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SPECIAL ISSUE: CELEBRATING 20 YEARS OF GEOGRAPHY IN KADUNA STATE UNIVERSITY - ADVANCES AND FRONTIERS IN GEOGRAPHY

Geospatial Analysis of Healthcare Facilities Distribution and Accessibility in Igabi LGA, Kaduna State, Nigeria

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ABSTRACT

The study analysed the spatial distribution of healthcare facilities in Igabi LGA of Kaduna State, Nigeria. Coordinates of healthcare facilities were obtained using a handheld GPS, while facility attributes were obtained from the Kaduna State Ministry of Health and the Igabi LGA Health Department. Data was analysed using the Average Nearest Neighbor Analysis and Kernel Density Estimation. The results revealed a clustered spatial distribution (ratio = 0.64, z-score = -7.77, p = 0.00). The KDE revealed that the highest density was observed in the Rigasa ward, with 17 facilities (13.6%), spreading to Rigachikun, Kwarau, and Zangon Aya, mainly due to proximity to the Kaduna metropolis, high population density, and ease of road access. However, Afaka, Birnin Yero, Sabon Birni, and Igabi showed a low density of healthcare facilities. Primary facilities accounted for the majority, with Primary Health Centers at 47.2% and Primary Health Clinics at 32.0%. Facilities were mostly publicly owned, with Local Government accounting for 52.0% and State PHCDA for 28.0%, while the private sector accounted for only 2.4%. The results reveal spatial inequities that affect equitable access to and universal coverage of SDG 3. The study recommends establishing new healthcare facilities in underserved areas of the northern and western parts of the LGA, and continuing the use of GIS for evidence-based planning in Igabi LGA and the state.

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1 Introduction

Access to healthcare facilities is a fundamental right for all citizens (Xiong et al., 2022). Hence, governments of developing countries have adopted the "Health for All" strategy, as outlined in the 1978 Alma-Ata Declaration (World Health Organization [WHO], 1978). According to the WHO (2025), healthcare facilities are essential for delivering high-quality, safe, and climate-resilient care, which is crucial for achieving universal health coverage. These facilities, such as hospitals and clinics, are considered the core of any health system. The spatial distribution of healthcare facilities plays a critical role in determining the accessibility, utilization, and overall effectiveness of healthcare delivery systems, particularly in rapidly growing urban and peri-urban regions (Pérez-Fernández & Michel, 2025). Thus, improved equitable access to healthcare requires innovative interventions and the strengthening of a service innovation operational model to achieve transformative change and ensure sustainability of public health interventions (Patel et al., 2024).

In Nigeria, healthcare services are the responsibility of all tiers of government to provide for the health needs of the populace. However, at least 70% of healthcare is provided by private hospitals, while 30% is supplied by federal, state, local, and even community-funded healthcare facilities (Nnadi et al., 2024). Communities in suburban and rural areas often have limited access to healthcare due to the limited availability and accessibility of standard healthcare systems (Mohammed et al., 2025). Consequently, Ishaq et al. (2023) argued that one of the imperatives of healthcare provision is a concern for both social and spatial justice.

Kaduna State, one of Nigeria's major population centers, faces significant challenges in delivering equitable healthcare services across its diverse urban and rural landscapes (Averik et al., 2023). Furthermore, due to urbanization, infrastructure development, and its proximity to the Kaduna metropolis, the Igabi Local Government Area (LGA) of Kaduna State has seen significant population growth and geographical expansion in recent years (Idris & Dahiru, 2023). The demand for healthcare services has grown with this rapid expansion, straining existing medical facilities and raising concerns about service coverage and spatial equity (Abdullahi et al., 2024). Silas et al. (2015) previously reported that 52.9% of the locals are not living within the WHO-recommended 0-4 kilometers of a health care facility. Nevertheless, thorough spatial analyses of healthcare facility distribution in the region remain scarce, despite the strategic significance of the local government (Abdulazeez, 2023; Abdulazeez et al., 2023).

A geographic information system (GIS) can analyze the spatial distribution of urban facilities and services using multiple criteria simultaneously. The use of GIS in this

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analysis (spatial distribution of urban facilities and services), enables the mapping of population cluster, service areas, and locational attributes of facilities and services, because it has the capability of large information data storage, integration of data, analysis of phenomenon, acquisition of data, and visualization of results or findings, towards enhancing fast and effective decision making process (Baba et al., 2020). In general, GIS provides a vast array of analytical capabilities that will enable managers to address complex issues in entirely new ways (Abubakar, 2019).

Achieving Sustainable Development Goal 3 (SDG 3), particularly target 8: achieve universal health coverage, including financial risk protection, access to quality essential health care services, and access to safe, effective, high-quality, and reasonably priced essential medicines and vaccines for everyone, requires improving accessibility of healthcare facilities. Governments and other development partners must allocate resources to the health sector due to the close relationship between health and development. Also, while previous studies in Igabi LGA have examined the general distribution and accessibility of primary healthcare facilities using basic GIS mapping (e.g., Ogunmola et al., 2020; Silas et al., 2015), this research represents a novel application of combined Average Nearest Neighbor Analysis and Kernel Density Estimation to quantify clustering patterns and visualize high- and low-density hotspots across all 125 healthcare facilities (including public, private, primary, secondary, and tertiary levels) in the specific context of Igabi LGA, providing more robust empirical evidence for targeted spatial planning.

