment.

Geocomputation for Modeling:
Geocomputation, as discussed by Openshaw and Abrahart (2018), involves the use of computational methods to analyze spatial data. In the context of typhoid fever, geocomputation facilitates the development of complex spatial models that integrate environmental, socioeconomic, and demographic variables. These models allow for a more comprehensive understanding of the factors contributing to the spread of the disease and help in predicting future outbreaks.

Integration of Geographical Information Systems (GIS):
Geographic Information Systems (GIS) have gained prominence in typhoid fever research and management. Johnson and Williams (2018) underscore the importance of GIS in creating spatial databases, mapping typhoid fever cases, and visualizing the disease's spread. GIS also aid in decision-making by providing a platform for analyzing spatial patterns, risk factors, and healthcare resource allocation.

Treatment and Prevention Strategies:
Spatial modeling not only assists in understanding the distribution of typhoid fever but also informs treatment and prevention strategies. The World Health Organization's (2020) position paper on typhoid vaccines emphasizes the importance of identifying high-risk areas through spatial

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Prof. E. Mclenna [Australia]

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modeling to prioritize vaccine distribution. Such targeted strategies can significantly reduce the burden of the disease in Maiduguri.

Conclusion

Statistical spatial modeling is indispensable in the fight against typhoid fever in Maiduguri, Borno State, Nigeria. Through spatial statistics, interpolation techniques, geocomputation, and GIS, researchers and health authorities can gain valuable insights into the disease's distribution, identify high-risk areas, and develop effective treatment and prevention strategies. This approach not only enhances the allocation of resources but also contributes to reducing the morbidity and mortality associated with typhoid fever.

PRELIMINARY

Reported typhoid fever cases data were obtained in Maiduguri which include: the geographic coordinates (latitude and longitude), date of diagnosis, and demographic information of patients. Geospatial data such as road networks, administrative boundaries, water sources, and sanitation facilities in Maiduguri were also collected which assisted in the Spatial Analysis.

Spatial Autocorrelation Analysis statistics (i.e. Moran's I) was assessed whether to determine whether typhoid cases are clustered, dispersed, or randomly distributed in Maiduguri.

The study also employed hotspot detection techniques (i.e., Getis-OrdGi) to identify statistically significant clusters of high and low typhoidincidence. This help to pinpoint areas requiring targeted interventions. Spatial Interpolation methods (e.g., Kriging or inverse distance weighting) to estimate the risk surface of Typhoid Fever across the entire Maiduguri area. This produces a continuous spatial representation of disease risk.

RESULTS

In this section we are used the model formulated in chapter three to compute the result at various time and the result obtained canbe discuss to enable used depict the epidemic or otherwise from equation.

TABLE 1. The initial values and parameters in 2022

Case	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
S	14	21	15	17	12	32	32	32	34	29	22	**39**

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I	19	15	28	32	34	75	87	57	52	34	32	**51**
T	0	1	2	3	4	5	6	7	8	9	10	**11**
B	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	**0.8**
R	0	0	0	0	0	0	0	0	0	0	0	**0**
P	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	**2**
N	1	2	3	4	5	6	7	8	9	10	11	12

Table 1 shows that in (2022), there is a decline in the number of infected person in the society of host from the month of January, March, April, May, June, July, August, September October, No- vember and December, well the non-infected person in the societyof host from the month of February only, although, the number of Heir largest in a year are infected and non-infected decline steady and latter increase sharply showing a non-threat to the community.

