MULTIVARIATE CLUSTERING ANALYSIS OF HUMAN SECURITY DIMENSIONS IN KWARA STATE, NIGERIA

By

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ABSTRACT

This study examined the spatial dimensions of human security in Kwara State, Nigeria, using a multivariate clustering approach embedded within a Geographic Information Systems (GIS) framework. Drawing on standardized indicators across six dimensions: economic, food, health, personal, political, and environmental security. The analysis identifies three major clusters of vulnerability and resilience across the State's sixteen Local Government Areas (LGAs). Results reveal that multidimensional hotspots, including Ilorin South and Ifelodun LGAs, face overlapping challenges such as high unemployment ($R^2 = 0.67$), limited agricultural land ($R^2 = 0.68$), and high crime rates (e.g., armed robbery, $R^2 = 0.92$), while coldspots like Ekiti and Patigi LGAs show relative stability across indicators. The study concludes that insecurity in Kwara is both spatially concentrated and thematically interconnected, demanding policy responses that move beyond aggregated, State-level strategies. By operationalizing a replicable, data-driven methodology, the study contributes to the advancement of spatially targeted governance and reinforces the value of geospatial diagnostics in human security planning across subnational contexts in Nigeria and beyond. The study, therefore, recommends that the Kwara State Government, through its Ministry of Planning and Economic Development, adopt spatially disaggregated, evidence-based policies in collaboration with local councils. Such place-sensitive planning is essential to address localized vulnerabilities and to ensure equitable security outcomes across the State

Keywords: GIS, Human security, Multivariate clustering, Policy, and Spatial analysis.

INTRODUCTION

Human security focuses on protecting individuals from critical threats that undermine their daily well-being, ranging from economic hardship and poor health to environmental hazards and personal insecurity (United Nations Development Programme [UNDP], 1994). This people-centred perspective is especially relevant in Kwara State, where multiple forms of vulnerability often occur together across Local Government Areas. Establishing this context is important because it justifies the need for a methodological approach capable of examining several dimensions simultaneously, thereby providing the basis for the multivariate clustering analysis adopted in this study.

Understanding the spatial distribution of human security threats requires methodological precision that captures both the complexity and interrelatedness of multiple vulnerability dimensions. In contexts such as Kwara State, Nigeria, where socio-economic inequality,

infrastructural deficits, health burdens, and political unrest co-occur, single variable assessments often fail to reveal the nuanced geography of risk. Rather than isolating indicators like poverty, water access, or violent crime, a multivariate clustering approach enables the simultaneous analysis of these dimensions, allowing researchers to identify joint vulnerability zones, geographic areas where multiple forms of insecurity converge.

This approach is particularly relevant given Kwara State's diverse socio-political and environmental conditions across its sixteen Local Government Areas (LGAs). Previous studies in the region have highlighted localized threats such as environmental degradation in Asa, high unemployment in Ifelodun, and rising personal insecurity in Ilorin South (Oladimeji et al. 2020; Usman, 2023; Alao et al., 2019). Yet, these studies often treat each dimension in isolation or rely on aggregated State-level data, obscuring spatial heterogeneity and limiting the precision of policy responses (Orire & Ogunfolaji, 2021; Nazarova et al., 2019). By integrating variables from domains such as economic, food, health, political, environmental, and personal security, multivariate clustering enhances our capacity to detect compound vulnerabilities and inform more coherent, multi-sectoral interventions.

Unlike traditional spatial techniques such as the Getis-Ord Gi*, which evaluate clustering within a single variable context, multivariate methods capture interdependencies among variables, revealing regions where multiple risks intersect. Recent literature underscores the power of such approaches. For instance, Aguilar and de Felice (2023) employed spatial clustering to analyze public health vulnerabilities in Tonga, while Mariosa et al. (2022) applied similar methods in the Amazon to guide sustainable development through socio-economic mapping. In Nigeria, Olawole et al. (2021) demonstrated how spatial-temporal analysis can uncover geographic inequalities in university enrollment, reinforcing the utility of location-based methods in identifying development disparities.

Despite the methodological promise of multivariate clustering, its application to human security studies in Nigeria remains limited. Existing analyses tend to privilege either qualitative case studies or broad national assessments that lack spatial specificity (Ukeje, 2005; Adaki, 2023). The absence of subnational, quantitative approaches hinders the development of evidence-based interventions tailored to Nigeria's highly localized patterns of insecurity. This paper responds to this gap by applying a multivariate clustering framework to human security indicators in Kwara State, drawing from an integrated dataset that includes both socio-economic and environmental variables.

Multivariate clustering further enhances analytical resolution by identifying not only hotspot zones but also coldspot regions with consistently low vulnerability across indicators. These spatial distinctions are crucial for resource prioritization, allowing policymakers to focus attention where the intersection of risk is most severe while recognizing areas of resilience that may serve as models. As noted by Sesgundo and Aranas (2024), clustering analysis enables the stratification of spatial patterns across multiple domains, thereby facilitating tailored policy frameworks responsive to local realities.

The study employs this analytical strength to classify human security in Kwara State across its LGAs, based on composite indicators spanning key development sectors. By embedding multivariate clustering within a Geographic Information Systems (GIS) framework, the study contributes both methodologically and empirically to the evolving discourse on spatialized human security. It offers a data-driven foundation for localized policy planning, ultimately

enhancing efforts to reduce insecurity and promote inclusive development in Nigeria's subnational regions.

THE STUDY AREA

Kwara State, located in the North-Central geopolitical zone of Nigeria, serves as the empirical locus for this study. Encompassing approximately 36,825 square kilometers between latitudes 7°N and 10°30'N and longitudes 3°E and 6°E. The state shares borders with five other Nigerian states and the Republic of Benin. It comprises sixteen Local Government Areas (LGAs), each characterized by distinct socio-economic patterns, ecological conditions, and urban-rural typologies (Fig. 1). This spatial heterogeneity makes Kwara a compelling site for analyzing the geospatial dimensions of human security (Morenikeji et al., 2023; Okeleye et al., 2023; Iyabo, 2024).