2 Materials and Methods

2.1 Study Area

The Igabi Local Government Area of Kaduna State. Which is located on Longitudes 7° 10' 00'' E to 8° 7' 30'' E and Latitudes 11° 00' 00'' N to 10° 24' 00'' N (Figure 1). Igabi is one of the historical Local Government Areas in Kaduna State. Igabi enjoys a tropical climate (*Aw*) with distinct wet and dry seasons (Abubakar et al., 2024). The region's maximum temperature is usually above 30°C, with March, April, and May the hottest months. Depending on the month, relative humidity typically ranges from 25% to 90%, with December and February having the lowest levels (Musa & Abubakar, 2024). The majority of their people are mostly farmers and are located in the center of the state (Abdulazeez et al., 2023). The LGA is bordered from the North by Zaria LGA, from the west by Birnin Gwari LGA, from the southeast by Chikun LGA, South–South East Kaduna South LGA, from the northwest by Giwa LGA, from the northeast by Kubau LGA, and SouthEast Kajuru LGA, respectively.

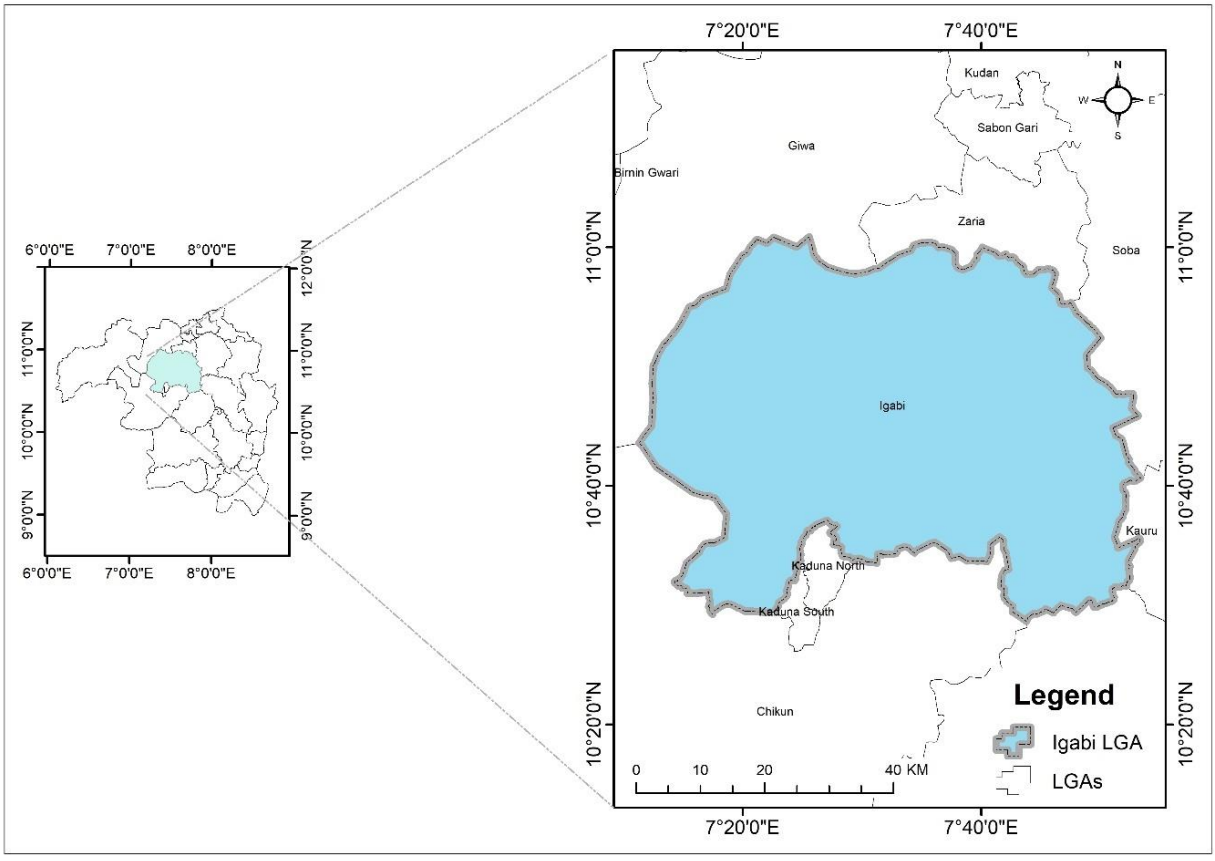

Figure 1: Map of the study Area
Source: Modified from the Administrative Map of Kaduna State

2.2 Reconnaissance Survey

As a preparatory step for the study, a reconnaissance survey was conducted to familiarize the researcher with the study area. The objective was to obtain available relevant information on healthcare facilities and establish a cordial working relationship with relevant authorities. The list and addresses of all registered public and private healthcare facilities within the study area were obtained from the Kaduna State Ministry of Health and the Igabi Local Government Department of Health.

