Healthcare Facilities Optimization in Phase 1 (Kogi and Nasarawa States) of the North-Central Geo-Political Zone of Nigeria Using Geospatial Techniques

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ABSTRACT

This study examines the healthcare landscape in Nasarawa and Kogi States, Nigeria, focusing on the distribution and functionality of healthcare facilities. It highlights challenges in the healthcare sector, including inadequate infrastructure and resources, which are prevalent in many developing countries. Nasarawa State has 1,170 healthcare facilities, with 933 functional and 237 nonfunctional. The majority are Primary Health Centers (PHCs), with 792 in total. Other facilities include maternity homes, general hospitals, and specialized clinics. Most facilities are state-owned, with limited local and federal government representation. 86.2% of built-up areas are within the recommended 5 km distance from state healthcare facilities. However, 13.8% are not covered, indicating gaps in healthcare access. Kogi State has 1,555 healthcare facilities, with 1,143 classified as functional, representing 73.5%. PHCs dominate (84.76%), with other types like maternity homes and general hospitals present but in smaller numbers. 89.96% of facilities are open to the public, with most built-up areas (98.5%) within 5 km of a facility. Despite the high functionality rate, some facilities have unclear statuses, highlighting a need for better data management and monitoring. While Nasarawa has a robust primary healthcare focus, the high number of nonfunctional facilities raises concerns about operational efficiency and resource allocation. Disparities in access, particularly in underserved areas, necessitate improvements in infrastructure and service delivery. Kogi's healthcare system shows a strong commitment to primary care, with nearly all areas within the recommended distance from facilities. However, the presence of nonfunctional and unknown facilities indicates a need for better monitoring and addressing uncovered regions. Strategic investments in infrastructure and workforce development are recommended to enhance healthcare delivery and improve health outcomes. Both states exhibit strengths and weaknesses in their healthcare systems, emphasizing the need for targeted interventions, better resource allocation, and collaborative efforts to improve healthcare access and quality.

Keywords: Healthcare Facilities; Distribution; Optimization; Functionality

INTRODUCTION

The optimization of healthcare facilities plays a vital role in ensuring equitable access to quality healthcare services. North Central Geo-Political Zone (NCGPZ), situated in central Nigeria, faces multifaceted challenges in its healthcare sector, primarily stemming from an uneven distribution of healthcare facilities. This issue contributes to stark disparities in healthcare access across various regions within the state. Furthermore, inadequate coverage of healthcare facilities in remote or underserved areas exacerbates the problem, leading to significant gaps in healthcare provision. Addressing these challenges is crucial to ensure equitable access to quality healthcare services for all residents of NCGPZ.

Uneven Distribution of Healthcare Facilities: The uneven distribution of healthcare facilities across NCGPZ generally, is a critical issue that perpetuates disparities in healthcare access. Urban areas tend to have a higher

concentration of healthcare facilities, while rural and remote regions suffer from a scarcity of such amenities. As a result, residents in remote areas face significant challenges in accessing essential healthcare services, leading to poorer health outcomes and exacerbating existing health inequalities.

Inadequate Coverage in Remote or Underserved Areas: Remote or underserved areas within NCGPZ often lack adequate coverage of healthcare facilities, further exacerbating disparities in healthcare access. These regions are characterized by limited infrastructure, geographical barriers, and a lack of healthcare professionals, making it challenging to establish and maintain healthcare facilities. Consequently, residents in these areas face significant barriers to accessing timely and quality healthcare services, resulting in increased morbidity and mortality rates.

Limited Availability of Data: A significant barrier to addressing the uneven distribution and inadequate coverage of healthcare facilities is the limited availability of comprehensive data for accurate analysis and decision-making. Without reliable data on population demographics, health needs, and existing healthcare infrastructure, policymakers and healthcare administrators struggle to effectively plan and optimize the distribution of healthcare facilities. This lack of data-driven decision-making hampers efforts to address disparities in healthcare access and allocate resources efficiently.

Lack of a Systematic Approach: The absence of a systematic approach to identify areas with high healthcare demand and prioritize resource allocation further compounds the challenges in NCGPZ States' healthcare sector. Without a standardized methodology for assessing healthcare needs and allocating resources accordingly, there is a risk of inefficient resource allocation and missed opportunities to address critical healthcare gaps. A systematic approach is essential to ensure equitable distribution of healthcare facilities and maximize their impact on improving health outcomes across the states.

Inefficient Utilization of Existing Facilities: In addition to the challenges related to distribution and coverage, inefficient utilization of existing healthcare facilities due to suboptimal location selection is a pressing issue in NCGPZ States. Poorly located healthcare facilities may fail to attract patients or serve the intended population effectively, leading to underutilization and inefficiencies in resource allocation. This results in wasted resources and missed opportunities to address healthcare needs in underserved areas.

The healthcare sector in NCGPZ States face significant challenges, including an uneven distribution of healthcare facilities, inadequate coverage in remote areas, limited availability of data, lack of a systematic approach to resource allocation, and inefficient utilization of existing facilities. Addressing these challenges requires concerted efforts from policymakers, healthcare administrators, and other stakeholders to prioritize equitable access to healthcare services, improve data collection and analysis, and implement evidence-based strategies for optimizing healthcare facility distribution and resource allocation. By addressing these issues, NCGPZ States can work towards ensuring that all residents have access to quality healthcare services, regardless of their geographical location or socioeconomic status.

