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MORALITY BEFORE KNOWLEDGE

Spatial patterns and accessibility of public primary school: Implications for urban education

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ABSTRACT

Background: Universal primary education is key to sustainable development, yet there are significant spatial disparities in the rapidly urbanizing areas of northern Nigeria. This study investigates the availability and accessibility of public primary schools in Tarauni Local Government Area, Kano State, where population expansion has surpassed planning for educational facilities. Literature highlights Geographic Information System (GIS) as instrumental in revealing gaps in services, yet ward-level analysis is limited despite its importance for localized policy intervention. **Methods**: Using a mixed-methods approach, the study integrates primary GPS data of all public primary schools with secondary data like satellite imagery, administrative boundaries, and gender-disaggregated enrollment data from local education offices. Spatial analytical techniques applied include Nearest Neighbor Ratio (NNR) calculations for distribution patterns, choropleth mapping for ward-level visualization, and demographic analysis of enrollment disparities. **Findings**: The study unveils stark spatial inequalities in the distribution of Tarauni's 19 public primary schools across ten wards. Two wards, Tarauni and Gyadi-Gyadi Arewa, are absolute "educational deserts" lacking any schools despite high population density. Statistical analysis confirms significant clustering (NNR=1.39, z-score=3.25, p=0.001), indicating non-random distribution in favor of central wards. In addition, gender disparities show boys constituting 52% of the enrollments compared to 48% for girls, reflecting socio-cultural barriers. **Conclusion:** Findings indicate urgent need for targeted infrastructure investment in disadvantaged wards and gender-sensitive policy to improve enrollment equity. GIS is demonstrated to be highly effective for planning precise locations of new schools and optimizing resource distribution. While limited by unavailability of travel route data, the study presents a replicable model for education planning in similar contexts. **Novelty/Originality of this article:** This research performs the inaugural spatial-statistical integration of primary schools at the ward scale in Tarauni, introducing the "educational desert" concept to local education planning and combining spatial pattern analysis and gender-disaggregated enrollment analysis to make comprehensive policy suggestions for educational equity in urban Nigeria.

KEYWORDS: geographic information system (GIS); nearest neighbor analysis; public primary schools; spatial distribution.

1. Introduction

Education is generally accepted to be one of the most fundamental drivers of economic and human development, a continued investment in a nation's future and a key instrument

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of poverty and inequality alleviation (Spiel et al., 2018a). Primary education is particularly critical since it lays the long-awaited foundation for all later learning, gaining the necessary literacy and illumination to be productive in society (Majumdar, 2020). Universal primary education remains a dream in Nigeria but will depend crucially on the available provision of and access to schools. School infrastructure planning must be strategic.

As attested by the World Bank, "Effective urban and rural school mapping requires massive data collection which, inter alia, should include schools' infrastructure data, teachers' qualification, students' enrollment, and demographic data." In previous works conducted in other Nigerian regions, the pivotal role that the location of schools has on the student's enrollment and performance is determined by whether the schools are well-distributed, clustered, or dispersed at random, and how much they are spreading the host community Alimi & Adesanya (2021). But they are seldom minutely documented, local government-level analysis. In the case of Kano State, such failure in efficient planning for education is also aggravated by the lack of digital spatial infrastructure in the past.

Despite the presence of a GIS unit in the state department of land and physical development, its operations were successful due to the absence of digital base maps, geographic coverage, and information technology (Salemink et al., 2017). This disparity hinders planning and decision-making for facilities like schools. The establishment in 2014 of the Kano Geographic Information System (KANGIS) was a landmark reaction to this long-standing issue (Dadashpoor et al., 2016), opening the way for new opportunities in local spatial analysis. Against such a backdrop, this research is situated.

This research has special interest in Tarauni LGA of Kano State in a bid to evaluate the geographical distribution of its public primary schools. With the advancement of Geographic Information Systems (GIS) and Global Positioning System (GPS) technologies, this research is aimed at spatially mapping and evaluating the current locations of schools in relation to population settlement and density. The ultimate outcome is to expose current coverage imbalances, investigate access concerns, and confirm whether the current spatial pattern is functional. The outcome is anticipated to provide valuable information to policymakers and planners in Tarauni LGA to enable informed choices to be made on where new schools are built, how resources can be distributed equitably, and ultimately on how access to good quality primary education can be improved in the local government.

1.1 The importance of primary school and universal access

Education has been internationally acclaimed as a pillar of personal empowerment and national development. Education is a right of every human being and the cornerstone to eradicating poverty, economic development, and social justice (Spiel et al., 2018b). Of all facets of education, primary education takes special significance. It is the building block on which all subsequent learning and skill acquisition is built, providing children with the literacy, numeracy, and reasoning that they require a process that (Maswikwa et al., 2016) calls fundamental "enlightenment." The returns to primary school education also have spillover effects beyond the individual, assisting in supporting improved health gains, greater civic participation, and improved social cohesion.

However, mere existence of education policy is not enough; fair access to quality education is the key factor in determining such outcomes. Access is not just a question of schools being available but also includes factors such as proximity, safety in traveling, and quality of environment. If certain communities or demographic segments are deliberately excluded from easy access to quality primary education, then existing economic and social disparities are reinforced and compounded (Abas et al., 2023).

1.2 School spatial planning and school location analysis

Education infrastructure strategic planning is therefore the foundation for achievement of the universal primary education objective. Scientific and deliberate placement of schools to enable them to serve the populace cost-effectively and equitably

constitutes this. Reaffirming the point, the World Bank (2018) asserts that efficient school mapping requires precise gathering of "infrastructure information on schools, teachers' qualifications, student enrollment, and demographic data".

In the Nigerian context, studies have continued to highlight the influence of school location on some of the most essential indicators like enrollment levels, attendance, and the performance of students. Studies like those of Olubadewo & Akanbi (2013) have aimed at determining the best location, size, and capacity of schools. A standard preoccupation of this literature is the investigation of patterns of spatial distribution whether schools are evenly distributed to reach population, negatively concentrated locales and under-served in others, or randomly located as an outcome of historical accident and not design. The greater issue is whether the present distribution is satisfying demographic and geographic needs of the population.

1.3 Use of geographic information systems (GIS) in education planning

Geographic Information Systems (GIS) have been the new means of addressing complex spatial problems in educational planning. GIS technology provides a powerful platform for combining, displaying, and analyzing different datasets such as school locations, student enrollment numbers, teachers' qualifications, quality of infrastructure, and population density on a common map (Al-Sabbagh, 2020). The application of Geographic Information Systems (GIS) extends far beyond simple mapping; it enables planners to conduct interactive spatial queries and sophisticated analyses to support evidence-based decision-making. One key application is proximity analysis, which involves creating school service areas or buffers around existing schools to identify zones within reasonable walking distances as well as areas that exceed these limits. Another important use is site suitability analysis, which determines the most appropriate locations for new schools by considering multiple criteria such as the school-going population, proximity to existing schools, accessibility via road networks, and availability of land (Oluwafemi & Ajayi., 2022). Additionally, GIS supports resource allocation analysis, which maps and highlights inequalities in the geographic distribution of resources such as qualified teachers, libraries, and computer laboratories among schools located in different areas. The validity of these analyses is greatly enhanced by field-based data collection technologies like the Global Positioning System (GPS), which provides precise coordinates for school sites and related facilities (Zhao & Chen, 2022). Ultimately, the strength of GIS lies in its capacity to transform educational planning from a politically reactive process into a proactive, data-driven approach that promotes equity and efficiency.