The State's population, estimated at over 3.2 million by the National Population Commission (2022), is unevenly distributed. Urban LGAs such as Ilorin South and Ilorin West are experiencing rapid population growth and infrastructural strain (Jimoh, 2023), while rural LGAs like Baruten and Patigi face chronic underdevelopment and environmental stressors (Olabanji et al., 2025). The economy remains predominantly agrarian, although informal trade, civil service employment, and small-scale manufacturing significantly contribute to livelihood structures (Adisa, 2024).

Recent human security challenges in Kwara State include diminished healthcare access, educational disparities, youth unemployment, political instability, and climate-induced environmental degradation (Ibor et al., 2024; Mbombo & Shittu, 2024; Sandra, 2025). These multidimensional stressors necessitate a spatially disaggregated approach. The mix of urban density, peri-urban expansion, and rural isolation offers a complex yet analytically tractable terrain for the application of geospatial clustering methods, offering broader relevance to urbanization and governance discussions in sub-Saharan Africa (Okeleye, 2023).

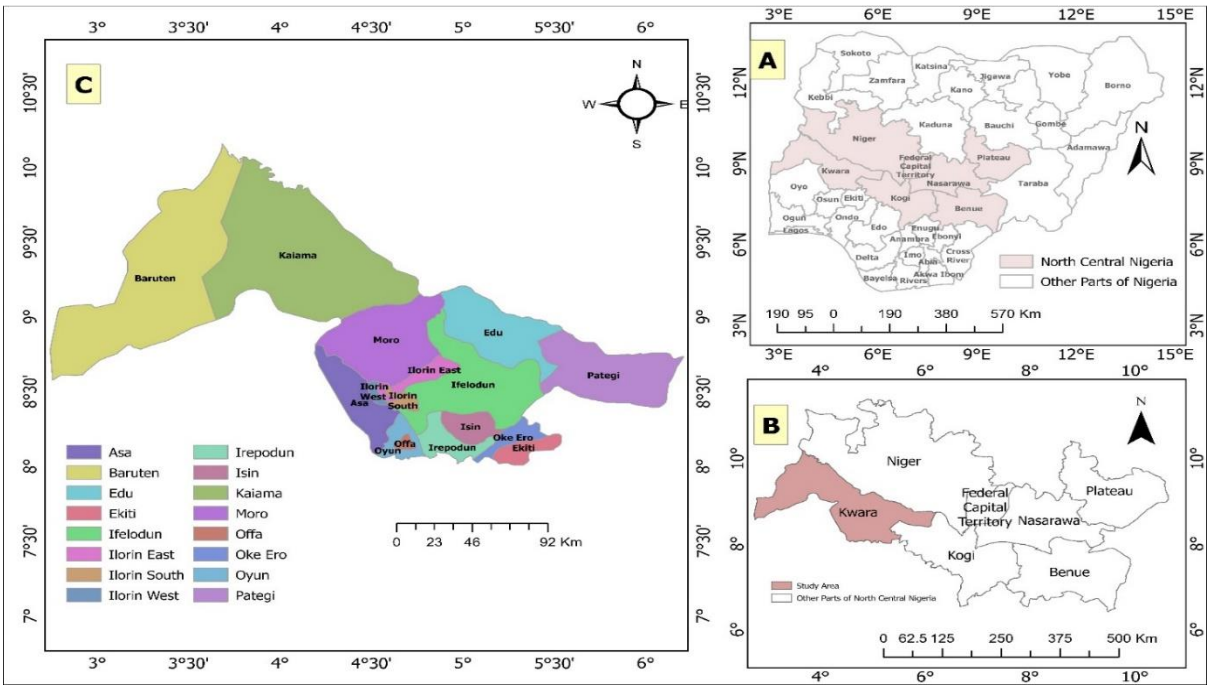

Figure 1: [A] Nigeria showing the North Central Zone, [B] North Central Showing the Study Area, [C] The Study Area showing the Sixteen LGAs in the Study Area

Source: Author's GIS analysis based on data from GRID 3 (2024).

MATERIALS AND METHODS

This study adopts a spatially explicit multivariate clustering approach to identify patterns of human insecurity across the 16 LGAs of Kwara State. Indicators were selected based on literature on human security frameworks (UNDP, 1994; Gasper and Gómez, 2022), contextual relevance, and data availability at the LGA level. The objective is to identify geographic hotspots and coldspots of human insecurity across the sixteen LGAs of Kwara State.

Secondary data on six indicators of human security dimensions were extracted from records on LGA bases from Kwara State Ministries of Education, Environment, Health, Agriculture, Bureau of Statistics, Police State Headquarters, Ilorin, among others. Indicators were grouped under six human security dimensions: economic (unemployment, industry), food (agricultural land use, markets), health (malaria incidence, access to clean water), personal (crime statistics, rates of armed robbery), political (protests, violence against civilians), and environmental (waste management, fire and flood). (See Table 1)

Table 1: Human Security Dimensions, Variables, Justification, and Data Sources

Human Security Dimension	Variable	Operational Definition	Justification	Source
Economic	Unemployment Rate	Percentage of labour force without paid employment.	Measures economic exclusion and income insecurity.	NBS, 2024
Economic	Number of Industries	Total number of registered industries per LGA.	Proxy for economic vibrancy and job opportunities.	NBS, 2024
Food	Agricultural Land Use	Total land area devoted to agriculture.	Reflects food production potential.	Kwara MOA; GRID3, 2024
Food	Functional Markets	Count of active markets per LGA.	Represents access to food and trade.	NBS; GRID3, 2024
Health	Malaria Incidence Rate	Number of confirmed malaria cases per 1,000 people.	Proxy for disease burden in tropical settings.	Kwara MOH, 2024

Note. This table presents the operationalization of human security dimensions in the study, outlining selected variables, rationale for inclusion, and primary data sources.

