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Location-Allocation Model for Optimising School Placement in Argungu Local Government Area, Kebbi State, Nigeria: A Geospatial Approach to Reducing Out-Of-School Children

Usman Lawal Gulma *, Garba Bala, Lawal Usman Hassan, Saad Ibrahim, Mustapha Atiku and Emmanuel Yaro

Department of Geography, Adamu Augie College of Education, P.M.B 1012, Argungu, Kebbi State, Nigeria.

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Abstract

Nigeria faces a critical challenge with out-of-school children (OOSC), particularly in northern states where Kebbi State records some of the highest numbers. The spatial distribution of educational facilities significantly influences school access and attendance rates. This study demonstrates how Geographic Information Systems (GIS) and location-allocation modelling can transform policy decision-making by enabling evidence-based, spatially optimised resource allocation to reduce OOSC. We used public primary schools in Argungu LGA, Kebbi State, a region with persistently high OOSC rates, as a case study. We analysed 208 settlements and 65 existing schools to assess spatial accessibility against Nigerian UBE guidelines (3km threshold). We then applied a maximal covering location problem (MCLP) algorithm to identify optimal sites for five new schools. The findings reveal spatial inequity; only 85.1% of settlements lie within 3km of a school, leaving a significant proportion of school-age children (14.9%) as OOSC due to distance alone. A strategic placement of five optimally sited new schools increases coverage to 95.7%, bringing an additional children within acceptable walking distance and reducing the OOSC population. For policy decision-making, GIS-based location-allocation offers a cost-effective pathway to reducing OOSC. Adopting this approach enables policymakers to move from reactive, resource distribution to proactive, equitable, data-driven governance that delivers education to the children who need it most.

Keywords: GIS; Location-Allocation; Out-Of-School Children; Policy Decision-Making; Spatial Accessibility

1. Introduction

Education is universally recognised as a fundamental human right and a powerful catalyst for achieving Sustainable Development Goal 4 (SDG 4) of the United Nations 2030 agenda (UN, 2015). Its transformative power lies in its ability to break cycles of poverty, foster economic growth, and promote social equity. Despite global commitments and significant progress in many regions, the promise of quality education for all remains unfulfilled for millions of school-aged children. According to UNESCO [1] global estimates, over 273 million children and youth are out of school, of whom 79 million are of primary school age. This crisis threatens to undermine broader developmental goals.

The challenge is acutely concentrated in sub-Saharan Africa, with Nigeria bearing one of the world's heaviest burdens. Recent reports indicate that Nigeria has an estimated 18.3 million out-of-school children, with no fewer than 10.2 million children not in school at the primary level and 8.1 million absent at the junior secondary level [1]. The country accounts for a substantial proportion of the global out-of-school population, a situation most acute in its northern regions, where 66 per cent of out-of-school children are concentrated in the North-West and North-East geopolitical zones [1]. UNICEF [2] defines OOSC as children within the official primary school age range who are not enrolled in either primary or secondary education, highlighting a critical gap in the educational system's reach.

* Corresponding author: Usman Lawal Gulma

Within Nigeria, the North-West geopolitical zone, including Kebbi State, reports the highest prevalence of educational deprivation, particularly affecting the girl-child. Here, complex socio-economic factors converge to create significant barriers to school enrollment and attendance. Insecurity has emerged as a critical driver of educational exclusion, particularly in northern Nigeria, where over 1.8 million people have been displaced. At the same time, schools have been destroyed, forcing many families to keep their children, especially girls, at home due to fear of abduction and attacks on educational institutions [3]. In states like Kebbi, Sokoto, and Zamfara, OOSC rates exceed 60% [4]. This situation represents not only a violation of children's right to education but also a significant impediment to human capital development, economic growth, and social cohesion [5]. Among the multiple factors driving high OOSC rates, one critical yet often overlooked factor is the spatial accessibility of schools. A growing body of research underscores that the spatial distribution and geographical accessibility of schools are fundamental determinants of educational outcomes. Recent studies employing Geographic Information Systems (GIS) have demonstrated that significant disparities in school distribution exist between urban and rural areas, with rural regions facing particular challenges in accessing educational facilities [6]. When schools are located too far from settlements, in difficult terrain or are unsafe, enrollment rates decline, dropout rates increase, and academic performance suffers even when other resources are available (UNICEF, 2021). These barriers disproportionately affect children from the poorest households and those in rural communities, effectively denying them their right to education. A 2025 county-level study found that rural students often spend considerably more time and energy to reach schools due to transportation limitations and limited school resources, directly impacting their educational opportunities [7]. Therefore, targeted interventions based on robust spatial analysis are urgently needed to address the root causes of non-enrollment [8].