The aim of this project is to optimize the allocation of healthcare facilities in the NCGPZ States (Phase One) by employing geospatial techniques. By leveraging spatial data analysis and advanced geospatial tools, the project seeks to enhance the accessibility, coverage, and efficiency of healthcare services in the region. Ultimately, the aim is to ensure equitable distribution of healthcare facilities and improve overall healthcare outcomes for the population in NCGPZ States. The objectives include: To assess the existing healthcare facility distribution in the states; to identify areas with inadequate healthcare coverage and assess the underlying factors contributing to the problem; to utilize geospatial analysis techniques to determine optimal locations for new healthcare facilities or the reallocation of existing facilities.

The Study Area

This study is proposed to address the challenge of healthcare facilities locational optimization in the NCGPZ phase one using geospatial techniques. The NCGPZ of Nigeria comprises several states. These are Benue, Kogi, Kwara, Nasarawa, Niger, Plateau and the (Federal Capital Territory) FCT. This phase of the project is concentrated on Kogi and Nasarawa States.

The Data Used

Data Collection: Built-up areas were acquired from satellite imagery (Nigeria Sat-X, Land Sat 7, Sentinel) to represent human settlements and urban infrastructure. Additional built-up area data came from the GRID3 project. Healthcare facilities data were sourced from GRID3 and included all public and private healthcare institutions, categorized by type and ownership. GPS locations were provided for each. Other Data: Road networks, socio-demographic, and health indicators were also integrated, along with a shapefile from the Office of the Surveyor General of the Federation (OSGOF) delineating boundaries.

METHODOLOGY

The satellite data processing involved atmospheric and geometric corrections using Erdas Imagine software, followed by image rectification, mosaicking, and sub-setting. Supervised pixel-based classification using the Maximum Likelihood Algorithm helped identify built-up areas. Accuracy was validated through a confusion matrix, leveraging terrain data and visual cues from satellite images and Google Earth.

Proximity Analysis: Aimed to measure the distance between built-up areas and healthcare facilities, utilizing a 5 km distance threshold recommended by WHO. ArcGIS proximity tools with Euclidean buffers (as the study area fell within one UTM zone) were used to assess healthcare accessibility. Publicly accessible healthcare centers were emphasized, including a variety of institutions from primary health clinics to federal hospitals, covering both governmental and NGO-managed facilities. This methodology ensures the transparency, reproducibility, and scientific rigor necessary for stakeholders to understand how the data was processed and how healthcare accessibility is spatially optimized in these regions.
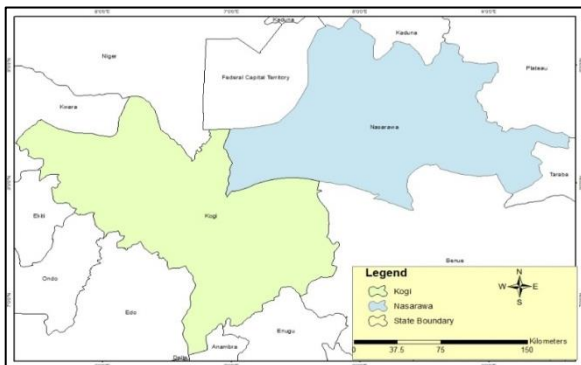

Figure 1: The study areas (Kogi and Nasarawa States)

FINDINGS AND ANALYSIS

This section presents the findings of the study and provides comprehensive analysis on the landscape of healthcare facilities in Nasarawa and Kogi States, Nigeria, focusing on both functional and nonfunctional establishments. By examining the types, distribution, and challenges faced by these facilities, this section provides valuable insights into the healthcare infrastructure of the state. Nigeria, like many developing countries, grapples with challenges in its healthcare sector, including infrastructure deficiencies and inadequate resources. Understanding the distribution and functionality of healthcare facilities is essential for assessing the state of healthcare delivery. This analysis aims to explore the healthcare landscape of Nasarawa and Kogi States,, highlighting both functional and nonfunctional healthcare facilities, commencing with Nasarawa state.

In the field of Earth observation remote sensing, built-up areas indeed represent human settlement. Built-up areas, also known as urban areas or urban land cover, are characterized by the presence of infrastructure and human-made structures such as buildings, roads, and other facilities. These areas are typically occupied by human beings and are associated with various human activities and functions, including residential, commercial, industrial, and institutional purposes. Overall, built-up areas in Earth observation remote sensing serve as a key indicator of human settlement and provide valuable information for understanding the dynamics of urban landscapes and their interactions with the environment.

Optimization of Healthcare Facilities in Nasarawa State

The total area of builtups in Nasarawa State is 542.7 Km^2 (figure 2). The state is home to a total of 1,170 healthcare facilities, encompassing both functional and nonfunctional establishments. Among these, 933 were found to be functional (figure 3), while 237 are nonfunctional (figure 4). This analysis focuses on dissecting these figures, shedding light on the types and distribution of functional and nonfunctional healthcare facilities across the state. Hospitals often provide intermediate and tertiary medical services, whereas clinics offer primary care, basic treatments, and first aid.

