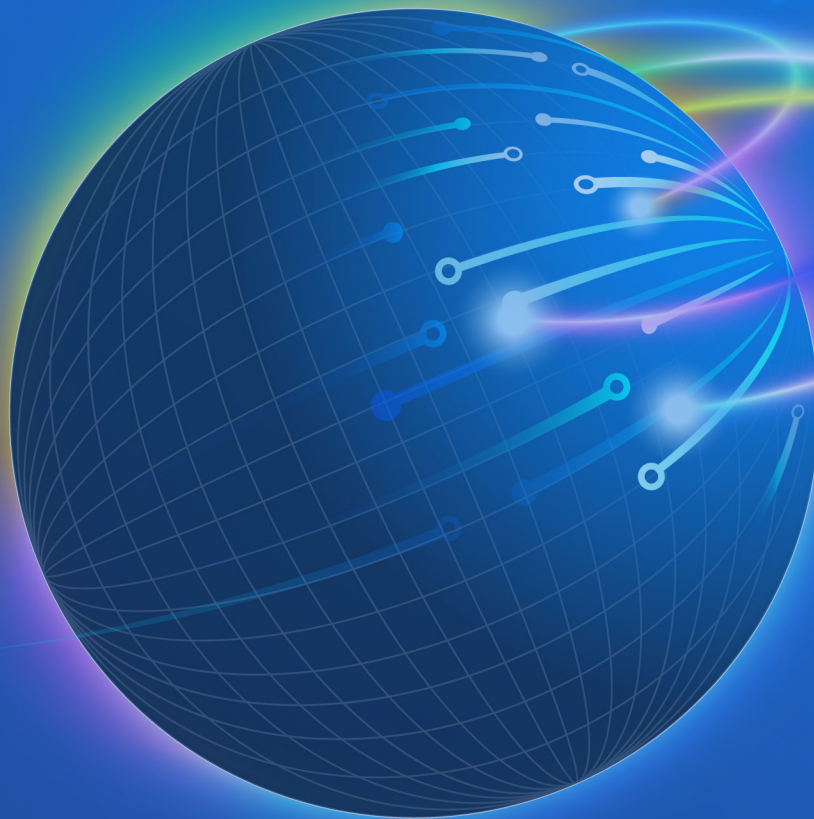




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Spatial Analysis of Internally Displaced Persons' Camps in Borno State, Nigeria

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ABSTRACT

The situation in Borno State, Nigeria has been exacerbated by the ongoing insurgency led by Boko Haram in northeast Nigeria, leading to widespread displacement and the establishment of Internally Displaced Persons (IDP) camps. This study aims to identify the locations of IDP camps in Borno State and analyze their spatial distribution, density, and clustering patterns. Furthermore, it seeks to investigate the geospatial implications of these patterns. To achieve this, the study employs geospatial analysis techniques such as Kernel Density Estimation, Cluster and Outlier Analysis, Nearest Neighbour Analysis, and Spatial Autocorrelation Analysis. The data collected for this study includes location coordinates, satellite imagery, demographic information, and administrative maps. The findings reveal that the distribution of IDP camps in Borno State is non-random and demonstrates varying camp densities across senatorial districts, with predominant high-high clusters and a deliberate, non-random arrangement. These results align with spatial analysis theories, emphasizing the importance of recognizing hidden inequalities in IDP camps and informing targeted interventions and resource planning for a more effective and equitable humanitarian response in Borno State. The implications extend to policy planning and enhanced vulnerability assessment for effective humanitarian responses, stressing the need for tailored interventions based on identified hotspots that address root causes and implement both immediate and long-term solutions. Future research directions could involve more in-depth investigations into the influencing factors, socio-economic impacts, and temporal dynamics of spatial patterns in displacement.

INTRODUCTION

Displacement is a complex issue that is driven by a range of factors. Adams (2021) and Tesfaw (2022) identified conflict and climate-induced factors as the major drivers of displacement. Northeast Nigeria has been grappling with a protracted humanitarian crisis primarily due to the activities of the Boko Haram insurgency which has persisted for over a decade, resulting in widespread displacement, with Borno state as the worst-hit state (Internal Displacement Monitoring Center (IDMC), 2020; International Organization for Migration (IOM) Nigeria, 2021; Omogunloye *et al.*, 2023). The impact of internal displacement in Borno State, Nigeria, is significant, with over 2 million people rendered homeless and compelled to seek refuge in Internally Displaced Persons' (IDPs') camps, resulting in a dire humanitarian crisis. (Internal Displacement Monitoring Center (IDMC), 2020; International Organization for Migration (IOM) Nigeria, 2021).