Table 1: Human Security Dimensions, Variables, Justification, and Data Sources (Cont'd)

Human Security Dimension	Variable	Operational Definition	Justification	Source
Health	Access to Clean Water (% Deprived)	Percentage of the population lacking safe drinking water.	Key determinant of health outcomes.	NBS; GRID3, 2024
Health	Secondary Health Facilities	Total secondary healthcare institutions per LGA.	Reflects healthcare infrastructure.	Kwara MOH, 2024
Health	Birth Rate	Live births per 1,000 people.	Demographic pressure on health services.	Kwara MOH, 2024
Personal	Armed Robbery Cases	Total recorded cases per LGA yearly.	Indicator of violent threats.	Kwara Police HQ, 2024
Personal	Rape/Indecent Assault	Yearly reported sexual assault cases.	Proxy for gender-based violence.	Kwara Police HQ, 2024
Personal	Culpable Homicide	Recorded homicide incidents per year.	Indicator of community safety.	Kwara Police HQ, 2024
Personal	Kidnapping Incidence	Total kidnappings per LGA yearly.	Reflects mobility-related insecurity.	Kwara Police HQ, 2024

Note. This table presents the operationalization of human security dimensions in the study, outlining selected variables, rationale for inclusion, and primary data sources.

Table 1: Human Security Dimensions, Variables, Justification, and Data Sources (Cont'd)

Human Security Dimension	Variable	Operational Definition	Justification	Source
Political	Riot/Protest Incidence	Frequency of riots or protests per year.	Indicator of political unrest.	ACLED, 2023
Political	Violence Against Civilians	Number of violent events targeting civilians.	Institutional fragility proxy.	ACLED, 2023
Political	Police Station Density	Number of police stations per square km.	Reflects state presence.	Kwara Police HQ, 2024
Political	Revenue Allocation to LGAs	Annual financial transfers to LGAs.	Measures administrative capacity.	Annual Abstract, 2024
Environmental	Affected by Flood	Number of people impacted by flooding.	Vulnerability to environmental shocks.	KSEMA, 2024
Environmental	Affected by Fire	People affected by fire disasters.	Proxy for climate and disaster risk.	KSEMA, 2024
Environmental	Waste Dump Sites	Count of dumpsites per LGA.	Indicator of environmental hygiene.	KSEMA, 2024
Environmental	Improved Water & Sanitation	Percentage with improved water and sanitation.	Proxy for environmental health risk.	Annual Abstract, 2024
Educational	Secondary School Facilities	Total number of secondary schools.	Indicates educational infrastructure.	Kwara MOE, 2024
Educational	Literacy Rate	Percentage of literate population.	Indicates educational achievement.	Kwara MOE, 2024
Educational	Educational Attainment	Percentage completing key education levels.	Measures attainment levels.	Annual Abstract, 2024
Educational	Secondary School Enrolment	Total enrolled students per LGA.	Measures participation in education.	Kwara MOE, 2024

Note. This table presents the operationalization of human security dimensions in the study, outlining selected variables, rationale for inclusion, and primary data sources.

Ensuring comparability, all variables were normalized using z-score standardization. This process involved converting raw values into standardized scores with a mean of zero and a standard deviation of one, allowing each indicator to contribute equally to the clustering process.

Multivariate clustering was conducted using R^2 scores to determine how well each variable contributed to the classification of LGAs into meaningful clusters. Higher R^2 values indicated greater discriminatory power. Boxplots and thematic cluster maps were used to visually analyze the spatial patterns, highlighting hotspots and coldspots within each dimension. This is

frequently accomplished via the K-Means clustering algorithm or analogous techniques. The principal aim of K-Means clustering is to divide the data into k groups, with each observation assigned to the cluster whose mean is closest. Below is the formula used in the K-Means clustering algorithm (Esri, 2023).

K-Means Clustering Objective Function

The goal is to minimize the within-cluster sum of squares (WCSS):

Minimize $\sum_{i=1}^{K} \sum_{x \in Ci} \|x - \mu_i\|^2$ 1

Where:

- K is the number of clusters.
- C_i represents the i-th cluster.
- X is a data point in cluster C_i.
- μ_i is the centroid of cluster C_i
- $\|x - \mu_i\|^2$ is the squared Euclidean distance between data point x and the centroid μ_i

Steps in the K-Means Algorithm

a. Initialization: Choose k initial centroids randomly from the data points

b. Assignment:

Assign each data point to the nearest centroid based on the Euclidean distance.

$C_i = \{x: \|x - \mu_i\|^2 \leq \|x - \mu_j\|^2, \forall j, 1 \leq j \leq k\}$ 2

c. Update:

Recalculate the centroids of the clusters by taking the mean of all points assigned to each cluster.

$$\mu_i = \frac{1}{|C_i|} \sum_{x \in C_i} x$$

Where $|C_i|$ is the number of points in cluster C_i

d. Repeat:

Repeat the assignment and update steps until the centroids no longer change or the changes are below a predefined threshold.

The Multivariate Clustering tool in ArcGIS Pro automates the process and delivers visual results for enhanced analysis. This instrument introduces an innovative multivariate spatial autocorrelation statistic aimed at identifying concurrent "hotspots" for several spatially correlated outcomes.

RESULTS AND DISCUSSION

This section presents a dimension-by-dimension synthesis of the multivariate clustering analysis, referencing Figures 1 through 12 and Tables 2 to 7. The findings provide empirical insights into the spatial manifestation of human security threats across the sixteen LGAs in Kwara State, structured to support spatially targeted development interventions.

Economic and Food Security

The multivariate clustering of economic and food security, summarized in Table 2, identified key differentiating variables, market access (R^2 = 0.87), agricultural land use (R^2 = 0.68), and unemployment (R^2 = 0.67) as the strongest contributors to spatial partitioning across Kwara's LGAs. As Figure 1 illustrates, the box plots show that the second cluster, highlighted in red, concentrated market density in LGAs such as Baruten, Ilorin West, and Moro. This clustering suggests localized food accessibility advantages, reinforcing findings by Sesgundo and Aranas (2024), who emphasized the strategic role of spatial economic services in shaping subregional development gradients. In contrast, the third cluster, marked in green, associated with Ifelodun, reflected coldspots in agricultural land use, indicating constraints in food production capacity. This aligns with observations by Mariosa et al. (2022), who noted that land availability remains a decisive factor in food security dynamics. Figure 2 further reveals that unemployment hotspots were also prominent in Ifelodun, underscoring its multidimensional insecurity. Together, these spatial patterns affirm that economic and food vulnerabilities are not randomly distributed but converge in specific LGAs demanding geographically tailored and multisectoral policy responses.