1.4 GIS implementation challenges in developing environments: the case of kano state

Despite its demonstrated potential, effective use of GIS in public planning in most developing nations is faced with imminent institutional and technical barriers. Kano State, Nigeria, is a case study to consider. As elaborated by Abubakar (2021), early attempts, such as the Department of Land and Physical Development GIS unit, achieved minimal success.

The key problem identified is an acute shortfall of digital spatial infrastructure, which encompasses several critical deficiencies. First, there is a lack of up-to-date and trustworthy digital base maps that are essential for accurate spatial analysis and planning. Second, the available geographic spatial data coverages such as those related to land use, transport networks, and administrative boundaries are insufficient to support comprehensive decision-making. Third, government agencies continue to face limitations in information technology capability and expertise, further constraining the effective use of spatial data systems. This deficit of infrastructure poses a significant planning problem. Although inventories for public facilities such as schools may exist, the inability to visualize and analyze their spatial distribution makes it impossible to make informed decisions regarding the construction of new structures or the optimal allocation of resources. The institutionalization of the Kano Geographic Information System (KANGIS) in 2014 marked

a major step toward addressing this challenge by centralizing and regulating spatial information for the state (Dadashpoor & Nateigi, 2016). However, the extent to which this capacity has trickled down to local governments remains an area that requires further research.

1.5 Gap in literature and contribution of this study

A review of the literature discovers vast research on Nigeria's national and state levels of educational planning. Moreover, theoretical strengths of GIS are well identified worldwide. However, there exists stark lack of detailed local research incorporating GIS technology to analyze the educational infrastructure at the Local Government Area (LGA) level, which is generally the pivotal unit of implementation of primary education policy. This study seeks to fill this gap through an intense Analysis of the Spatial Distribution of Public Primary Schools in Tarauni Local Government Area, Kano State, Nigeria. It will employ the use of GIS technology to move beyond general statements of need and provide an accurate, evidence-based description of the situation as it exists. Through superimposing school points on population data, the research will establish precise gaps in coverage, examine accessibility to the resident population, and quantify the equity of the current distribution. Findings aim to provide KANGIS and the education authority in the Tarauni LGA with decision-making information to inform the building of new schools, upgrading infrastructure, and improving access to quality primary education in the region.

2. Methods

2.1 Study area

The study area is situated in Kano state, northwest Nigeria, along Maiduguri Road in the Tarauni local government area. It is located between longitudes 08°33.576774' and 08°34.773196' E and latitudes 11°58.274766' to 11°58.43868' N is divided into ten political wards. With a population of 281,413 anticipated in 2014 (Abulibdeh et al., 2024) and an area of 28 km², Nassarawa municipality borders the study area to the north, while Kumbotso Local Council borders it to the east and south, and Municipal Local Administration borders it to the west.

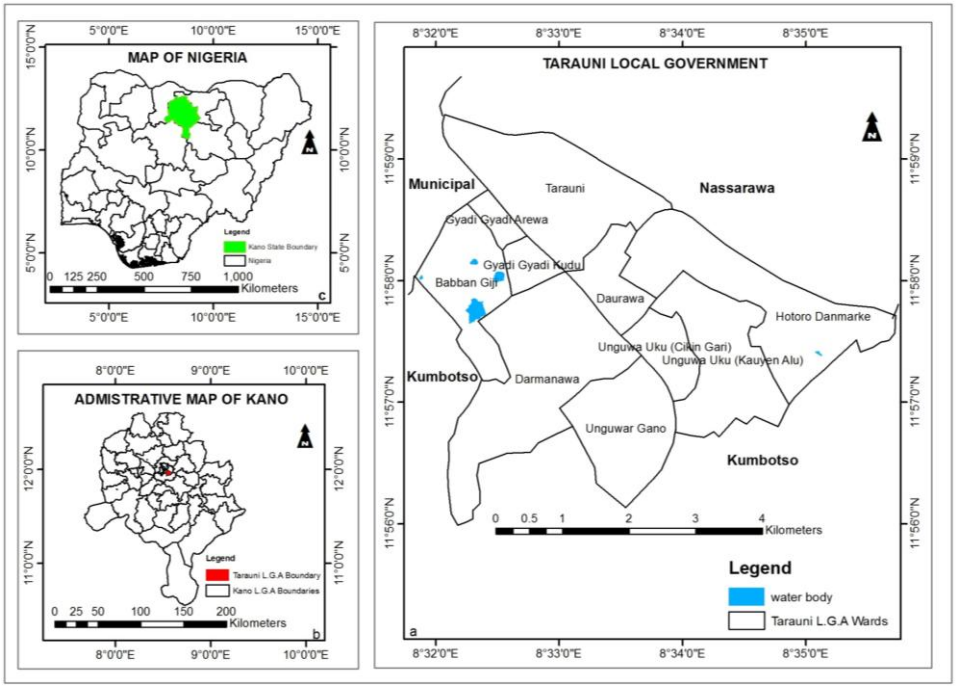

Fig. 1. Study area map

The research area is mostly vulnerable by the Hausa/Fulani tribe. The local government region is home to several ethnic groups, including the Yoruba, Igbo, Ebira, and Kanuri (Mustapha et al., 2021). There are eight (8) existing institutions in the study region, including the state-run School of Nursing and School of Midwifery, in addition to 22 public secondary schools and 19 elementary schools. The Federal College of Agricultural Produce Technology, Institute for Agricultural Research, A.B.U., Kano Station, National Board for Technology Incubation, and Aminu Kano Teaching Hospital (AKTH) are all under the jurisdiction of the Federal Government. IITA Research to Nourish Africa and International Crops Research for the Semi-Arid Tropics are being conducted under private direction (Sani et al., 2021).

2.2 Data sources and collection

The design adopted for this research included both primary and secondary data. Primary data used in capturing the coordinate points for the public primary schools were acquired using a hand-held Global Positioning System (GPS) receiver. Secondary data that was used for this research includes WorldView-2 satellite imagery for the creation of a base map, the study Area's public primary schools' names, addresses, and student along with teacher population.