This crisis has not only affected the socio-economic and political fabric of Borno State, but has also drawn attention to the urgent need for humanitarian assistance and intervention for IDPs in the region (Musa *et al.*, 2019; Patrick & Terungwa, 2022). Various international organizations provide essential healthcare, education, shelter, security, food and non-food items, orientation, durable solutions, and psychosocial support for IDPs (Adeleye & Osadola, 2022). However, lack of a clear

national policy and institutional framework in addressing internal displacement in Nigeria has further intensified the plight of the IDPs (Akujobi & Awhefeada, 2021; Gbigbiddje *et al.*, 2020; Gwadabe *et al.*, 2018). The humanitarian crisis in Borno State emphasises the need for a comprehensive understanding of the spatial distribution and patterns of these IDP camps to facilitate effective planning, management, and resource allocation. In the context of Borno State, where the displacement crisis is exacerbated by security concerns, environmental conditions, and resource availability, geospatial analysis has become an indispensable tool (Anselin, 1995).

Research on the vulnerability and risk assessment of internal displacement (Mbaya *et al.*, 2017; Mohammed, 2017; Granville, 2020) commonly omits the spatial dimension of displacement, creating an analytical gap. Goodchild and Janelle (2010) posited that geospatial analysis harnesses the power of spatial data and technologies, providing valuable insights for a holistic perspective into the spatial intricacies of the distribution, density, and clustering of IDP Camps.

Several studies have successfully employed a range of geospatial techniques to analyse the distribution of IDP camps in contexts similar to internal displacement in Borno State. Tiede and Lang (2009) applied object-based image analysis algorithms to extract dwellings and calculate value-added products such as dwelling density and camp structure. Bramante and Raju (2013) used

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logistic regression to predict the distribution of IDP camps in Port-au-Prince, Haiti, based on factors such as the distance from the international airport, distance from the city centre, and elevation. Füreder *et al.* (2015) provided Earth observation-based information services to support humanitarian operations in refugee/IDP camps, including population monitoring and analysis of camp structure and evolution. Dobryakova *et al.* (2023); Weigand *et al.* (2023) highlight the use of geospatial techniques to analyse the distribution pattern of IDP camps. Weigand's work focuses on the structural morphology of these camps using satellite imagery and machine learning to create a global database of settlement structures. This approach can be further enhanced by incorporating the findings of Dobryakova, who emphasised the importance of geoinformation mapping in understanding the spatial dynamics of population distribution.

Thus, this study seeks to examine the spatial patterns associated with the distribution, density, and clustering of IDP camps in Borno. This involved mapping IDP camps in Borno State, examining their spatial distribution, density, and clustering patterns, and analysing the geospatial implications of the identified patterns. The outcomes of this geospatial analysis are anticipated to guide targeted interventions, enhance the efficiency of resource allocation, and ultimately improve the overall management of IDP camps in Borno.

The Study Area

Borno State is located in north-eastern Nigeria, with Maiduguri as the capital city. The state's absolute geographic location lies between latitudes 10° 01' 37" and 13° 74' 49" North of the equator and longitudes 11° 54' 26" and 14° 67' 30" East of the Greenwich meridian, as illustrated in Figure 1. It shares borders with Niger to the North, Cameroon to the East, Adamawa State to the South, Gombe State to the Southwest, Yobe State to the West, and a greater part of the Chad Basin to the Northeast. Borno State as at 2006 had a population of 4,171,104, projected to be around 7,498,333 in 2021, spread across three Senatorial Districts comprised of nine (9) Local Government Areas (LGAs) each aggregating to twenty-seven (27) LGAs (National Population Commission of Nigeria (NPC), 2006). The state has a predominance of Kanuri people and other ethnic groups, such as the Lapang, Babur, Bura, Mandara, Marghi, and Shuwa Arabs among others (Scheinfeldt *et al.*, 2010). Like many states in the northeast of Nigeria, their predominant occupation is agriculture. Borno state being the epicentre of conflict-induced displacement and humanitarian crisis in Nigeria, it is therefore crucial to understand the spatial distribution and patterns of IDP camps in Borno.