Table 2: Summary of Economic and Food Security Variables in the Study Area

Variable	Mean	SD	Min	Max	R^2
Market	6.24	7.30	0.00	25.00	0.87
Plantation	6.26	7.86	0.30	28.00	0.68
Unemployment	6.28	4.39	0.00	20.00	0.67
Industry	6.25	10.83	0.00	37.50	0.09

Note. SD = standard deviation. R^2 = coefficient of determination.

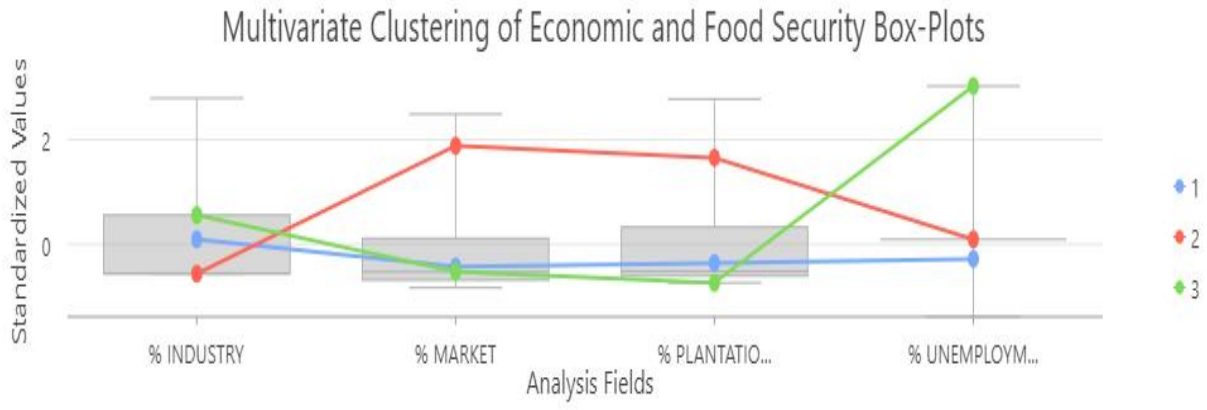

Figure 1: Economic and Food security Box-plots in the Study Area

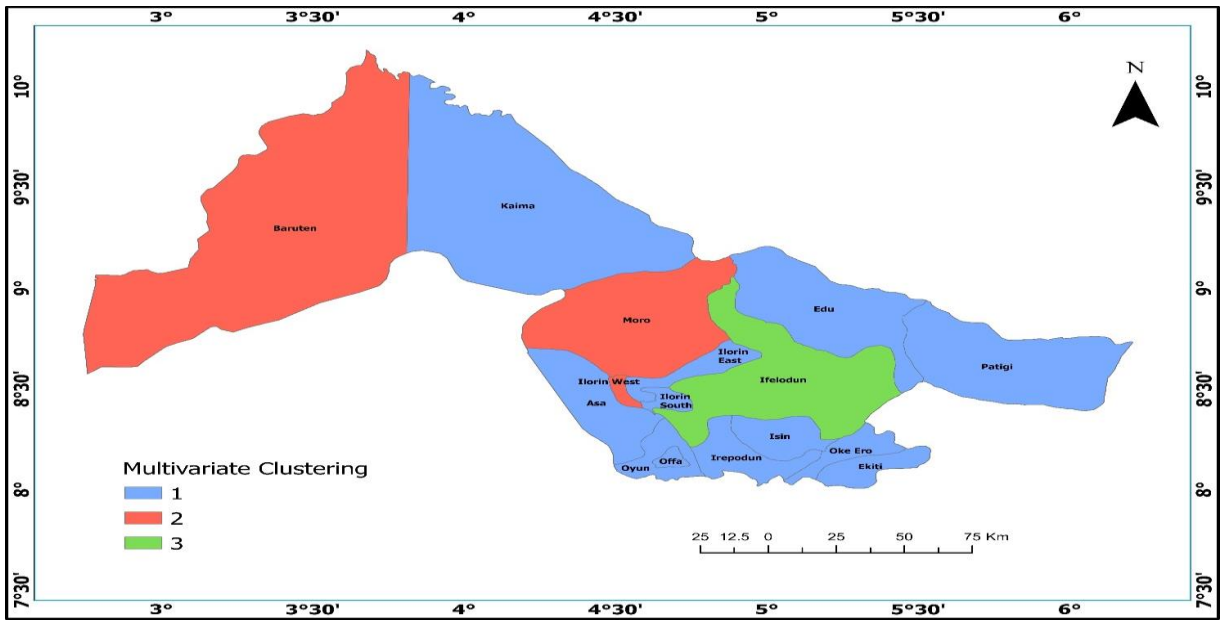

Figure 2: Multivariate clustering of Economic and Food Security in the Study Area

Health Security

The results of health security in Table 3 and Figures 3 - 4 reveal spatial disparities in health security, with birth rate ($R^2 = 0.615$) and lack of access to clean water ($R^2 = 0.754$) as the most influential indicators. The box plots in Figure 3 show hotspots for both variables in the second cluster, particularly in Ifelodun, indicating acute health service deficiencies. Aguilar and de Felice (2023) emphasize that such spatial overlays of demographic pressure and lack of access to clean water significantly increase human insecurity. Conversely, LGAs like Moro, Ilorin East, Patigi, Oyun, Offa, Oke-Ero, and Ekiti, grouped in the third cluster, showed coldspots in water deprivation, suggesting more robust infrastructure. Figure 4 illustrates that secondary health care facility distribution was a prominent feature in Baruten, Ilorin West, and Irepodun, affirming previous insights by Ilesanmi and Rotowa (2020) that health infrastructure plays a spatially uneven but critical role in shaping local security outcomes.