Of the 933 functional healthcare facilities in Nasarawa State, the majority (792) are Primary Health Centers (PHCs), reflecting a strong emphasis on primary healthcare delivery. Additionally, there are 44 Non-profit Private Hospitals, 26 Maternity Homes, 21 General Hospitals, 18 Dispensaries, and 10 Medical Centers (figure 5). This distribution indicates a varied landscape of healthcare services, catering to different levels of medical needs within the state. In addition to primary healthcare centers, Nasarawa State also hosts specialized healthcare facilities to address specific medical requirements. These include 5 Primary Health Clinics, 4 Specialist Hospitals, and 4 Educational Clinics. Furthermore, the state accommodates 2 Comprehensive Health Centers, 2 Military and Paramilitary Clinics, and 1 Federal Medical Center, underscoring efforts to provide specialized care across various sectors.
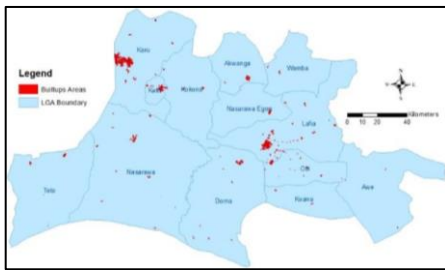
Figure 2: Built-up areas
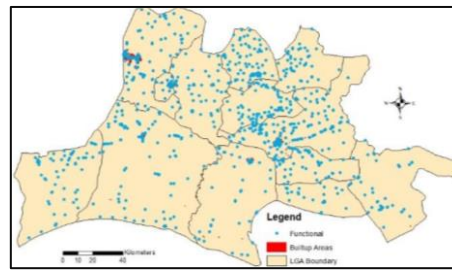
Figure 3: Functional healthcare facilities
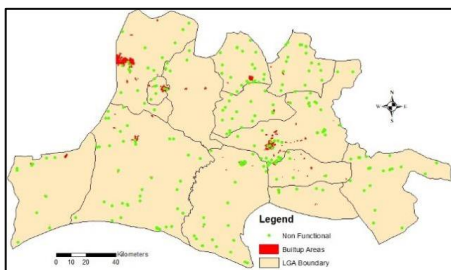
Fig. 4: Nonfunctional healthcare facilities
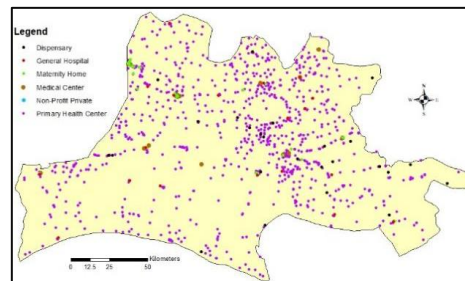
Fig. 5: First category of healthcare facilities

Apart from primary and specialized healthcare establishments, Nasarawa State houses a range of other healthcare facilities, albeit in smaller numbers. These include 1 Cottage Hospital, 1 Private Clinic, and 2 healthcare facilities whose classification remains unknown (figure 6). While few in number, it is safe to assume that these facilities contribute to the overall healthcare infrastructure of the state, addressing specific medical needs within their communities. Most of the healthcare facilities in Nasarawa State are owned by the State Government. Only one of them is owned by the Local Government and few by the Federal Government (figure 7).
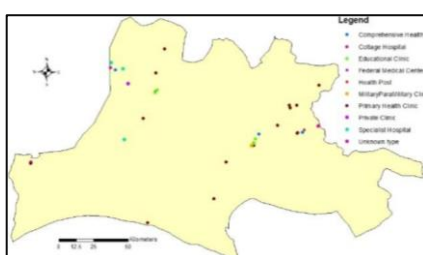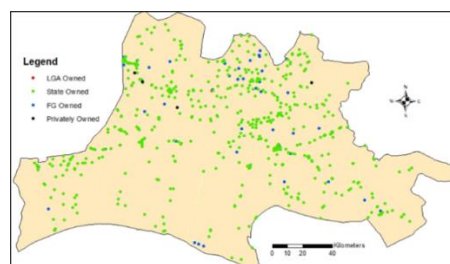

Fig. 6: Second category of healthcare facilities

Fig. 7: Public healthcare facilities

The government owned healthcare facilities that were buffered with the WHO's recommended 5km is presented in figures 8, 9 and 10. From the result, it was found that with the 5 km buffer, 468 Km^2 of the total built-up areas in Nasarawa State are located within the recommended distance from State owned health-care facilities (figures 10 & 11). This represents 86.2% of the total built-up areas. The total built-up areas that are located farther than the recommended distance cover 74.7 Km^2 approximately, representing 13.8% of the total built-up in Nasarawa State (figure 12).
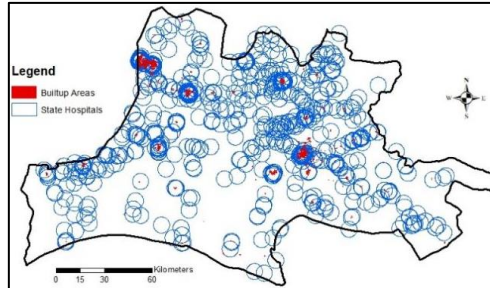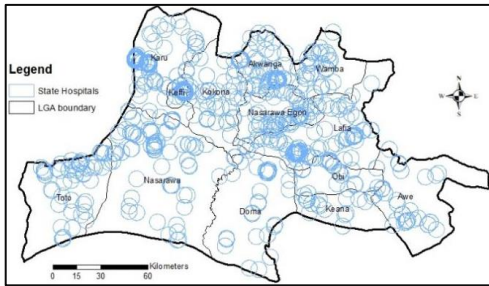
Fig. 8: Buffered state healthcare facilities

