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Spatial Distribution of Public Boreholes in Kaduna North, Kaduna State, Nigeria

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ABSTRACT

This study aimed to mapping the spatial distribution of functioning public borehole water facilities in Kaduna North for effective water supply. The spatial information of the water borehole facilities were determined using hand-held GPS (Garmin GPSMap 78s), attribute data and a well-structured checklist was used to gather appropriate information from 240 households on accessibility and the implication of inaccessibility. The data generated was analyzed using QGIS 3.0 software and descriptive statistics. A total of 101 functional public borehole facilities were identified within an area of 70.8km^2 which were unevenly distributed in the study area. The result shows that, in the Hayin-Banki ward area 31 functional public boreholes are distributed within 23.6km^2. Also in Badarawa ward (8.1km^2) 9 functional public boreholes were identified. About 35% of the entire 12 wards are currently enjoying functioning public boreholes water whereas 64.9% remain deprived of this essential facility. The result revealed that, the households which lack direct access to functional public boreholes resolved to alternatives like drilling private boreholes (24%), water truckers (30%), rainwater harvesting (16%) and enduring longer trek to access the available ones (18%). This research further revealed that there are 104 non-functional public boreholes in the study area which if to be repaired, they would bring succor to the households in the area. It is recommended that non-governmental organizations and both state and local government water agencies should assist in the provision of more water facilities and repair non-functional ones in the study area for effective water supply and development.

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1.1 INTRODUCTION

Several governments (Federal, State and Local) levels have made their efforts to provide adequate water supply to its peoples. These because water is vital for man's existence and without it there would be no life on earth. Water is the resource that sustains all life on earth and is a key element of sustainable development (Eljamassi and Abeaid, 2013). Over 70% of the earth surface is covered by water in Oceans, lakes, rivers, ponds, lagoons and other water bodies (Rilwanu, 2014). It was reported by Timothy et al., (1994) in Rilwanu (2014) that lack of adequate potable and agricultural water supplies inhibits the progress of developing countries and is the cause of considerable hardship to humans worldwide. It is estimated that just 12% of the global population consumes 86% of the available water while 1.1 billion people (one sixth of the world's population) has no access to adequate water supplies, World Bank (2015). Yatsuka (2002) in Rilwanu (2014) reported that it is projected that by 2025, about 3.5 billion people-approximately 6.5 times as many people as in the year 2000 will live in water stressed countries.

As population increases and socio-economic lives of the populace improve, there is more pressure put on the available water resources thereby making the supply of water in most communities or settlements inadequate particularly in the developing countries like Nigeria. Governments both at State and Local Governments, even individual organizations, have been contributing to the supply of water to the people through its Public Service Infrastructure Policy (Lawal, 2003).

Despite the efforts by state and local government on drilling public boreholes in the study area, supply of potable water in the Kaduna North remain very scarce. The effective and regular water supply in many of our cities particularly Kaduna north, proved inefficient as a result of poor distribution system. Water sourced from the government is generally irregular or unreliable thus inadequate to meet the needs of the households (Adepoju and Omonona, 2009). The demand for water has been on the increase while the supply has been so low in Kaduna North that it hardly serves the people of the town. The situation of the low supply of water in areas like Tudun-Nupawa, Tudun Wada North and West, Kurmin-Mashi, and Rigasa are even worse. Also, only the borehole drilled by Local Government is most prominent in the community. Therefore there is need for proper evaluation of the spatial distribution of borehole facilities. Water projects constructed over 40 years ago when the state was created are no longer capable of providing enough water for the ever-growing population. This development has subjected the people of the study to reliance on other sources of water including rain water and groundwater.

Various studies have been carried out on the assessment and analysis of the spatial distribution of borehole facilities using GIS methods in Nigeria e.g. Awodumi and Akeasa (2017) and Mustapha and Adamu (2017) etc. Matthew and Faruq (2016) in their research, "A GIS-Based Assessment of Potable Water Network Distribution in Oshogbo, Osun State" with a view to generating baseline information for optimizing water supply and distribution systems in the city. Analogue water utility sketch map, geo-referenced, Google Earth, Landsat 8 and ASTER GTM images of the study area, were used for various analysis in ArcGIS environment. Also, the land use land cover analysis was carried out to depict urban expansion that had taken place over the years in the study area. They revealed that the city had really expanded beyond the coverage of the existing pipeline networks having covered just 21.5 sq.km (32%) of the present municipal area (67.07 sq.km).