Table 3: Summary of Health Security by Variable in the Study Area

Variable	Mean	SD	Min	Max	R^2
DEPRIVED	6.237500	3.163439	2.300000	13.60000	0.754081
BIRTH	6.256250	5.454696	1.200000	20.80000	0.614516
MALARIA	6.243750	3.789124	2.000000	15.10000	0.422737
SHCF	6.237500	3.339700	2.200000	15.20000	0.186680

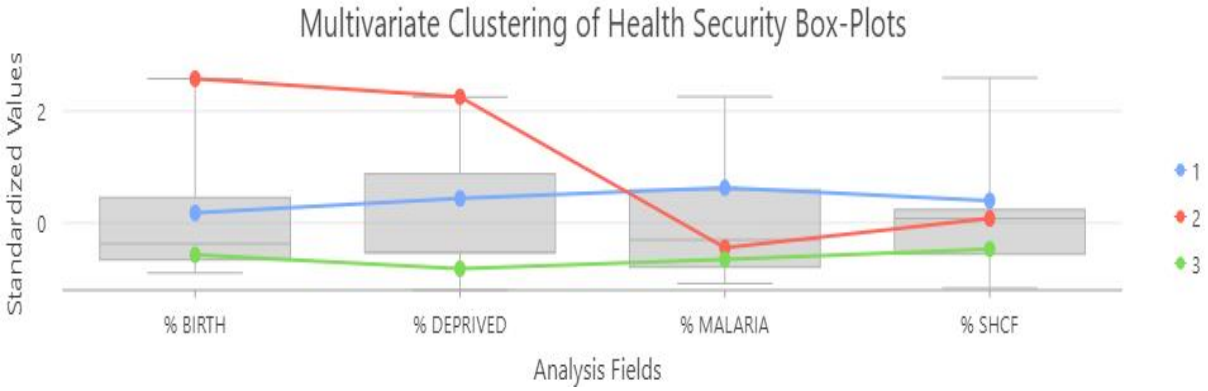

Figure 3: Box Plots of Health Security in the Study Area

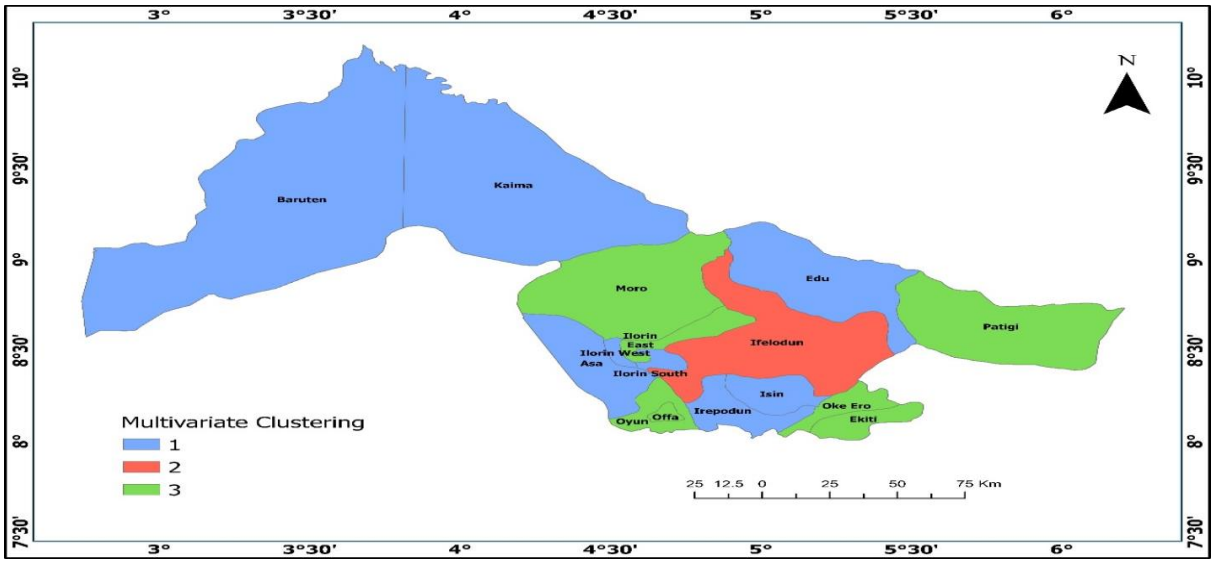

Figure 4: Multivariate Clustering of Health Security in the Study Area

Political Security

Political insecurity, illustrated in Table 4 and Figures 5 - 6, was defined by high values in violence against civilians ($R^2 = 0.727$), riots and protests ($R^2 = 0.639$), and limited state presence, proxied by revenue allocation and police station distribution. The box plots in Figure 5 reveal that the second cluster, comprising LGAs like Ifelodun and Irepodun, experienced the most acute political instability in violent against civilian, riot and protest, affirming Rüttinger et al.'s (2023) assertion that institutional fragility often overlaps with political unrest at subnational levels. Figure 6 further supports this, showing low spatial allocation of police stations in these LGAs. Meanwhile, coldspots such as Ekiti and Isin clustered in the first group benefited from relative political calm and stronger public administrative footprints, reinforcing the value of spatial resilience analysis in human security planning.

Table 4: Summary of Political Security by Variable in the Study Area

Variable	Mean	SD	Min	Max	R^2
AGAINST CIVILIANS	6.250000	6.797058	0.000000	23.50000	0.727399
RIOT OR PROTEST	6.237500	14.578403	0.000000	60.00000	0.639217
REVENUE	6.231250	1.375554	4.400000	9.400000	0.517441
POLICE STATION	6.256250	4.379493	1.200000	19.40000	0.367455

