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Modelling Geographic Accessibility of Primary Health Care Facilities in Bauchi Local Government Area

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Abstract

Achieving universal health care (UHC) coverage has been at the forefront of the United Nations (UN) agenda for 2030. Inequality in health care service provision continues to increase, hence militating against the achievement of reducing unequal access to health care. Access is a critical component of the healthcare delivery system that is impacted by both spatial and non-spatial elements. This study utilized health facilities, population, and other open-source data to analyze the distribution and spatial accessibility of healthcare service centers by using Geospatial technologies in the Bauchi Local Government Area of Bauchi State - Nigeria. Two traveling scenarios (Driving and Walking) were used to determine the travel time to the nearest health facilities, defined within a maximum of 30 minutes traveling time using AccessMod (Online) and ArcGIS Pro. It was found that 87% and 75% of the population are within 15 and 30 minutes of travel time by driving and walking, respectively, while 1.3% of the population are outside a 15 km radius of any health facility with a ratio of 1 to 4,454 population to a health facility. The result shows a significant spatial disparity in geographic accessibility and spatial coverage, with some parts of the rural areas not having access to the existing health facility network, regardless of the travel scenario chosen. This will offer an innovative approach to reducing gaps in healthcare access and subsequently enhance the efficient and effective delivery of healthcare services in low- and middle-income countries (LMIC) to achieve UHC.

Keywords*: AccessMod, Bauchi Local Government Area, Geographic Accessibility, Health Facilities, Spatial Coverage, Universal Health Coverage.*

Introduction

The relationship between the geographic location of health facilities and the population they are serving is progressively limiting access to health care, which exacerbates health disparities (defined as variations in health status between social groups) [1].

The third Sustainable Development Goal (SDG), one of the 17 global objectives created by the United Nations, is to ensure healthy lifestyles and promote the well-being of all people of all ages. Inequalities in geographic access to health care are one of the key hurdles in attaining the third SDG, resulting in unfulfilled objectives for decreasing maternal and newborn mortality, HIV/AIDS, Malaria, Hepatitis B, and Tuberculosis epidemics [2, 3].

The term “access” refers to “the degree of fit between the system and the patient”. Different aspects aid in providing an overview of healthcare access. Access dimensions include things like accessibility, availability, accommodation, price, and acceptability [4]. The connection between the location of health

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services and the location of a patient determines accessibility [5]. The World Health Organization (WHO) defines accessibility in a variety of ways, including economic, informational, and physical accessibility. Each level of accessibility tackles a distinct set of health needs and challenges [6]. Access to relevant information reinforces an individual's or group's right to seek and receive health-related information. However, after being told of their need, there is still the financial element to consider, as well as the proximity of the desired health services to the individuals in the community. Geographic accessibility becomes a significant aspect in measuring access, along with travel time, ease of travel, and distance to health care services, among other considerations. Travel, cost, and duration [7].

There exist different approaches that proved to be effective in measuring accessibility to health care services, which include, among others, catchment area, kernel density, and seriousness. But in public health research, Euclidean and network distance techniques are still commonly used [8], because it is generally driven by the distance relationship between the population and the location where the health services are provided.

The network distance is the path taken to reach the destination [9]. However, there is no universally approved distance for people to travel for medical care, implying that no one factor can be used to decide how far healthcare services may be termed as inaccessible. But the World Health Organization (WHO) and other key stakeholders recommend the use of journey time as against travel distance in measuring accessibility for healthcare, as these methods assess the road condition and the transportation mode [10].

Healthcare service planners and policymakers provide comprehensive healthcare planning that addresses the health requirements of a country's whole population. As a result, individuals must have a precise understanding of healthcare units, identify regions of need, and distribute units to these areas to resolve their health condition [11].

Accessibility to healthcare services is a critical issue to society, which cannot be over-emphasized. In this context, accessibility refers to physical or spatial accessibility that is expressed as geographical accessibility. Ebener opined that physical accessibility is influenced by a substantial interdependence between population distribution and the availability of healthcare services [12]. Accessibility has been a topic of concern to policy and healthcare planners, as it is generally influenced by many factors such as cost, distance, and other behavioral factors [13-16].