MATERIALS AND METHOD

Theoretical Framework of the Research

To understand the spatial intricacies of IDP camps in Borno State, our study adopted a multidimensional approach, drawing insights from human geography,

critical spatial analysis, and spatial justice to ensure a comprehensive analysis. Guided by Harvey's (2009) critical spatial analysis, our methodology explored the dialectic relationship between space and society. This approach explores the impact of political decisions, conflict dynamics, and power relations on the distribution and management of IDP camps, thereby revealing hidden inequalities and social injustices. Complementing this, Soja's (2010) spatial justice concept has become pivotal, advocating for the fair distribution of resources within a given space. This framework evaluates resource distribution patterns and addresses both physical structures and demographic characteristics (Harvey 2009; Soja 2010). Aligning with the quantitative geography theoretical framework, Tobler's (1970) First Law of Geography justifies the application of spatial analysis techniques to unveil patterns, clusters, and relationships within the IDP camp dataset. Thus, this study integrates geospatial analysis, including GIS and spatial statistics, using techniques such as Kernel Density Estimation (KDE), Cluster and Outlier Analysis, Nearest Neighbour Analysis, and Spatial Autocorrelation.

Ahasan *et al.* (2022); Getis and Ord (1992) Goodchild (1992) emphasised the importance of geospatial analysis in visualising distribution patterns. Anselin's Local Moran's I gained prominence in analysing spatial clustering and outliers, contributing to the identification of High-High (HH) and Low-Low (LL) clusters of IDPs' camps (Anselin, 1995). The Nearest Neighbour Analysis, rooted in Clark and Evans (1954), assesses spatial patterns in point data. Spatial Autocorrelation Analysis, particularly Moran's I statistic, which is widely used across disciplines, helps to examine spatial patterns (Cliff & Ord, 1970). This approach allows for the aggregation of statistical data and enhances analytical capabilities through geospatial methods including data integration, visualisation, Exploratory Spatial Data Analysis (ESDA), Confirmatory Spatial Data Analysis (CSDA), and statistical modelling. The selection of clustering as a primary analytical method was motivated by its ability to automatically aggregate displacement operation data, identify an appropriate scale of analysis, and correct for both multiple testing and spatial dependence.

In exploring the spatial arrangement of objects in this context, IDP camps and Point Pattern Analysis have emerged as the most appropriate methods to address the challenges surrounding IDP camp distribution and evaluate the effectiveness of humanitarian responses. Scholars like Ahasan *et al.* (2022); Dobryakova *et al.* (2023) and Weigand *et al.* (2023) have successfully employed these techniques to analyse the spatial distribution, density, clustering, and dispersion of IDP camps, treating them as points in space.

Data Collection

The data collected for the research includes location coordinates of the IDP camps, satellite imagery, demographic information, and administrative maps. Table 1 presents the details of the data acquired in this study.

Table 1: Details of the data collected for the study

Datasets	Description	Sources	Uses in the study
Location coordinates	Northing Easting coordinates of the IDP camps in projected as UTM Zone 33N, WGS 84 datum	Field surveys, humanitarian organizations and government agencies reports	For determination of the precise locations of the existing IDP camps
Satellite imagery	High-resolution satellite images obtained from	GeoEye, now part of Maxar Technologies,	served a powerful tool for the geospatial analysis
Demographic and aspatial attribute	the number of households and individuals in each IDP camp,	International Organization for Migration (IOM) dataset.	Essential for understanding the population density and assessing the impact on the camps.
Administrative maps	Information on Senatorial district boundaries, Local Government Areas (LGA), wards, neighborhoods	Grid 3 Nigeria and Ministry of lands	This dataset forms the foundation for the geospatial analysis