2.3 Data Sources

A reconnaissance survey was conducted to familiarize with the study area and establish contacts with relevant authorities. A comprehensive list of registered public and private healthcare facilities, including addresses, was obtained from the Kaduna State Ministry of Health and the Igabi LGA Health Department.

Primary data included the geographic coordinates of healthcare facilities, collected using a Garmin 76CSx handheld GPS receiver during field surveys in 2025. Facilities were categorized as primary, secondary, or tertiary based on services offered. This is shown in Table 1.

Table 1: Types and Sources of Data

Data Type	Description	Source
Facility Locations	Coordinates and attributes	GPS field survey (2025)
Facility List	Names, types, ownership	Kaduna State Ministry of Health & Igabi LGA Health Department
Administrative Boundaries	Wards and LGA boundaries	Administrative maps
Base Maps	Topography and satellite imagery	Modified administrative maps & Google Earth

2.4 Data Analysis

Data processing and analysis were performed using ArcGIS 10.8 software.

i. Database Creation: GPS coordinates were transferred to Microsoft Excel, then imported into ArcGIS to create a geodatabase. Point features were generated for each healthcare facility, attributed with name, type (primary, secondary, tertiary), ownership (public/private), and ward.

ii. Spatial Mapping: Facilities were overlaid on the administrative base map of Igabi LGA. Thematic maps were produced to visualize:

- Overall distribution of all healthcare facilities.
- Distribution by category (primary, secondary, tertiary).
- Distribution by ward.

iii. Descriptive Analysis: Counts, percentages, and proportions of facilities per ward and category were calculated. Tables summarized distributions, and percentages were derived to assess proportionality.

iv. Pattern of Spatial Distribution: Visual interpretation identified clustering (e.g., eastern predominance due to flatter terrain). Nearest-neighbor analysis or kernel density could be applied for clustering statistics, though primarily for descriptive purposes here. The density of healthcare facilities is analysed using Kernel Density Estimation.

3 Results

3.1 Distribution of Healthcare Facilities in Igabi of Kaduna State

The spatial distribution of all healthcare facilities in Igabi Local Government Area was determined. The result is shown in Figure 2.