Different published literature attempted to document factors that influence the acceptability and use of healthcare services. In 2003, a study was conducted to examine the effect of distance, where they determined that residents in rural areas traveled longer distances to access healthcare services as compared to those in metropolitan areas [17]. Another study examined the association between several indicators of physical access to health care, and distance was found to be one of the aspects, distance [11]. These findings and others suggest that the utilization of healthcare services is increasingly seen to have a direct relationship to accessibility.

Therefore, it can be said that the proximity of healthcare services plays an important role in delivering primary healthcare services to people [8, 17-19]. It was established that traveling long distances to seek health care services discourages people from seeking these services [20].

The use of geographic information systems (GIS) in analyzing geographical geographic accessibility has proven to be a reliable and robust tool used by policymakers and health planners in reducing inequality due to accessibility. It enables monitoring of issues related to healthcare planning regarding catchment area population and health facility management [21, 22]. Here is a considerable number of published materials available on the use of GIS for evaluating geographical accessibility to healthcare, which enabled an important tool for measuring healthcare services [17, 23-26].

In Nigeria, the health policy institutes the timely evaluation of primary health care (PHC) accessibility with a special focus on rural areas. Hence, their spatial structures and locations impact accessibility and utilization, even though neither is spread uniformly across space [27]. Accessing healthcare services in a timely manner protects and saves patients from many types of health-related disasters, enhancing accessibility and reducing inequalities in healthcare with a view to supporting the achievement of universal health coverage. Therefore, the objective of this study is to analyze the health facilities distribution and their geographical accessibility using GIS and Remote Sensing technologies in the Bauchi Local Government of Bauchi State, Nigeria. The study also aims to evaluate the geographic coverage of all health facilities in the local government to identify areas with good accessibility as relates to travel times (car and walking), as well as identify catchment populations with poor accessibility and under-served settlement for health care services. Accessibility to health care services is a societal right that must be met without bias or discrimination; hence this study will help in identifying the gaps that exist in health care facilities distribution in the local government and support policy and health planners on effective distribution of these facilities towards reducing the closing inequality to services provision and consequently support the achievement of universal health coverage.

Study Area

The study was conducted in Bauchi Local government Area (LGA), which is the capital city of Bauchi state–Nigeria, located between 9° 3’ and 12° 3’ North latitude, and 8° 50’ and 11° East longitude (Figure 1).

The local government is one of the largest LGAs in the state, divided into twenty (20) political wards. The LGA is unique in its characteristics of having both urban (9) and rural (11) wards. It has two types of vegetation (Sudan and Sahel Savanna) and an altitude of 785.2 meters. It has an average annual rainfall of 1,091.4 mm, with the highest temperature being 40.56℃ and the coldest temperature of 6.11℃ the LGA has a population of 493,810 and 672,540 (2006 population census projected– a 3.4% growth rate applied at the state level for all LGAs) and Rapid population Estimate (RPE-WorldPop).

The total area covered by the district is 3,687 $km^{2,}$ and it holds the most populous LGA in the state and the 5th largest position among the LGAs of the states in terms of size area. A total of 19 tribes are dominant in the LGA, with a literacy rate of 26.60%, with most of the population living below the poverty line. There are a total of 151 health facilities (6 hospitals [teaching/specialist/general/military], two educational medical clinics, 12 maternity homes, 80 primary health care centers, 44 health clinics/posts, and 7 private on-profit clinics) providing healthcare services (Figure 2) [28].

