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Geospatial mapping of healthcare facility distribution in Makurdi local government area, Benue state

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Abstract

Globally, quality healthcare is a priority and right of the citizenry of any nation. Thus, an excellent Healthcare delivery system is an indispensable part of any robust society. This study seeks to investigate the degree of equity and spatial justice in the distribution of healthcare facilities in the local government area. Geospatial techniques, particularly Geographic Information Systems (GIS), have revolutionized healthcare planning and resource allocation. GIS allows for the visualization, analysis, and interpretation of spatial data, enabling healthcare planners to identify underserved areas, optimize the placement of facilities, and improve accessibility for populations in need. This study, therefore, investigates the spatial distribution of healthcare facilities, their spatial coverage and the proportion of the population served adequately within Makurdi LGA of Benue state. The methodology employed several approaches to unearth relevant information concerning the state of primary healthcare within Makurdi. INEC data for the local government area under consideration was obtained from the INEC office in Makurdi, the state capital and projected to cover the entire population of the area of interest. The LGA current population was estimated. Thereafter, generated population density data in a continuous raster format such that population density values can be obtained for each point within our area of interest. To accomplish this task, inverse distance weighted interpolation analysis was employed. Buffer rings of 1, 2 and 3 Km were generated around the healthcare facilities using analysis tools in ArcGIS and used in acquiring subsets of the population density raster. To determine the degree of clustering, randomness or dispersal of healthcare facilities, the average nearest neighbor analysis was carried out. Spatial intersections and overlays were performed between the buffer zones and the built-up areas of the LGA, facilitating the determination of coverage and distribution of PHC services. Areas falling within the 2km buffer zones of one or more PHCs were identified as having optimal service

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coverage, labeled as "served" or "over-served" areas. Areas that did not fall within any 2km buffer zone were classified as "under-served" areas, indicating a lack of access to PHC facilities within the recommended distance. 11 proposed sites for new PHCs were identified distributed across five wards: Agan (2), Bar (2), Fiidi (3), Modern Market (2), and North Bank I (2). Analysis of Primary Health Care (PHC) coverage and delivery across the Local Government Area (LGA) revealed significant disparities in access to essential primary healthcare services with some areas well-served by existing PHC facilities, while others remain under-served, lacking adequate access to these vital resources.

Keywords: Geographic Information System; Primary Health Care; Spatial Analysis; Health Care Facility Distribution; Buffer Analysis

1. Introduction

Soil is the basis for the growth of terrestrial plants and animals. It is closely related to the material cycle and ecosystem service supply[1]. The ecosystem services provided by soil are crucial for achieving the United Nations' sustainable development goals (SDGs), such as food security guarantee, ecosystem health maintenance, climate change mitigation, and biodiversity conservation [2]. However, in recent decades, soil degradation has intensified because of the changing environment and human activities[3]. Therefore, studies of the environmental capabilities for food production are essential in ensuring food security for the increasing population worldwide. One of the important factors in food production is soil fertility and its measurable parameters. A gradual decline of soil fertility induced by some management practices, especially in intensively cropped areas, is a major cause of decreased yields and food production per capita. Soil properties, in association with environmental factors such as topography, climate and parent materials, plays a significant role in sustainable food production. Among these soil parameters, soil pH has an influential role. Soil pH is one of the most essential and important physicochemical properties for the chemistry and fertility of soils. The pH of the soil has great influence on soil biogeochemical properties[4]. pH is the negative logarithm of the hydrogen ion concentration (more exactly, the activity) or algebraically $pH = -\log10\ [H+]$ or $pH= \log101/[H+]$ [5]. Soil pH is the measure of the hydrogen ion (H^+) concentration in the soil. In other words, it is the degree of acidity or alkalinity of the soil. Studies have shown that soil pH can influence crop yield, soil nutrient, and soil microbial activities to a large extent [6]. Abnormal changes in soil acidity and alkalinity are a major form of soil degradation characterized by the acceleration of nutrient leaching, reduction in nutrient availability, activation of heavy metals, and suppression of microbial activity [6-9].

[10] in his study; factors affecting variation of soil pH in different horizons in hilly regions, reported that climate and topography have influence on soil pH variation. Temperatures mostly affect rock weathering and precipitation affect flow of materials. The authors also noted that soil chemical reactions are affected by climate, the soil from different climates have different soil pH ranges. In arid climate, the soil pH is highly alkaline while soil of humid climate is acidic with low pH values. Changes in climatic conditions influence rainfall leading to increased precipitation which accelerates leaching, causing basic cations to leach from topsoil and making the topsoil more acidic. These leached cations include $Mg2+$, $K+$ and $Na+$. Topography also affects soil pH by affecting the rate of water flow and material transport. Elevation and climate influence local temperature and precipitation, that is, low temperature and abundant rainfall occur at higher altitudes.

[11] reported a relationship between soil pH and soil organic matter in both the top and bottom soil profile respectively. The soil organic matter in the topsoil was found to be below the desired values while the soil organic carbon showed a spatial variability in both top and sub-surface layers. Soil pH ranges from acidic to almost neutral in topsoil but tends to increase with an increase in depth of soil. Soil carbon and nitrogen correlate negatively with soil pH meaning low pH (acidic soils) favors accumulation of organic matter[12]. Furthermore, bush burning and the irrigation systems employed are found to contribute to pH variability [11].

Variability in soil pH is also influenced by several other factors such as soil physicochemical properties, atmospheric deposition, fertilizer application, and land use change (LUC) [13]. LUC refers to changes in surface cover and soil use, which can alter the influence of natural conditions (such as topographical and meteorological factors) and human activities (such as human disturbance and nitrogen application) on soil properties and environment [14]. Such alterations may affect soil pH status and variability patterns, leading to challenges for soil management [15].