Argungu Local Government Area (LGA) of Kebbi State exemplifies this pressing national challenge, persistent low primary school enrollment and high dropout rates. The core of the problem is a critically insufficient and spatially uneven distribution of public primary school infrastructure. Rural communities bear the consequences of this disparity, facing acute geographical barriers to access. The resultant long travel distances, combined with existing resource constraints, function as a significant deterrent to school attendance. This study aims to conduct a comprehensive assessment of the geospatial distribution and accessibility of public primary schools in Argungu LGA using Geographic Information Systems (GIS) and spatial analysis techniques, following established methodological frameworks for educational accessibility analysis [6, 9]. The findings will generate critical, evidence-based insights into the educational landscape of Argungu. The study will provide actionable data to inform targeted strategies that improve school accessibility, reduce the number of OOSC, and contribute to achieving equitable education for all in the area.

2. Review of Related Literature

2.1. The Spatial Dimension of Educational Access

Research has consistently demonstrated that distance to school is a significant predictor of enrollment and attendance. Proximity to schools significantly influences enrollment rates and broader educational achievements [1]. For example, a study in rural India found that each kilometre of distance to a primary school reduced the probability of attendance by 16 percentage points [10]. Similarly, in sub-Saharan Africa, children living more than 2km from a school are significantly less likely to enrol and more likely to drop out [11].

Geographic Information Systems (GIS) have become an increasingly valuable tool for evaluating school accessibility, enrollment trends, and educational outcomes [10, 12]. Through geospatial analysis, researchers can identify areas with limited access, thereby supporting optimal school placement and efficient resource allocation [13, 14] (Cobb, 2020; Sakti et al., 2021). These tools enable evidence-based policymaking by pinpointing regions where access is constrained [15]. The relationship between geospatial accessibility and metrics such as enrollment and academic performance for educational planning is well-documented [16].

The Nigerian context illustrates these challenges acutely. The Nigerian Education Sector Analysis reports that in many northern states, school density is as low as one school per 50km^2, with some settlements located more than 10km from the nearest school [17]. This spatial inequity compounds existing socioeconomic barriers to education. Recent studies emphasise the need to incorporate geographical factors, such as distance, terrain, and transportation infrastructure into school siting decisions [9, 18].

2.2. Location-Allocation Modelling in Educational Planning

Location-allocation modelling is a powerful GIS-based technique for optimising the placement of facilities to maximise coverage of target populations [19]. Originally developed for urban planning and emergency services, these models have been increasingly applied to educational infrastructure planning in developing countries.

Within Nigeria, researchers have applied these geospatial techniques to examine educational disparities. For example, Aroge, Adewole [20] used GIS to assess school distribution in Ado LGA, Osun State, Nigeria, and found significant disparities in primary school accessibility across the LGA. Similarly, Adeleke and Alabede [21] explored the correlation between out-of-school children and socio-economic factors in northern Nigerian states. Their results identified Kebbi, Sokoto, Zamfara, Yobe, Taraba, and Plateau as OOSC hotspots and revealed spatial variations in the predictors of school non-attendance.

Despite Nigeria's acute educational access challenges, limited research has applied location-allocation modelling to school placement in the country. This study addresses this gap by focusing on Argungu LGA in Kebbi State, a region with persistently high OOSC rates. Collectively, the reviewed studies affirm the importance of geospatial accessibility in public primary education and advocate for informed, evidence-based policies to ensure equitable educational opportunities for all children.

3. Materials and Method

3.1. Study Area

Argungu LGA is located in Kebbi State, northwestern Nigeria, between latitudes 12°35'N and 12°50'N and longitudes 4°25'E and 4°50'E. The LGA covers approximately 1,200 km^2 and had an estimated population of 247,000 [4]. The LGA comprises 11 Wards. Figure 1 shows the location map of Argungu LGA ward boundaries.