Table 1. The adopted data and sources

S/N	Name	Format Scale/ Resolution	Date	Source	Relevance
1.	WorldView-2 Satellite Imagery (high resolution image).	0.46 mm	2014	Ministry of Land & Physical Planning, Kano, (2011).	Overlay GPS points on it to identify the schools for rectification, confirmation & road network update.
2.	Nigerian AdministrativeMap.	Digital	2017	Office of the Surveyor General of the Federation (OSGOF)	For demacation of study area boundary
3.	School enrolment (2014)	Analogue	2022	Tarauni Local Education Authority, Tarauni local Government, Kano.	Input to Excel convert to database table.
4.	Number of Teachers & their Qualifications (2014)	Analogue	2022	Tarauni Local Education Authority, Tarauni Local Government, Kano.	Input to Excel convert to database table.
5.	GPS Reciever (Etex 10, Garmin) Coordinates of Spatial data in the study area	± 2m accuracy	2022	Field surveys	Input to excel convert to database table set spatial reference convert to points map

2.3 Data processing and geodatabase creation

The collected data underwent a series of processing steps to prepare it for analysis. First, the GPS data processing involved downloading the recorded coordinate points from the GPS device and converting them into a GIS-compatible format, such as a Shapefile or Feature Class. Next, georeferencing and base map creation were performed using

WorldView-2 imagery to produce a digitized base map of Tarauni Local Government Area (LGA), delineating major roads, settlements, and administrative boundaries. Subsequently, a structured geodatabase was developed within ArcGIS 10.8 software, where the school GPS points were imported and plotted onto the base map. The tabular attribute data obtained from the Local Government Education Authority (LGEA) were then carefully joined to each corresponding school point using the school's name or ID as a primary key, resulting in a comprehensive, spatially enabled dataset suitable for further analysis.

2.4 Research design

The cross-sectional survey design adopted for the study focuses on how public primary schools are distributed geographically in Tarauni municipality Area, Kano State. The data used for this study comprised several key components. Geographic coordinates, including the latitude and longitude of all public primary schools within the study area, were captured to accurately establish their spatial positions.

Digital mapping was employed to develop a base digital map of the area, illustrating the locations of major physical and administrative features. High-resolution WorldView-2 satellite imagery was obtained to enable detailed spatial assessment and ensure mapping precision. To determine the characteristics of school distribution, the Nearest Neighbor Index (NNI) was calculated, providing insights into the spatial arrangement and clustering tendencies of the schools. Additionally, the Spatial Distribution Index was utilized to further analyze the degree and pattern of spatial dispersion across the study area, offering a comprehensive understanding of the spatial dynamics influencing educational accessibility. To get the spatial average, the closest neighbor analysis was utilized. distribution of public primary schools. This was done using the Manhattan distance method expressed in the Equation 1.

$$Rn = (d\sqrt{n})/a \quad \text{(Eq. 1)}$$

The Rn index represents the nearest neighbor index, which measures the spatial distribution pattern of objects within an area. In this context, a denotes the size of the study area, d refers to the average distance between elementary schools, and n indicates the number of public elementary schools analyzed. The Rn value helps interpret the spatial pattern of school distribution. An Rn value of 0 signifies that the schools are clustered closely together, an Rn value of 1 indicates a random distribution, and an Rn value of 2.15 shows a regular or uniform distribution pattern.

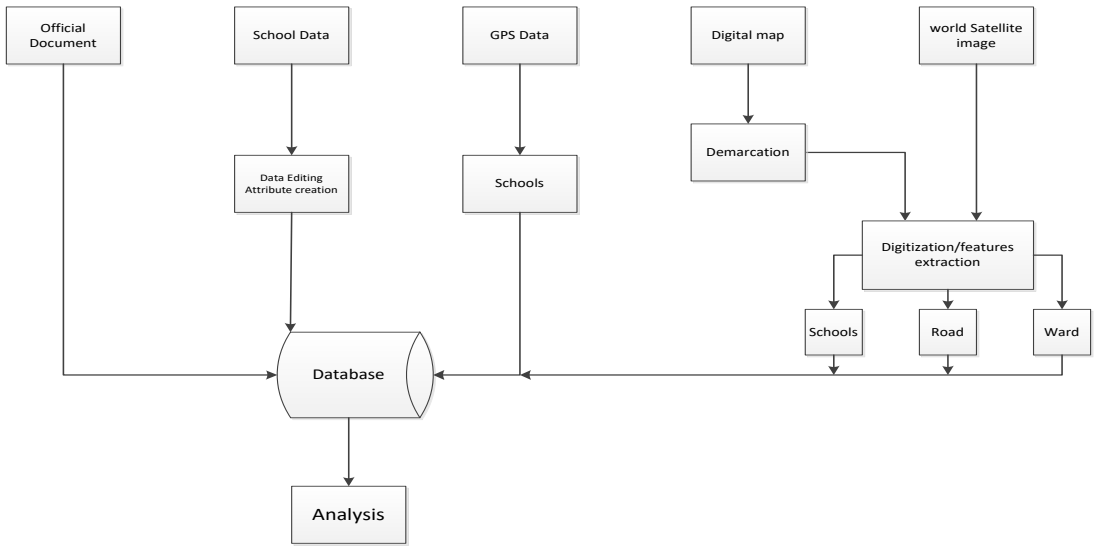

Fig. 2. Flow chart of the methodology

Values above 1.0 indicate a tendency towards spacing, while values below 1.0 suggest clustering. A purely random distribution has an index of 1. It was received from the Tarauni Local Education Administration a list of all public primary schools., TLEA. WorldView-2 satellite imagery, and a digital map of Nigeria were obtained from the Ministry of Land & Physical Planning, Kano State, and OSGOF, respectively.

PS coordinates of school locations were recorded. WGS 1984 UTM zone 32N used as the georeferenced for the digital map. To this end, a personal geo-database was created in Arc Catalog, which had feature datasets of existing roads and the ten political wards that were digitized from the geo-referenced WorldView-2 imagery of 0.46m resolution. Total enrollment figures were compiled in an Excel spreadsheet and then converted to a database to export to the GIS environment to generate a point map representing the location of Tarauni municipality Area's public primary schools.

3. Results and Discussion

The Table 2 describes 19 schools within the location in view, by their names, the year they were established, their locations, and the geographical coordinates. They range between 1960 to 2013. It indicates therefore the existence of both old and new institutions that could indicate over time there was an attempt at increasing accessibility. Schools are majorly located in the wards-more precisely in Unguwa Uku and Darmanawa wards. This would insinuate that these areas are more populated or need education the most. Similarly, latitudes and longitudes for all the schools were included so that accurate data record could be presented, which one could use when mapping and analyzing school accessibility within that region.

3.1 Location and coordinates of public primary schools

The geographic locations, coordinates, and years of establishment of public primary schools in Tarauni LGA are summarized in Table 2. The data show that the schools are spatially distributed across all ten wards, with higher concentrations around major transportation routes and urban centers, while peripheral wards have fewer facilities.