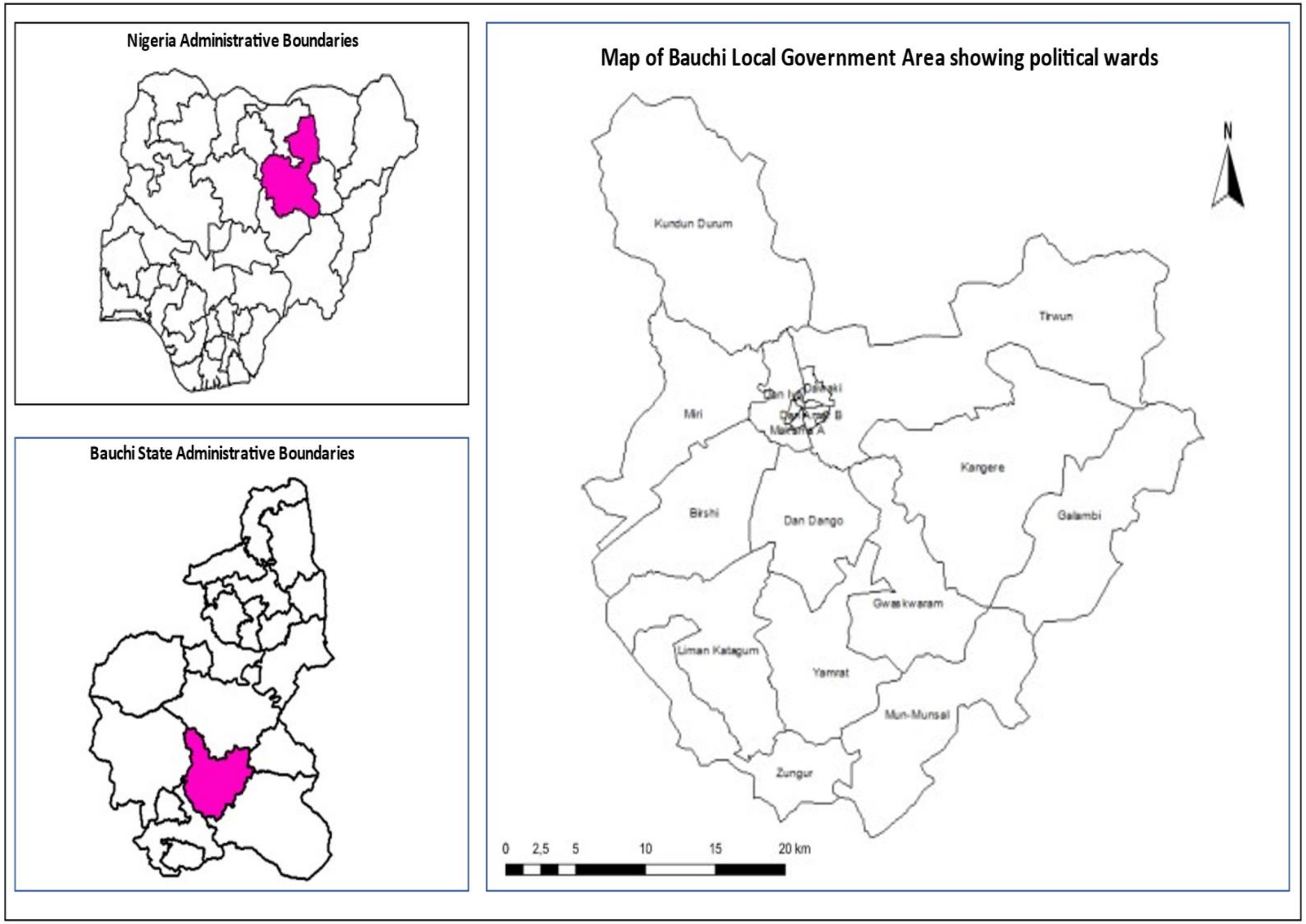

Figure 1. Map of the Study Area

Materials and Methods

Different datasets were collected for the study, including the location of all health facilities, land cover, population data, settlement points, the slope, digital elevation model (DEM), and the road network. The location of health facilities was obtained from GRID3 (https://data.grid3.org/datasets/), and then validated with the ISS data from ODK/ONA (https://analytics.afro.who.int/whonghub/13/829), which was collected during supportive supervision by WHO and government staff. Digital Elevation Model (DEM) with 30m resolution was obtained from the United States Geological Survey (USGS), which was downloaded from the website (https://lpdaac.usgs.gov/products/astgtmv003/) and used to generate the slope. The settlement points and road travel network was also obtained from GRID3 (https://data.grid3.org/datasets/).

Other data sets that contain spatial attributes used for the study were sourced from the Open Street map (OSM), which includes the waterways, road network, and natural features, which may serve as impediments preventing direct access to health facilities in the computation of travel times. The travelling speed used for the study was adopted from published literature, which uses similar patterns and settings based on the range of 2 km/hr to 5 km/hr in urban wards and up to 50 km for rural wards by Lawal, O. & Anim, F.E. (2019). Traveling speeds in different land use types by different means of transportation are indicated in Table 1.