Audu and Ehiorobo (2015) focus attention on mapping water distribution network in Warri Port Complex Nigeria using Global Positioning System (GPS), Haestad Water CAD environment, Total Station Instrument in combination with Remote Sensing imagery in developing Warri port complex water supply network was conducted. The results of the study revealed that with the provision of accurate, up-to- date geospatial information, the physical location of Nigerian Port Authority water infrastructure on or beneath the earth's surface can be determined. Also the interpretation of the geospatial database with analytical tools allowed the water distribution network to be planned more economically and effectively.

Although several researches have been done on the distribution of borehole facility as evident in the literature above, none has been done in Kaduna North despite the persistent scarcity of water supply in regions within the study area like Tudun-Nupawa, Tudun-Wada North and West, Kurmin-Mashi, and Rigasa-Wards. In addition, this research will use a high-resolution Spot imagery of 0.5 meters resolution to delineate and map the distribution of public borehole facilities within the Wards of the study area. Thus, the aim of this research is to examine the spatial distribution of functioning public borehole water facilities within Kaduna North. It is in line with the aim that the following objectives were drawn; to map out the spatial distribution of functioning public boreholes water facilities within the study area, to determine the area coverage of functioning public boreholes water facilities in respect to building in the study area, to determine areas that lack access to functioning public boreholes water and to assess the implication to lack of access public boreholes in the area of study.

2.1 METHODS

2.1.1 The Study Area

Kaduna North lies between Latitude 7°25'N to 7°29'N and Longitude 10° 35'E to 10° 29'E. Kaduna North headquarter is in the town of Doka. It is bordered by Kaduna South by the South, Igabi by the North and Chikun by the East (Figure 1). Kaduna North has an area of about 72km^2. Kaduna North headquarter is in the town of Doka. The study area is underlain by a basement complex of igneous and metamorphic rocks of mainly Jurassic to Pre-Cambrian ages. Kaduna North lies within the Tropical Continental Climate environment (Humid Tropical), characterized by a relatively long period of dry season that last between 6 to 8 months (October to April) and a shorter period of wet season i.e. (May to September) with a cool harmattan season in between these two major season.