1.1. Study area

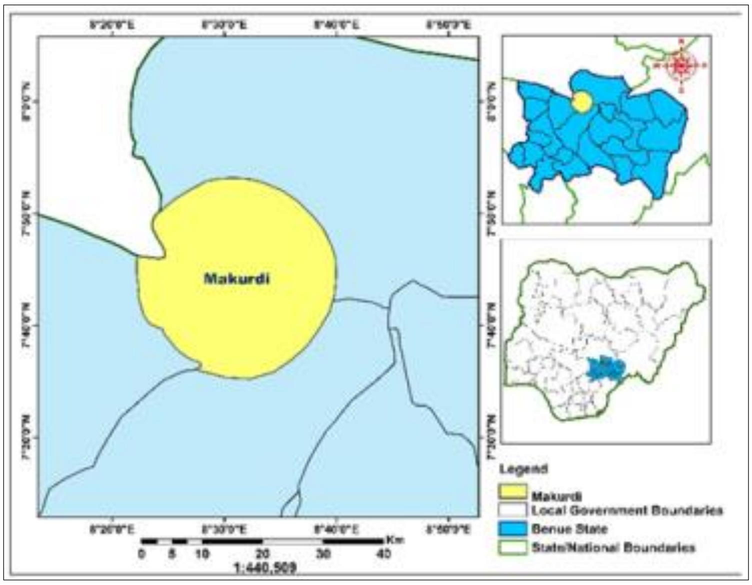

Figure 1 Study Area Showing Makurdi LGA

Makurdi, the administrative centre and capital of Benue State, North Central Nigeria is located between Longitudes 8°23′8.34′′and 8°42′56.183′′E, and Latitudes 7°33′2.999′′and 7°51′2.858′′N. The city has a rich agricultural heritage, earning Benue the nickname "The Food Basket of the Nation" due to its large-scale production of crops like yam, rice, maize, and soybeans. Makurdi is home to several important institutions, including the Federal University of Agriculture and the Nigerian Air Force Base. The city also has a railway station and a major bridge linking the northern and southern parts of Nigeria. The city experiences a tropical climate with a distinct wet and dry season, which supports its thriving agricultural economy. Despite facing challenges such as seasonal flooding and infrastructural strain, Makurdi continues to grow as a regional center for trade, education, and public administration in the Middle Belt of Nigeria.

The ethnic and socio-cultural composition of the population is diverse (being a cosmopolitan urban centre), comprising the Tiv, Idoma, Igede, Etulo, Jukun, and Hausa, Abakwa as well as other ethnic nationalities. Like any other cities in Nigeria, there are 3 levels of health care delivery in Makurdi: these are the tertiary, secondary and primary levels. The second largest River in Nigeria (River Benue) is by far the most prominent geographical feature in Benue State and, also, Makurdi LGA. The incessant conflicts in the hinterlands have led to the massive proliferation of internally displaced persons (IDPs) which had further exacerbate pressure on the available healthcare facilities.

2. Methods and Materials

The materials and equipment employed in this study include hardware such as Handheld GPS (Garmin GPSMap 78s), Inspiron 27 All-in-One Workstations, Field notebooks, External hard drives and USB drives. Software employed consists of ArcGIS 10.8, QGIS, Google Earth Pro, Microsoft Excel and Microsoft Word. Data ranged from primary data, consisting mainly of GPS readings recorded at the location of facilities in each local government area to attribute data were gathered in-situ, helping in ascertaining the differentiation of approved facilities and those that are not approved by the state ministry of health. This information includes (but is not limited to) the presence of solar power, powered boreholes and several other amenities in the approved facilities. Some of the approved facilities were even noticeably bigger and housed more staff and patients, and secondary data including data sourced from the Health Management Information Systems of the state ministry of health, non-approved facilities identified from sources such as Google Earth Pro and their corresponding spatial coordinates as well as necessary attribute information. Other secondary data include digitized shapefiles of relevant land surface features like settlements, roads, political boundaries and such like. Also, the population statistics for 2006 were obtained from the National Population Commission (NPC) [9] and those for 2023 voters, registration exercise conducted by the Independent national Electoral Commission (INEC). These were then used as baseline data to generate projected updates that equate current population data.

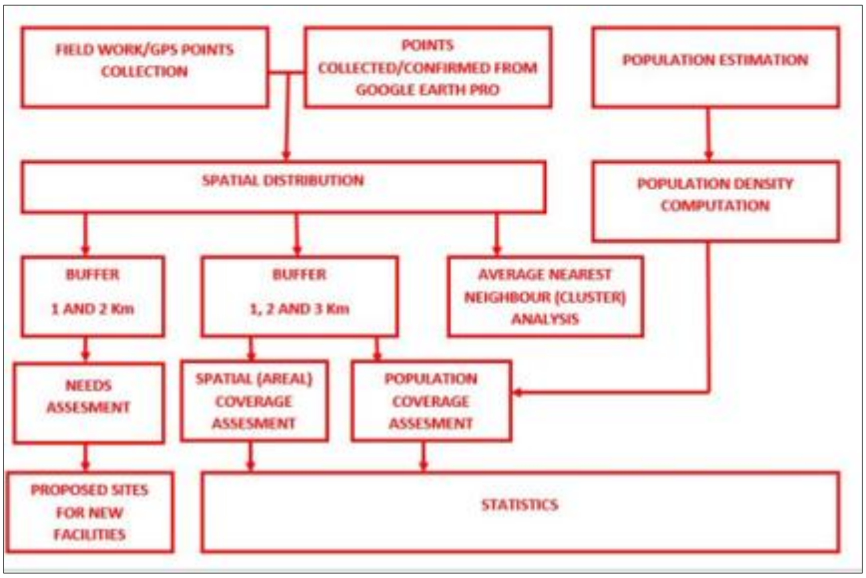

Figure 2 Workflow Chart

This study employed several different approaches to unearth relevant information concerning the state of primary healthcare within Makurdi. This multidimensional approach is meant to maximize sparse data such that as many as possible cogent findings are reached and necessary conclusions and attendant recommendations made.