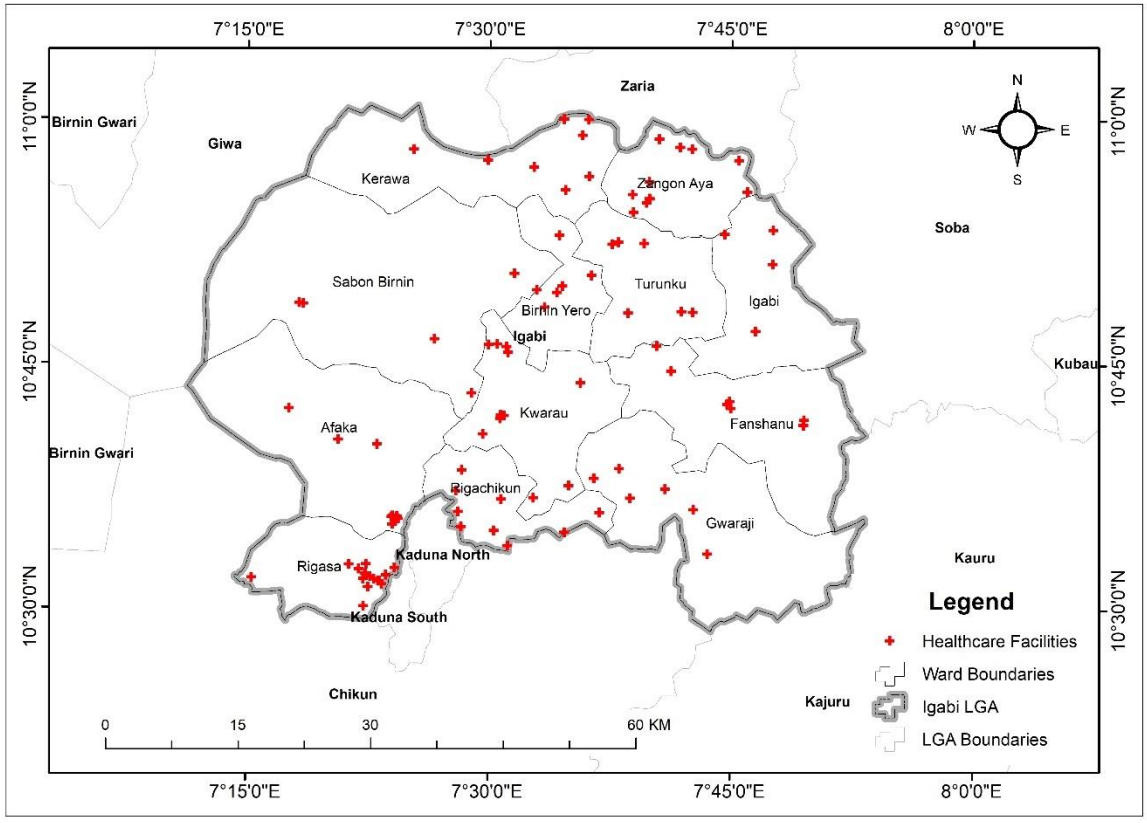

Figure 2: Spatial distribution of healthcare facilities in Igabi LGA

Figure 2 shows the spatial distribution of health facilities within the Igabi Local Government Area (LGA) of Kaduna State, Nigeria. The healthcare facilities are represented by point symbols, indicating a clear trend towards a higher facility density in the southeastern region of the LGA, particularly in Rigasa ward, around areas bordering Kaduna North and Kaduna South LGAs. This could reflect the higher density of health facilities near the city center. However, the wards in the northern and western areas have significantly lower densities of health facilities, indicating a large gap between urban and rural areas. The spatial distribution pattern is shown in Table 2.

Table 2: Average Nearest Neighbor Result

Observed Mean Distance (m)	Expected Mean Distance (m)	Nearest Neighbor Ratio	z-score	p-value
1632.3	2563.5	0.64	-7.77	0

According to Table 2, the Nearest Neighbor Analysis results indicate that the spatial distribution of healthcare facilities in the study area is strongly clustered. The mean distance between facilities is 1,632.3 m, much smaller than the 2,563.5 m expected under random distribution. This yields a Nearest Neighbor Ratio of 0.64, less than 1, indicating clustering. The very large negative z-score of -7.77 further confirms that the distribution is not random, and the p-value of 0.00 indicates that this clustering is statistically significant. This is illustrated in Figure 3.

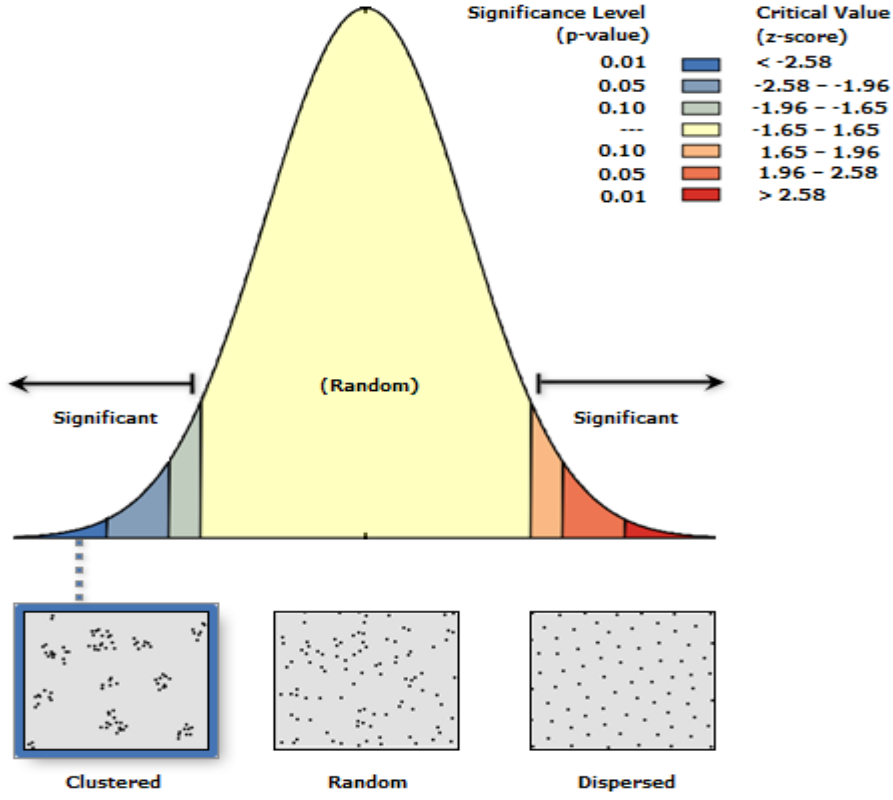

Figure 3: Spatial Distribution Pattern of Healthcare Facilities in Igabi LGA

Additionally, Kernel Density Estimation was used to identify areas with high and low concentrations of healthcare facilities in Igabi LGA. The result is shown in Figure 4.