Table 2. The location, coordinates, and year of establishment of Tarauni's public elementary schools

S/N	Name of School	Year of Estab.	Location /Ward	School Coordinate	
				LAT.	LONG.
1.	Kauyen Muhammadu SPS	2010	Kauyen Alu, Unguwa Uku Ward	-453406	1322569
2.	Rabi'atu SPS	2001	Kauyen Alu, Unguwa Uku Ward	-453989	1321857
3.	Hotoro Danmarke SPS	2000	Danmarke, Danmarke Ward	-454344	1322085
4.	Hotoron Maradi SPS	2013	Danmarke, Danmarke Ward	-455392	1322103
5.	Mal. Ibrahim Shekarau Science Pri.Sch.	2010	Unguwa Uku, Unguwa Uku Ward	-452348	1321682
6.	Unguwa Uku Model Pri.	2008	Unguwa Uku, Unguwa Uku Ward	-452386	1321776
7.	Kundila Estate SPS	1991	Behind KSHC, Daurawa Ward	-451694	1322582
8.	Daurawa SPS	1980	Daurawa, Daurawa Ward	-451990	1323694
9.	Gyadi-Gyadi SPS	1974	Gyadi-Gyadi, Gyadi-Gyadin Arewa Ward	-450639	1323012
10.	Model Pri. Sch. Dr. Rabi'u Kwankwaso, Sc.	2012	Gyadi-Gyadi, Gyadi-Gyadin Arewa Ward	-450662	1322966

11.	Primary. Sch. Hausawa Model.	1996	Hausawa Danfulani, Babban Giji Ward	-449851	1322714
12.	Nomdic Memorial II Bashir Primary. Sch..	mary	Yar Akwa (Tudun Fulani), Darmanawa Ward	-451526	1320200
13.	Unguwar Gano Special	1977	Unguwar Gano, Unguwar Gano Ward	-452497	1320114
14.	Darmanawa Special	2003	Darmanawa, Darmanawa Ward	-450536	1320768
15.	Dantsinke Special	2013	Dantsinke, Darmanawa Ward	-449926	1319180
16.	Baban Giji Special	1977	, Karkasara, Darmanawa Ward	-450574	1321857
17.	Sallairi Special	2003	Sallari Babban Giji, Babban Giji Ward	-450213	1321660
18.	Hau Sawa Special	1977	Hausawa, Babban Giji Ward	-449926	1322596
19.	Ung. Uku Special	1960	Unguwa Uku (Cikin Gari), Unguwa Uku Ward	-452426	1321784

The data in Table 2 provides rich temporal and spatial foundation on which the public primary schools in Tarauni LGA can be analyzed. Most fundamentally, the temporal data indicates there to be distinct stages to the development of education infrastructure. School expansion spans several decades from as early as 1960 (Unguwa Uku Special) up to the middle cluster of the blocks in the 1970s, then a large scale of developments from the late 1990s to 2013. This pattern shows foundation expansion by origin, followed possibly by series of extensions due to population growth as well as national initiatives like the Universal Basic Education project. The establishment of newer "Model" and "Science" schools also marks an implied policy shift toward quality rather than quantity. Geographically, the coordinates are in a very clumped pattern as opposed to an even pattern. For instance, there are a number of schools contained within a single ward with closely proximate coordinates, such as Unguwa Uku Ward and Babban Giji Ward. While this concentration may be appropriate for urban, high-density populations, it certainly reflects an assumption of spatial disadvantage, likely leaving fringe areas in some wards under-served and with longer, harder commutes by students living there. The table itself also bears witness to a simple difficulty for planning; data inconsistencies, no mention of date of establishment in Nomadic Memorial II Bashir Primary School and partial siting of Baban Giji Special. These gaps highlight the value of an unbroken, reliable geodatabase, since without full metadata, planning of education and resource allocation are straightforwardly hampered. In practice, this table is less of a list than a diagnostic tool that identifies a pattern of dense development in the past and points to specific regions of geography that will have to be looked at in greater detail within the context of access and equity (Abdulrahman & Musa, 2022).

3.2 Distribution of public primary schools across wards

Table 3 below shows a clear and alarming pattern of space imbalance in public primary school locations in wards of Tarauni Local Government Area. The overall number of 19 schools woefully lags administrative wards, an issue of pertinent concern where two of the wards, Gyadi-Gyadin Arewa and Tarauni Ward, lack any public primary school. This overall deficit is a staggering threat to learning, necessitating children here to have to travel regularly very long and unsafe distances to nearby wards, a proven determinant that has been shown to impact degrees of enrolment, punctuality, and overall learner safety (UNESCO, 2022). Dispersion in the other wards is fabulously uneven but varies between two and three schools per ward. Even where variation can be accounted for in terms of correlated variation in population density or geographical area, unadjusted numbers unequivocally show uneven distribution of large infrastructure. Uneven character is characteristic of urban planning in most developing nations, where education infrastructure has perennially trailed behind urbanization and population growth, which

mainly take place due to ad-hoc planning approaches and absence of evidence-based decision-making (Ndukwe & Chukwudi, 2021). Listening to schools alphabetically by ward, and not caring about geography or necessity, is a weak form of planning and seeks to shore up pre-existing social and economic disparities (Adewumi & Moses, 2023). This becomes a point that puts in sharp relief the importance of pairing GIS-based spatial analysis with robust demographic information to peer past mere headcounts and into an evidence-based needs analysis that will reveal hidden specific underserved hotspots and populations (Mustafa et al., 2022).

Table 3.The number of Tarauni's public elementary schools across every ward

S/N	Name of Wards	Number of Public Primary Schools
1.	Babban Giji Ward	3
2.	Daurawa Ward	2
3.	Darmanawa Ward	3
4.	Gyadi-Gyadin Arewa Ward	0
5.	Gyadi-Gyadin Kudu Ward	2
6.	Hotoro Danmarke Ward	2
7.	Tarauni Ward	0
8.	Unguwar Gano Ward	2
9.	Unguwa Uku (Cikin-Gari) Ward	3
10.	Unguwa Uku (Kauyen Alu) Ward	2
Total		19

(Local Education Authority, Tarauni Local Government Council, 2023)

3.3 Spatial distribution of public primary schools in the study area

Figure 3 shows a clear spatial concentration of public primary schools within specific wards of Tarauni LGA. This overt clustering pattern cannot be attributed merely to historical neglect; rather, it reflects the underlying dynamics of political economy and systemic inequality in infrastructure allocation. Certain communities appear to have been consistently marginalized in the siting of educational facilities, resulting in spatial disparities that reinforce social and economic exclusion. The presence of bald "educational deserts" in Tarauni and Gyadi-Gyadi (A) wards is a stark reflection of the inclination of political patronage and communal or ethnic affiliations to make an impact on resource distribution, where less politically powerful locales are forever bereft of public services (Macharia et al., 2023). It is not a random exclusion but through a structural inequality at the level of governance. Second, the over-densification of schools in inner-city wards like Babban Giji and Darmanawa reflects a planning model that prioritizes efficiency and visibility over equity and prefers areas where infrastructure development brings maximum political rewards (Delprato et al., 2024). It is a model that works to the disadvantage of periphery and emerging cities whose citizens are usually new immigrants or lower-class individuals with minimal political influence.