Source: Author's Computation, 2023

Method of Data Processing and Analysis

Data preprocessing for the analysis involved importing the IDP camp location data into GIS software and converting them into a point feature layer. Cleaning and filtering of the data were then performed to remove errors or duplicates. Thus, the GIS and demographic datasets were standardised to ensure consistency and accuracy in subsequent analyses. The geospatial analysis carried out in this study involves a workflow of sequential application of Kernel Density Estimation (KDE), Cluster and Outlier Analysis (COA), Nearest Neighbour Analysis (NNA), and Spatial Autocorrelation Analysis (SAA). The uniqueness of each step contributes to a holistic understanding of the spatial patterns, clusters, and relationships within IDP camps across Borno State. KDE was employed to perform point density analysis which aided in understanding the overall spatial patterns and variations. This technique enabled the visualisation of the distribution and concentration of IDP camps, identifying hotspots and coldspots, by creating a density surface that shows the number of IDP camps per unit area across Borno State. NNA was used to determine if the IDP camps were randomly distributed, clustered, or dispersed. This analysis involves comparing the observed nearest neighbour distance with the expected distribution under randomness which implies measuring the distance between each IDP camp and its nearest neighbour. Clustered patterns have smaller distances between their nearest neighbours, whereas dispersed patterns have larger distances. Anselin Local Moran's I was used to identify groups of points that were closer to each other than to other points in the study area. This technique helped detect hotspots or outliers and uncover clusters of high-density camps (High-High), low-density camps (Low-Low), and areas with unexpected patterns (High-Low and Low-High). The Anselin Local Moran's I was required to weigh the COA. To understand the distribution of the weighting, a summary statistic of individuals in the IDPs camps in Borno State was calculated. Moran's I statistic was employed for SAA to assess and measure the degree to which spatially adjacent observations tended to be

more similar (positive spatial autocorrelation) or dissimilar (negative spatial autocorrelation) than would be expected by chance. This analysis helped to determine if there was a significant spatial correlation between the IDP camp locations and other spatial variables such as elevation, land use, population density distance to resources, or vulnerability index. The methodology adopted was based on the global Moran's I statistic calculated using Equation (1) (Chainey *et al.*, 2008).

$$I = \frac{N \sum_{i=1}^N \sum_{j=1}^N \omega_{ij} (X_i - \bar{X})(X_j - \bar{X})}{W \sum_{i=1}^N (X_i - \bar{X})^2} \quad (1)$$

Where:

- N = number of spatial units indexed by i and j;
 - X = variable of interest, u
 - \bar{X} = mean of X; and
 - ω_{ij} = element of a matrix of spatial weights. with zeroes on the diagonal (i.e., $\omega_{ii}=0$)
 - W = sum of all ω_{ij} (i.e. $W = \sum_{i=1}^N \sum_{j=1}^N \omega_{ij}$)
- The value of Moran's I ranges from -1 (perfect negative spatial autocorrelation) to 1 (perfect positive spatial autocorrelation), with values close to 0 indicating no spatial autocorrelation.

RESULTS AND DISCUSSION

Presentation of Results

The geospatial analysis conducted in this study utilised a combination of Kernel Density Estimation (KDE), Cluster and Outlier Analysis, Nearest Neighbour Analysis, and Spatial Autocorrelation Analysis techniques. This required mapping IDP camps location in Borno State (Figure 1). The results presented in the analysis were derived from a series of geospatial techniques aimed at understanding the spatial patterns and distribution of Internally Displaced Persons (IDP) camps in Borno State. Kernel Density Estimation (KDE) analysis was used to estimate the distribution of IDP camps in Borno state. This analysis visually highlighted the varying camp densities (Figure 3a). Extending the exploration of spatial patterns, Weighted Cluster and Outlier Analysis (Anselin Local Moran's I) was employed to understand

spatial variations in the prevalence and concentration of camps. The results categorised camps into different clusters (High-High, High-Low, Low-High, Low-Low) based on their counts and neighbouring camps (Figure 3b). Prior to this, Summary Statistics were conducted to evaluate the spatial distribution of weighting parameters, considering both the values and their spatial relationships spanning the study area, which covers approximately 79823060373.942566 square meters. This revealed the distribution and variability in the number of individuals across the camps (Figure 2a). To provide additional information, the spatial relationships between the values and their lags were evaluated using a Moran's scatter plot (Figure 2b). Consequently, Nearest Neighbour Analysis (Figure 3c) was used to assess the spatial arrangement of IDP camps by comparing the observed distances between them to the expected distances in a random

distribution. Spatial Autocorrelation Analysis (Figure 3d) employed the Global Moran's Index to evaluate the degree of similarity between neighbouring IDP camps in terms of a specific variable. Statistically significant positive spatial autocorrelation revealed a non-random pattern in the distribution of IDP camps based on the analysed variables.