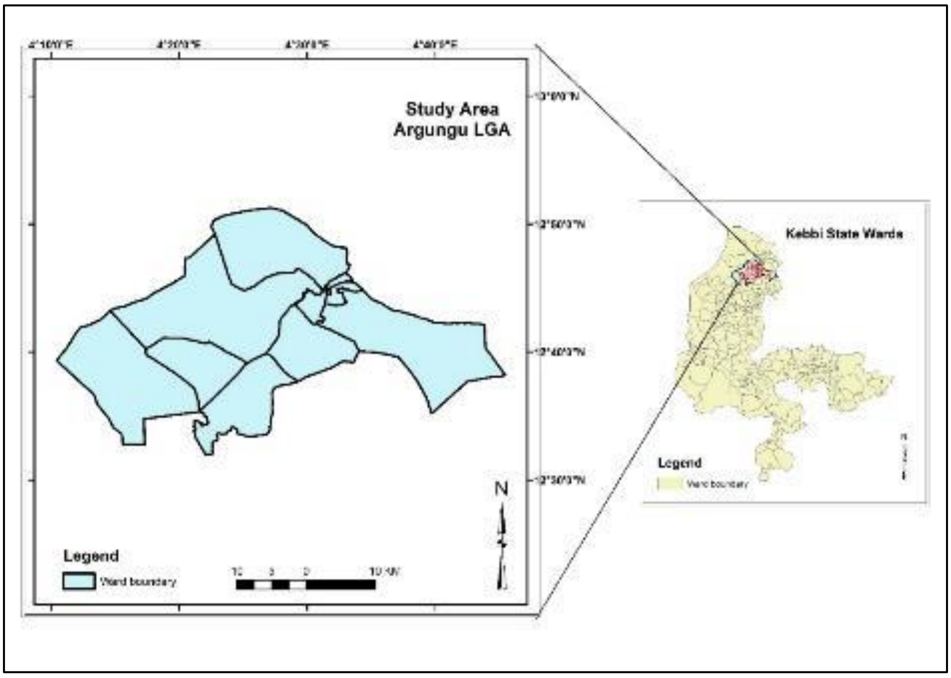

Figure 1 Location map of Argungu LGA ward boundaries

3.2. Data

This study utilised three categories of data: settlement data, school data, and spatial data, all covering Argungu Local Government Area (LGA) in Kebbi State, Nigeria. A comprehensive list of 229 settlements in Argungu LGA was compiled from the National Population Commission's settlement registry and validated through consultation with local education authorities. For each settlement, school children (aged 6–14 years) population estimates were derived from the 2006 census projected to 2024 using a 2.8% annual growth rate. Data on 64 existing schools (public) were obtained from the

Kebbi State Ministry of Education. Base maps and administrative boundaries were obtained from the eHealth Africa data portal (https://hfr.health.gov.ng/facilities).

3.3. Method of Data Analysis

This study employed a cross-sectional spatial analysis design, combining Geographic Information Systems (GIS) with location-allocation optimisation modelling. The data analysis proceeded through six sequential steps to assess current spatial accessibility to public primary schools in Argungu LGA and identify optimal locations for new schools.

3.3.1. Distance Matrix Calculation

A distance matrix was calculated between all settlements and all schools in the R programming environment. We computed Euclidean distances in metres, which were subsequently converted to kilometres for analysis. To assess spatial accessibility, the centroid of each demand location was used to calculate travel distances between school locations and demand areas [22].

3.3.2. Current Coverage Assessment

For each settlement, the distance to the nearest school was calculated. Settlements with a nearest school distance of ≤3km were classified as "covered" based on Nigerian Universal Basic Education (UBE) guidelines [23].

3.3.3. Candidate Site Generation

A grid of 100 candidate locations for new schools was generated across the study area to ensure comprehensive geographic coverage. This approach allows the optimisation algorithm to select from potential sites rather than being restricted to existing settlements [24].

3.3.4. Optimisation Algorithm

A greedy algorithm was implemented to solve the Maximal Covering Location Problem (MCLP). Using the location-allocation function in the R programming environment, the algorithm identifies optimal candidate school locations to serve the demand population according to specified parameters. Specifically, the greedy algorithm iteratively selects the candidate site that maximises the increase in population coverage, continuing until five new schools are selected. This approach is computationally efficient and has been shown to produce near-optimal solutions for facility location problems [25].