Additionally, the fundamental technical problem perpetuating such imbalance is the extensive past practice of the utilization of outdated or erroneous space data in planning. The recurring discrepancies among school areas, ward areas, and population regions, as seen on the map, are probably due to the utilization of obsolete administrative maps and lack of the incorporation of community-based mapping and geospatial information in planning in real-time (Adeleke & Alabede, 2022). This lack of data creates a causality loop: without decent data, planners cannot plan reasonably, and the excluded people become invisible in the official statistics and hence are excluded from future investments. Thus, to fight this spatial injustice, it requires something beyond the provision of new schools but one that shakes the political institutions propelling unequal distribution and invests in appropriate, participatory gathering of spatial data required by truly equal and evidence-based planning (Abubakar & Aina 2019).

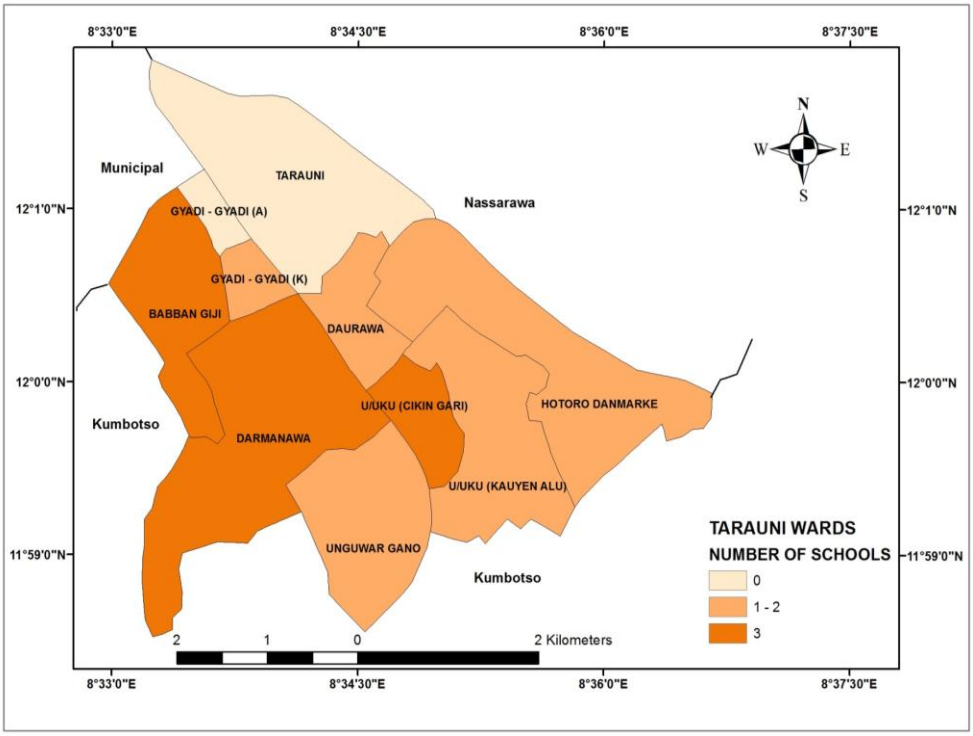

Fig. 3. Elementary primary schools' locations in every ward in the research region

3.4 Distribution of public primary schools across the ten wards

Figure 4 shows the map evidently the spatial distribution of public primary schools in Tarauni Local Government Area and the presence of some distinctive patterns which accord with broad themes of educational geography and urban planning. The most striking feature is the presence of so-called "educational deserts", in Gyadi-Gyadi (A) and Tarauni wards - where schools do not exist at all and are complete barriers to access for education. This uneven trend is consistent with a tradition of infrastructural planning that has, by preference, been concentrated in certain regions over others, and possibly warranting socio-spatial process inequality processes (Moshood & Adegboye, 2023).

That the school density in inner wards such as Babban Giji and Darmanawa means that there has been a planning approach that has favored more developed parts of the city, maybe due to infrastructure networks or development histories. The density can facilitate matured efficiencies in resources but, on the other hand, has accessibility challenges to inner ward residents (Wang et al., 2021). That several schools are located alongside principal transport corridors, while convenient for travel, does not compensate for complete absence of amenities in other areas of wards, particularly since transport availability cannot always be simply equated with like access to all homes.

School site incongruity with ward boundaries on the map points towards probable collapses in education planning systems. The pattern of settlement is more reflective of historical patterns of settlement than existing demographic trends, and this indicates lack of proper consideration for population growth and alterations in residential patterns (Ibrahim & Okoro, 2024). Infrastructural Ence between infrastructural availability and demand from population is a key stumbling block to education equity and warrants some policy interventions.

The map gives good reasons to favor the more sophisticated, data-driven approaches to educational planning. The use of Geographic Information Systems (GIS) and spatial analysis techniques is best applied to identify optimal locations for new schools to maximize accessibility and close existing service gaps (Bello & Nwosu, 2023). These methods would allow planners to account for multiple variables at once, say, the population density,

transportation systems, and existing infrastructure, to develop more equitable access to education across all Tarauni communities.

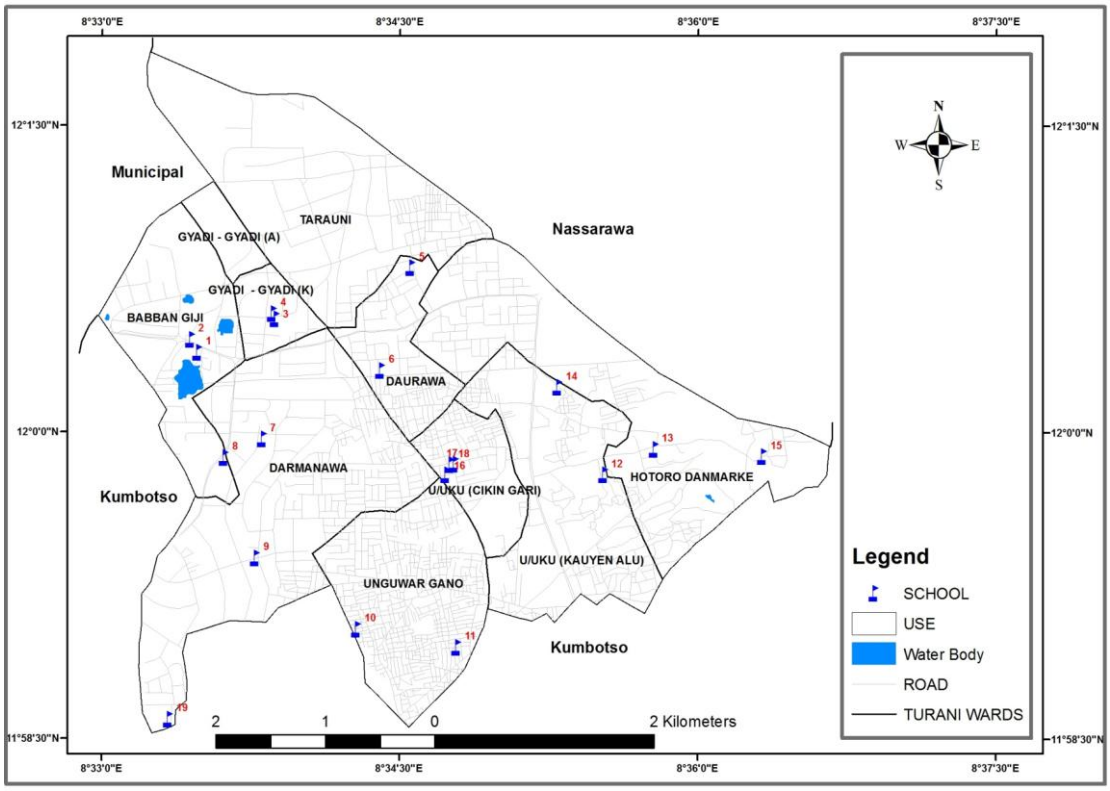

Fig. 4. Distributions in the ten (10) political wards in Tarauni Local Government