The analysis used the "IDP_Camps" feature class, focusing on the "INDIVIDUAL" field. The conceptualization method employed was "INVERSE_DISTANCE," with a distance method of "EUCLIDEAN." Row standardisation was applied (True), and a distance threshold of 337873.2495m was used to capture spatial dependencies or patterns. This specific context considered the scale of the study, the nature of the data, and characteristics of the spatial processes being investigated (Getis, 2010).

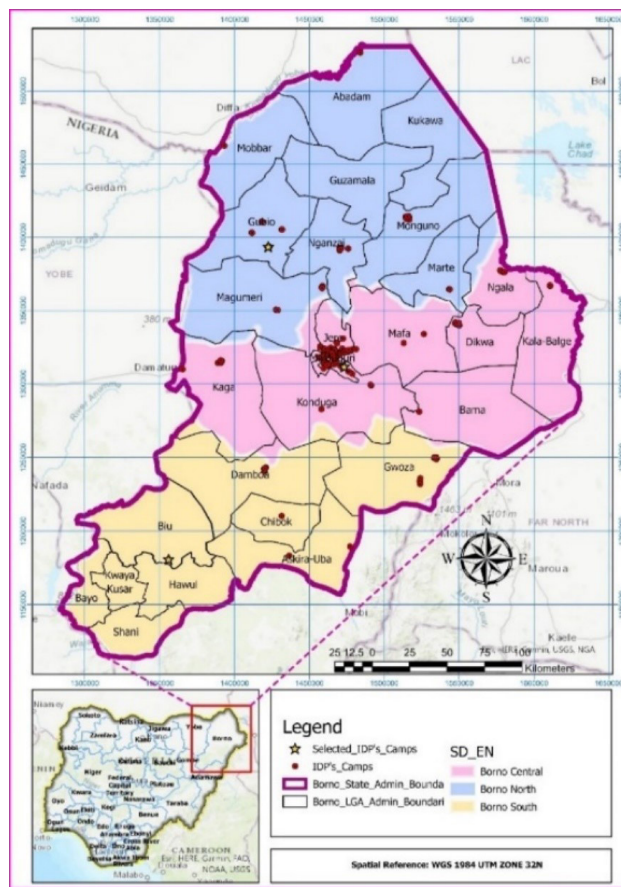


Figure 1: Locations of IDP camps by their respective senatorial districts in Borno State, Nigeria. *Source: Vectorised from Digital Global Satellite Imagery at @0.6-meter resolution (2021), paper map acquired from the Borno State Ministry (Borno State Ministry Physical Planning and Urban Development, 1988; International Organization for Migration (IOM) Nigeria, 2021).*