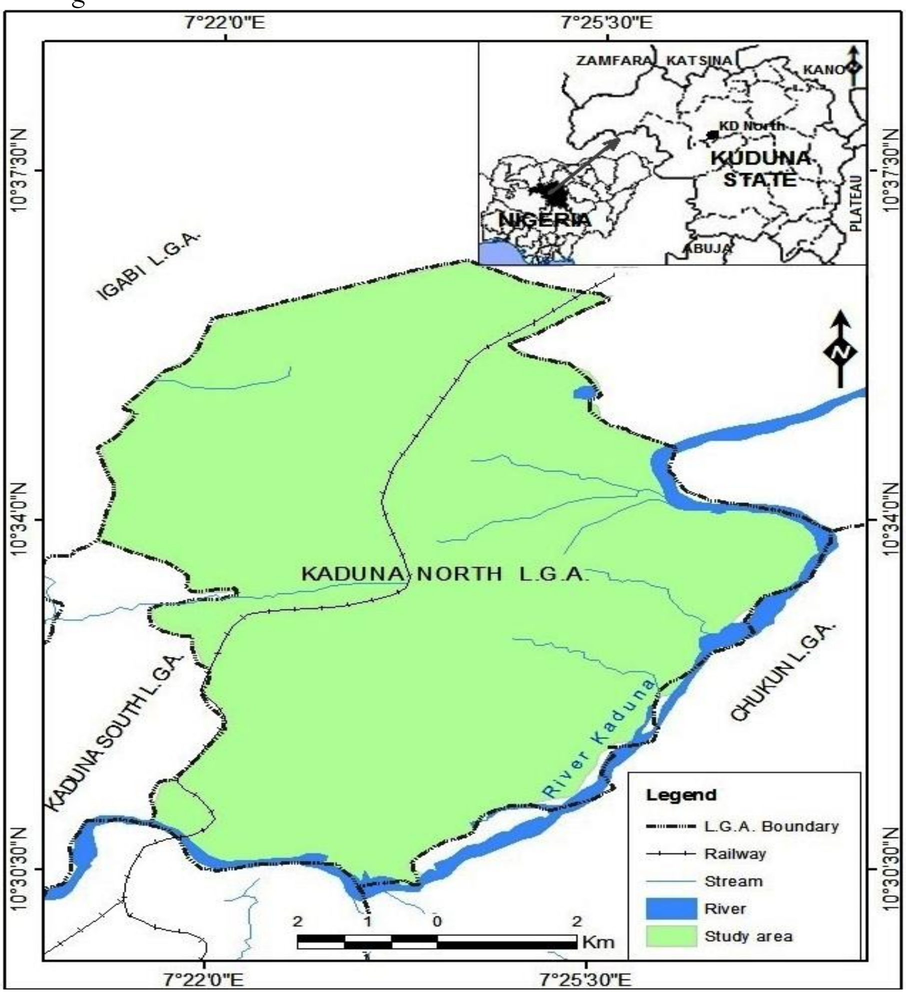

Figure 1: The Study Area; **Source:** NASA Spot Image, 2019

Kaduna North is characterized by two distinct seasonal regimes, oscillating between cool to hot dry and humid to wet season. It has an annual rainfall of between 1250 and 1500mm (NIMET, 2018). There are two main seasons; the wet and dry seasons. Wet starts in May and lasts until November and the dry season from November to April. The average annual rainfall received over 28 years is 1158.9mm, and the highest concentration of rains is in the month of August and September (NIMET, 2018). The highest temperature of 36.7°C occurs in the month of March while the lowest temperature of 30.8°C occurs in July at the peak of the rainy season; this indicates the hotness throughout the year in Kaduna. Kaduna North falls within the North central plain which the entire region is drained by the Kaduna River which is a major tributary of the River Niger. According to the 2006 figure, Kaduna North has a population of 357,694 persons and when projected to 2018 gives 1,093,725 persons (National Population Commission, 2018). In Kaduna north, the main river is River Kaduna (Figure 2). River Kaduna is a tributary of the River Niger with its source from Kujama Hill in Plateau state and flow for 210km before reaching Kaduna town. It crosses the city dividing it into north and south areas (Ogbozige *et al*, 2017).

2.1.2 Data Collection

Creation of spatial database for the assessment of boreholes is expected to aid the production of geospatial information that could serve as decision support system for borehole distribution in Kaduna North. Field survey revealed that about101 functioning boreholes are currently available in Kaduna North as at the time when this research was conducted. Therefore, the complete 101 functioning boreholes that spread across the entire 12 wards were used as the sample size. These wards are, Badarawa, Dadi-Riba, Hayin-Banki, Kabala Doki, Kawo, Maiburiji, Sardauna, Shaba, Unguwan-Dosa, Unguwar-Rimi, Unguwar-Sarki, and Unguwar-Shanu. Also, in order to have equal chance in sampling the households of the 12 wards, 20 households were randomly sampled in each of the wards making a total of 240 households in the entire Kaduna North to get residents opinion.

In designing the sampling technique for the survey, the study considered the need for an efficient spread of the sample and an even distribution of the survey. The structure of the population necessitated that the survey should cover 90% of the study area. Treating each of the wards as a separate stratum is essential to ensure a fair representation of the different segments of the population. Having considered all the relevant factors involved in the research design, it is expected to choose the stratified random sampling with optimum allocation of samples as the sampling design. The population was stratified into twelve (12) based on the wards in the study area, each selected ward representing a stratum. Since a stratified sample consists of elements selected separately from each stratum, it is generally considered a better representative of the population.

The primary instrument employed in this research for data collection is the Global Positioning System (GPS). GPS (X, Y) Coordinates of each borehole site within the study area was used to Map the spatial distribution of borehole facilities within the 12 wards. In addition, check list and interview was administered to acquire information relevant to the research such as access to public boreholes water, availability and functionality of public boreholes facility in the area, implications of inaccessibility and alternative to public boreholes water facility in the study area.

2.1.3 Data Analysis

To map the spatial distribution of functioning public water boreholes facilities in the study area, field visitation conducted with the aid of handheld Garmin GPSMap 78s receiver to acquire the coordinates of the existing functioning public borehole within the study area. The handheld GPS field record downloaded into the computer system using GARMIN Map Source 4.09 software as interface provided the ease of analysis. The downloaded GPS points were converted to text file and were added to excel. In "Open Text File", the create feature from x, y was used to display the GPS point into QGIS environment and a table created depicting the actual coordinates of each boreholes with their location address.

To determine the coverage area of functioning public boreholes with respect to building in the study area, On-screen digitization was carried out with features such as ward boundary, river, and rail-track in the study area digitized as line features; these spatial data was organized in layers. The digitizing process started by creating layer in "Create New Layer" in QGIS 3.6 Geographic Information System software. QGIS was chosen because of its flexibility in On-screen digitization. The features on the scanned image were geometrically represented as poly-line, and point. The layers created with the same reference system were added to the Map Canvas/Environment where the sketch tool was used as a "Toggle Edit" to trace the spatial feature. The road network was carefully extracted using poly-line; and the spatial distribution of the existing boreholes displayed in the GIS environment. The created vector map was overlaid on the 0.5m imagery of Kaduna North to provide a clear and accurate visualization of buildings around the public water facility. Thus, the numbers of public borehole within each ward was established. To compliment this, a Nearest Neighbor Analysis was carried out on the QGIS software to establish the pattern of distribution of the functioning public borehole water facilities.