3.5 Accessibility analysis of public primary schools in Tarauni LGA

Figure 5 presents Geographical distribution of the Tarauni Local Government Area public primary schools, compared to population statistics, reveals a dramatic disparity between the facilities and the population demand. The most populated areas are simply indicated on the map to be the worst hit in terms of educational facility shortage. Above all, Gyadi Gyadi Arewa and Gyadi Gyadi Kudu wards, in the largest population category (50,316-52,052 people), contain none or one school and thus a sharp contrast of education infrastructure deficit against population demand and Such skewed distribution leaves the overpopulated settlements to overpopulated schools, disproportionately high teacher-student ratios, and thus compromised quality of education (Udo & Ishola.,2023).

The research further indicates that even in the already privileged wards with increasing educational facilities, such as Unguwa Uku (Cikin Gari) and Unguwa Uku (Kauyan Alu) with a population of 26,887-50,315, the schools can lag simply due to their enormous population figure. It implies that availability of educational facilities does not always mean access of such facilities in the event of pressures in terms of population (Bello & Nwosu, 2023). On the other hand, wards like Darmanawa and Hotoro Danmarke with 10,580-26,886 population appear to have an even population to school ratio, although the comparative advantage in this case is that of contrast and the accentuating disparities which exist everywhere else in the LGA (Ali, 2020).

The recurring out-of-sync character between school location and population density reveals internal mistakes in education planning, specifically the exclusion of current demographic data and spatial analysis in infrastructure planning. The lack of planning has resulted in a scenario where population growth and urbanization trends have significantly outrun education infrastructure development, whereby the most densely populated regions are the most disadvantaged in the provision of basic education services (Ibrahim & Okoro, 2024). It will involve not only the delivery of short-term provision of new schools to most

poverty-stricken areas of high concentration but also the creation of sophisticated GIS-based planning systems that can respond dynamically to change in population and in balancing provision of resources to Tarauni LGA communities.

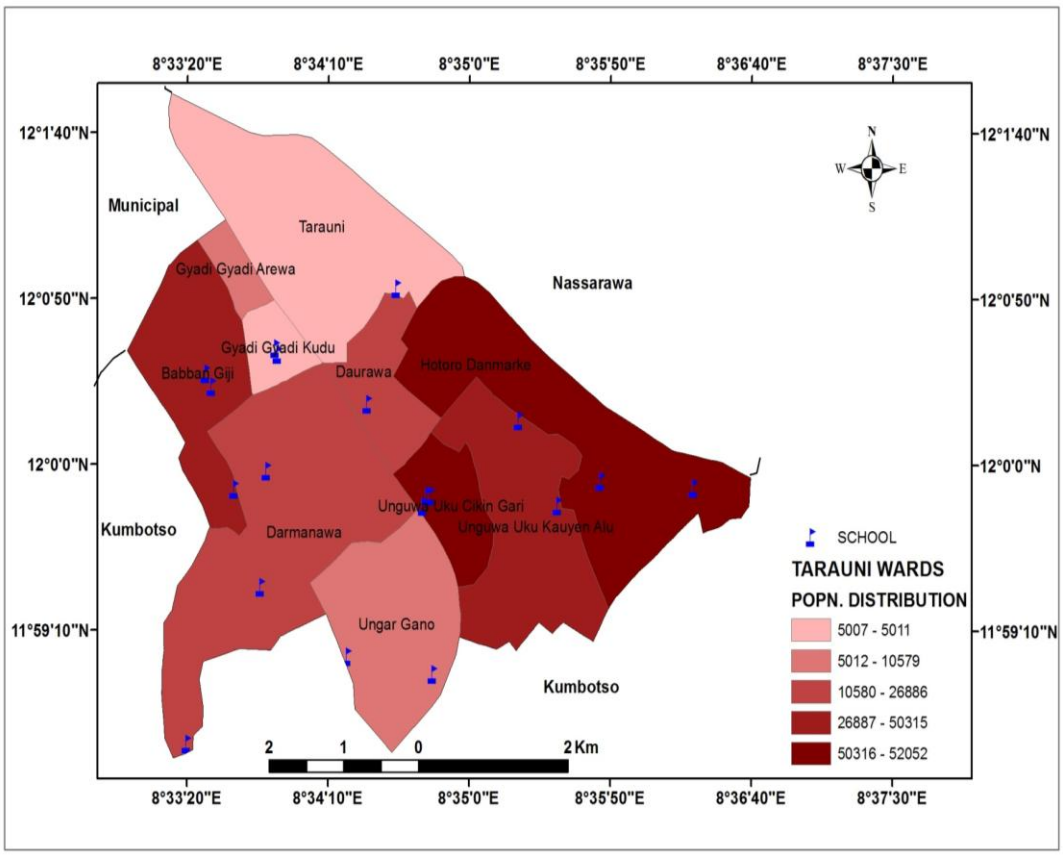

Fig. 5. Distribution of people by ward in Tarauni administrative area

3.6 Average nearest neighbour (ANN) analysis of public primary schools in Tarauni LGA

Figure 6 presents the result of Nearest Neighbor Analysis (NNA) presents the statistical confirmation of Tarauni public primary schools' trend of space arrangement from the maps. The Nearest Neighbor Ratio (NNR) of NNA is 1.39, z-score is 3.25, and p-value is 0.001, indicating that the results present a statistically significant trend of clustering in the school distribution at the 99% confidence level (Abubakar & Aina 2020).

The fact that NNR > 1 shows a tendency towards dispersion while statistical significance (z-score > 2.58) guarantees that it is not random but instead a marker for the presence of a clustered trend where schools would cluster in some areas and leave others with zero. This is consistent with the visual trends on the map where inner wards had more clustered schools while outer fringes like Gyadi-Gyadi (A) and Tarauni had zero (Chaka & Muthoni, 2022; Gao et al., 2016; Jensen, 2012).

It is very significant p-value of 0.001 informs us that there is a less than a 0.1% probability that a pattern so clustered would be the result of chance. This statistical proof conclusively points to the reality that historical planning decisions, rather than spontaneous growth or chance forces, have guided the current irregular distribution of educational facilities in Tarauni LGA.