In Nigeria, there is a unique issue with getting accurate and current population estimates. This arises from the fact that the last national census was held as far back as 2006 and subsequent national databases which contain a population component, such as the national identity management commission database, bank verification database and independent electoral commission voters' register and the likes, each have certain limitations which make them inadequate, on their own, and rather hard to manipulate for tangible data to be extracted from them. But among these, the most current happens to be the voters; register which was updated by INEC in 2023 and, for which, credible data for use in its upgrade and projection is readily available.

Thus, the INEC data for the local government area under consideration was obtained from the INEC office in Makurdi and projected to cover the entire population of the area of interest. This data, the voters' register, contains only information about registered voters. Therefore, it lacks information about those younger than 18 years old, as at the time of the update of the register, and those who, despite being eligible to vote, are not captured on the register. For the portion of the population below voting age, data obtained from [10] showed that 43% of the Nigerian population are under the age of 14 years while those between 14 and 18 years old were estimated to be about 4.5%. Unregistered voters (people who are eligible to vote, by age, but are not registered) are reported to make up a further 1.5% of the general population. This leads to the conclusion that an estimated 49% of Nigerians were not captured in the voters' register as at the close of the registration update exercise in 2023. Armed with this data, necessary projections could be made using the INEC voters' register population data for polling units in each of the wards of Makurdi. This was calculated thus:

$$P_c = P_i \times 100/61 \text{ ---------------- Equation (1)}$$

Where; P_c = Total Population

P_i = INEC Voters' Register Population

$$K_1 = P_c/D_{IDW} \times A \text{ ---------------- Equation (2)}$$

Where; P_c = Total Population

A = Area

D_{IDW} = Sum of IDW 'Population Density' Estimate

2.1. Population Density Computations

After obtaining a current estimate of the population in the local government, there was a need to generate population density data in a continuous raster format such that population density values can be obtained for each point within our area of interest. To accomplish this task, inverse distance weighted interpolation analysis was employed. This generated a raster which took into cognizance distance from points that contained the population attributes so that the effect of the population dwindled with distance, creating a realistic representation of population spread over these areas. Furthermore, each population point from the input data had an input towards how it covered spaces around it from its nearest neighboring input points. As a result, the raster was able to model what population density characteristics should look like on the ground realistically. The raster thus generated was then reprojected to the metric system (Universal Transverse Mercator, UTM) for easier spatial calculations, resampled to 10m resolution to ease further conversion of information from the raster data to numeric values and reclassified into 25 classes for ease of handling and extraction of useful data from the raster.

Of course, producing the interpolated raster was only a step towards unearthing the total populations covered by the healthcare facilities under study, several other steps needed to be carried out to generate “edible” information. In the course of interpolation, the population data was processed through a summation sequence which altered its character in certain ways which a linear mathematical operation would not have. Consequently, extracting meaningful and accurate output from the resultant raster dataset entailed some calculations which generated constants of proportionality K_1 and K_2 that can be applied to retrieving population numbers attached to each pixel (see Equations 2 and 3). While K_1 is applied to regularizing the population density, K_2 is applied to retrieving exact population values from IDW generated data. The intent is to make the values generated equivalent to values obtainable in reality and which, when used, give an insight into the population situation on the ground

$$P_n = A_n \times D_n \times K_2 \text{ --------------- Equation (3)}$$

Where; P_n = Section of Population covered by the n^{th} segment of the population density raster.

A_n = Area, Km^2, covered by the n^{th} segment of population density raster

(A_n = Raster count x 100/1000000 for pixel resolution of 10m x 10m)

D_n = Adjusted Population density value for the n^{th} segment of the population density raster.

K_2 = constant of proportionality for population conversions (like K_1, this constant is specific to each data set; in this case, each local government)

n = Number of segments the population density raster is reclassified into i.e.; 1 to 25

Buffer rings of 1, 2 and 3 Km were generated around the healthcare facilities using analysis tools in ArcGIS and used in acquiring subsets of the population density raster covering corresponding 0 – 1, 1 – 2 and 2 – 3 Km distances. The population covered by these areas was then calculated from the count of pixels recorded, the spatial resolution of the raster, the generated IDW values (which are a pseudo-population-density value) and the constants of proportionality (which are meant to rectify the IDW values to supply actual population density and population values). The collation of these results gives population figures for each of the buffer zones and, thus, the population covered by healthcare facilities within those distances. Subsequently, other statistics are generated from these results and reported as necessity requires.

2.2. Average Nearest Neighbour

To determine the degree of clustering, randomness or dispersal of healthcare facilities, average nearest neighbor analysis was carried out. All results generated employed Euclidean distance as the distance method. The analysis generates statistical measures of randomness such as z-scores and p-values along with expected mean distance and observed mean distance. Altogether, these results indicate the degree of clustering in the input data and can be used as an indicator of areas where more justiciable distribution of facilities is required.

2.3. Needs Assessment and Proposed Facility Sites

The analysis of Primary Health Care (PHC) coverage and delivery across Makurdi employed a comprehensive geospatial approach. First, a comprehensive list of existing primary healthcare centers (PHCs) within the LGA, including their names and locations, was obtained. Simultaneously, spatial data in the form of shapefiles or geodatabases, encompassing the built-up areas and administrative boundaries of the LGA, was acquired.

Leveraging Geographic Information System (GIS) software, such as ArcGIS and QGIS, the addresses or coordinates of the existing PHCs were geocoded and mapped onto the spatial data of the respective LGAs, creating a layer of point features representing the PHC locations. Subsequently, a buffer zone of 2 kilometers was created around each geocoded PHC location, adhering to the World Health Organization (WHO) standard for optimal access to primary healthcare services. These buffer zones represented the service areas or catchment zones of each PHC, delineating the areas within reasonable proximity to the facility. Spatial intersections and overlays were performed between the buffer zones and the built-up areas of each LGA, facilitating the determination of coverage and distribution of PHC services. Areas falling within the 2km buffer zones of one or more PHCs were identified as having optimal service coverage, labeled as "served" or "over-served" areas. Conversely, areas that did not fall within any 2km buffer zone were classified as "under-served" areas, indicating a lack of access to PHC facilities within the recommended distance.

