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Research Paper

Analysis of Distribution of Domestic Water Sources in Fufore Town, Fufore Local Government Area of Adamawa State, Nigeria – Using GIS Techniques

[1]Suleiman Baba Mustapha and [2]Gidado Bakari
[1&2]*(School of Environmental Sciences, Department of Surveying and Geo-Informatics, Adamawa State Polytechnic, Yola, Nigeria)*
Corresponding Author: Suleiman Baba Mustapha

ABSTRACT: *The study examined access to domestic water supply in Fufore town using geospatial analysis. To carry out the research, the spatial and attribute data were obtained from the field and the base map of the study area was extracted from Environmental System Research Institute (ESRI) topographic base map. The digital map was created by downloading satellite imagery of Fufore town at a maximum resolution of 8192 x 4639 pixels from Google Earth Pro. The downloaded image was geo-referenced and digitized on-screen in ArcMap 10.5 environment to create the digital map of the study area. The domestic water sources data base was created by importing the spatial and attribute data in CSV format from Microsoft Excel to Arc Catalog were geodata base was created. Various analysis was carried out which include density analysis to ascertain the concentration pattern of domestic water supply sources and proximity analysis using multiple ring buffering in ArcGIS10.5 of distance in meters was adopted, this depicted four levels of accessibility which include; optimum, intermediate, basic and no access levels of accessibility to domestic water sources within the study area. The geodata base created was also queried, this will facilitate quick possible planning alternatives which will give decision makers and stake holders' easy access to information on water sources and supply within the study area. It was found that 67% of the built-up area has basic access to water and 21% has no access to water and the residents have to travel more than 1000m to access them. It is recommended that government and non-governmental organizations should sink more boreholes in no - access water areas, and in order to have steady supply of water in the area, electric boreholes should be incorporated with solar panels as an alternative to power failure from the national grid which is the main power source for operating electric boreholes in the town.*

KEY WORDS: *Satellite Imagery, Maps, Water Sources, Analysis, Accessibility*

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I. INTRODUCTION

Water as a vital resource in the environment, has unique characteristics which makes it a desirable resource. As a universal solvent, there is no life, no economic production, and no environment without it. There is no human activity that does not depend on water. (Savenije and Vanderzaag 2002). About 97% of water on earth has high salinity content while only 3% is assumed to be safe for human consumption (Oguntoyinbo 1983). Water makes life possible as without it; life and civilization cannot develop or survive. As man's standard of living increases; so does his need for consumption of water. It is therefore not surprising that early civilizations flourished around river valleys such as those of the Nile in Egypt, Indus in India, Hwang Ho in China and Euphrates and Tigris in ancient Mesopotamia (Ayoade, 1988).

According to World Health Organization (WHO) 2003, domestic water is water used for all domestic purposes which include drinking, cooking and bathing. Therefore, when measuring adequacy of water in the household, all such uses should be considered. Bustamante et al., (2004) defined domestic water as the water needs of families for drinking, cooking, washing, sanitation and hygiene. It is not only water quality but also water quantity that is important in achieving health improvements, and quantity in turn is dependent on accessibility. The benefits of improved water supply and sanitation are many, including prevention of disease, improved basic health care, better nutrition, increased quantity and access to water, reduction in time and effort required for water collection, promotion of economic activity, strengthening of community organization, improvements in housing, and generally improved quality of life (Okun, 1988).

Adequate and safe water supply is one of the basic services, which influences economic progress of human settlements and the health of the dwellers. Although household water demands constitute the least water use in the world, which is about 6% (Cunningham and Cunningham 2004), it is however, a use that has no clearly defined substitute. It is thus a critical demand that is not negotiable. This is because domestic water use, including drinking, cooking, washing and general sanitation which entails a number of health implications. In many parts of Africa, domestic water supply is mainly the function of different traditional water supply sources; which often poses challenges to Households as supply is affected by such factors like income, household size and distance. The impact of inadequacy manifest strongly on households in terms of time and distance taken to obtain water. In modern times, there is a close relationship between water availability and economic development, especially in the developing countries.