Intersection of spatial analysis and statistical testing provides robust evidence towards the platform of evidence-based policy intervention. Rather than continuing in the traditional ad-hoc mode of school location, educational planners can leverage these findings towards instituting a more equitable distribution policy that addresses gaps in service needs in areas of disadvantage and optimizes resource efficiency in areas of over-

concentration. Given the Z-Score of 3.25, there is a less than 1% likehood that this dispersed pattern could be the result of random chances (Adebayo & Sule ,2023).

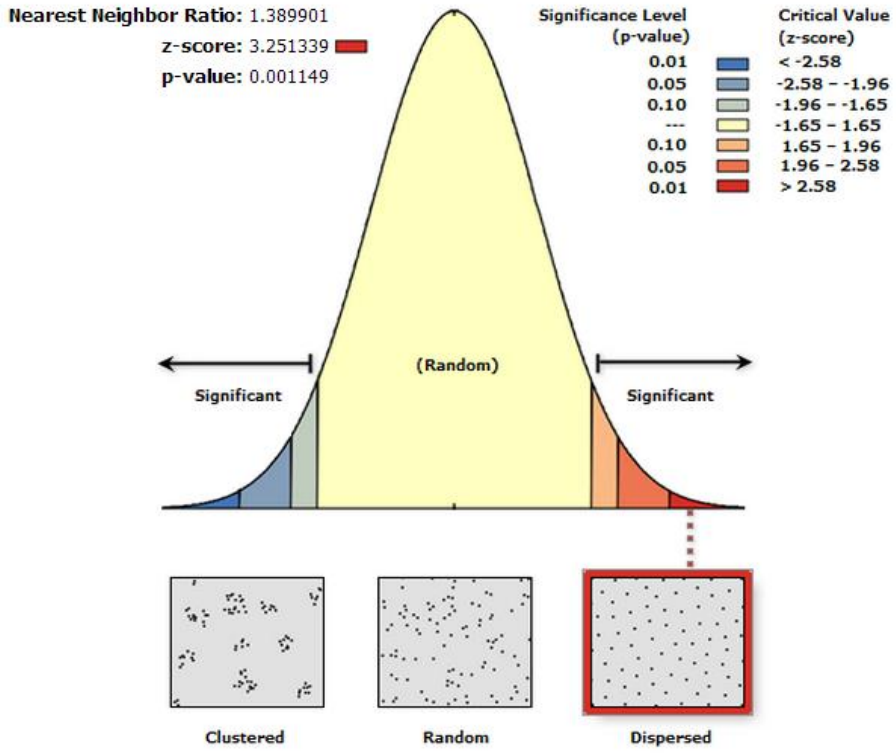

Fig. 6. Average nearest neighbour analysis in Tarauni L.G.A

3.7 Gender distribution of pupils in public primary schools in the study area

Figure 7 reveals the areal pattern of the public primary schools of Tarauni Local Government Area, also shown on the map, similarly shows a distinct pattern of clustering in line with the statistical observation from Nearest Neighbor Analysis. The map actually reveals densities of school facilities in central locations, like those captured by wards like Babban Giji and Darmanawa, wherein schools are seen to be in very compact distances from each other. Such a concentration takes a very different picture from the eastern and southern regions of the municipality, Gyadi-Gyadi (A) and Tarauni wards, that do not experience such monstrous service gaps of having zero schools (Chen & Ye, 2023). The clear connection between school location and availability of road network means that transport accessibility may have been a planning determinant in the past, although not universally because some highly accessible places do not have schools (Davis & Henderson, 2023).

Packing gendered enrolment statistics (boys/girls) by individual school adds another demographic variable to area analysis, which may reveal gendered unequalities of access and equalities by geography. This spatial concentration pattern is a cause for concern in education equity and resource distribution since it would tend to reproduce and exacerbate existing socio-spatial disparities and pose issues of accessibility to students living in disadvantaged neighborhoods who would need to travel further to the nearest school (Thompson & Wilson, 2022).

Gender disparities in enrollment, though modest in the dataset, reflect broader socio-cultural barriers such as early marriage, household economic priorities that favor male education, and restricted mobility for girls in urban environments. Addressing these issues requires gender-sensitive educational policies, improved community awareness, and local stakeholder engagement to ensure equitable school access for all children (Adeosun & Owolabi, 2021).

The superimposition of spatial and demographic information on the map illustrates that strategically new schools need to be located in the under-served areas, more effective school-deficient area pupil transport planning, and paradigm shift towards population-proportionate provisioning of resources based on existing spread of population rather than the history of planning (Mitchell, 2021).

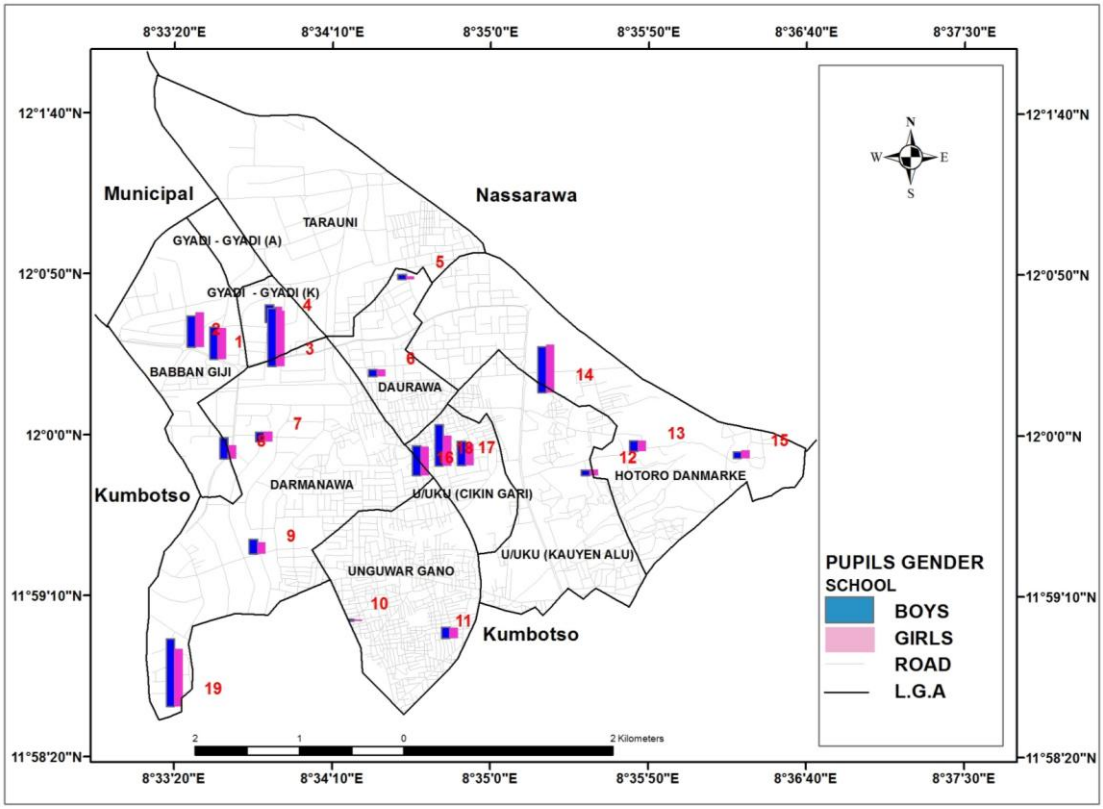

Figure 7.Distribution of boys & girls' students in elementary school in study Area