Quantitative measures were employed to calculate the percentages of served, over-served, and under-served areas within the built-up areas of the LGA. Thematic maps and charts were created to visualize the distribution of PHCs, their service areas, and the areas with varying levels of service coverage, providing a comprehensive spatial representation of the findings. Based on the identified under-served areas, potential locations for new PHCs were proposed to optimize coverage and ensure equitable access to primary healthcare services. These proposed sites were determined through spatial analysis, taking into account factors such as the distribution of existing PHCs, population density, accessibility, and existing healthcare infrastructure.

3. Results

3.1. Population Coverage and Spatial Distribution of Healthcare Facilities

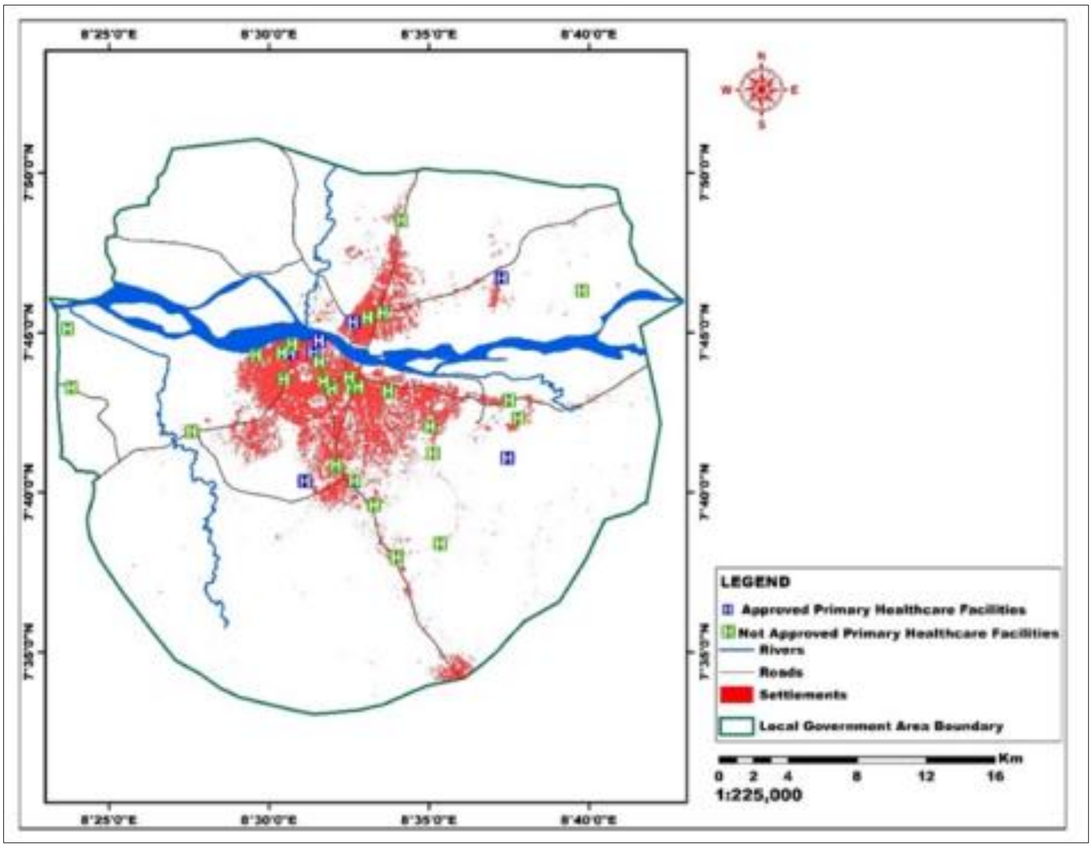

Figure 3 Makurdi Showing the Distribution of Primary Healthcare Facilities

This portion of the study focused on analysis of the distribution of approved facilities and of those not approved, their population and spatial coverages along with their degree of clustering within Makurdi. There are 12 approved facilities located within Makurdi local government area and 29 that are not approved. The approved facilities display are equipped solar panels for electrical energy, boreholes with attendant power installations to pump water for the community around these facilities and adequate space for attending to both outpatients and those on brief admissions. Thus, these facilities double as community centres and also serve as places where potable water can be accessed readily. The distribution of both sets of facilities can be seen in Figure 3.

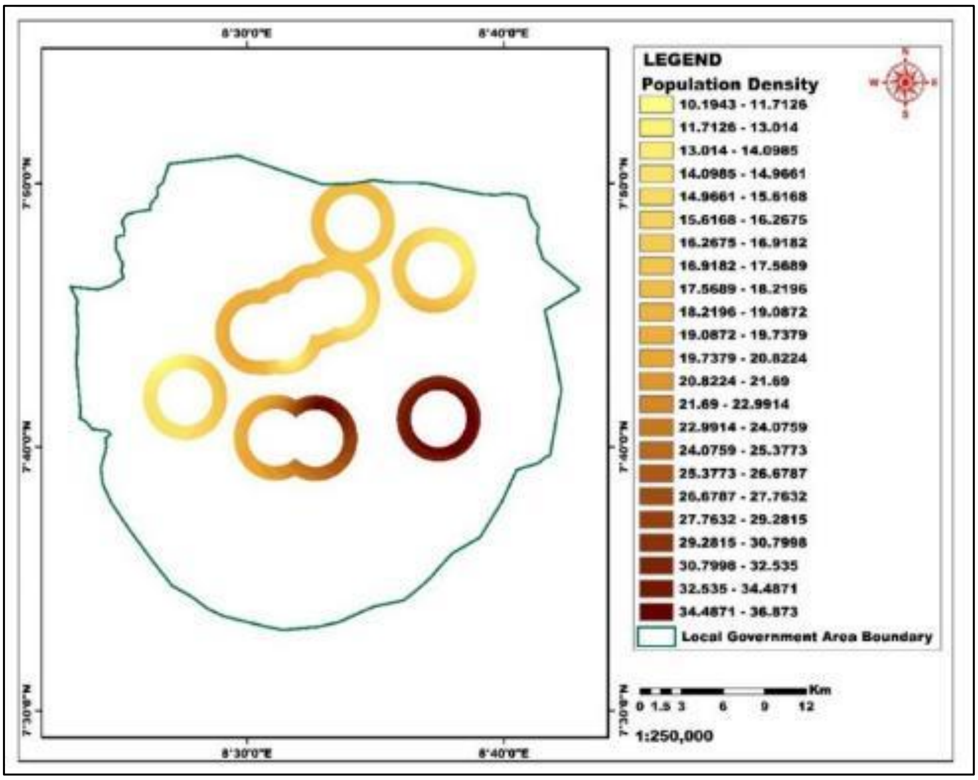

Figure 4 Areal and Population Coverage of Approved PHC within 2 to 3 Km Radius in Makurdi