Fig. 9: Built-up areas on buffered state facilities

The built-up areas in Nasarawa State that have no public healthcare facility situated within the recommended distance, are found within six wards. These wards include Duduguru, Gidan Ausali and Obi wards in Obi LGA; Shabu kwandare and Akurba wards in Lafia LGA; Alagye, Madaki, Agbashi and Akpanaja wards in Doma LGA; Tungan Bakano and Odeni Gida wards in Nasarawa LGA, Gidan Ausa; and Tunga ward in Awe LGA (figures 14 & 15).
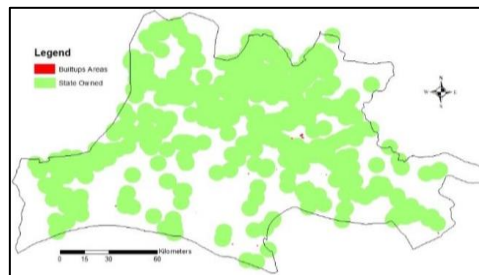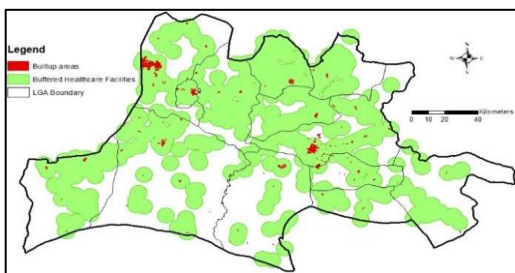
Fig. 10: Merged buffered state healthcare

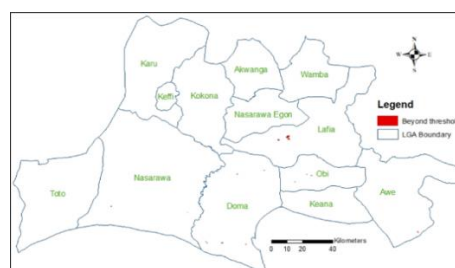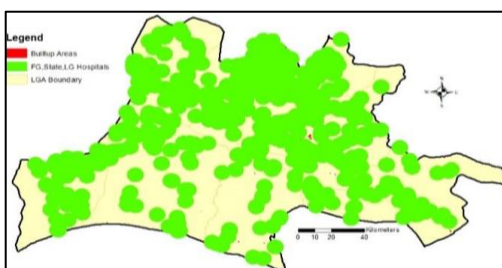Fig. 11: Built-up areas far from state healthcare

Fig. 12: Built-ups far from public health facilities
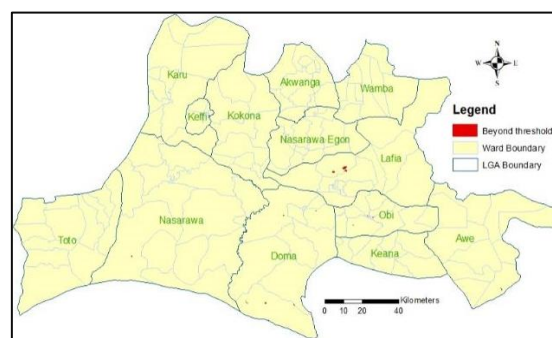
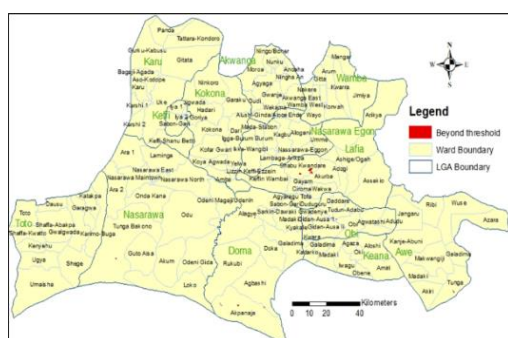Fig. 13: Built-up areas outside threshold

Fig. 14 & 15: Built-up outside threshold with ward boundaries

Optimization of Healthcare Facilities in Kogi State

The total area of built-up areas in Kogi State is approximately 932.3 Km^2 (figure 16). The state is home to a significant number of healthcare facilities aimed at providing essential medical services to its residents. The analysis of these healthcare facilities, their distribution, and functionality offers insights into the healthcare infrastructure of the state, highlighting areas of strength and areas needing improvement.

The provided data outlines the distribution of healthcare facilities across various categories in Kogi State. The majority of healthcare facilities fall under the category of Primary Health Centers (PHCs), comprising 84.76% of the total facilities (table 1 and figure 17). This indicates a focus on primary healthcare services, which are crucial for addressing basic health needs and promoting preventive care within communities.