Table 1. Travel Scenarios to the Health Facilities

Landcover type	**Travel speeds (km/hr) [10]**	
	Scenario 1 (Driving)	**Scenario 2 (Walking)**
Mosaic: Cropland/Shrub and/or Grass Cover	-	2
Open/Closed Evergreen/Deciduous Shrub Cover	-	2
Regularly Flooded Shrub and/or Herbaceous	-	2
Sparse Herbaceous or Shrub Cover	-	3
Tree Cover: Broadleaved, Deciduous, Open	-	2
Artificial and Associated Areas	-	5
Mosaic: Cropland/Tree Cover/Other Natural Vegetation	-	2
Tree Cover: Needle-leaved, Evergreen	-	2
Cultivated and Managed Areas	-	2
Mosaic: Tree Cover/Other Natural Vegetation	-	2
Water bodies	-	-
Tree Cover: Broadleaved, Evergreen	-	1
Herbaceous Cover, Closed-Open	-	2
Primary Roads	50	5
Secondary Roads	30	5
Tertiary Roads	20	5

ArcGIS Pro was used to conduct spatial analysis with additional licenses for spatial and network license functionality. The service accessibility analysis was conducted using AccessMod (online version), which has a high classification capability and was used to create satellite pictures for land cover categorization.

AccessMod is a World Health Organization (WHO) tool which was developed by the Department of Health Systems Governance and Financing (WHO/HIS/HGF), in consultation with other departments and educational institutions. The tool was designed primarily for accessibility analysis (physical/spatial accessibility) to healthcare services. It is a free and open-source standalone program used to estimate the portion of the target population that would not receive care despite being physically accessible due to a shortage of capacity in these services (either human or equipment). It measures referral times and distances between health facilities and determines where to locate new health facilities to increase population coverage [29].

The location of health facilities was imported into AccessMod (Online) to generate the accessibility analysis, which is used as an input to further generate the zonal statistics. The main outputs generated are the health facility population coverage table, the travel time analysis for all the health facilities, and the health facility catchment area network. Other outputs generated from the tool are the uncovered population distribution grid and population coverage distribution grid. The health facilities were further analysed using ArcGIS Pro to generate the catchment areas of each health facility through the creation of a 5km buffer at the centroid of each health facility to determine the population coverage of each health facility and find the settlements that are not covered.

In Nigeria, the population coverage of a health facility is defined as the number of people that a health facility serves. The ward minimum health care package stipulates that a health post should cater for 500-person, a health clinic to cover between 2,000 and 5,000 people, and a Primary Healthcare Centre must cover a community with 10,000 and 20,000 residents. Hence, In accordance with the MoH standard that the population should have access to a health centre within an hour of walking, the maximum journey time allowed was set at 60 minutes [30].

Using AccessMod and considering the travel scenarios in table 1. The least-cost path algorithm is used in the computation, which considers the topography of the terrain, landcover, road, and river networks, as well as the associated travel speeds via each of the road and landcover classes. Patients who want to go to the closest primary health centre may encounter obstacles in the form of water bodies. The pace of movement was adjusted to 0 to mark this landcover category as a barrier and prevent catchments from encroaching on these places. The DEM makes it possible to include a slope in the study, which is crucial because the topography of the ground can either increase or decrease travel speed, especially when walking or driving. This model incorporates speed adjustments and Tobler's formula-based slope corrections for both walking and driving [31-32].

In this study, the accessibility analysis considered four scenarios based on the mode of transport used (Walking and Driving).

1. 15 minutes travelling time to the health facility by walking.
2. 30 minutes travelling time to the health facility by walking.
3. 60 minutes travelling time to the health facility by walking.
4. 15 minutes travelling time to the health facility by driving.
5. 30 minutes travelling time to the health facility by driving.
6. 60 minutes travelling time to the health facility by driving.