The need for domestic water supplies for basic health protection exceeds the minimum required for consumption (drinking and cooking). Additional volumes are required for maintaining food and personal hygiene through hand and food washing, bathing and laundry. Poor hygiene may in part be caused by lack of sufficient quantity of domestic water supply which depends on the level of accessibility and efficiency of the existing facilities, in this case accessibility plays key role in domestic water supply. According to WHO (2004), access revolves around distance and time indices. These indicators show four (4) paramount levels of accessibility; No access, for the worst scenario; Basic access; Intermediate access and Optimal access all on the basis of time and distance.

Adeyemo and Afolabi, 2006 defined accessibility as the balance between the demand for and the supply of consumer services over a geographic space, and narrowing or bridging the gap between geographic spaces is all about the significance of transport. Spatial technology refers to technology used for estimation, measurement, analysis and visualization of features or phenomena that occur on the earth. This includes various technologies specially related to mapping features on the surface of the earth (Thakur et al. 2011).

Integrating Geographic Information System (GIS) database can provide utility managers reliable and scientific support decision making on water distribution network management and rehabilitation. Urban drinking water supply network is made of over ground and underground intake, pumping, improving the quality of the water, storage and transport to the user's connections in GIS environment (Pandure, 2006). Population explosion and resulting demand of appropriate infrastructure facilities are posing serious challenges for administrators and planners. Technology has emerged with solution of sustaining data on existing utilities. Obviously, effective management and planning requires updated maps and information and recent developments in the area of science and technology like GIS, Global Positioning System and Remote Sensing have come up as powerful tools. These advanced technologies can effectively be used to handle the present complex problems related to optimum utilization of available resources and infrastructure. Today, it is possible to produce accurate mapping of the underground infrastructure facilities like electrical and telecommunication cables and water pipelines (Rana, 2011).

Statement of the Problem:

The pattern of water supply varies from one settlement to another, generally as the population of a settlement increases, the service efficiency to the expanding population decreases. Only 58% of Nigerians have access to safe water (WHO and UNICEF, 2012). Thus, most households have to source drinking water from wells and streams especially in the rural and sub-urban communities. This research will however use spatial techniques in mapping, to examine the source, the pattern and level of access to domestic water supply in Fufore town as the study area as well as creating geo-database and the use of GIS techniques such as density and proximity analytical techniques to analyze the pattern and level of accessibility to domestic water supply source in Fufore town, which will assist the local community dwellers, planners, and government in solving the problems of water sources in the area.

Aim and Objectives:

The aim is to analyze the distribution of Domestic water sources in Fufore town using GIS techniques. The aim of the study will be achieved through the following objectives:

i. Identify and map domestic water supply sources in Fufore town
ii. Evaluate the distribution pattern of domestic water supply sources in the study area
iii. Assess the level of domestic water supply sources in the study area.

Scope and Limitation of the Study:

This research work was limited to Fufore town in Fufore Local Government Area of Adamawa State, Nigeria. GIS techniques was applied to determine the distribution of both private and government water sources within Fufore township with the view to determining the adequacy and accessibility of those water sources.

Justification of the Study:

There are diverse sources of supply of domestic water supply in rural and urban areas. These include; conventional communal sources and self-supply sources. The conventional communal sources are justified for improved water quality and use of high-level technology like drilled boreholes equipped with hand pumps, collection tanks and protected springs as well as concrete lined wells (Carter et al., 2005). However, the conventional communal facilities in most of the rural areas in the developing countries have been proved not to be sustainable because of their high rate of breakdown as a result of poor operation and maintenance, congestion, difficulty in operating the pumps and long distances because sources are too few and yet rural households are many and scattered (Brett et al., 2007). To ensure that rural households are water secure, it necessary to evaluate the number, geographic location, yield, dependability, season and quality of the water sources (Kahinde et al., 2007).

Research Questions:

i. Are the domestic water Sources within Fufore Township identified and mapped? ii. Are the distribution pattern of domestic water sources within Fufore Township evaluated? iii. Are the domestic water supply sources in Fufore town accessible to the inhabitants within short range distances?

Research Hypothesis:

1. HO: There is no optimum access to domestic water supply in Fufore town.
2. H1: There is optimum access to domestic water supply in Fufore town.