Maternity Homes, comprising 3.4% of the total facilities, play a vital role in maternal and child health services, ensuring safe deliveries and postnatal care for women and newborns. Dispensaries, Cottage Hospitals, General Hospitals, and Private Non-Profit Hospitals each contribute to the healthcare landscape; albeit in smaller proportions compared to PHCs and Maternity Homes (table 1 and figure 18). Specialized healthcare facilities, such as Specialist Hospitals and Military and Paramilitary Clinics, cater to specific medical needs, providing specialized care and treatment options. The presence of Educational Clinics and Comprehensive Health Centers further enhances the healthcare ecosystem by integrating education and comprehensive care services.

It is pertinent to note that the total of 1399 healthcare facilities, which include; Primary Health Center, General Hospital, Private Non Profit, Primary Health Clinic, Comprehensive Health Center, Medical Center, Specialist Hospital, District Hospital, Federal Hospital and Federal Medical Center are opened to the general public because they are owned by NGOs, religious organizations, or government at local, state or federal levels. These healthcare facilities represent 89.96% of the total healthcare facilities in the state (figure 19).

Of the total 1555 healthcare facilities in Kogi State, 1143 are reported to be functional, representing 73.5% of the total (figure 20). This indicates a relatively high proportion of functional healthcare facilities, reflecting a commitment to providing accessible healthcare services to the population. However, 26.5% of the facilities (figure 21) have unclear functionality status, indicating potential challenges in assessing and ensuring the operational status of all healthcare facilities.

The buffered public healthcare facilities are presented in figures 22 to 26. Figure 22 shows that buffered rings for individual healthcare facility while figure 23 presents the same information with built-up areas of the state. Figure 24 shows the buffered public healthcare facilities that have been merged and dissolved into one feature. In order to determine the LGAs that are less covered by the buffered healthcare facilities, figure 25 presents the merged and dissolved buffered public healthcare facilities with LGA boundaries of the state. Figure 26 presents the built-up areas in the state with the merged buffered healthcare facilities. The findings revealed that 918.6 Km2 of the total built-up areas in the state fall within the recommended maximum distance of 5 km from the public healthcare facilities. This is 98.5% of the total built-up areas in the state (figures 26 and 27). 13.7Km^2 is the total built-up areas that are beyond the recommended distance. This is 1.5% of the total built-up areas (figures 27 & 28).

Table 1: Healthcare Facilities' Distribution

Primary Health Center	1318	84.76%
Maternity Home	54	3.4%
Dispensary	47	3.02%
Cottage Hospital	29	1.86%
General Hospital	21	1.35%
Private Non Profit	21	1.35%

Primary Health Clinic	18	1.16%
Educational Clinic	14	0.90%
Comprehensive Health Center	9	0.58%
Medical Center	5	0.32%
Federal Staff Clinic	5	0.32%
Specialist Hospital	3	0.19%
Military and Paramilitary Clinic	2	0.13%
District Hospital	2	0.13%
Private Clinic	2	0.13%
Federal Hospital	1	0.06%
Federal Medical Center	1	0.06%
Laboratory	1	0.06%
Unknown	2	0.13%
	1555	100
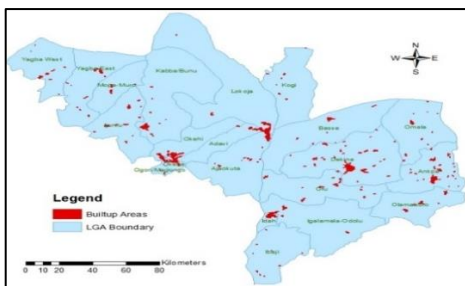
Fig. 16: Built-up areas
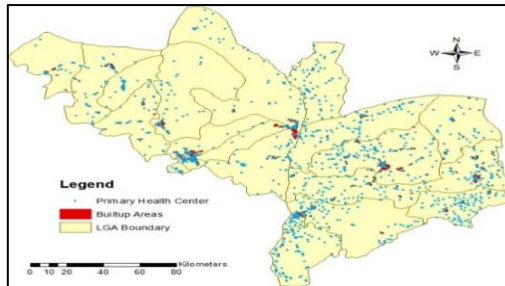
Fig. 17: Primary health centers
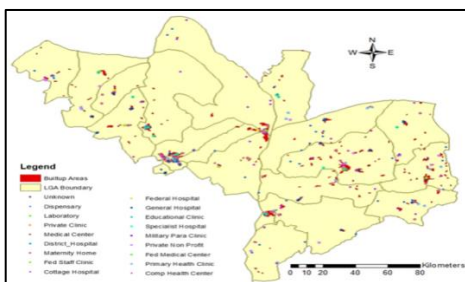
Fig. 18: Other healthcare facilities
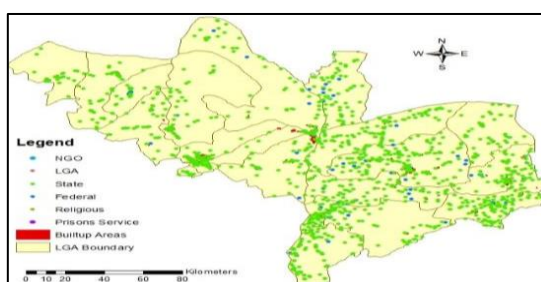
Fig. 19: Public healthcare facilities
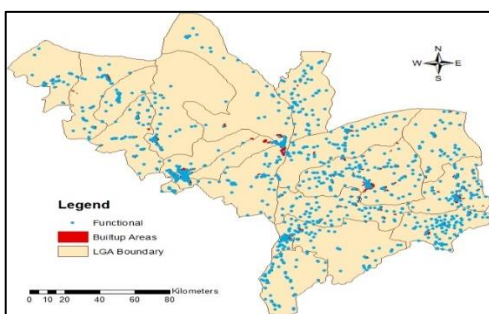
Fig. 20: Functional healthcare facilities
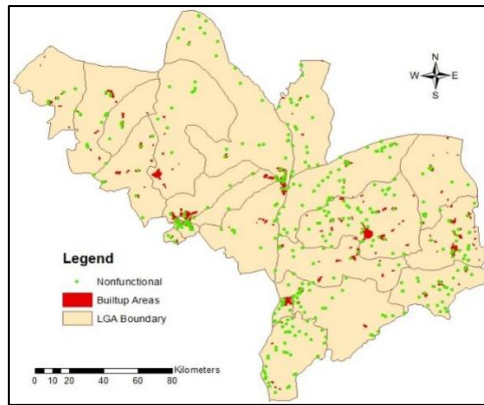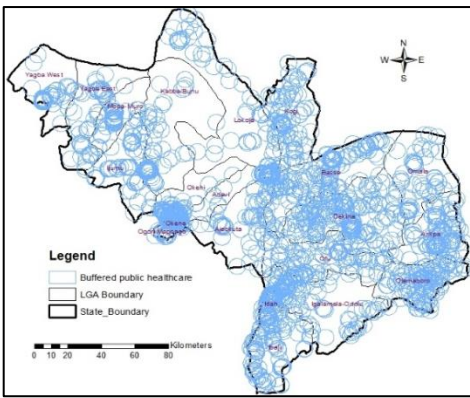
Fig. 21: Nonfunctional healthcare facilities