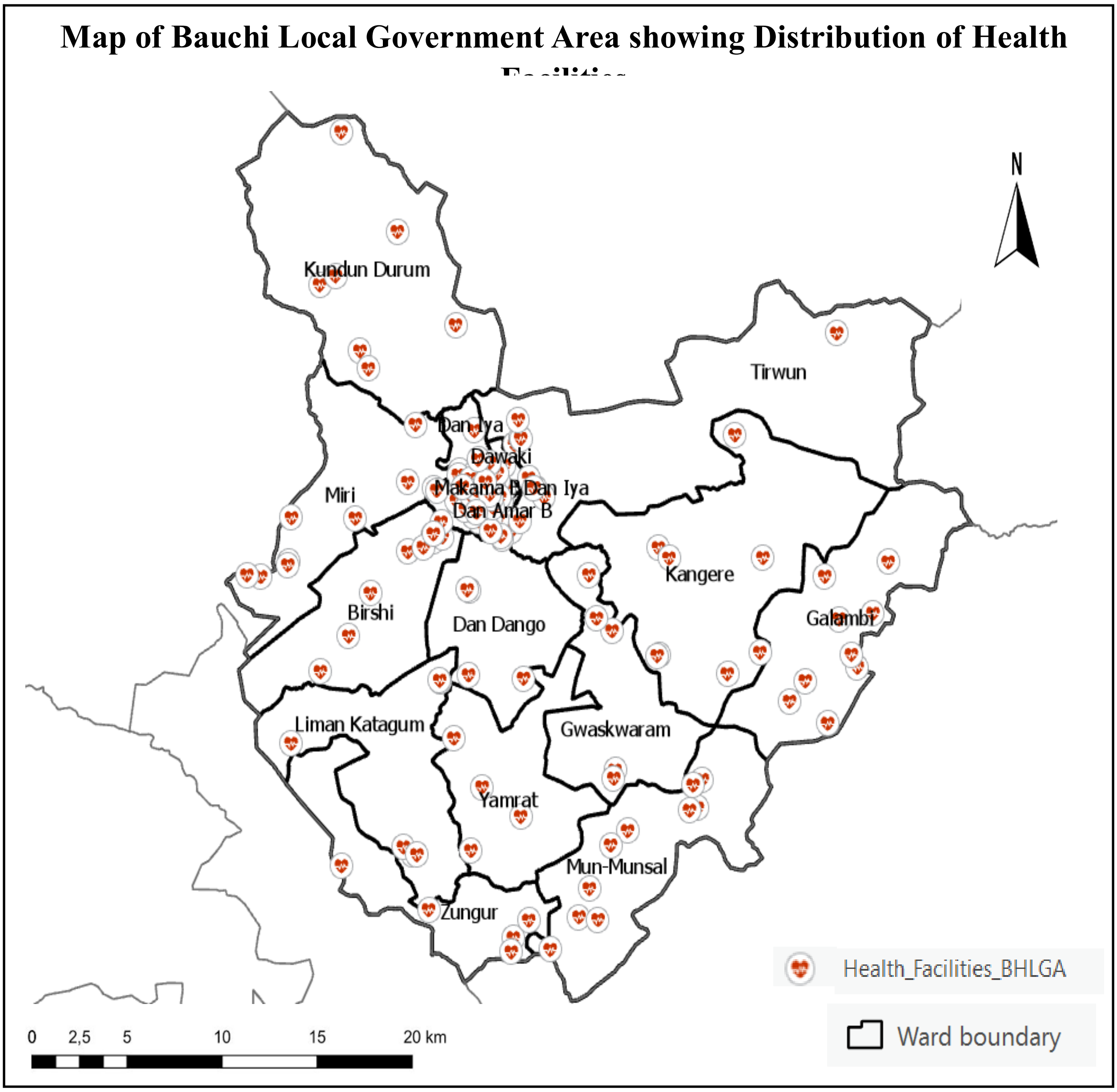

Figure 2. Distribution of Health Facilities in the Study Area

Results

The geographical accessibility analysis to primary health care in the LGA takes into consideration the constraints of landscape, which was then carried out using the two different travel scenarios, summarized in Table 1, and assuming the maximum of 60 minutes of travelling time to any health facility. Figure 3 depicts the accessibility to primary health care in Bauchi local government for the two scenarios. The first scenario (Driving) shows the maximum degree of geographical accessibility in the local government by political ward. There exists a significant increase in accessibility for facilities that are closer to the main roads, with the urban wards having a travel time of fewer than 15 mins. The use of motor vehicles or motorcycle along both the national, province and district roads tend to significantly reduce the travelling distance within the maximum travelling time set for the study. The minimum level of geographical accessibility can be seen in the second scenario (Walking), especially in the rural wards, with little access road, most of the population are either walking or cycling along the rural/feeder roads, which constitute most of the access road infrastructure in the wards.

Table 2 summarizes the accessibility status of the local government, In the first scenario (Driving), 87% of the population is within 15 minutes of travel time to the health facilities, and almost 100% of the population is within 60minutes of driving time to all health facilities in the local government. However, only 55% of the population is within 15 minutes of travel time using the second scenario (walking), and 91% of the population is within 60 minutes of travel time by walking. From the accessibility analysis, it was observed that 1,641 km^2 and 1,153 km^2 catchment areas is within 30 minutes of driving time to health facilities representing 886,061 and 652,588 population covered in the first scenario. Moreso, using the second walking scenario, 372,677 and 506,577 people could access health services in the health facilities with 336 km^2 and 538 km^2 catchment areas, respectively (Table 3; Figure 3).