Significant of the Study:

Demands for household water have no clearly defined substitute. It is thus a critical demand that is not negotiable. The outcome of this study will test the strength of households' water supply in the study area, which includes the number, geographic location, yield, dependability, condition and quality of the water sources. Additionally, the study will provide various levels of accessibility of household water ranging from optimum, intermediate, basic and no-access which will serve as reliable and scientific support decision making strategy on water distribution, management and rehabilitation. This research will help in solving reality of complexities on access to domestic water source relation to population growth through mapping and creating of geo-database which will assist to create awareness in both government and individual on proper distribution and management of this invaluable resource, and at the same time provide quick possible planning alternatives, giving decision makers and stakeholders better choices.

II. STUDY AREA

Fufore town is the headquarters of Fufore Local Government Area situated in the North-Eastern part of Nigeria and located between latitude 8^0 45′ and 9^0 35′ North and longitude 12^0 15′ and 13^0 15′ east. The local government area has a total land mass of about 3,666 sqkm (Musa and Tukur 2009), and a total population of 207,287 (NPC, 2006) and 2022 projected total population of 371,255. The area is regarded as low lying with about 80% of the entire area being at less than 300m above sea level, while the remaining 20% are hills and mountains (Fadama II, 2008).

The area has a Sudan type of vegetation and a tropical climate marked by wet and dry seasons (zemba et al, 2010). The minimum temperature recorded is about 15^0C and a maximum of about 40^0C (104.00F). Day time temperatures can easily exceed 40^0C during the dry season (April/May). The local government area shared a common boundary with Girei local government area on the North and Cameroon Republic on the East divided by river Faro. It's also shared a boundary with Jada local government area on the South and Yola South local government area on the West.

The major indigenous ethnic group found are Fulanis, however, there are some indigenous groups found in minority such as Bata, Vere, Chamba and Hausa. There are some few immigrants known as Godogodo/Laka who migrated from neighboring countries like Cameroon and Chad and are based permanently within Fufore town and the local government at large. The major occupation of these people are cattle rearing by the Fulanis and crop farming by the minority tribes and immigrants. Both rainy and dry seasons farming are practiced in the area. The major crops produced are guinea corn, maize, groundnut, rice, and vegetables. Figure 1 below shows the maps of Nigeria, Adamawa state, Fufore local government area and Fufore town, the study area.

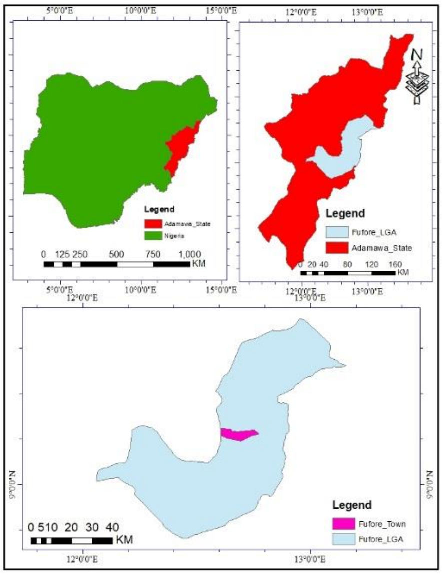


Figure 1: Maps of Nigeria, Adamawa state, Fufore local government area
and Fufore town, the study area.

III. MATERIALS AND METHODS

The materials/equipment used include; 1. Hard wares and 2. Soft wares. The hard wares include; a. one Differential Global Positioning Systems (DGPS) Promac-3 b. one HP Laptop altech G61 with 2.00 GB RAM & 250GB Hard disk plus 500GB external hard disk storage capacity. c. One HP Printer P1102 series and d. one HP 1310 Photocopier. The Soft wares includes; a. ArcGIS 10.5 b. Google Earth Pro c. Microsoft Excel 2013 and d. Microsoft word 2013. There were two types of data acquired for the research. These include; i. Spatial data and ii. Non spatial data. The spatial data are X,Y,Z coordinates of the locations of all water sources within Fufore town and topographic maps and satellite images covering the study area. The water sources include electric boreholes, solar boreholes, hand pump boreholes and wells. The non-spatial data otherwise known as attribute data were information obtained through social interview on the residents where those water sources are located. The attribute information includes name of the developer, private/public, sources type, address of the water sources and the condition of the water sources whether functional or not. The sources of data for this research is classified in to primary and secondary sources of data. The primary sources of data are Adamawa State Ministry of Land and Survey, Yola and Google Earth where analog topographic maps and satellite images covering the study area were respectively obtained. The secondary sources of data is direct survey field work where DGPS equipment was used to obtain X,Y,Z coordinates of the locations of all domestic water sources and their attribute data which was obtained by administering social interviews on the residents where those water sources are located.