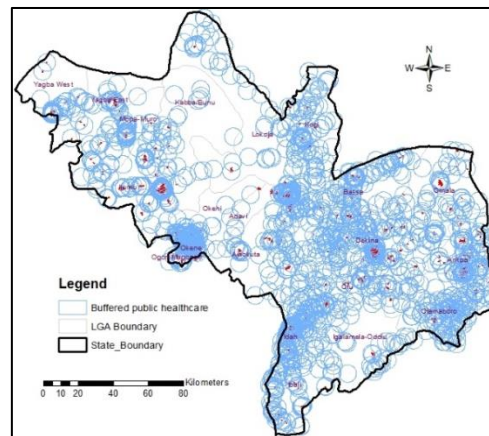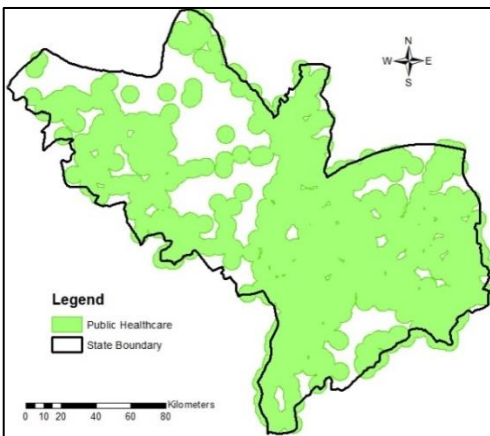Fig. 22: Buffered public facilities

Fig. 23: Buffered public facilities with built ups

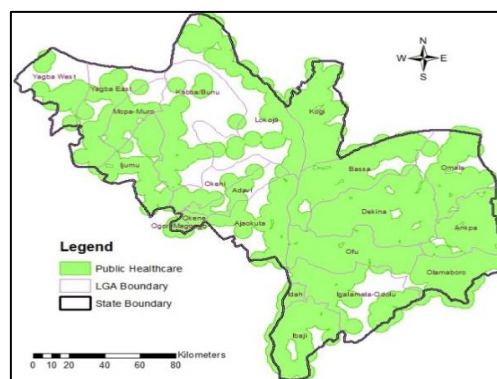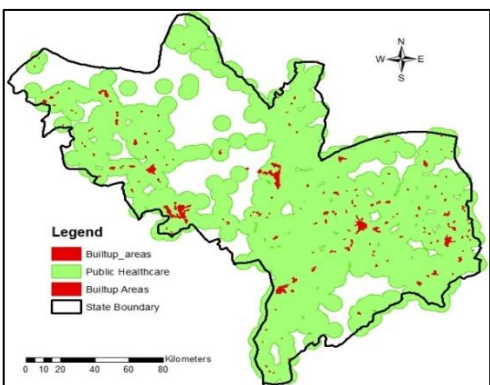Fig. 24: Merged buffered public facilities

Fig. 25: Merged buffered public healthcare on LGA
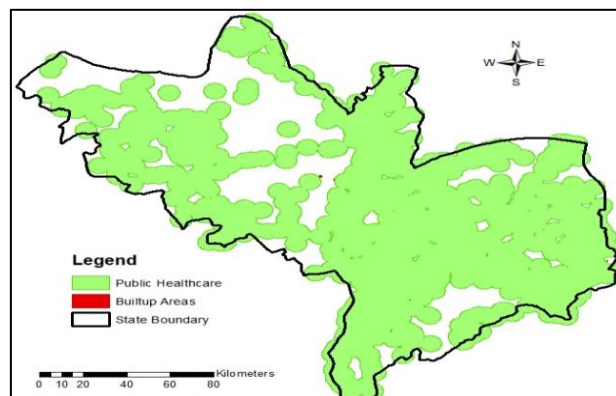