To determine areas within Kaduna North that lack adequate access to functioning public boreholes water, mapping the spatial distribution of boreholes as stated above, it get easier to display areas or localities that lacks access to the facility within the study area. Output map revealed and examined to ascertain the specific locations that lack access. Hence, a choropleth mapping displaying the concentration of the functioning public borehole water facilities within the study location. This enabled the researcher to define areas that these facilities were inadequate or lacking. The choropleth map has five distinct classes that explain the cluster density. The implications of areas that lack the functioning public borehole water facilities were established based on the results generated from the distributional map and the choropleth map. However, actualities were detailed base on the reconnaissance survey undertaken and guided by a checklist. The implications of areas that lack the functioning public borehole water facilities were established based on the results generated from the distributional map and the choropleth map. The data obtained in this research involved descriptive and inferential statistical analysis. Data that were extracted in the GPS coordinates was analyzed and presented using percentages, chart and Nearest Neighbor Analysis.

3.1 RESULT AND DISCUSSION

There are one hundred and one active (functioning) public borehole facilities obtained from the field using the Global Positioning System (GPS) within Kaduna North and their distributions across the 12 wards (Figure 2) varies irrespective of the area extent of each ward and the population of inhabitants. It could be seen from Figure 2, that the public functioning boreholes are unevenly distributed in Kaduna North. Kabala, Badarawa and Unguwan Dosa have 9 (8.9%) functioning public boreholes each which constitute 26.7% of the entire functioning public boreholes in Kaduna North. Hayin-Banki have the highest number of functioning public boreholes, which constitutes 31 (30.7%) while Unguwar Sarki and Unguwar Rimi wards are next in number of functioning public boreholes with 10 (9.9%) each of the ward. The presence of the highest percentage (30.7%) in Hayin-Banki was attributed to the ward having the largest area extent within the study area.

Meanwhile, Maiburiji has the lowest functioning public boreholes which constitutes 2 (1.9%) only. This signifies that wards like Dadi-Riba, Maiburiji and Shaba which has some of the lowest distributions of functioning public boreholes would in no doubt rely solely on alternatives sources of water to meet their domestic, agricultural and industrial usage. According to Onugba and Yaya, (2008) in Rilwanu (2014), groundwater development is an excellent option for sustainable water supplies in Nigeria. However, to achieve a sustainable supply, planning is required hydrological and spatial data, as well as information on water demand and general socioeconomic conditions. Hence, adequate supportive services from both private and public agencies are very vital for residents in Kaduna North to enjoy sufficient hygienic water supply.

The total areas extent of the 12 wards in Kaduna North is approximately $70.8km^2$ whereas an estimated $24.8km^2$ of the entire area accommodate the functioning public boreholes (Table 1). Hence, only about 35% of the entire 12 wards are currently enjoying functioning public boreholes water whereas 64.9% remain deprived of this essential facility. This finding is support with that of Rilwanu (2016) which said that, there are 26 solar borehole in Kumbotso out of which 11 are functioning and 15 are not functioning and also it is established that there is significant difference among the eight study wards in terms of functioning and non-functioning solar boreholes at 0.05 level of significant.