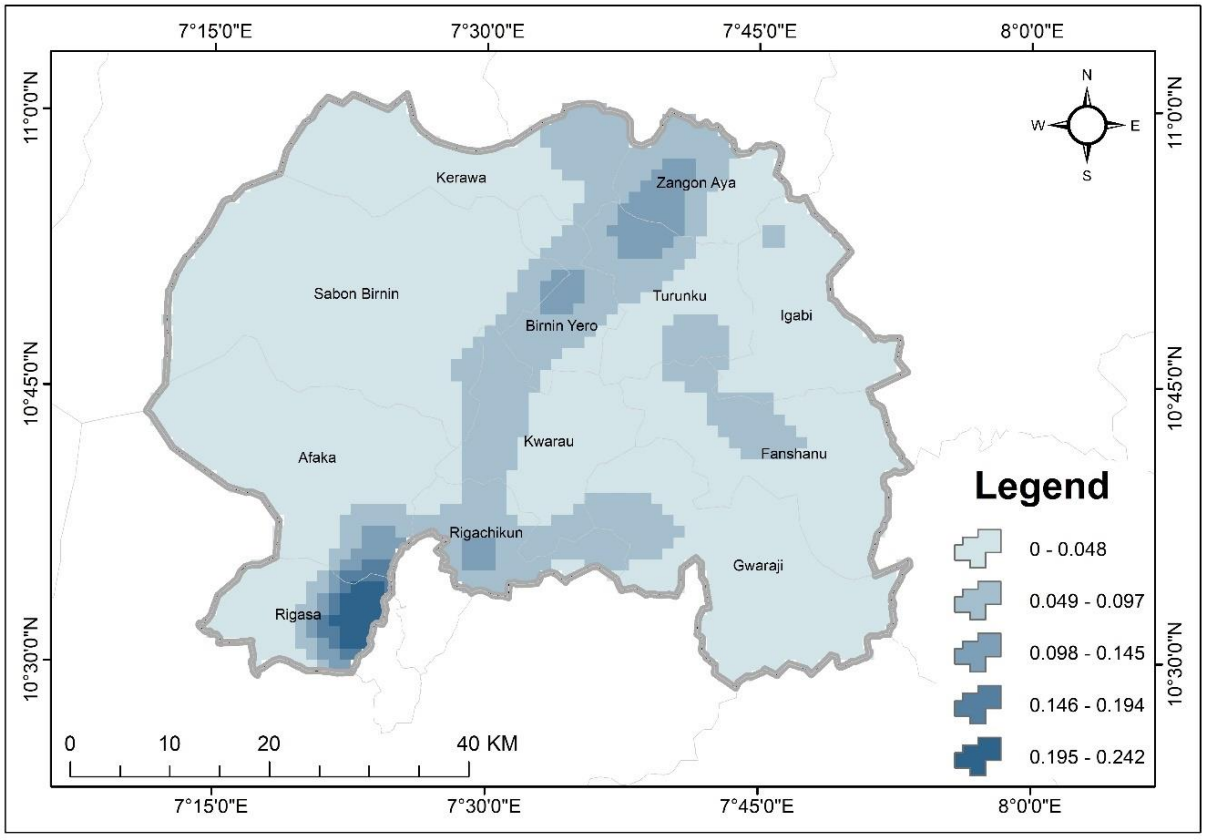

Figure 4: Spatial clustering of Healthcare Facilities in Igabi LGA

Figure 4 visualizes the spatial concentration of the 125 healthcare facilities across Igabi Local Government Area (LGA) in Kaduna State, using a smooth, continuous surface rather than individual points. KDE estimates the density of facilities per unit area by placing a kernel (typically a quartic or Gaussian probability density function) at each facility location and summing the overlapping influences across a grid. Higher density values (darker blue shades) indicate greater clustering or proximity of facilities, while lower values (lighter or white areas) show sparsity. The legend categorizes density from 0 (no facilities influence) to 0.242 (highest concentration), with the scale likely normalized based on the chosen search radius/bandwidth and area units.

The map reveals a clear urban-peri-urban bias in healthcare facility distribution. The highest concentration (deepest blue, peaking around 0.195–0.242) is centered in and around Rigasa ward in the southwestern part of the LGA. Rigasa, a densely populated, rapidly urbanizing peri-urban ward directly adjacent to Kaduna metropolis (which serves as a major transportation hub, including the Kaduna-Abuja rail terminal), shows the strongest clustering. This aligns with earlier ward-level frequency data (Rigasa having the highest number of facilities, 17, 13.6%) and reflects higher demand, better road access, population density, and economic activity, drawing more public and private providers.

Secondary concentrations appear in a north-south trending band of moderate to high density (medium to darker blues, 0.098–0.194). Rigachikun and parts of Kwarau extend the southwestern hotspot northward. Zangon Aya (northeast-central) shows a notable patch of elevated density, consistent with its 14 facilities (11.2%). Moderate clustering occurs around Kwarau, Rigachikun, and parts of Zangon Aya and Kerawa. In contrast, large swathes of the LGA exhibit low to very low density (light blue to near-white, 0–0.097), particularly the western and central-northern areas, including Afaka, Birnin Yero, Sabon Birni, Igabi, and Turunku (LGA headquarters), which have fewer facilities and appear more dispersed or isolated. Eastern and southeastern wards, such as Fanshanu, Gwaraji, and parts of Kerawa, have relatively sparse coverage.

This pattern indicates significant spatial inequity, with healthcare facilities disproportionately concentrated in wards near Kaduna city (especially Rigasa and adjacent areas along major transport corridors), likely due to higher population density, better infrastructure, and easier service delivery. Remote or more rural peripheral wards have lower accessibility, increasing travel burdens for residents seeking care and highlighting gaps in equitable distribution under Nigeria's primary healthcare framework. These results underscore the value of KDE in revealing non-obvious clustering beyond simple counts.

3.2 Distribution of Healthcare Facilities By Wards

Table 3 shows the distribution of healthcare facilities in Igabi Local Government Area by political ward.