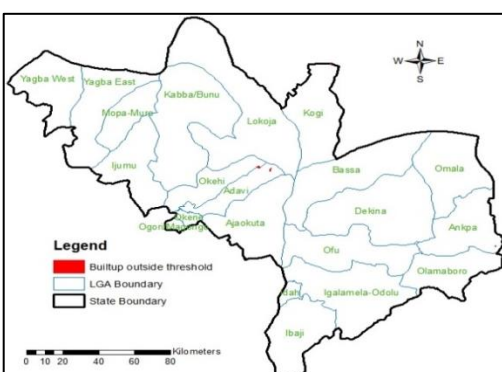Fig. 26: Built-ups on merged buffered public

Fig. 27: Built-up areas outside threshold

Fig. 28: Built-up outside threshold with LGA

DISCUSSION ON NASARAWA STATE

Nasarawa State boasts a diverse array of healthcare facilities, ranging from primary health centers to specialized hospitals. However, the state grapples with challenges related to healthcare delivery. The presence of 237 nonfunctional facilities highlights issues such as inadequate infrastructure, resource constraints, and operational inefficiencies. Furthermore, the concentration of functional facilities in certain areas may result in disparities in healthcare access, particularly in remote or underserved regions. Efforts to decentralize healthcare services and improve infrastructure in these areas are essential to ensure equitable access to healthcare for all residents of Nasarawa State. It is interesting to finding out that 86.2% of the total built-up areas in Nasarawa State are located within the WHO recommended distance from healthcare facilities. However, the 74.7 Km^2 representing 13.8% of the total built-up that were found to be outside the recommended distance, raises concern. The built-up areas in Nasarawa State that have no public healthcare facility situated within the recommended distance, are found within six wards as obtained from the analysis.

It can be deduced from the above analysis and discussion that Nasarawa State possesses a diverse array of healthcare facilities, with a notable emphasis on primary healthcare delivery. However, despite the relatively large number of healthcare facilities, the State faces challenges related to functionality and quality of care, highlighting the need for targeted interventions and resource allocation. The presence of a significant number of nonfunctional facilities underscores the need for infrastructure improvement and resource allocation. Secondly, the areas that were found to be uncovered by the facilities though small in size need to be provided. Additionally, ensuring the quality of care across all healthcare facilities remains a pressing issue.
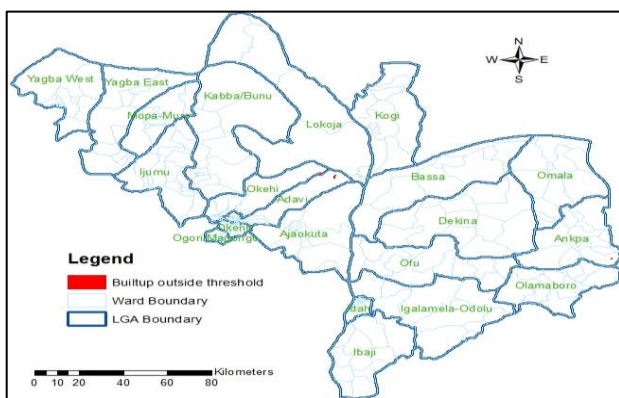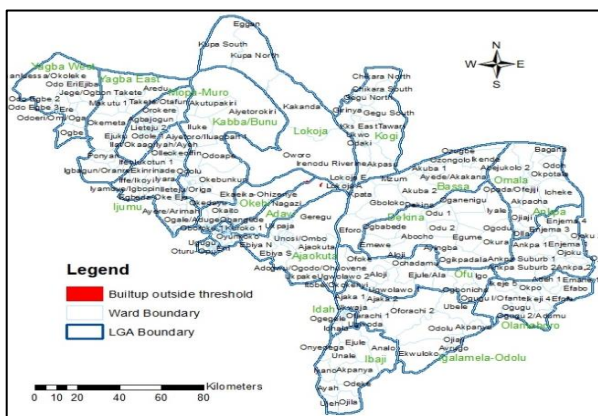

Fig. 29 & 30: Built-ups outside healthcare threshold with wards and ward names

Lastly, this analysis provides valuable insights into the healthcare infrastructure of Nasarawa State, laying the foundation for further research and policy initiatives aimed at improving healthcare delivery in the region.

Discussion on Kogi State

The analysis of healthcare facilities in Kogi State highlights the diverse landscape of healthcare services available to the population. While primary healthcare services, represented by PHCs, form the backbone of the

healthcare system, specialized services cater to specific medical needs. The relatively high functionality rate of healthcare facilities indicates a commitment to providing accessible healthcare services. Another interesting finding is the fact that almost the entire built-up areas in the state (98.5%) are within the buffer zone. This is to say that they are within the WHO's recommended distance from the available healthcare facilities. It is interesting to find out that the built-up areas that are outside the recommended threshold represent only 1.5% of the total built-up areas. They are the only areas that have not been provided with any healthcare facility. However, challenges such as unclear functionality status and the presence of unknown hospitals underscore the need for improved monitoring, evaluation, and data management within the healthcare system. Likewise, those areas outside the threshold need to be served as well, since provision of healthcare services to everyone is mandatory. Providing solutions to these challenges presents opportunities for strengthening the healthcare infrastructure, enhancing service delivery, and ultimately improving health outcomes for the residents of Kogi State. There is the need to further advance the healthcare system and ensure the well-being of the population by prioritizing transparency, accountability, and ensuring that resources are used efficiently and effectively.