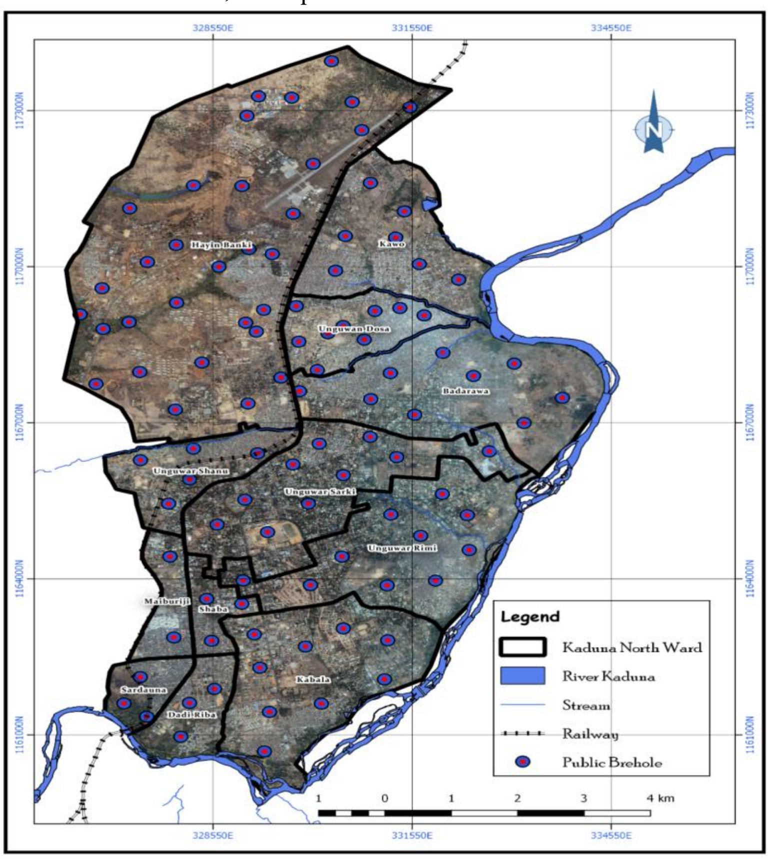

Figure 2: *Spatial Distribution of Functioning Public Borehole Facility in Kaduna North;*

Table 1: *Area Coverage of Functioning Public Boreholes Water Facility in Kaduna North*

Wards	Total Ward Area (Km^2)	Total Borehole Area (Km^2)	Percentage of Borehole Area per Ward
Unguwar Shanu	2.8	0.7	25
Shaba	1.1	0.1	9.1
Hayin-Banki	23.6	12.8	54.2
Sardauna	1.2	0.1	8.3
Unguwar Sarki	7.1	2.1	29.6
Unguwar Rimi	7.5	2.1	28
Kawo	5.6	1.2	21.4
Unguwan Dosa	2.8	0.8	28.6
Maiburiji	1.5	0.1	6.7
Badarawa	8.1	2.2	27.2
Dadi-Riba	2.0	0.1	5
Kabala	7.5	2.5	33.3
Total	70.8 (64.9%)	24.8 (35%)	

Source: Field work, 2019

Table 1 and Figure 3 describe the observed areas covered and general functionality of public boreholes water in Kaduna North. Accordingly, Hayin-Banki with the largest area amongst the 12 wards occupying approximately 23.6km^2 of the entire land area has the widest area coverage of functioning public boreholes (Table 1). This finding is similar to that of Anwuri at. El., (2015) in part of River State where a total of 197 borehole facilities were identified within an area of 8,033 square kilometers and out of this, in the Bori area 71 boreholes are located within 500 square meters radius while the total area of Woji was 30,195 square kilometers with 1756 borehole facilities. About 54.2% of the whole Hayin-Banki wards are currently enjoying adequate functional public boreholes water facility. Kabala, Unguwar Rimi and Unguwar Sarki all have an estimated ward area cover of 7.5km^2, 7.5km^2 and 7.1km^2 respectively with different area coverage as regards to the presence of functional public boreholes.

While Kabala has covered an area of 7.5 km^2 (33.3%) functional public boreholes, Unguwar Rimi and Unguwar Sarki constitutes 28% and 29.6% respectively. Out of the 70.8km^2 area of entire Kaduna North only an estimated 24.8km^2 constituting 35% are currently accessing functional public boreholes in the study area whereas about 64.9% are not (Table 1). This situation is not too good and requires paying urgent attention to, taking into consideration the rapid population increase in the study area. Furthermore, it was also observed that Shaba and Sardauna wards recorded the smallest areas extent 1.1km^2 and 1.2km^2 respectively (Table 1) but have more numbers functional public boreholes than Maiburiji ward (Figure 1). This result is substantiated by that of Awodumi and Akeasa (2017) were Alowolodu, Femi Fajobi, Tola, Boroboro and oyekola area all in the centre of the community have a clustering arrangement, possesses much amount of boreholes and hand dug wells thereby have large access to water supply in the study area while Isale-yidi Agunpopo, Ahoyaya, Estate and Adewale area all in Atiba Local Government, Oyo State have a low numbers of borehole and hand dug wells and have little or no access to water facilities.