Table 3: Distribution of healthcare facilities by wards

Ward Name	Frequency	Percent
Afaka	12	9.6
Birnin Yero	8	6.4
Fanshanu	10	8
Gwaraji	9	7.2
Igabi	6	4.8
Kerawa	10	8
Kwarau	12	9.6
Rigachikun	12	9.6
Rigasa	17	13.6
Sabon Birni	6	4.8
Turunku	9	7.2
Zangon Aya	14	11.2
Total	125	100

Table 3 shows that Rigasa has the highest number of facilities with 17, contributing 13.6% to the total, which shows that the ward has a relatively higher concentration of healthcare facilities. Zangon Aya follows this with 14 facilities (11.2%), while Afaka, Kwarau, and Rigachikun each have 12 facilities, contributing 9.6% each. Fanshanu and Kerawa have 10 facilities each (8.0%), while Gwaraji and Turunku have 9 facilities each (7.2%). Birnin Yero has 8 facilities (6.4%), while Igabi and Sabon Birni have the fewest with 6 each, contributing 4.8% each. This shows that the distribution of healthcare facilities is uneven across wards, with some wards having a relatively higher

concentration of facilities. In contrast, others have limited access, underscoring the need for spatial planning in the LGA's healthcare sector.

3.3 Distribution of Healthcare Facilities By Service Level

Table 4 shows the distribution of healthcare facilities in Igabi Local Government Area by service level.

Table 4: Service level of healthcare facilities in Igabi LGA

Category	Frequency	Percent
Primary Health Clinic	40	32.0
Primary Health Center	59	47.2
Dispensary	4	3.2
Health Post	9	7.2
Maternity Home	2	1.6
General Hospital	1	0.8
Comprehensive Health Center	1	0.8
Laboratory	1	0.8
Private Clinic	7	5.6
Others	1	0.8
Total	125	100.0

Table 4 shows that Primary Health Center (PHC) has 59 facilities (47.2%), which are usually the most comprehensive primary healthcare facilities, providing a wide range of preventive, curative, and promotive services, including antenatal care, immunization, general consultations, minor treatments, and sometimes basic emergency obstetric care, usually performed by nurses, community health officers, and sometimes physicians. Very closely associated with the PHC are the Primary Health Clinics, with 40 facilities (32.0%), which offer similar services, though slightly less comprehensive, primarily for outpatient primary healthcare, health education, and basic diagnostic services for common ailments.

The lower hierarchy includes Health Posts, with 9 facilities (7.2%), which are usually small facilities located in remote or rural areas, providing very basic services, usually performed by community health workers, with limited services such as health promotion, first aid, and referral services; Dispensary, with 4 facilities (3.2%), primarily focused on providing medications and treating minor ailments with limited diagnostic capabilities; and Maternity Home (2 facilities, 1.6%), which specialize in the care of pregnant women and their newborn babies, including delivery services. There is a general lack of higher-level or specialized care, with only one facility, the General Hospital (0.8%), operating as a secondary care referral center for more complex cases beyond the scope of primary care. There is one Comprehensive Health Center (0.8%), which is often a PHC that has been upgraded to provide more services, closer to secondary care levels. There is one Laboratory (0.8%), dedicated to providing diagnostic services, and one Private Clinic (7 facilities, 5.6%), which is privately owned and provides a range of primary care services. The single "Others" category (0.8%) likely covers a variety of miscellaneous or uncategorized types of health facilities. This result is illustrated in Figure 5.

3.4 Distribution of Healthcare Facilities By Ownership

Based on the findings, the ownership pattern of healthcare facilities in the study area is dominated by the public sector. This is evident from the fact that the largest proportion of facilities is managed by Local Government Authorities (LGAs), which account for 52.0% (65 facilities). This is understandable, considering that local governments are central to the delivery of primary healthcare services. The second largest proportion is managed by the State Primary Health Care Development Agency (SPHCDA), accounting for 28.0% (35 facilities). In comparison, those managed by the National Primary Health Care Development Agency (NPHCDA) account for 12.0% (15 facilities). On the other hand, the proportion of the privately owned healthcare facilities is very low, accounting for only 2.4% (3 facilities), while those managed by NGOs account for 1.6%. The rest are accounted for by other ownership types, contributing 4.0%. The findings indicate that the public sector dominates ownership and management of healthcare facilities, with very little participation from the private and non-governmental sectors. This result is illustrated in Figure 6.