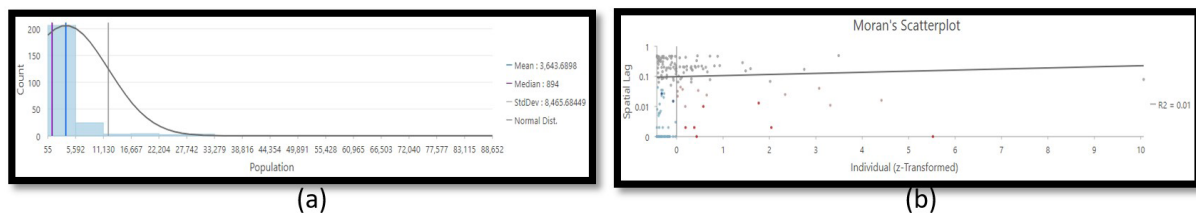
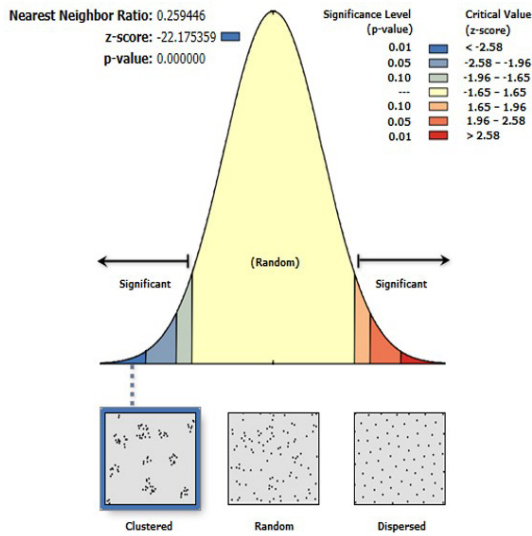
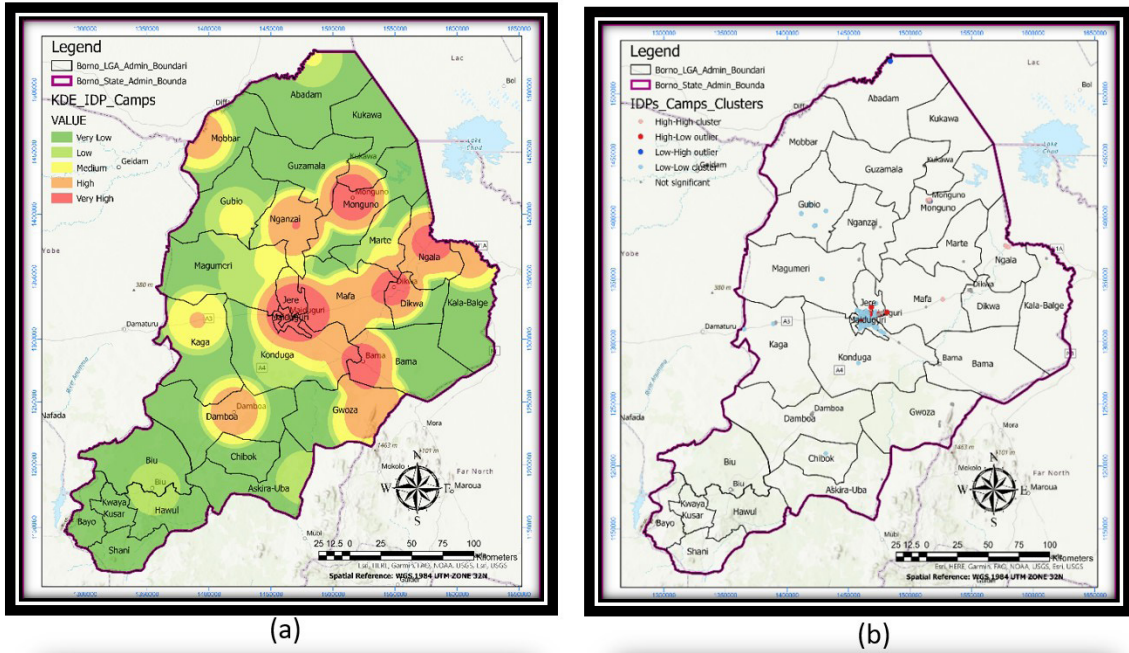


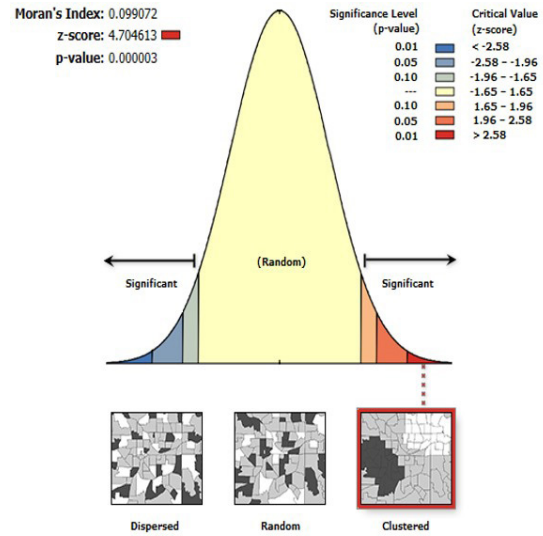
Figure 2: (a) Dataset for weighting of Cluster and Outlier Analysis of IDPs Camps distribution in Borno state; (b) Moran's Scatterplot of Cluster and Outlier Analysis (Anselin Local Moran's I) of IDPs Camps distribution in Borno state. *Source: Author's Computation, 2023.*



Given the z-score of -22.175359, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Average Nearest Neighbour Summary	Dataset Information
Observed Mean Distance: 2341.5215 Meters	Input Feature Class: XYTableToPoint
Expected Mean Distance: 9025.0819 Meters	Distance Method: EUCLIDEAN
Nearest Neighbour Ratio: 0.259446	Study Area: 79823060373.942566
z-score: -22.175359	Selection Set: False
p-value: 0.000000	