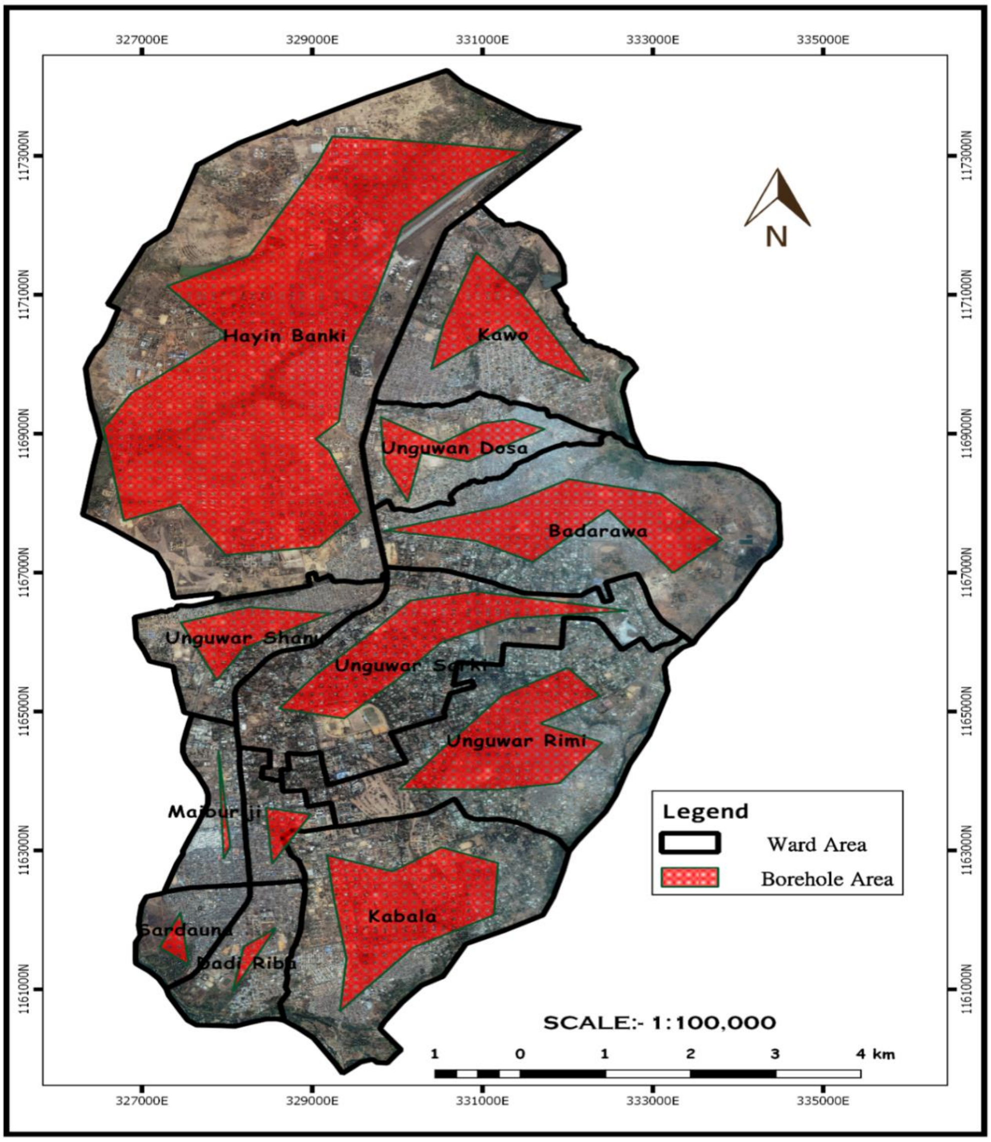

Figure 3: *Area Covered by Public Borehole Water Facilities in Kaduna North; Source: Field Work, 2019*

Table 2 reveals the functionality (101) and non-functionality (104) public boreholes in the twelve wards of Kaduna North. It could be noted that, non-functionality of public boreholes water infrastructure is also high in places like Unguwar Shanu (13), Badarawa (8) and Kawo (11), respectively (Table 2). Thus, efforts must be intensified to curb the negative trend of non-functionality of public boreholes water system in the study area. Maiburiji has only 2 functioning public boreholes and 14 non-functional; Hayin-Banki has 31 functional and 3 non-functional. This result is substantiated by that of Wali and Modibbo (2015) were out of the one hundred and forty public sources of water, seventy two (representing 51.4%) are non-functional. This indicates a poor maintenance culture of public facilities. If not rectified, initial investments made in providing the facilities will become wasted.

From table 3, 106 households of the entire sampled households constituting 44% maintained and insisted that functioning public boreholes are very accessible to them while 134 of the household respondents declared that functioning public borehole water are not accessible constitute about 56%. It can be inferred that there are several variation in wards response to accessibility of functioning public boreholes water. The highest proportion of household respondents (table 3) found in Unguwar Rimi ward indicated that they have access to functioning public boreholes with just a spatial spread of 10 functioning boreholes (Table 2). As such, inaccessibility to functioning public boreholes in the study area is more prominent in wards like Dadi-Riba (18), Maiburiji (17) and Unguwar Shanu (15) as responses by the households (Table 3). These result are opposite with the finding of (Clement at el., 2019) which stated that the borehole functionality, 195 boreholes (68.4%) were functioning while 90 boreholes (31.6%) were found non-functional in Okene.