Table 2. Health Facility Accessibility Analysis

Scenarios	**Statistics**	**<15 m**	**15m – 30 m**	**30 m – 45 m**	**45 m – 60 m**	**>=60 m**
Driving	Total Population	672,540	672,540	672,540	672,540	672,540
	Total Covered Population	586,061	652,588	668,769	672,332	672,478
	% Covered Population	87%	97%	99%	100%	100%
	Catchment area (km^2)	1,645	1,153	554	228	107
Walking	Total Population	672,540	672,540	672,540	672,540	672,540
	Total Covered Population	372,677	506,577	568,768	610,879	637,793
	% Covered Population	55%	75%	85%	91%	95%
	Catchment area (km^2)	336	538	641	591	1,581

The health facility to population ratio for the local government is 1:4,454, with the minimum being 1:1,220 (Makama A Ward) per population and the maximum being 1:11,949 (Dawaki ward).

The proportion of health facilities to settlement is 21%, while 357 settlements representing 11.2% are outside the 5km buffer of any health facility in the local government (Table 3).

Table 3. Health Facilities Analysis Including Under-Served Population, and Population Coverage

Wards	Total No of HF [N]	Total Settlements [N]	Settlements/HF Ratio [%]	Settlements Under-served (>15km) [N]	Proportion of Under-served Settlements [%]	Total Population (RPE - WorldPop)	HF to Population Ratio (RPE - WorldPop)
Birshi	10	259	26	4	1.5	76,865	1:7,687
Dan Amar A	4	53	13	0	0.0	7,741	1:1,935
Dan Amar B	5	102	20	0	0.0	22,899	1:4,580
Dan Dango	4	132	33	7	5.3	16,204	1:4,051
Dan Iya	25	155	6	0	0.0	94,479	1:3,779
Dan Kade	4	71	18	0	0.0	8,167	1:2,042
Dawaki	3	97	32	0	0.0	35,848	1:11,949
Galambi	9	224	25	11	4.9	29,582	1:3,287
Gwaskwaram	5	125	25	24	19.2	15,472	1:3,094
Hardo	2	38	19	0	0.0	4,628	1:2,314
Kangere	9	300	33	64	21.3	38,410	1:4,268
Kundun Durum	7	248	35	42	16.9	24,850	1:3,550
Liman Katagum	6	150	25	4	2.7	24,831	1:4,139
Makama A	13	91	7	0	0.0	15,865	1:1,220
Makama B	7	80	11	0	0.0	16,013	1:2,288
Miri	7	187	27	12	6.4	46,961	1:6,709
Mun-Munsal	10	166	17	11	6.6	28,909	1:2,891
Tirwun	13	430	33	160	37.2	130,510	1:10,039
Yamrat	4	168	42	10	6.0	20,819	1:5,205
Zungur	4	102	26	8	7.8	13,487	1:3,372
Grand Total	151	3,178	21	357	11.2	672,540	1:4,454