In the 2 Km to 3 Km distance (Figure), 60815 to 63934 people representing between 12.2 and 12.8% of the population are covered. Thus, the total population covered within a 3 Km radius of any approved facility is upwards of 122388 to 128835 people at 24.5 and 25.8% respectively. This means that proximal access to approved facilities plateaus at about a quarter of the population of the local government area. This leaves almost 75% of the population unserved by these facilities. It bears mention, though, that this model is based on a population density spread that covers the whole surface of the local government without eliminating areas that are unpopulated. On the other hand, the IDW analysis used takes into account distance of each area in the generated raster from each population point or centre such that areas further and further away from population have progressively less population density and, therefore account for less populationprimary healthcare facilities located in the local government area

Table 1 Population Statistics for Approved Primary Healthcare Facilities in Makurdi

Distance	Minimum Population	Maximum population	Minimum Popuation %	Maximum Population %
0 – 1 Km	18360	19328	3.7	3.9
1 – 2 Km	43215	45573	8.6	9.1
2 – 3 Km	60813	63934	12.2	12.8
Total	**122388**	**128835**	**24.5**	**25.8**

3.2. Average Nearest Neighbour Analyses

Given the z-score of 2.72001524887 for approved primary healthcare facility data in Makurdi local government area, there is a less than 1% likelihood that this dispersed pattern could be the result of random chance. The observed mean distance (3303.5603m) about a third more than the expected mean distance (2342.2194m) indicative of issues of spatial accessibility. The distribution has a nearest neighbour ratio of 1.41044 and p-value 0.006528.

Table 2 Average Nearest Neighbour Statistics for Approved Primary Healthcare Facilities in Makurdi

Observed Mean Distance:	**3303.5603 Meters**
Expected Mean Distance:	2342.2194 Meters
Nearest Neighbour Ratio:	1.410440
z-score:	2.720015
p-value:	0.006528

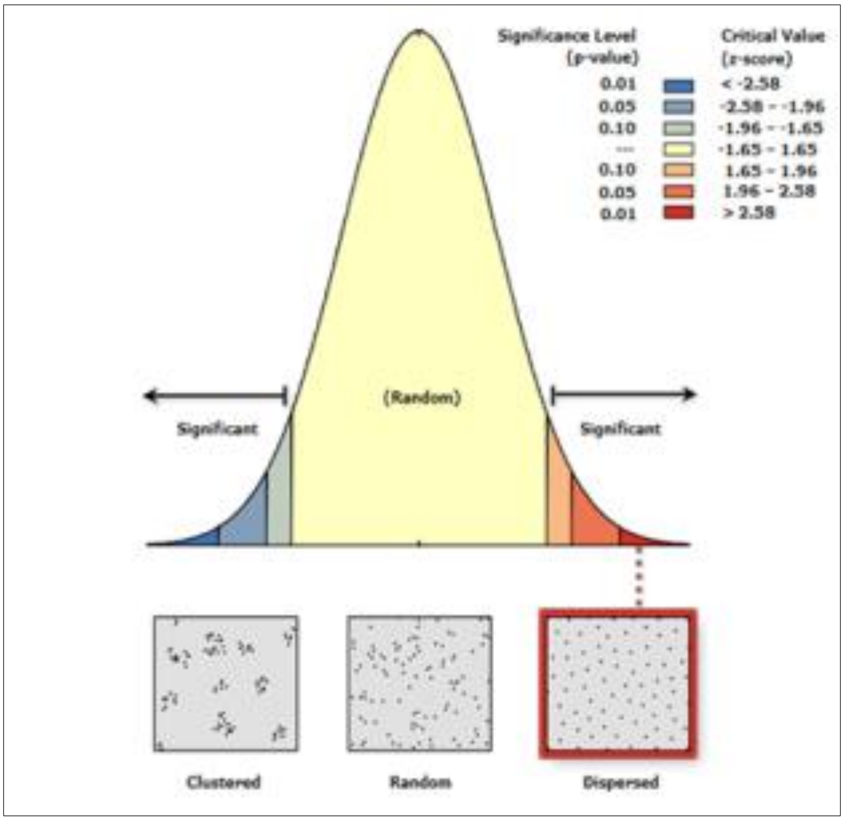

Figure 5 Average Nearest Neighbour Analysis of Approved Facilities in Makurdi

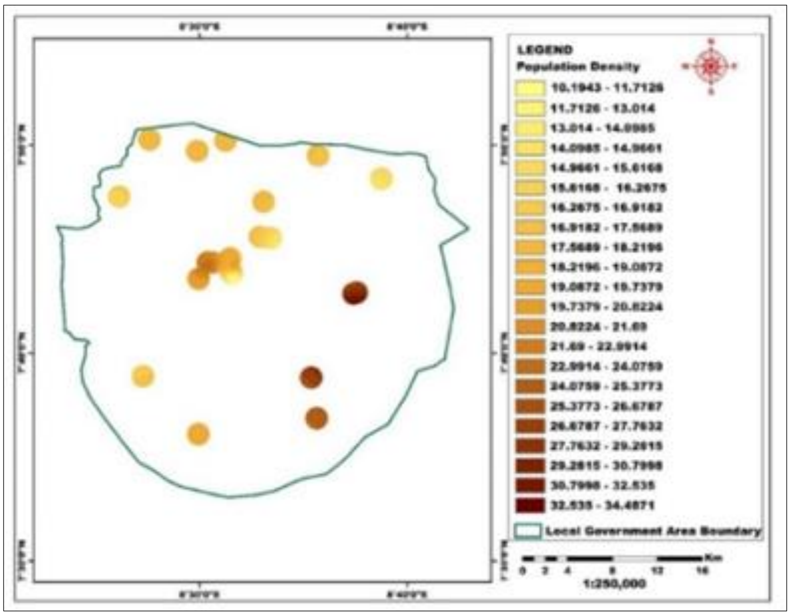

Figure 6 Map Showing Areal and Population Coverage of Not Approved PHC within 0 to 1 Km Radius in Makurdi