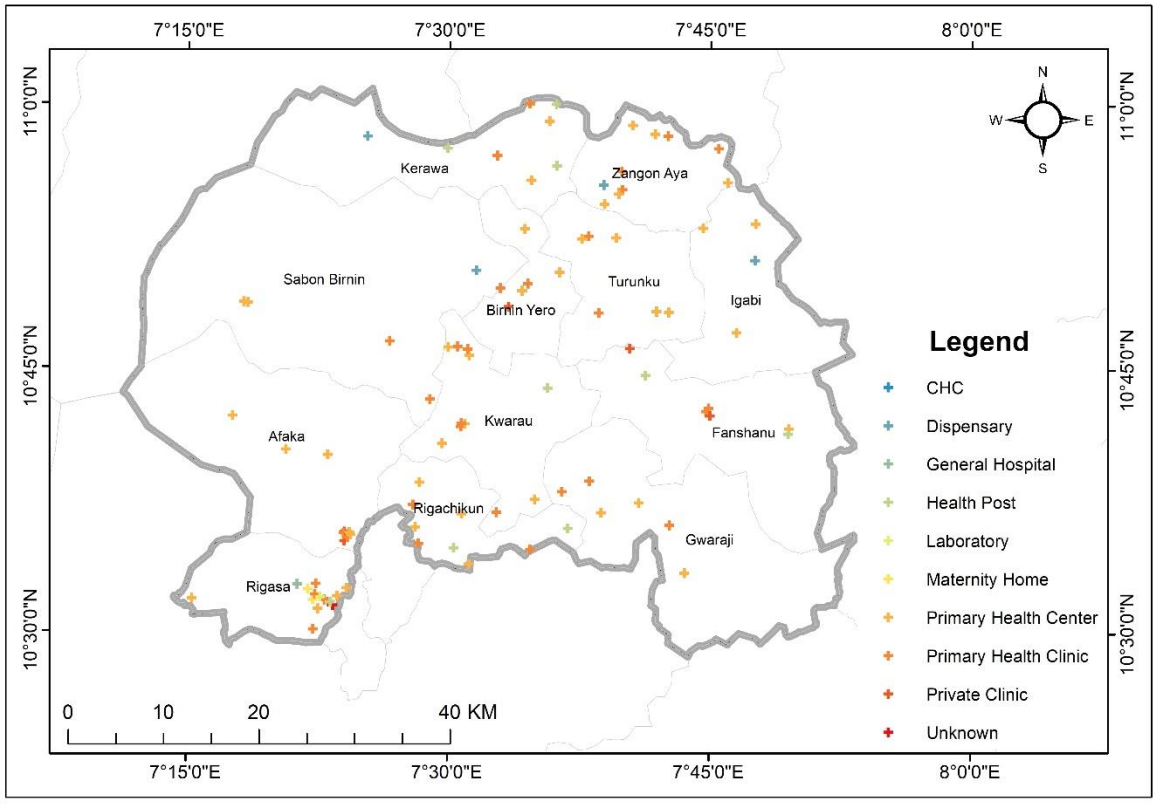

Figure 5: Distribution of healthcare facilities by service level in Igabi LGA

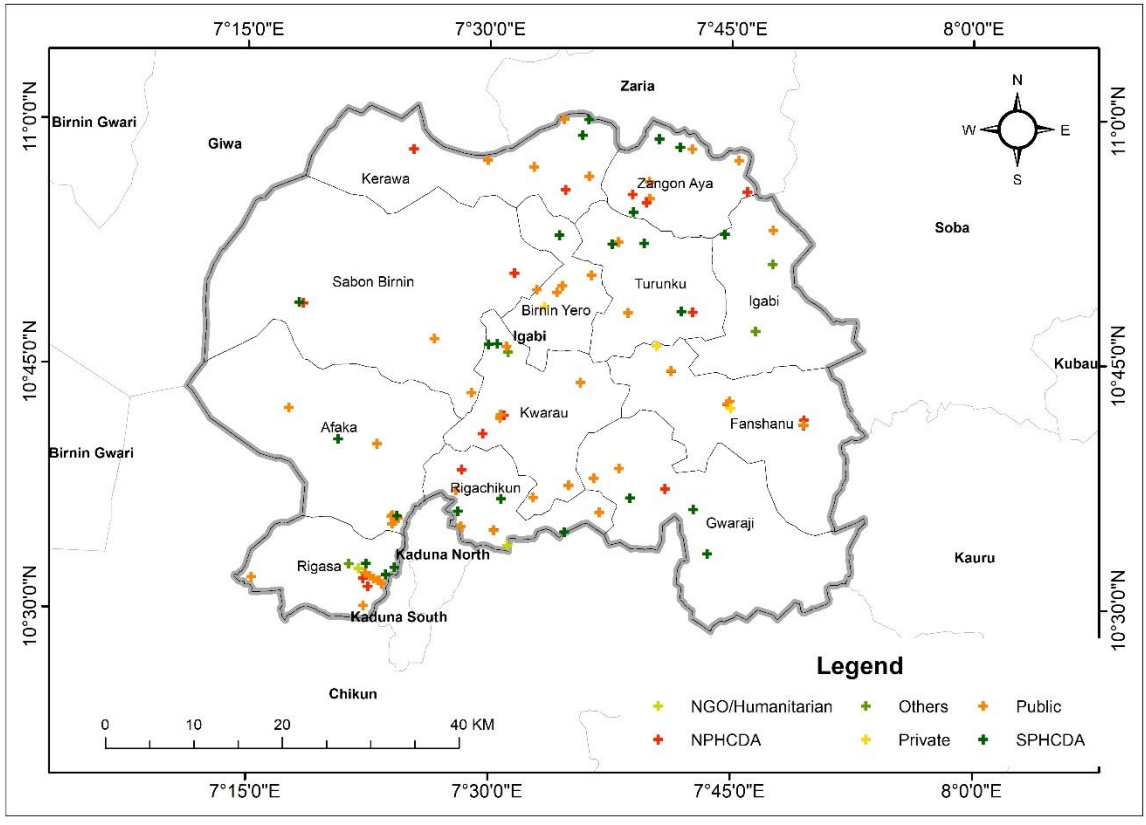

Figure 6: Ownership of healthcare facilities in Igabi LGA

4 Discussion

The results of this study indicate a significant clustering of healthcare facilities in Igabi Local Government Area. The Nearest Neighbor Ratio of 0.64 with a probability value of 0.00, as well as the Kernel Density Estimation surface, confirm that healthcare facilities are concentrated in particular areas of Igabi Local Government Area, especially in the southwest, where Kaduna metropolis is located. This is not a random distribution of facilities, as socio-economic and infrastructural gradients are evident. The high-density hotspot of healthcare facilities, as shown by the KED surface, is concentrated around Rigasa, a major hub given its proximity to the Kaduna city center and its key role in transport between Abuja and Kaduna, as indicated by Idris & Dahiru (2023). This is a key area for investment, both private and public, owing to its high population density, a good road network, and economic activities that create a self-reinforcing cycle of investment.

On the contrary, the extensive areas of low and very low density, especially in western and central-northern wards such as Afaka, Birnin Yero, and Sabon Birni, indicate significant gaps in access to healthcare. In these rural wards, people have to travel considerably longer distances to access primary healthcare, and inferior road conditions may worsen this. This is consistent with the findings of Mohammed et al. (2025), which showed healthcare facilities are more concentrated in the urban areas. This is one of the issues that has affected Nigeria's health sector, with such disparities evident in many areas where health infrastructure and personnel are concentrated in urban areas, leaving rural areas with inadequate access (Nnadi et al., 2024).

Analysis of the service levels and ownership further helps us understand the nature of healthcare provision. The overwhelming presence of Primary Health Centers (47.2%) and Clinics (32.0%) indicates a healthcare system primarily focused on basic, preventive, and outpatient care. Although this aligns with local governments' primary healthcare agenda, the dearth of secondary and tertiary care facilities is alarming. The fact that there is only one General Hospital (0.8%) in the entire LGA suggests that the healthcare system may rely on facilities in the Kaduna metropolis, which may be causing delays in healthcare services. The ownership analysis points to the central role of the public sector, with Local Government Authorities managing 52% of the healthcare facilities. However, the meager contribution of the private sector (2.4%) points to the potential benefits of public-private partnerships, especially in rapidly growing areas.