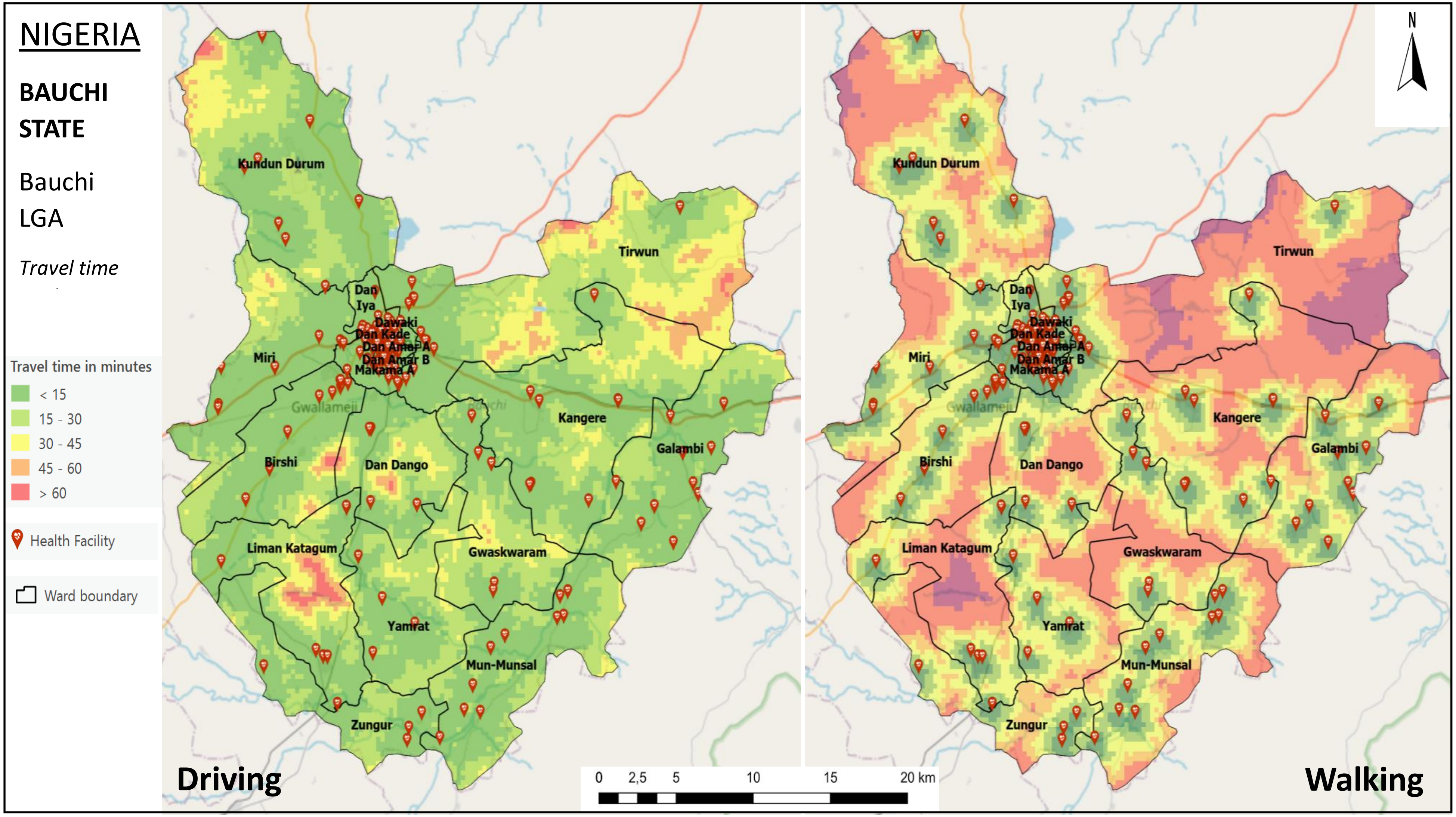

Figure. 3. Travel Time Analysis to Nearest Health Facilities

Discussion

The current study used realistic estimations of the travel times by driving and walking to healthcare facilities to characterize the diversity of healthcare services in the local government. We examined the geographical accessibility and spatial coverage of health care facilities of the Bauchi local government using a maximum traveling time of 60 minutes to the health facilities. The result showed that the second scenario of driving seems to be the best model, with a coverage of 99% of the population, with disparity across the political wards. The result from this study is in harmony with previous studies that relate the maximum travel time to a health facility should be within 60 minutes, where the areas considered with good accessibility are within 30 minutes and those considered under-served have more than 30 minutes [33-35].

The findings from this study demonstrate the travelling time to the nearest primary health facility, which provides a good measure of physical accessibility to health services. The amount of time a patient can spend traveling to a specific primary healthcare center sometimes depends on the severity of the patient's condition and is coupled with the global standard of ensuring that each population should have access to a health service within 60 minutes of walking time [35]. This justifies the reason for considering a maximum of 60 minutes of travel time in this study. The study uses the combination of road networks, topography, different land cover, and the speed of travel in the different categories of roads and land cover. These findings offer a helpful visual summary of the local government's level of accessibility, highlighting areas that are both fully, partially, and in-accessible. The first scenario of driving indicates the highest degree of accessibility as compared to the second scenario of walking.