Regarding facilities that are not approved, the total covered population rises to between 179441 and 187619 (35.9% to 37.5%). This is distributed such that 28171 to 29442 people (5.6% to 5.9% of the population) reside less than or equal to 1 Km from a facilility, 66107 to 69088 (13.2% to 13.8%) are located within the 1 Km and 2 Km distances while 85162 to 89089 (17% to 17.8%) are domiciled within the 2 Km and 3 Km distances from at least one primary healthcare facility. These facilities, therefore, provide proximal access to healthcare for over a third of the population of Makurdi local government. Futhermore, within the WHO recommended 2 Km distance, 18.8% to 19.7% of the population have access to healthcare.

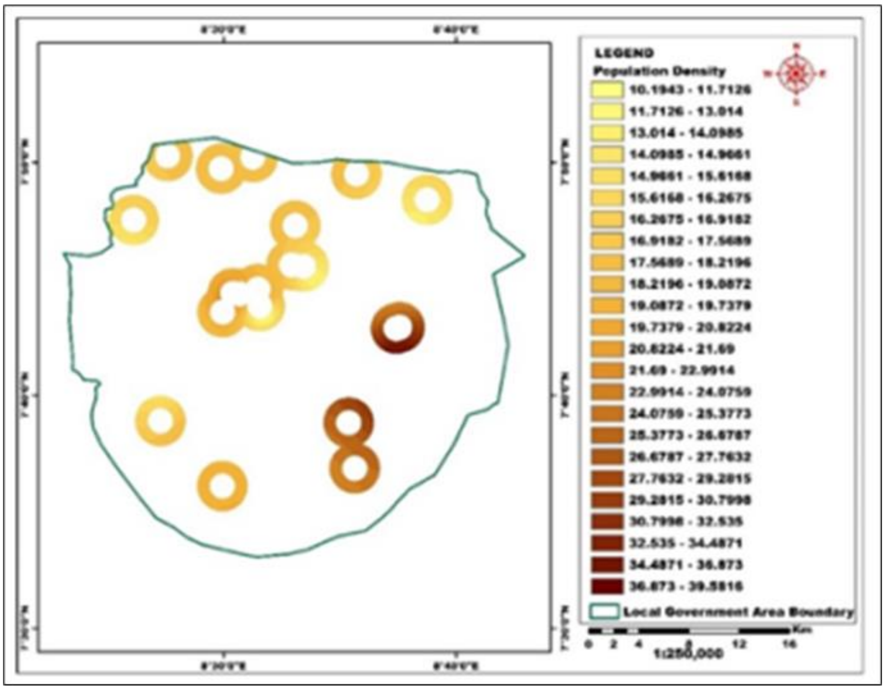

Figure 7 Map Showing Areal and Population Coverage of Not Approved PHC within 1 to 2 Km Radius in Makurdi

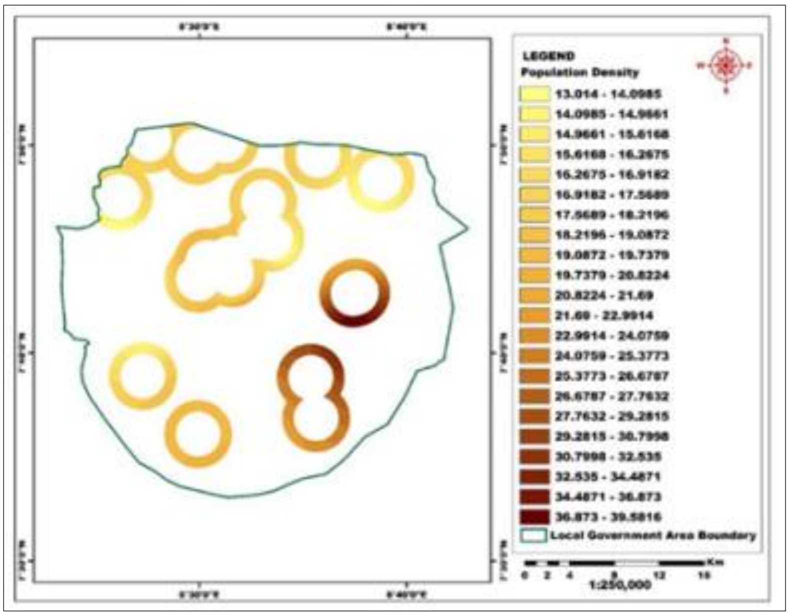

Figure 8 Map Showing Areal and Population Coverage of Not Approved PHC within 2 to 3 Km Radius in Makurdi

Table 3 Population Statistics for Not Approved Primary Healthcare Facilities in Makurdi

Distance	Minimum Population	Maximum population	Minimum Popuation %	Maximum Population %
0 – 1 Km	28171	29442	5.6	5.9
1 – 2 Km	66107	69088	13.2	13.8
2 – 3 Km	85162	89089	17.0	17.8
Total	**179441**	**187619**	**35.9**	**37.5**

The z-score of -1.46912155862 for facilities that are not approved within Makurdi indicates that the pattern does not appear to be significantly different than random.