Table 2: *Functional and Non-Functional Public Boreholes in the Study Area*

Wards	Number of Functional Public Borehole	Number of Non-Functional Public Borehole
Unguwar Shanu	5	13
Shaba	3	13
Hayin -Banki	31	3
Sardauna	3	9
Unguwar Sarki	10	7
Unguwar Rimi	10	6
Kawo	7	11
Unguwan Dosa	9	5
Maiburiji	2	14
Badarawa	9	8
Dadi-Riba	3	11
Kabala	9	4
Total	101	104

Source: Field Work, 2019

Table 3: *Public Functioning Boreholes Accessibility per Household in the study area*

Wards	Accessibility of Functioning Boreholes Per Household	
	Yes	No
Unguwar Shanu	5	15
Shaba	7	13
Hayin -Banki	12	8
Sardauna	9	11
Unguwar Sarki	10	10
Unguwar Rimi	17	3
Kawo	8	12
Unguwan Dosa	14	6
Maiburiji	3	17
Badarawa	11	9
Dadi-Riba	2	18
Kabala	8	12
Total	106	134

Source: Field Work, 2019

Figure 4 shows more clarity of household accessibility to functioning public boreholes in the study area. Hanyin-Banki, Unguwan-Sarki, and Unguwan Rimi have the highest access to the public borehole facilities given the presence of approximately 9.8 – 31 numbers functioning of boreholes (Figure 4). The implication of lack of access to functioning public borehole water is another issue that is of significance in the study area. The decisive majority of sampled household respondents confirmed the situation to be truly dramatic in this respect.

Figure 5 is explicit of household opinion of the consequences to lack of access to functioning public borehole water in the study area. Out of the 134 households (table 3) that have no access to functioning public boreholes in the study area, 32 (24%) of the respondents indicated that moderating against negative implication of inaccessibility to functioning public boreholes water believe drilling private boreholes will help to checkmate the pressure on the available functioning public ones. Most of the household respondents constituting 40 (30%) remaining committed to seeking alternative through water truckers and this is attributed to affordability. 22 (16%) and 24 (18%) households respectively maintained that collection of rainwater and enduring a longer distance walk to the available functioning public boreholes help checkmate inaccessibility, while only 16 (12%) said that, water vendors are there alternative. This finding is similar to that of Wali and Modibbo (2015) which reveal that residents of Misau town under served by public water sources they rely exclusively on buying from local water vendors as alternative to access domestic water.

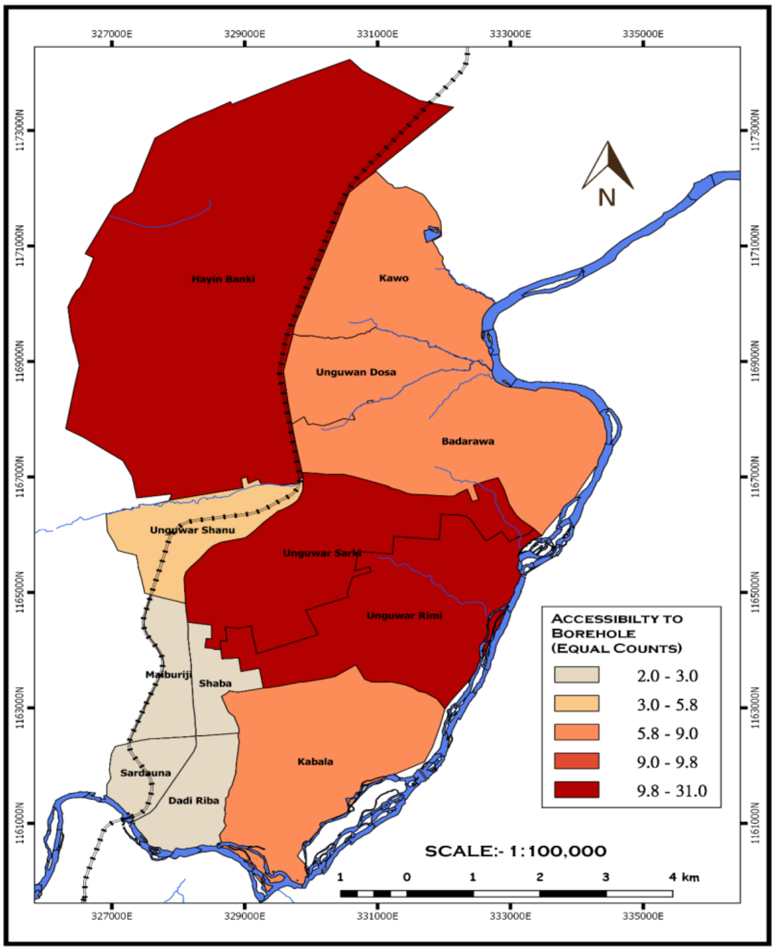

Figure 4: *Accessibility Hierarchy of Public Borehole Facilities in the Study Area; Source: Field Work, 2019*