(c)



Given the z-score of 4.704613, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Dataset Information
Input Feature Class: IDP_Camps
Input Field: INDIVIDUAL
Conceptualization: INVERSE_DISTANCE
Distance Method: EUCLIDEAN
Row Standardization: True
Distance Threshold: 337873.2495 Meters
Weights Matrix File: None
Selection Set: False

Global Moran's I Summary
Moran's Index: 0.099072
Expected Index: -0.004098
Variance: 0.000481
z-score: 4.704613
p-value: 0.000003

(d)

Figure 3: (a) Spatial Patterns and Hotspot Analysis of IDPs' Camps in Borno State: A Kernel Density Estimation Approach (b) Spatial Distribution Patterns of IDPs' Camps in Borno State: A Cluster and Outlier Analysis (c) Spatial Analysis of IDPs' Camps Distribution in Borno State: Nearest Neighbour Analysis (d) Spatial Analysis of IDPs' Camps Distribution in Borno State: Spatial Autocorrelation Analysis

Source: Author's Computation, 2023

DISCUSSION

Integrated geospatial analysis involving Kernel Density Estimation (KDE), Cluster and Outlier Analysis, Nearest Neighbour Analysis and Spatial Autocorrelation

Analysis was employed to understand the spatial patterns, distribution, and management of IDP camps in the study area. This is rooted in the theoretical framework of quantitative geography Tobler (1970) First Law

of Geography, stating that “Everything is related to everything else, but near things are more related than distant things” underpins the rationale for employing spatial analysis techniques to uncover patterns, clusters, and relationships within the IDP camps. This synthesis yielded a comprehensive and dynamic assessment of the spatial patterns of IDP camps in the region for effective planning and allocation of resources.

The Kernel Density Estimation (KDE) analysis in Figure 3a reveals distinct spatial patterns of IDP camps in Borno State. Visual representation indicates varying camp densities, with the Borno Central Senatorial District showing a significantly higher concentration, while camps in the Northern and Southern districts appear more dispersed. These patterns are indicative of the underlying dynamics of conflict, accessibility, and resource availability in Borno State. This aligns with the literature on the subject (Bramante & Raju, 2013), confirming the vulnerability of certain regions to hosting higher numbers of IDP camps.

Results from the summary statistics of individuals in IDP camps in Borno State for the weighted Cluster and Outlier Analysis revealed a right-skewed distribution, as indicated by the significant difference between the mean (3643.69) and median (894). With a high standard deviation of 8465.684, the data exhibited substantial variability in the number of individuals across camps, ranging from a minimum of 55 to a maximum of 88652. The skewness value (5.893874) suggested a few camps with exceptionally high numbers, contributing to the rightward tail, whereas the kurtosis value (49.27554) indicated extremely heavy tails and the presence of extreme outliers (Figure 2a). The right-skewed distribution and heavy-tailed nature of the data imply that certain camps had significantly higher numbers of individuals. Spatial analysis using Anselin Local Moran’s I identified clusters, outliers, and spatial patterns, contributing to the understanding of the distribution of IDPs’ camps in Borno (Figure 2b). Moran’s Scatterplot from the weighting of cluster and outlier analyses depicted a weak positive relationship between z-transformed values and their spatial lags. This suggests a tendency for locations with higher values to be surrounded by neighbouring locations with similarly elevated values. These insights provide valuable information for targeted intervention and resource allocation in this region.

The Cluster and Outlier Analysis (Anselin Local Moran’s I) conducted on the spatial distribution of IDP camps in Borno State, as depicted in Figures 3b, reveals notable patterns. Of the 245 assessed IDP camps, 4.49% (11 camps) were identified as High-High (HH) clusters, indicating locations with a high number of neighbouring camps with high counts. Additionally, 2.86% (seven camps) exhibited a High-Low (HL) pattern, signifying areas with a high number of neighbouring camps but with low counts. A mere 0.82% (two camps) displayed a Low-High (LH) pattern, suggesting locations with a low count of camps surrounded by areas with high

counts. The majority, comprising 53.06% (130 camps), were categorised as Low-Low (LL), representing locations with a low number of neighbouring camps and low counts. Furthermore, 38.78% (95 camps) were deemed insignificant. The identification of distinct patterns, including High-High clusters and Low-Low locations, suggests spatial variations in the prevalence and concentration of camps. These results build upon existing research on the spatial dynamics of displacement, contributing to the broader discourse on the geographical aspects of humanitarian crises (Dobryakova *et al.*, 2023; Weigand *et al.*, 2023). The observed patterns may indicate underlying socio-economic or environmental factors that influence the distribution of IDP camps.