Strategic investment in healthcare infrastructure, workforce development, and technology can further advance the healthcare system in Kogi State. This includes investing in infrastructure upgrades, training healthcare professionals, and implementing digital health solutions to improve access, quality, and efficiency of healthcare services. Overall, by addressing these challenges and seizing opportunities for improvement, Kogi State can enhance its healthcare system, ultimately leading to improved health outcomes and well-being for its residents. This requires a multi-sectoral approach involving government agencies, healthcare providers, community organizations, and other stakeholders working together to prioritize the health needs of the population.

CONCLUSIONS

Access to healthcare is a fundamental human right, as recognized by international treaties and organizations like the World Health Organization (WHO). However, ensuring adequate access to healthcare facilities remains a challenge in many regions, including NCGPZ States, Nigeria. This study aimed to analyze the spatial distribution of healthcare facilities in NCGPZ State phase one (Nasarawa and Kogi States) and assess the accessibility of these facilities to the population, with a focus on the WHO-recommended 5 km radius criterion.

The findings of this study revealed several important insights regarding healthcare facility distribution and accessibility in Nasarawa and Kogi States. Out of the healthcare facilities identified in the two states, most of them were found to be functional, while few were non-functional. These facilities were observed to be concentrated mainly in urban areas, with limited coverage in remote locations. However, despite the overall distribution of healthcare facilities, a small percent of the population could not access these facilities within a 5 km radius. This lack of accessibility disproportionately affects vulnerable populations, such as senior individuals with chronic diseases and women in labor, who may face significant time and financial burdens when seeking specialized healthcare services. The study underscores the importance of optimizing healthcare facility planning using Geographic Information System (GIS) tools to improve healthcare coverage in Nasarawa and Kogi States. By identifying areas lacking spatial coverage of health facilities, policymakers can prioritize resource allocation and infrastructure development to address these gaps. Moreover, the study highlights the potential of GIS-based analyses in estimating healthcare access based on established criteria like the WHO's 5 km radius recommendation. However, it is essential to acknowledge the limitations of this study. Factors such as socio-economic status, availability of healthcare personnel, and drug supplies were not considered in the analysis. Future research should incorporate these variables to provide a more comprehensive understanding of healthcare accessibility in Nasarawa and Kogi States. Additionally, exploring the potential of digital healthcare solutions to improve accessibility and quality of services in areas with varying levels of accessibility is warranted.

In conclusion, this research contributes valuable insights into the spatial distribution of healthcare facilities and accessibility challenges in Nasarawa and Kogi States. By leveraging GIS-based analyses and considering additional socio-economic factors, policymakers can develop targeted interventions to enhance healthcare access and quality, ultimately improving the well-being of the population. Further research and investment in

digital healthcare solutions are crucial steps toward achieving equitable healthcare access for all residents of Nasarawa and Kogi States. The beneficiaries of the project include Federal Ministry of Health, National Health Insurance Scheme (NHIS), Health Insurance Schemes at the states level, National Primary Health Care Development Agency (NPHCDA), Central bank of Nigeria (CBN), as well as the states governments.

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REFERENCES

1. George Ashiagbor, Richard Ofori-Asenso, Eric K. Forkuo, Seth Agyei-Frimpong (2022), Measures of geographic accessibility to health care in the Ashanti Region of Ghana, Scientific African, Volume 9,2020,e00453,ISSN 2468-2276, https://doi.org/10.1016/j.sciaf.2020.e00453.
2. Gyuse AN, Ayuk AE, Okeke MC (2018). Facilitators and barriers to effective primary health care in Nigeria. Afr J Prim Health Care Fam Med. 2018 Feb 22;10
3. Kress DH, Su Y, Wang H (2016). Assessment of primary health care system performance in Nigeria: Using the primary health care performance indicator conceptual framework. Health Syst Reform. 2016; 2:302–18.
4. Le, K.H., La, T.X.P. & Tykkyläinen, M.(2022) Service quality and accessibility of healthcare facilities: digital healthcare potential in Ho Chi Minh City. BMC Health Serv Res 22, 1374 (2022). https://doi.org/10.1186/s12913-022-08758-w
5. Olagundoye OA, Akinwunmi OO, Onafeso ET, Henshaw I, Odujoko A, Oladipo-Badmus MA, Amosun FT, Ajumobi IO. Comparative assessment of the quality of the primary care system: A survey of family physicians' perspective at a tertiary health facility and a new family medicine training facility in the Lagos State health system. J Family Med Prim Care. 2020 Feb 28;9(2):871-876.
6. The Global Historical Weather and Climate Data (GHWCD) (2024). Weather and Climate https://weatherandclimate.com/nigeria/kogi
7. World Health Organization (WHO). Service availability and readiness assessment (SARA). Version 2.2. 2015. https://apps.who.int/iris/handle/ 10665/149025. Accessed11 Jan 2024