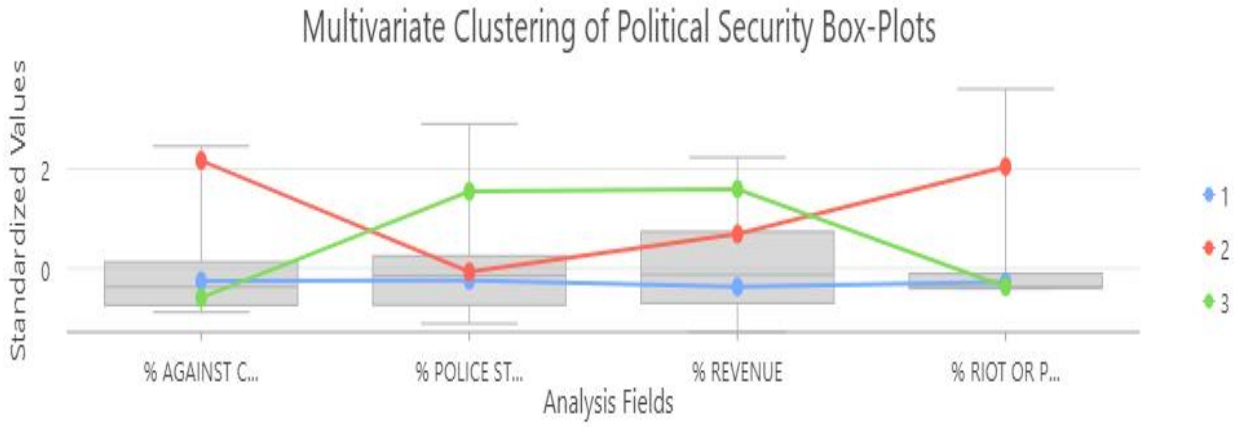

Figure 5: Political Security Box-plots in the Study Area

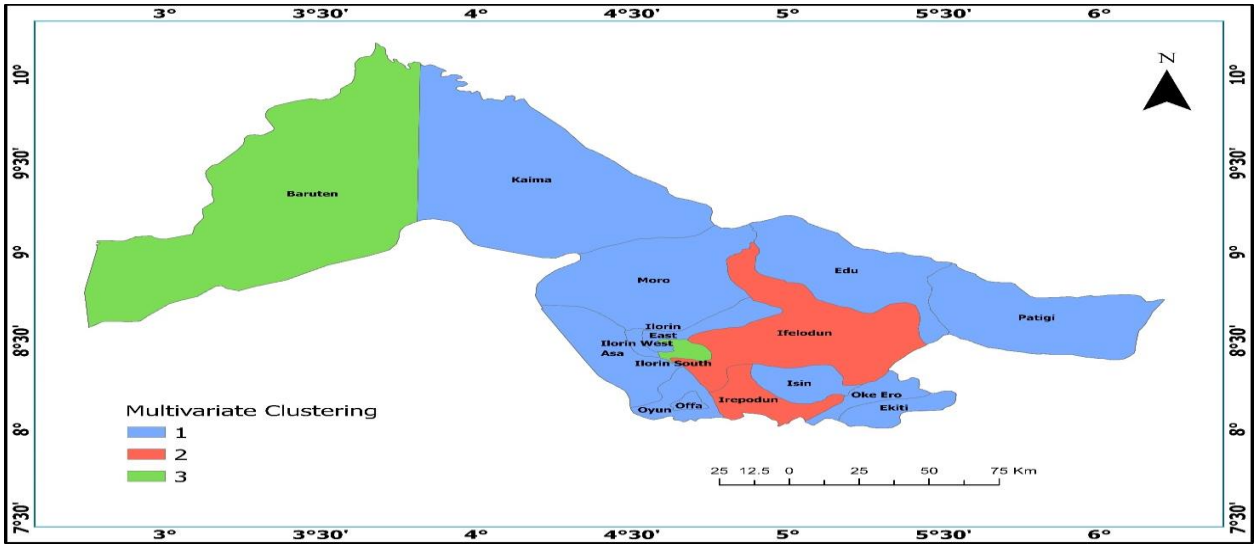

Figure 6: Multivariate Clustering of Political Security in the Study Area

Personal Security

Personal security outcomes, displayed in Table 5 and visualized in Figures 7 - 8, were shaped primarily by armed robbery (R^2 = 0.917), rape/indecent assault (0.808), and culpable homicide (0.773). The box plots in Figure 7 identify Ilorin South within the third cluster as a multidimensional hotspot, with high incidence rates across all three variables. Mariosa et al. (2022) highlight that spatial clustering of violent crime often corresponds to concentrated socio-

political and economic marginalization conditions clearly observable here. Conversely, LGAs such as Edu, Ilorin West, and Moro, situated within the first cluster, exhibited coldspots, particularly in kidnapping, suggesting localized resilience. Figure 8 reinforces these patterns, in the cluster 2 as indicated by red colour exhibited coldspots for human security in the region. Incidents such as armed robbery, culpable homicide and rape/indecent assault shown to have been low but exhibit high concentration of kidnapping (see Figure 8). However, Asa, Baruten, Kaima, Ilorin East, Ifelodun, Patigi, Oyun, Offa, Irepodun, Isin, Oke-Ero, and Ekiti are associated with these incidents (see Figure 8).

Table 5: Summary of Personal Security by Variable in the Study Area

Variable	Mean	SD	Min	Max	R^2
ARMED_ROBBERY	6.243750	11.257385	0.000000	38.60000	0.917386
RAPE_INDECENT_ASSAULT	6.243750	12.670831	0.000000	50.00000	0.808218
CULPABLE_HOMICIDE	6.243750	11.674222	0.000000	44.40000	0.772712
KIDNAPPING	6.250000	7.933710	0.000000	25.80000	0.086000