However, travelling time does not necessarily signify good accessibility as there exist other factors that are associated with health care access, as issues related to the health facility's supply of care or accessibility should be considered in combination with demand and supply measures to better overall causes of poor health system performance [36]. But this study provides a robust and realistic approach, in which it looks at both the accessibility in terms of geographical distance to the health facilities and travel time as compared to other methods that take only one aspect into consideration. This research may help identify potential gaps and foster a deeper understanding of how the health system is performing toward reducing inequality in accessibility. As a result, the findings might be a valuable tool for decision-support in enhancing health planning and developing evidence-based policies to achieve universal health coverage.

It can also be seen from the study that the spatial extent of each health facility catchment area is defined based on the maximum population capacity and/or maximum travel time reached. Therefore, the spatial coverage analysis determines the extension of the health facility catchment area. Most of the health facilities in the urban wards have a good spatial coverage within 60 minutes of both driving and walking, and the population-to-health facility ratio has shown that these wards have the lowest health facility for population ratio, with only Dawaki ward having a higher ratio (Table 3). This also goes on to demonstrate that transportation mode has a significant impact on the population that the health facility serves, which corroborates similar findings [37].

The study equally shows that the urban wards, which are densely populated, are all accessible within 15 to 30 minutes of travel time in both scenarios and have more health facilities when compared to the rural wards (Table 3; Figure 3). Another study indicates similar results, pointing out that the urban population tends to have better accessibility than the population in rural areas [38]. The location of health facilities is disproportionally based on the settlement aggregation level, and hence the need to prioritize rural and scattered populations in the sighting and locating health facilities to address the inequality in access to health care.

Travel impedance to the nearest health provider has been found to be an accurate measure of spatial accessibility in remote and scattered populations, particularly where the choices are limited, indicating that the population will travel to the closest health facility to seek care [39-40]. This can work effectively in the setting of Bauchi local government, as most of the population lives in rural wards with little or no access to private healthcare services due to their concentration in urban wards.

This type of analysis always comes with some limitations that must be taken into account when evaluating the findings. We assumed that patients would always go to the closest health facility. Going to the closest health facility is still the most typical behavior in the vast majority of cases. However, some people might be persuaded to visit further-flung health facilities that are perceived to offer higher-quality services due to qualified staff and the availability of drugs and staff [41-42]. Another presumption is that the routes of travel are those with the shortest total travel times. Therefore, it is presumed that the predicted travel time is an accurate representation of actual travel timings. But published literature has gone to prove that calculated travel times using GIS estimates are always in harmony with reported times [43]. While certain population members may choose to travel by other routes due to customs, social considerations, environmental and surface conditions, or other reasons, the least expensive option reflects the general way that people prefer to travel [42].

Conclusion

The geographical access and the spatial coverage modelling generated from this work offer a simple but visually effective tool that may be used to support planning and resource allocation in the local government. Across the two different travel scenarios, the analysis shows considerable spatial disparities in the primary health system's geographic accessibility and spatial coverage. Most of the rural population is outside the standard 30 minutes walking distance to access healthcare, and more than half of the facilities are operating at more than their capacity with a high health facility-to-population ratio. The study shows that inequality exists despite efforts by the government to address primary healthcare issues, a lot needs to be done regarding inequality in access, shortage of staff and infrastructure, and poor quality of care, especially in the remote and rural areas of the local government.

To achieve high quality and cost-effective health system for achieving improved health outcomes requires a strong primary health system that is devoid of inequality. In many low-and-middle-income countries where sizable portions of the population reside in rural areas, physical accessibility to health care remains a problem. Different efficient initiatives are required to expand access to healthcare services and strengthen health systems for the optimal delivery of healthcare. Hence, knowledge and awareness of population distribution and health utilization patterns are essential. Our findings demonstrate the usefulness of GIS to leverage multiple datasets from different sources in a spatial framework to provide support to evidence-based planning and resource allocation decision-making in developing countries. The study area is characterized by different features, such as a combination of both rural and urban settlements that are densely populated, scattered, and geographically isolated, with topographical adversities which affect accessibility. Hence, the study can be generalized to fit into different areas with similar resource settings.

Authors' Contributions

IMB conceptualized the study, wrote the original draft, and served as the guarantor for the paper. IMB, GUA, CYM, and FS compiled the data sets and did the analysis. KIM and SB provided comments and edits. All authors contributed to reviewing and editing of the manuscript. All the authors have read and agreed on the final manuscript.

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Conflicts of Interest

The author declares that there is no conflicts of interest.

Ethical Approval

It is not required. This analysis used open-source data, which is publicly available.

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