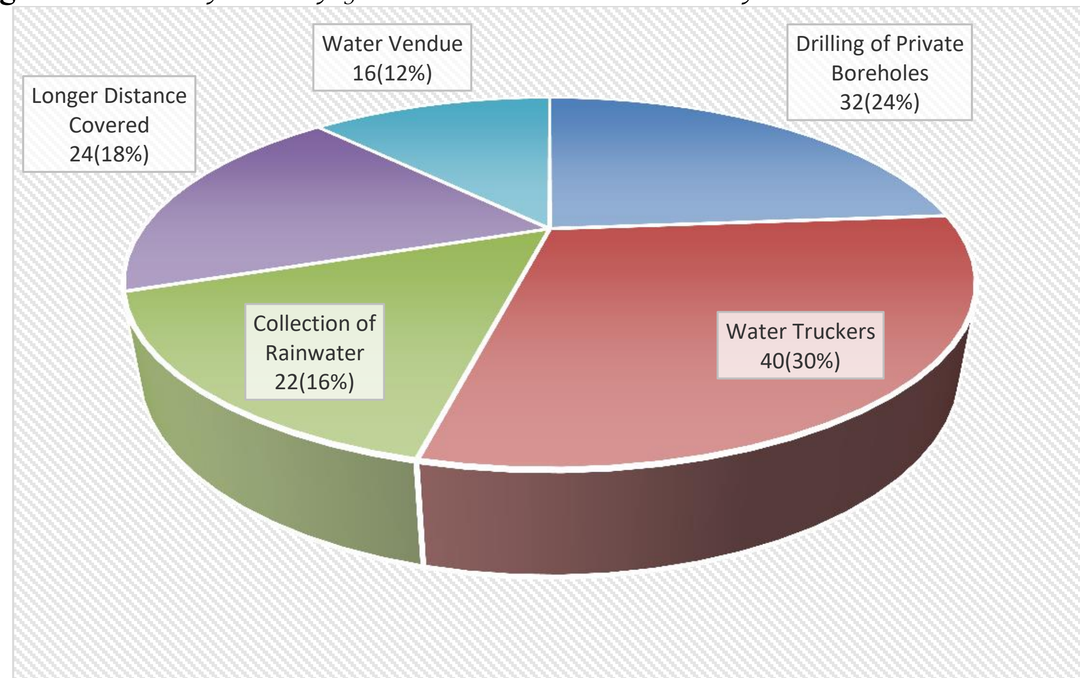

Figure 5: *Implication to Lack of Access to Functioning Public Borehole Water Supply in the Study Area*
Source: Field Work, 2019

4.1 CONCLUSION AND RECOMMENDATIONS

The findings of this research revealed that 101 functioning public boreholes were available and distributed across the study area. Out of the 12 wards that made up the entire study area, Hayin-Banki has the highest presence of functioning public boreholes with 31, followed by Unguwar Sarki and Unguwar Rimi with 10 each. The lowest number of functioning public boreholes is found in Shaba, Sardauna and Dadi-Riba wards each with 3% of the entire functioning public boreholes facilities. However, 134 household respondents declared that functioning public borehole water is not accessible in the study area constitute 56% whereas, 106 (44%) households maintained and insisted that functioning public boreholes are very accessible to them. It was discovered that 30% of sampled households upheld that curbing the implications of inaccessibility of functional public boreholes in the study area can be mitigated using water truckers.

It can be concluded that, there is inadequately functional public boreholes water facilities in the study area and the few available ones were unevenly distributed given the concentration of public boreholes in some wards that was around the city centre while other wards were inadequately served. The spatial pattern of the areas coverage of the functional public boreholes in Kaduna north was statistically proven to be random as shown by the result of the average nearest neighbour analysis. It is established that there is a relationship between the ward area covered and the availability of the functioning boreholes facilities for water supply in the study area. Wards with high area covered have more functioning public boreholes then less area covered wards. Also, the functioning public boreholes in the study area are not adequate for effective water supply.

Base on the outcome of this research, this research recommended that, non-governmental organizations, Government and well-meaning individuals should volunteer to renovate all the existing non-functional boreholes within the study area and proper maintenance practice should be carried out periodically by the communities. Also, public awareness campaigns on effective water management should be organized coupled with the establishment of water committee that will help in organizing the communities to finance the repair of non-functioning and maintenance of the boreholes. Also, more public boreholes are to be constructed in all the 12 wards of the study area by all levels of governments and non-governmental organizations for more effective water supply in the areas.

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