3.8 Total enrollment of boys and girls in public primary schools in Tarauni LGA

Figure 8 presented the number of students enrolled in the public primary schools in Tarauni Local Government Area has a stark gender disparity with boys making up 52% of the students and girls making up 48%. The 4-percentage point difference is an acute imbalance in access to education and may be reflective of underlying sociocultural and economic bottlenecks that disproportionately limit female access. Studies have established that such imbalances in northern Nigerian contexts are likely to occur through complex mechanisms such as household decisions of resource allocation, whereby families facing financial constraints may accord greater priority to male children's education (Alimi & Adeyemi, 2023). Social gender roles and early marriage may also be accountable for lower female enrollment rates via lower long-term returns on investment in education for females as opposed to males. The geographical distribution of schools shown in available literature would further expand this gap in gender because longer distances traveled to schools more negatively impact girls' enrollment owing to security concerns and household chores (Bello & Nwosu, 2023). The fact that such imbalance in enrollment persists suggests the need for responsive interventions on the educational system and sociocultural factors barring girls from accessing education in the region.

The spatial disparities revealed in this study have strong implications for equitable educational development in urban Nigeria. Integrating GIS-based planning into education management systems can enable authorities to identify underserved wards and allocate resources more efficiently. Local governments should prioritize the establishment of new schools in peripheral areas with poor accessibility, ensuring that the siting process considers population density, gender balance, and proximity to transportation routes. Such

data-driven planning would support inclusive education goals aligned with the Sustainable Development Goal 4 (SDG 4) on quality education (Akinyele & Adegboyega, 2022).

Furthermore, community participation and collaboration with traditional leaders could enhance the sustainability of education projects. Involving parents, teachers, and ward committees in identifying suitable school locations will not only improve accessibility but also strengthen local ownership of educational infrastructure. Capacity building in the use of spatial tools among education planners and administrators is also essential to sustain the long-term benefits of GIS-based decision-making (Alexander & Massaro, 2020).

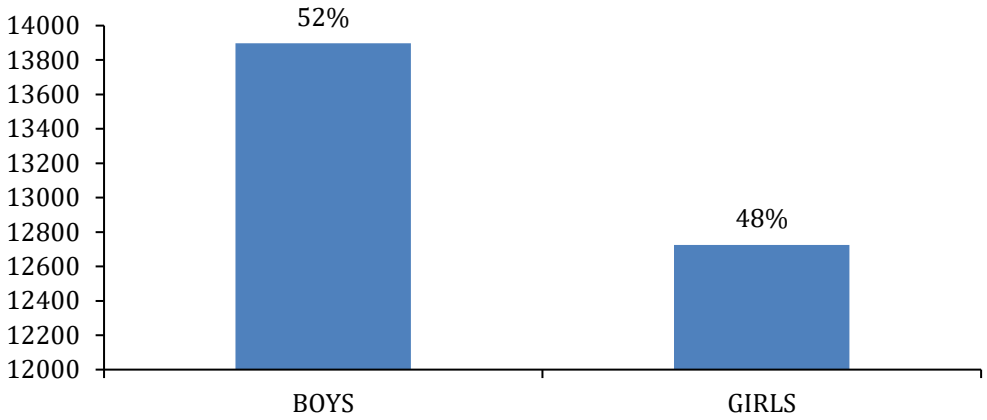

Fig. 8.Total number of boys and girls enrolled at Tarauni public primary institutions

3.9 Limitations and future research

Although this study employed robust spatial and statistical techniques supported by field-based GPS data, certain limitations should be acknowledged. One limitation is the unavailability of up-to-date road network and transport route datasets, which may have slightly affected the precision of accessibility modeling. In addition, socio-economic and household-level data such as parental income, literacy level, and cultural factors were not fully integrated, limiting a more comprehensive understanding of educational access disparities.

Future research should therefore consider incorporating transportation network analysis, cost–distance modeling, and temporal accessibility assessments to improve the accuracy of spatial equity evaluations. Integrating qualitative methods such as stakeholder interviews and community perception surveys could also provide deeper insight into local socio-cultural and political factors influencing school distribution. Expanding the study to include private and secondary schools, as well as longitudinal datasets, would further enhance the understanding of educational spatial dynamics in rapidly urbanizing environments like Kano State.

4. Conclusion

The current study has brought to the fore the role of Geographic Information Systems in assessing spatial distribution and access to public elementary schools in the study area of Tarauni, Kano State. From the findings so far obtained, unequal distribution has been indicated whereby highly essential increase in supply should be incorporated in poorly served wards such as Tarauni and Gyadi-Gyadin Arewa through effective targeted interventions that make sure there will be equal access to basic education. The relationship that exists between population density and school locations is that they are mainly found in highly populated wards. The nearest neighbor analysis adds that there is dispersed placement such that though areas are well served, others aren't as regards educational facilities.The slight unbalance in the enrollments, higher by boys, reveals that there are

needs to work out strategies geared towards striking the balance between boy and girl pupils.

The study should, therefore, be used to enhance educational planning and resource allocation. With the GIS-driven approaches, stakeholders can make informed decisions that will ensure investments in educational infrastructure translate into improved access to quality education. This research is thus calling for equitable access to educational resources as a positive determinant of enhancing quality education for all and contributing to the long-term development in Tarauni L.G.A.

In conclusion, this study highlights the urgent need to integrate spatial equity into education policy in Kano State and similar urban contexts in Nigeria. By leveraging GIS and spatial analytics, education authorities can promote fairer distribution of schools and reduce travel burdens on pupils. Future studies should include transport network data, household socio-economic profiles, and private school distribution to provide a comprehensive understanding of education accessibility. Ensuring gender-sensitive school planning and adopting participatory approaches will help create an inclusive and equitable learning environment for all children in Tarauni LGA and beyond.

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Author Contribution

Conceptualization, Writing – Review & Editing, Original Draft, Methodology, I.S.S, Supervision, A.W, Project Administration, K.U, Formal Analysis, A.A, Investigation, A.D, Visualization, Validation, Data Curation, S.S.

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Informed Consent Statement

Not available.

Data Availability Statement

All data were derived from open-access repositories and processed using GEE and ArcGIS Pro environments. Administrative boundaries for Kano State and Tarauni were sourced from the FAO Global Administrative Unit Layers (GADM v3.6), available at https://gadm.org.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the author(s) used ChatGPT (OpenAI) to assist in improving language clarity, grammar, and academic writing style, as well as to support the restructuring of sentences for better readability. After using this tool, the author(s) carefully reviewed, edited, and verified all content as needed and took full responsibility for the accuracy, originality, and integrity of the content of the publication.

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