These spatial inequities have important implications for achieving universal health coverage (SDG 3.8) within the LGA. The clustering violates the concept of spatial justice in access to health care (Ishaq et al., 2023). Although it may be economically viable for the health care providers, it creates geographical barriers that disproportionately impact disadvantaged, low-income, and rural populations. This appears to be a form of distance-based availability, where proximity to urban centers determines the availability of facilities (Asemahagn et al., 2020). Thus, there is a need to move from a demand-following approach to a needs-based approach.

4.1 Limitations

Although this study represents an initial foundational spatial analysis, several limitations suggest directions for future research. Firstly, the accessibility analysis conducted within this study represents a more geometric approach. To better understand accessibility, future research should use more sophisticated approaches, such as network analysis with shapefiles that include attributes for road type and condition, in addition to population data available at the sub-ward level, to determine more precise travel times and service areas (Pérez-Fernández & Michel, 2025). Secondly, this study did not consider facility capacity, such as bed count, staffing levels, and equipment availability per facility. The geographic presence of a facility does not necessarily indicate functional service readiness or its effective service delivery. Thirdly, this study employs a cross-sectional design, whereas future research should use longitudinal data to assess facility distribution patterns in relation to population growth and migration. Fourthly, although GPS accuracy was high, there is potential for slight positioning errors, though it is unlikely that such errors would affect overall distribution patterns.

5 Conclusion

The findings reveal that the majority of farmers in Jama'are LGA are male, mostly within the economically active age group (90%). This outcome suggests a promising future for the region, with more farmers likely to increase crop production, contributing to food self-sufficiency in Jama'are LGA and neighbouring areas. Moreover, irrigation is a central pillar of agricultural production in the area, with most farmers (80%) cultivating rice and other crops using pump-based irrigation systems supported by fertilizer application. Across the surveyed communities, irrigation significantly enhanced farm productivity (95%), crop profitability, household welfare, and income stability. The chi-square (χ^2) test results further confirmed a strong association between irrigation activities and improved farmers' livelihoods, underscoring the critical role of irrigation in supporting rural development in Jama'are LGA.

Despite the highlighted positive outcomes, challenges such as limited access to credit, low association membership, declining soil fertility, and inconsistent

fertilizer use were encountered in the LGA and continue to constrain optimal productivity. Essentially, to make irrigated agriculture more sustainable in Jama'are LGA, governments and NGOs need to address these issues through improving institutional support, strengthening farmers' cooperatives, enhancing access to agricultural finance, and implementing integrated soil and water management strategies.

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