The Nearest Neighbour Analysis of IDP Camps distribution in Borno State, as depicted in Figure 3c, revealed a highly significant clustered pattern with a z-score of -22.175359 and a corresponding p-value of 0.000000. This result indicates a less than 1% likelihood that the observed clustered pattern could be attributed to random chance, suggesting a non-random deliberate arrangement of IDP camps in the region. The Average Nearest Neighbour analysis further quantified the spatial distribution, with an observed mean distance of 2341.5215m, which is significantly lower than the expected mean distance of 9025.0819m. The Nearest Neighbour Ratio of 0.259446 supports the presence of a clustered pattern, highlighting the non-uniform distribution of the IDP camps. This significant clustering aligns with previous studies that emphasise the importance of understanding the spatial organisation of IDP camps for effective humanitarian responses (Füreder *et al.*, 2015). Deliberate clustering may be influenced by factors such as security concerns, resource accessibility, and governmental policies.

The spatial autocorrelation analysis of IDP camps in Borno State, as illustrated in Figure 3d, employed the Global Moran’s Index to reveal a statistically significant positive spatial autocorrelation ($I = 0.099072$, $z = 4.704613$, $p < 0.001$). This result indicates a tendency for similar values of the individual variables to cluster in space, suggesting a non-random pattern in the distribution of IDP Camps based on the analysed variable. The observed variance of 0.000481 and strong positive spatial autocorrelation emphasise the presence of a structured arrangement of IDP camps, reinforcing the importance of understanding the spatial organisation of displaced populations.

The findings from the integrated geospatial analysis of IDPs’ Camps in Borno State imply that the spatial arrangement of IDP camps in Borno State is not random, suggesting a localised and concentrated arrangement rather than a uniform distribution. This aligns with previous analyses, emphasising the need for spatial analysis in humanitarian studies to uncover patterns and inform effective intervention strategies (Ahasan *et al.*, 2022; Dobryakova *et al.*, 2023; Füreder *et al.*, 2015; Weigand *et al.*, 2023). Statistically significant positive autocorrelation suggests that areas with similar characteristics tend to

host IDP camps in close proximity. The implications of this non-random pattern extend to policy planning and resource allocation, emphasising the importance of tailoring interventions based on specific characteristics and spatial distribution of displaced populations.

CONCLUSION

The geospatial analysis shed light on the intricate dynamics of IDP camp placement in Borno State, as a consequence of the enduring Boko Haram insurgency. Examining the spatial distribution, density, and clustering patterns facilitated a comprehensive understanding of the dynamics of IDP camps placement in Borno State. This was achieved by employing an array of geospatial analysis techniques, including Kernel Density Estimation, Cluster and Outlier Analysis, Nearest Neighbour Analysis, and Spatial Autocorrelation Analysis, which enabled a holistic interpretation of the data.

The uneven distribution of displaced populations, particularly concentrated in areas like Maiduguri Metropolitan Council and Monguno LGA highlights the underlying dynamics of conflict, accessibility, and resource availability. Cluster and Outlier Analysis provided further granularity for tailored interventions, emphasizing the need for intensified support in High-High clusters and proactive measures in Low-Low areas to prevent further vulnerability. Conversely, highly significant clustered patterns in the distribution of IDP camps, coupled with the low nearest-neighbour ratio, confirmed a localised and concentrated distribution rather than a random one, echoed by the statistically significant positive spatial autocorrelation.

This emphasises the need for distinct and localised interventions, considering the unique challenges faced by different regions. By recognizing hidden inequalities and social injustices in IDP camp arrangements, policymakers and humanitarian organizations can align resource allocation, aid distribution, and infrastructure planning more effectively. This approach, in line with critical spatial analysis theories, ensures that interventions address the unique needs of different areas, promoting more equitable support for the well-being of IDP populations.

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