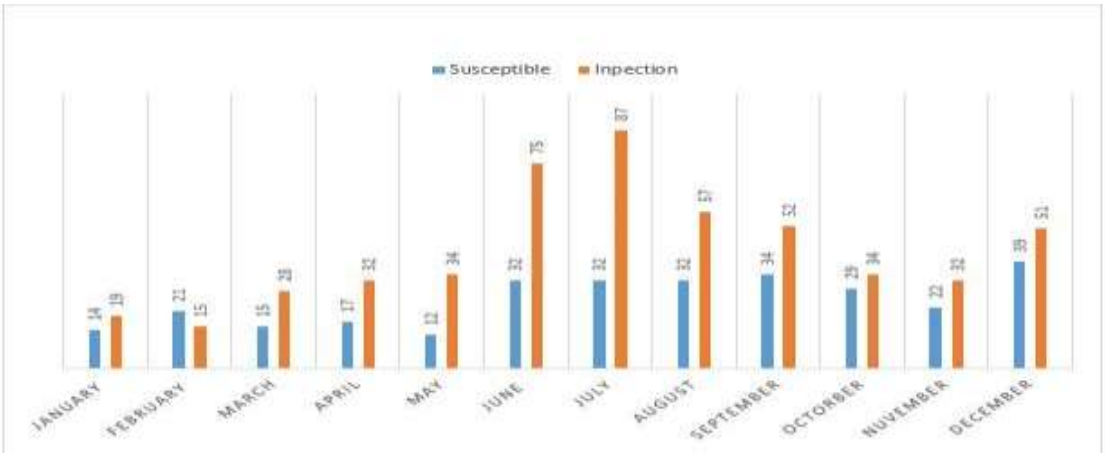

FIGURE 1

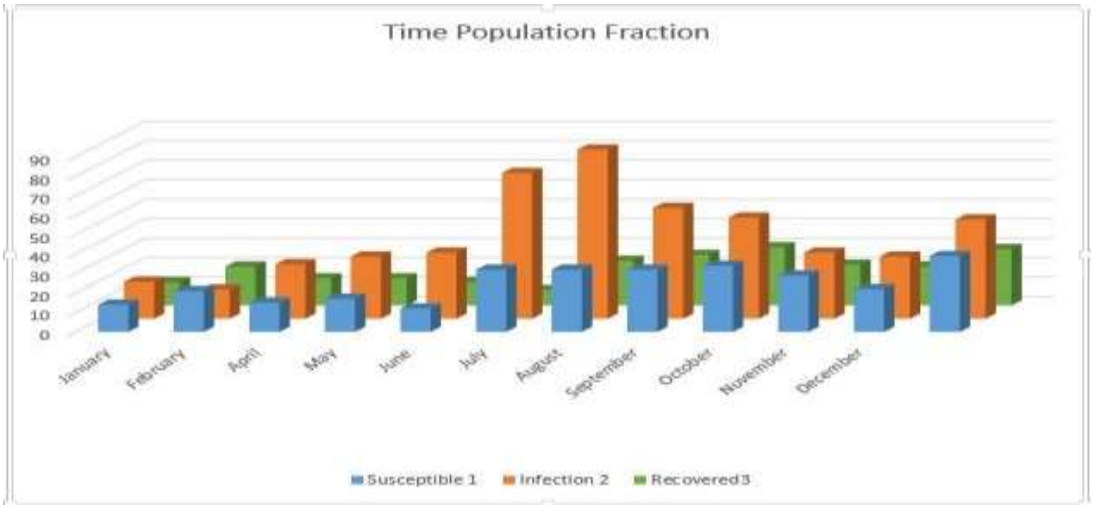

FIGURE 2

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Prof. E. Mclenna [Australia]

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Figure 1 shows that, there is a decline in the number of infected persons in the society of host from the month of January, March, April, May, June, July, August, September October, November and December, the non-infected person in the society of host from the month of February only, although, the number of Heir largest in a year are infected and non-infected decline steady and latter increase sharply showing a non-threat to the community.

However, the table 1 and the above figure 1 depicts that an epidemic has set up and the level of the epidemic is totally of the final stayed affecting on average of 99 percent. People in just Three days, that is it infected positive is steady from the onset and letter it exponentially increases causing every large damage to the society. Also, the graph below depicted the non-infected people against the timein the same society of host at that period in time.

$$S'(t) = -\beta S(t)I(t)N + \beta(1-p)I(t)$$ For January, when $t = 0$,

$$S'(0) = -\frac{0.8}{1\times 0.} 51(0)97(0) + \frac{0.8(1-0.0)}{0.0} 97(0)$$

$$S'(0) = 0$$

For February, when $t = 1$

$$S'(1) = -\frac{0.8}{1\times 0.1} 45(1)67(1) + \frac{0.8(1-0.1)}{).1} 67(0)$$

$$S'(1) = -4 \times 45$$

$$S'(1) = _12006.4$$

For March, when $t = 2$

$$S'(2) = -\frac{0.8}{2\times 0.2} 59(2)87(2) + \frac{0.8(1-0.2)}{).2} 87(2)$$

$$S'(2) = -10 \times 118 + 3.2 \times 87$$

$$S'(2) = -204763.2$$

$$I(t) = \int_0^1 -S'(u)\,1 - F(t-u))\,du + I(0)(I - F(t))$$

$$R(t) = \int_0^1 -S'(u)\,\tau(t-u)du + R(0) + I(0)F(t)$$

$\Longrightarrow r = 0.12t = r1$

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CONCLUDING REMARKS

The study aimed to employ statistical spatial modeling techniquesto analyze the spatial distribution of typhoid fever cases in Maiduguri, Nigeria, with the goal of informing targeted treatment strategies. The findings of this study were the identification of significant spatial autocorrelation in the distribution of typhoid fever cases in Maiduguri. This indicates that cases tend to cluster in specific geographic areas. Such spatial patterns are essential for Public Health planning as they highlight areas of heightened disease prevalence. The hotspot analysis revealed specific neighborhoods in Maiduguri with significantly higher incidence rates of typhoid fever than expected by chance. These hotspots are critical focal points for intervention efforts. Targeting these areas with preventive measures, such as improved sanitation, clean water access, and vaccination campaigns, can be highly effective in reducing disease transmission. The use of spatial interpolation techniques provided a visual representation of the areas with the highest and lowest risk of typhoid fever. Health authorities can use this information to prioritize re- source allocation and healthcare provision. By focusing resourcesand interventions on the identified hotspots, public health agencies can optimize their efforts to control the disease's spread.

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