Before executing the research, office and field reconnaissance survey were firstly carried out. Office reconnaissance survey involved arrangements of survey team and a vehicle for the field work operation. Also, during this period, satellite imageries covering the study area was downloaded from the Google Earth Pro. (See figure 2 below). Master control station available in the study area was also identified from the topographic map covering Fufore town and its coordinates extracted. The Satellite imagery showing Fufore town at a maximum resolution of 8192×4639 pixels was also downloaded from Google Earth Pro. The imagery served as a preliminary step in producing the base map showing features of interest in the study area. The field reconnaissance survey involved arrangement for acquisition of DGPS equipment and identification of all domestic water sources within Fufore town and the available master control station on the ground. One master control station was identified on the ground which was used as a reference point for determining the X,Y,Z coordinates of all available domestic water sources within Fufore township. Having carried out reconnaissance survey, the spatial data were obtained in the field using DGPS equipment and the attribute data were obtained through social interview administered on the residents where those water sources were located. The spatial and attribute data were obtained simultaneously.

Figure 2: Satellite image of Fufore town

IV. DATA PROCESSING

To process the data, the base map for the study area was extracted from Environmental Systems Research Institute (ESRI) topographic base map. The base map was extracted in Arc Map 10.5 environment as shown in figure 4. The digital map was created by downloading satellite imagery of the study area at a maximum resolution of 8192 x 4639 pixels via Google Earth Pro. The downloaded imagery was geo-referenced using the tool in Arc Map 10.5 to register the imagery to a known ground coordinates at a projected coordinates system of WGS 1984 UTM Zone 33N. The imagery was digitized on screen in Arc Map 10.5 where buildings, roads, river, markets etc. shape files were created from the Arc catalog to create a digital map of the study area showing various sources of water supply in Fufore town as presented in figure 5. Having created the digital map of the study area, domestic water sources database was created by importing the spatial data and the attribute data in CSV format from Microsoft Excel to Arc catalog where geodatabase was created. The data analysis was performed to obtain level of accessibility of various domestic water sources in the study area such as electric boreholes, solar boreholes, well and hand pump boreholes. Multiple ring buffer tool of the Arc tool box was used to create buffer distances of 1-30m, 31-100m, 101-1000m and 1000m and above around each sources type. Queries were also made to test the efficacy of the system. The flow chart of the methodology is here by presented in figure 3 below.

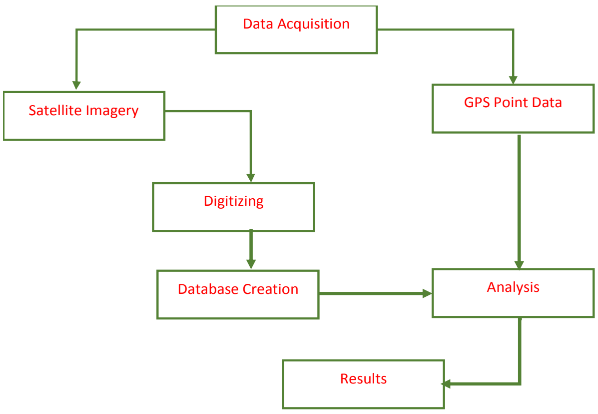
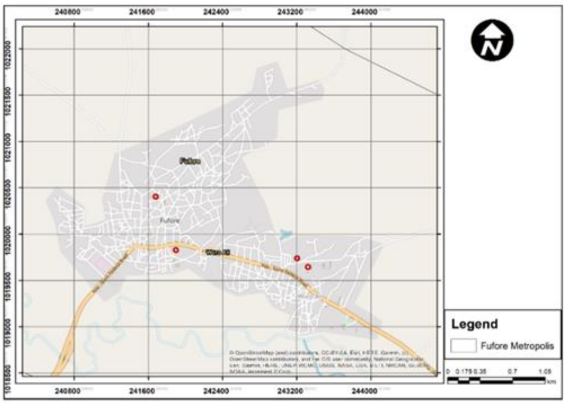