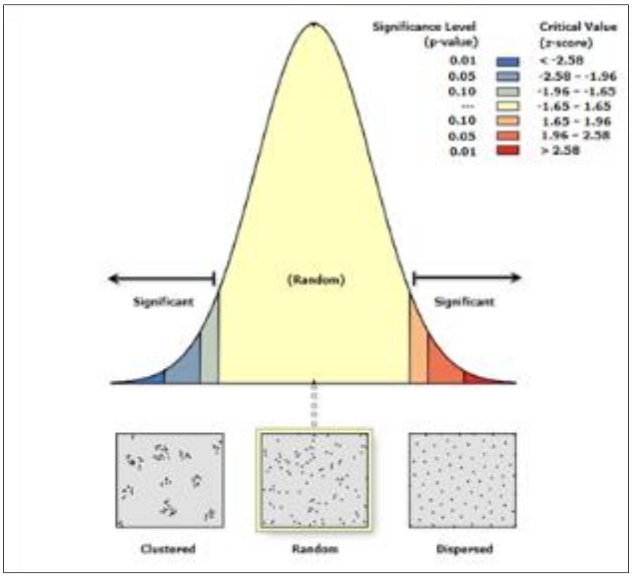

Figure 9 Average Nearest Neighbour Analysis of Not Approved Facilities in Makurdi.

Table 4 Average Nearest Neighbour Statistics for Not Approved Primary Healthcare Facilities in Makurdi

Observed Mean Distance:	**1728.5675 Meters**
Expected Mean Distance:	2016.0637 Meters
Nearest Neighbour Ratio:	0.857397
z-score:	-1.469122
p-value:	0.141800

Table 5 Areal Statistics for Primary Healthcare Facilities in Makurdi

DISTANCE (Km)	**AREA KM² (APPROVED)**	**% TOTAL AREA (APPROVED)**	**AREA KM² (NOT APPROVED)**	**% TOTAL AREA (NOT APPROVED)**
0 – 1	33	3.7	55	6.2
1 – 2	77.9	8.7	128.8	14.4
2 – 3	112.3	12.6	163.4	18.3
Total	223.2	25	347.2	38.9

The total area covered by approved facilities in Makurdi is 223.2 Km2. This translates to 25% of the total area of the local government and is comprised of 3.7% (33 Km2) within a 1 Km radius, 8.7% (77.9 Km2) between 1 and 2 Km from the facilities and 12.6% (112.3 Km2) which falls between 2 and 3 Km. This, by inference, means that 75% of Makurdi local government's area is not covered by any approved facility. Furthermore, less than half of this area (110.9 Km2 of 223.3 Km2) is covered by the WHO-standard 2 Km buffer. Thus, accessibility to these facilities is relatively restricted. Necessary consideration, though, must given to the fact that the local government has the highest population density in the state and small areas contain relatively high populations. Despite this, the area covered by the approved facilities is still quite small.

For facilities that are not approved, the areal coverage is slightly better with a total area of 347.9 Km2 accounting for 38.9% of the total area of the local government. Of this area, 6.2% (55 Km2) is located between 0 to 1 Km, 14.4% (128.8 Km2) lies between 1 and 2 Km and 18.3% (163.4 Km2) between 2 and 3 Km of the facilities. The percentage area of the 2 Km buffer is 20.6%, comparing favourably with the total percentage coverage of the approved facilities (25%), and rises to 38.9% at the 3 km radius mark (an increase of 13.9% over the approved facilities).

3.3. Needs Assessment, Coverage Optimization and Proposed Interventions

Employing geospatial analysis techniques, existing PHCs were mapped, and their service areas were assessed based on the World Health Organization's recommended 2km buffer zone for optimal access. The results revealed disparities, with some areas being over-served while others lacked adequate PHC coverage. Proposed interventions, such as establishing new PHCs in under-served areas, are explored to optimize coverage and address identified disparities. This comprehensive assessment provides valuable insights and evidence-based recommendations to guide resource allocation and enhance primary healthcare delivery in Makurdi.

3.4. Optimizing Primary Healthcare Coverage: Spatial Analysis and Proposed Interventions in Makurdi LGA

The analysis of Primary Health Care (PHC) delivery in Makurdi LGA reveals several key findings. According to Table 6, there are currently 95 existing primary healthcare centers distributed across various wards in the LGA. However, the distribution of these facilities is uneven, with some wards having a higher concentration of PHCs than others.

Table 6 Breakdown of Existing Primary Healthcare Centers by Ward in Makurdi LGA

Wards	Total
Agan	2
Ankpa/Wadata	7
Bar	24
Central/South Mission	5
Clerk/Market	20
Fiidi	18
Mbalagh	4
Modern Market	1
North Bank I	8
North Bank II	3
Wailomayo	3
Grand Total	95

Table 7 provides a breakdown of PHC service delivery within the built-up areas and wards of Makurdi LGA. It shows that 68.78% of the built-up area is over-served, meaning it has an excessive number of PHCs, while 12.56% is under-served, lacking sufficient PHC coverage. This imbalance in service delivery highlights the need for a more equitable distribution of PHC facilities across the LGA.

Table 7 Distribution of PHC Service Coverage across Built-up Areas and Wards in Makurdi LGA

Wards	Over Served Area	Served Area	Under Served Area	Grand Total
Agan	0.62	0.59	2.83	4.04
Ankpa/Wadata	2.76	0.00	0.00	2.76
Bar	19.14	2.40	2.08	23.63
Central/South Mission	2.48	0.00	0.00	2.48
Clerk/Market	5.18	0.00	0.00	5.18
Fiidi	17.92	7.12	2.96	28.00
Mbalagh	0.96	0.96	0.21	2.13
Modern Market	2.42	2.74	3.21	8.37
North Bank I	7.90	3.89	1.09	12.88
North Bank II	3.13	0.00	0.00	3.13
Wailomayo	6.27	0.96	0.17	7.40
Grand Total	68.78	18.66	12.56	100.00

To address the issue of under-served areas and optimize PHC coverage, a buffer of 2km was created around all existing PHCs to determine their service coverage. Based on this analysis, 11 proposed sites for new PHCs were identified, as shown in Table 8. The proposed sites are distributed across five wards: Agan, Bar, Fiidi, Modern Market, and North Bank I.