Figure 7: Personal Security Box-plots in the Study Area

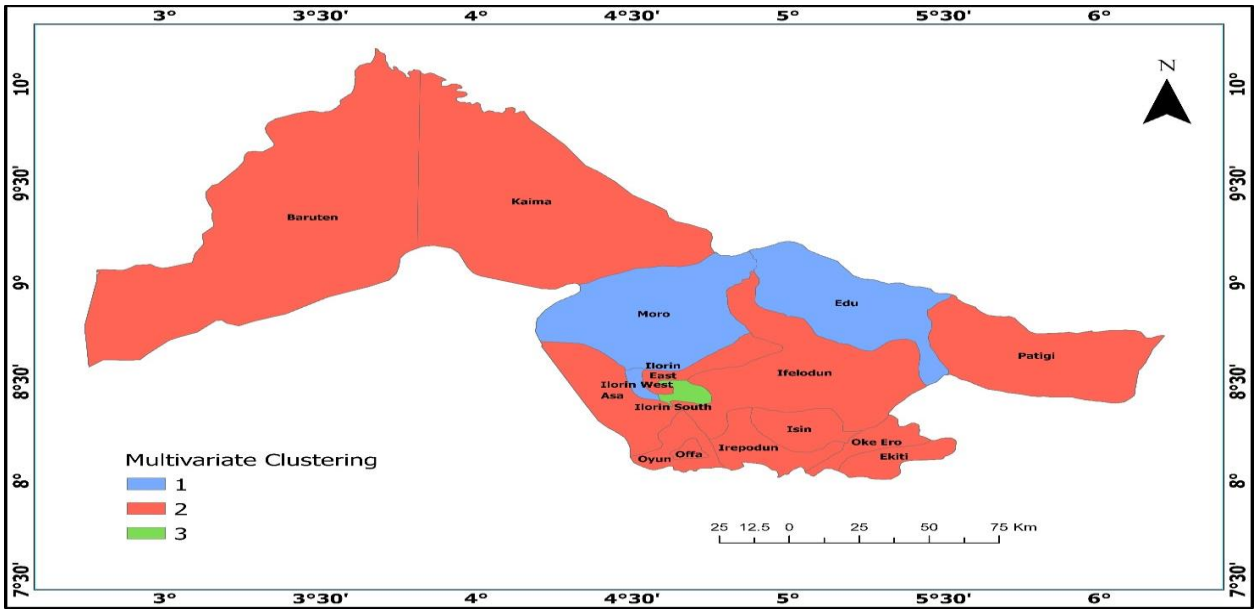

Figure 8: Multivariate Clustering of Personal Security in the Study Area

Educational Security

As presented in Table 6 and Figures 9 - 10, educational disparities were prominent among the clusters, with educational attainment ($R^2 = 0.775$) and senior secondary school enrollment ($R^2 = 0.680$) emerging as key variables. Box plots in Figure 9 illustrates a clear trend; in cluster 1, represented by the color blue, all variables were at the average level. Cluster 2 displayed hotspots for all variables, specifically educational attainment, secondary school enrollment, literacy rates particularly for a girl child and the quality of school facilities, all of which are notably high. Figure 10 illustrated that Ifelodun is correlated with this trend, although its multidimensional insecurity in other sectors tempers the implications of this strength. Nonetheless, the box-plot results in Figure 9 indicated a divergent trend; educational attainment, enrollment in senior secondary school, literacy rate, and secondary school facilities displayed cold spots within the cluster. Ilorin East, Offa, Patigi, Oke-Ero, and Ekiti were identified as being related with this. These results align with Olawole et al. (2021), who emphasized that such localized disparities often reflect deeper structural inequities within state education systems.

Table 6: Summary of Educational Security by Variable in the Study Area

Variable	Mean	SD	Min	Max	R^2
EDUCATION	6.231250	3.401786	2.500000	16.00000	0.775366
ESS	6.250000	5.074692	1.600000	21.30000	0.679876
LITERACY	6.250000	3.527393	1.400000	14.60000	0.575301
SFS	6.237500	2.548253	2.400000	11.20000	0.364412