3.3.5. Projected Coverage Improvement

After selecting optimal new school locations, coverage statistics were recalculated to include both existing and proposed schools. This final step quantifies the potential reduction in the number of OOSC and the improvement in spatial accessibility resulting from the optimised placement of new schools.

4. Results and Discussion

4.1. Current School Distribution and Coverage

The spatial analysis revealed significant inequities in the distribution of educational facilities across Argungu LGA. Of the 208 settlements, only 177 (85.1%) are within 3km of an existing school, leaving 31 settlements (14.9%) beyond the acceptable walking distance. This coverage rate is substantially below the Universal Basic Education Commission's target of 100% coverage [23].

The concentration of schools in the central zone around Argungu town reflects historical patterns of infrastructure development that prioritise urban areas [26]. This urban bias in educational investment perpetuates rural-urban disparities in educational outcomes, as documented across sub-Saharan Africa [27].

The average distance of 4.2km to the nearest school in Argungu exceeds the 3km threshold considered acceptable by Nigerian education authorities. For comparison, a study in neighbouring Sokoto State found an average distance of 3.8km [27], while research in Osogbo, Osun State, reported 2.9km [28]. The particularly poor access in Argungu may reflect the LGA's rural character and limited road infrastructure. Figure 2 shows the current school coverage in Argungu LGA.

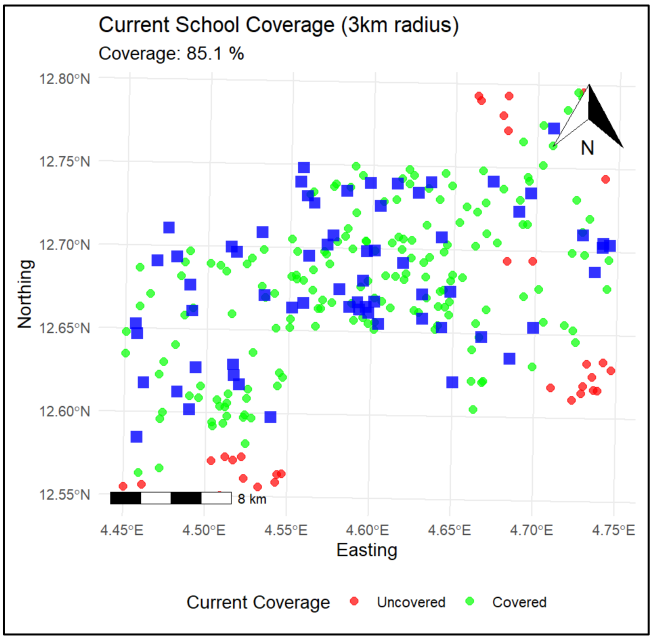

Figure 2 Map of current school coverage in Argungu LGA

4.2. Optimal Locations for New Schools

The location-allocation optimisation identified five priority locations for new schools that maximise additional population coverage. The strategic placement of just five new schools could increase coverage by 24.4 percentage points, reaching an additional 8,450 school-age children. This finding aligns with similar studies in other contexts. In Egypt, [29] achieved a 54.9% increase in coverage, adding 20 new schools, while in Malawi, [30] reported a 40% improvement, adding 15 schools.

If the five new schools were placed arbitrarily (e.g., based on political considerations rather than spatial analysis), the coverage would likely be much lower. A study in China found that unplanned school placement achieved only 30-40%, and an optimisation approach can effectively determine the best possible coverage locations [30].

4.3. Projected Coverage Improvement

The addition of five optimally located schools has increased significantly. The settlement coverage increases from 177 (85.1%) to 95.7%, an improvement of 10.6% percentage points (22 additional settlements gain access within 3km). Figure 3 shows the optimal locations of five new schools.