Table 8 Proposed Locations for New Primary Healthcare Centers in Makurdi LGA

Wards	Total
Agan	2
Bar	2
Fiidi	3
Modern Market	2
North Bank I	2
Grand Total	11

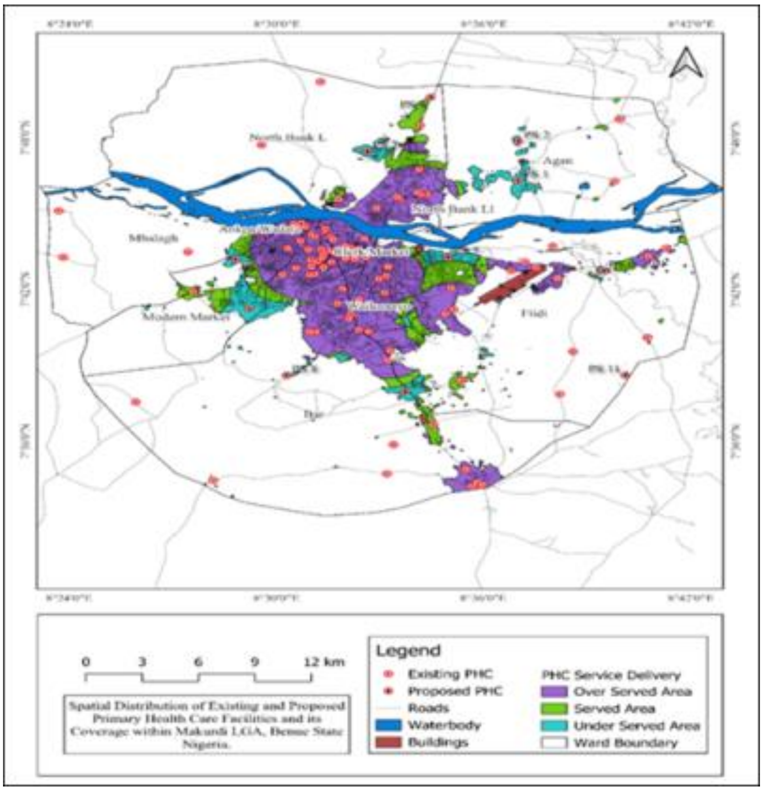

Figure 10 Spatial Distribution of Existing and Proposed Primary Healthcare Centers in Makurdi LGA

4. Discussion

Overall, the analysis highlights the need for a more balanced distribution of PHC facilities within Makurdi LGA. While some areas are well-served, others lack adequate access to primary healthcare services. The proposed 11 new PHC sites aim to address this issue by providing coverage to under-served areas, ultimately improving access to essential healthcare services for the entire population of the LGA.

Regarding under-served areas, Makurdi LGA has 12.56% indicating a greater need for additional PHC facilities to improve coverage in those areas. Consequently, Makurdi has need of 11 new PHCs to address the under-served areas. The spatial analysis and creation of buffers around existing PHCs played a crucial role in identifying the specific wards and areas that required additional PHC facilities. This data-driven approach ensured that the proposed interventions were targeted and based on empirical evidence rather than assumptions.

Overall, the assessment revealed that the LGA faced challenges in ensuring equitable access to primary healthcare services. Addressing these disparities through the establishment of new PHCs in under-served areas, coupled with optimal resource allocation and management, can contribute to achieving universal health coverage and improving public health outcomes across Makurdi

5. Conclusion

The comprehensive geospatial analysis of Primary Health Care (PHC) coverage and delivery across Makurdi Local Government Area revealed significant disparities in access to essential primary healthcare services. While some areas within the LGA are well-served by existing PHC facilities, others remain critically under-served, lacking adequate access to these vital resources.

The study's findings demonstrate that only 12.3% to 13% of Makurdi's population resides within the WHO-recommended 2km distance of approved primary healthcare facilities, leaving approximately 75% of the population without optimal access to quality healthcare services. This spatial inequality is further compounded by the dispersed pattern of approved facilities (z-score: 2.72), indicating suboptimal distribution that fails to maximize population coverage. The analysis revealed that 68.78% of built-up areas are over-served while 12.56% remain under-served, highlighting inefficient resource allocation.

The identification of 11 strategically located sites for new PHCs across five wards (Agan, Bar, Fiidi, Modern Market, and North Bank I) provides a data-driven roadmap for addressing these disparities. Implementation of these recommendations, coupled with optimization of existing facility operations and improved resource allocation, is crucial for achieving universal health coverage and improving public health outcomes in Makurdi. This research underscores the critical importance of evidence-based spatial planning in healthcare delivery systems to ensure equitable access for all communities.

Compliance with ethical standards

Disclosure of conflict of interest

The authors of the paper " Geospatial Mapping of Healthcare Facility Distribution In Makurdi Local Government Area, Benue State" declare that they have no financial or non-financial conflicts of interest that could have influenced the research, analysis, or interpretation of the findings presented in this paper.
Author Contributions:

- Dr. Omomoh Emmanuel contributed to the conceptualization of the study and interpretation of results.
- Dr. Nannim Sunday coordinated the fieldwork and data collection manuscript editing.
- Dr. Rogers Rengje D. Gujahar contributed data analysis and manuscript writing.
- Mr. Mairiga Boyi contributed to the analysis of soil samples and laboratory work.
- Mr. Gyang Davou Yusuf assisted in the fieldwork and data collection.
- Mr. Moses Omitunde Omirinde provided expertise in geospatial analysis and contributed to the interpretation of geospatial data.
- Mr. Ponsah Emmanuel Gwamzhi contributed to the spatial analysis and mapping of PHCs.
- Mrs. Gloria U. M. Mashat assisted in fieldwork and data collection

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Statement of informed consent

Informed consent was obtained from all the Chairman of the LGA wherein the study was tailored

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