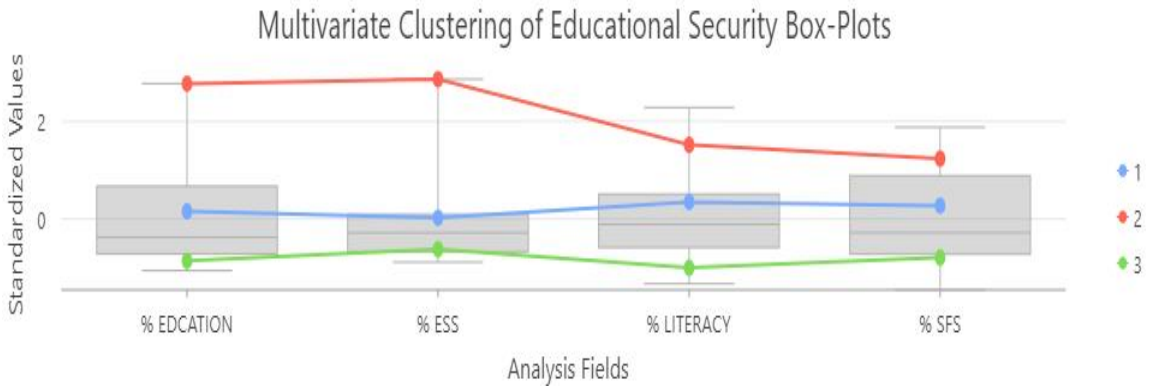

Figure 9: Educational Security Box-plots in the Study Area

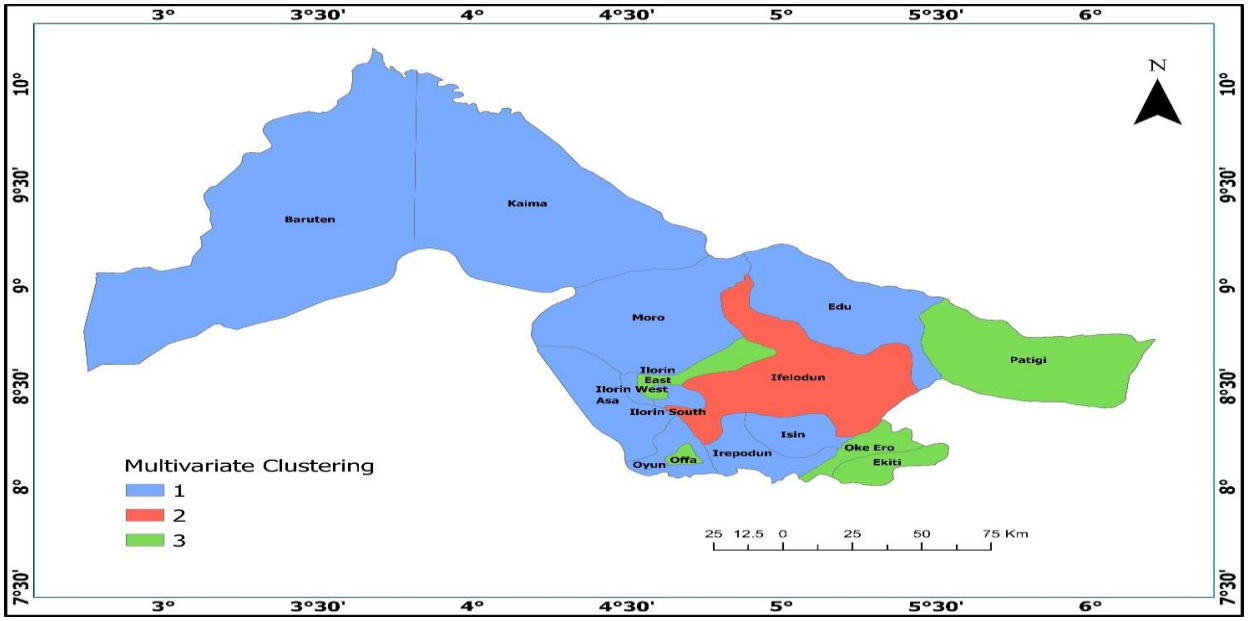

Figure 10: Multivariate Clustering of Educational Security in the Study Area

Environmental Security

Environmental vulnerabilities were primarily shaped by fire incidence (R^2 = 0.735) and sanitation access (R^2 = 0.515), as shown in Table 7 and Figures 11 - 12. Box plots in Figure 11 highlight Asa as an environmental hotspot within the second cluster, with heightened floods and inadequate waste disposal systems consistent with Ilesanmi and Rotowa's (2020) findings on the role of localized ecological pressures in shaping subnational risk profiles. Data indicate that cluster 3, denoted by the green color, has demonstrated hotspots for fire occurrences as well as improved water sources and sanitation. The frequency of fire occurrences was high in the following Local Government Areas: Baruten, Moro, Ilorin South, Ifelodun, Irepodun, and Isin (Figure 12).

Table 7: Summary of Environmental Security by Variable in the Study Area

Variable	Mean	SD	Min	Max	R^2
WASTE	6.250000	24.206146	0.000000	100.0000	1.000000
FIRE	6.250000	7.267565	0.000000	20.60000	0.734949
WATER SANITATION	6.218750	2.664399	4.300000	13.00000	0.515275
FLOOD	6.243750	8.971411	0.000000	29.40000	0.118407

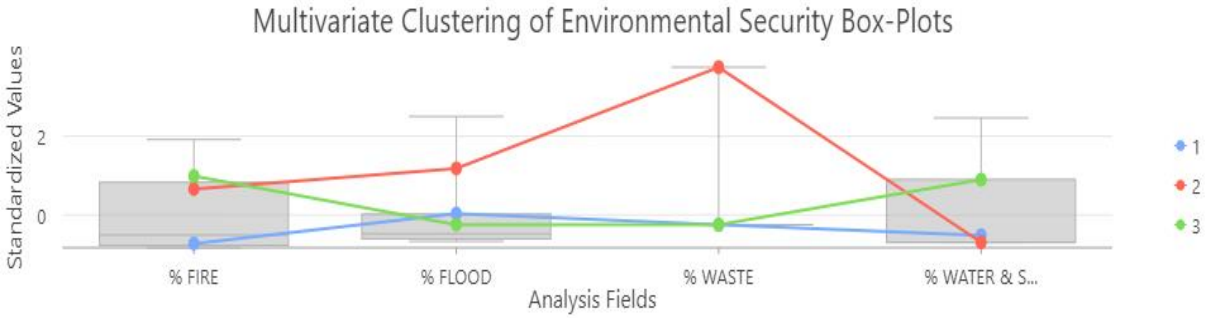

Figure 11: Environmental Security Box-plots in the Study Area

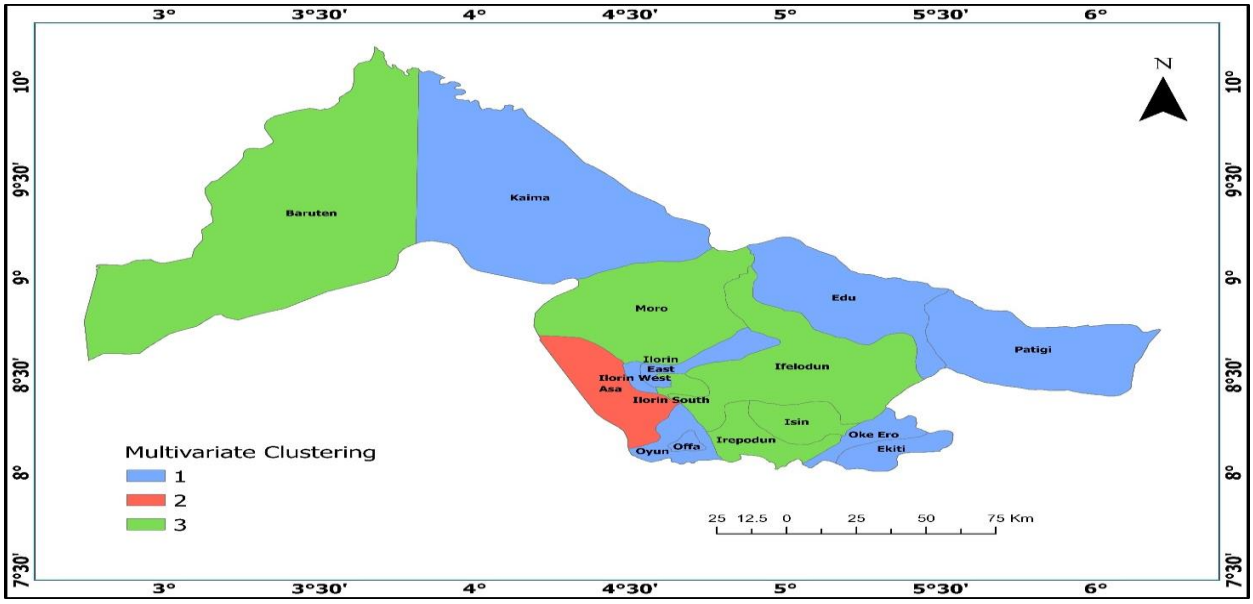

Figure 12: Multivariate Clustering of Environmental Security in the Study Area

CONCLUSION

These findings collectively affirm Gasper and Gómez's (2022) assertion that human security must be understood as a multidimensional and spatialized construct. The clustering framework presented here advances this discourse by producing empirically grounded, geographically nuanced insights for evidence-based planning in Kwara State.

Based on these findings, the study recommends that human security interventions in Kwara State be spatially targeted and multi-sectoral, rather than uniform across Local Government Areas. Policymakers should prioritize identified hotspot LGAs where multiple vulnerabilities intersect, focusing on coordinated actions that simultaneously address economic inclusion, health service provision, environmental risk reduction, and personal safety. Strengthening local governance capacity, improving data-driven planning through GIS integration, and institutionalizing regular spatial vulnerability assessments are also essential for sustaining effective human security management. Such place-specific, evidence-based strategies will enhance resource efficiency and promote more resilient and inclusive development outcomes across the State.

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