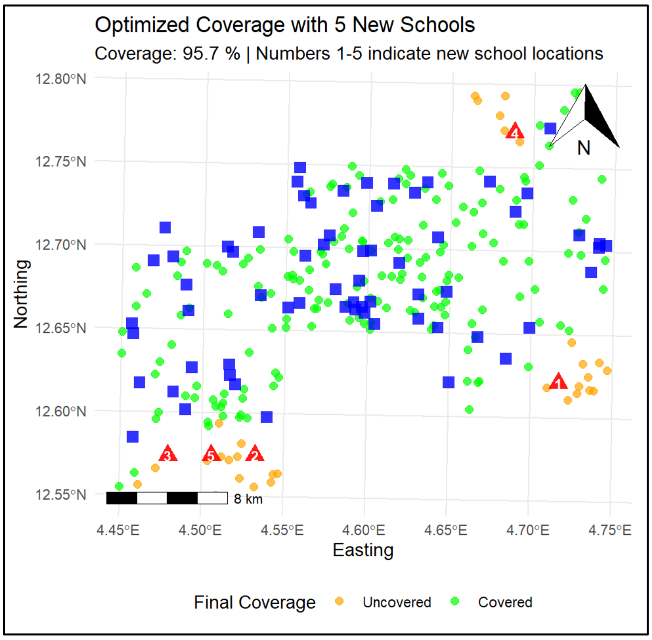

Figure 3 Map of optimised school location in Argungu LGA

The average walking distance also decreases from 4.2km to 1.7km, the maximum distance decreases from 6.6km to 4.6km. This improvement is likely to increase accessibility and decrease the current OOSC population in Argungu LGA. This magnitude of impact is comparable to successful interventions elsewhere. The provision of additional schools in Ethiopia achieved a 35% reduction in OOSC over five years [31].

However, improved spatial access does not automatically translate into enrollment. Other barriers, including socioeconomic factors and traditional norms, must also be addressed [5]. Realistic enrollment rates might be 50-70%, suggesting actual OOSC reduction of 4,200-5,900 children. Figure 4 indicate the distance improvement with addition of five new schools

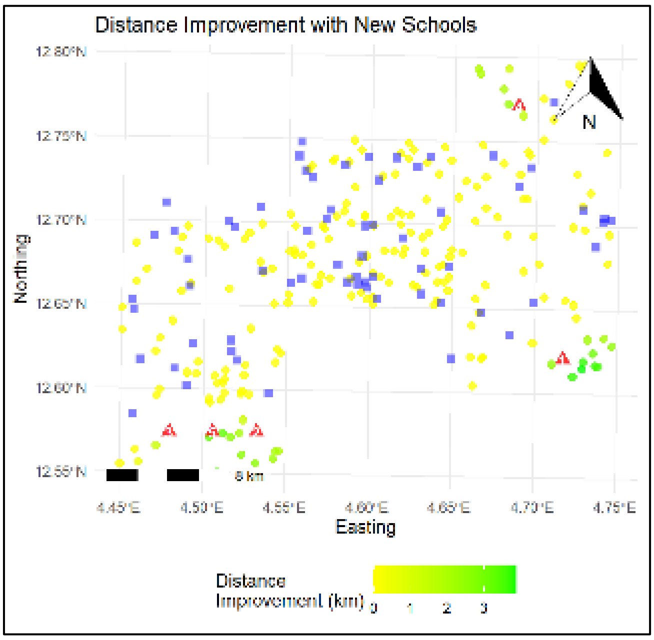

Figure 4 Map of walking distance improvement to school with five new schools

Despite the addition of five new schools, 9 settlements would remain beyond a 3km distance from any school. For these persistently uncovered settlements, conventional school construction may not be cost-effective. Other alternative interventions, such as mobile schools, should be considered.

5. Conclusion

This study assessed the geospatial distribution and accessibility of public primary schools in Argungu LGA, Kebbi State, using GIS-based location-allocation modeling. The findings reveal significant spatial inequity in educational access, with only 85.1% of settlements currently within the acceptable 3km walking distance to a school. Consequently, about 14.9% school-age children remain underserved.

This study underscores the value of evidence-based, geospatial planning for educational infrastructure. By adopting GIS-based decision-making, policymakers and educational planners can target resources more efficiently, reduce the number of out-of-school children, and make meaningful progress toward equitable education for all in Argungu LGA and similar contexts across northern Nigeria.

However, this study only classified settlements within a 3km Euclidean distance; it does not account for terrain conditions, river crossings and security concerns. The location-allocation model assumed that new schools have unlimited capacity to absorb all eligible children. If enrollment exceeds available classrooms or teachers, some children may remain unserved despite proximity. Future studies should move beyond a fixed distance threshold and incorporate terrain, infrastructure, and safety factors into accessibility modelling. We also recommend the inclusion of school capacity and teacher availability into location-allocation models. Finally, future studies should adopt dynamic modelling approaches that account for population growth, migration, and seasonal movements.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors have declared no conflict of interest.

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