Figure 3: Flowchart of the Methodology

V. RESULTS PRESENTATION AND DISCUSSION

The results of this research are basically in the form of maps, charts and tables as presented below:



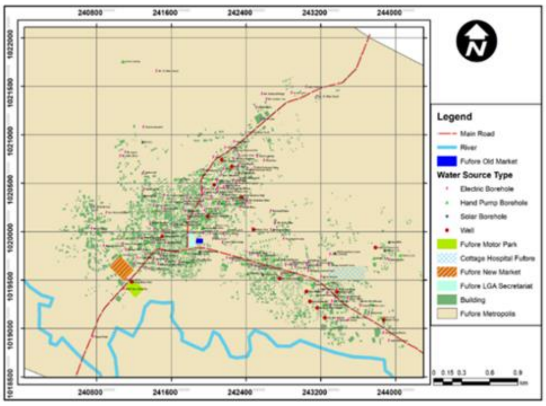


Figure 4: Base map of the Study Area **Figure 5: Various Source of Water Supply in Fufore Town**

A topographic base map that serves as the basis depicting mapping elements in their geospatial context, was extracted from Environmental Systems Research Institute (ESRI) topographic base map. The map was extracted in Arc Map 10.5 environment. The base map is shown in the figure 4 below. Figure 5 shows how various sources of water supply are distributed on the base map of the study area. It was compiled from the geo-database created from the coordinates of public water supply source in the study area.

Sources of Domestic Water Supply

Table 1 below shows the summary of various sources of domestic water supply in Fufore metropolitan area. These sources include water supply source, whose coordinates (XYZ) were taken on the field to create geo-database for the spatial analysis.

Table 1: Sources of Water Supply in Fufore Town.

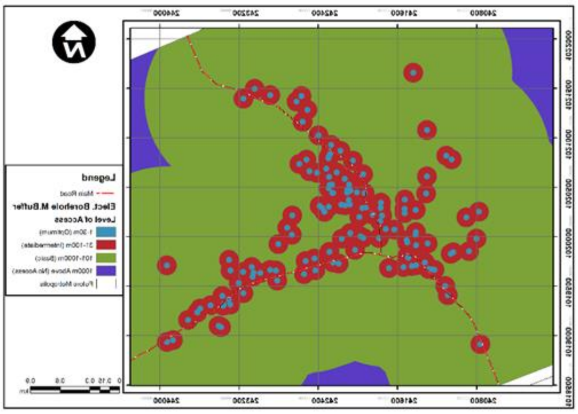
S/N	Source of Water Supply	Number of Points	Percentage (%)
1.	Electric Borehole	130	69.15
2.	Solar Borehole	7	3.72
3.	Well Water	16	8.51
4.	Hand pump Borehole	35	18.62
Total		**188**	**100**

From Table 1 above, it can be deduced that in the study area, electric borehole is largely accessible with a large margin (69.15% coverage) when compared to other sources of water supply. This can be attributed to the fact that the study area is the capital of Fufore L.G.A. and access to electricity in the area could be the reason for these results.

Accessibility to Domestic Water Supply Source

Accessibility to Electric Borehole

Figure 6 shows the spatial distribution of electric boreholes and its level of accessibility to the built-up area. Large area falls within the level of basic source which covers 15482044.493871 square meters. This implies that it takes majority of people 100m to 1000m to reach a particular electric borehole in Fufore metropolis.



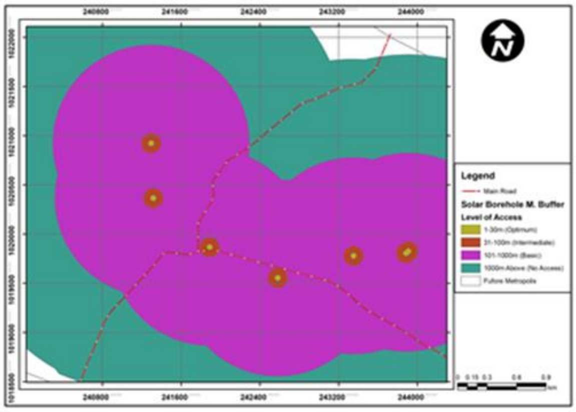
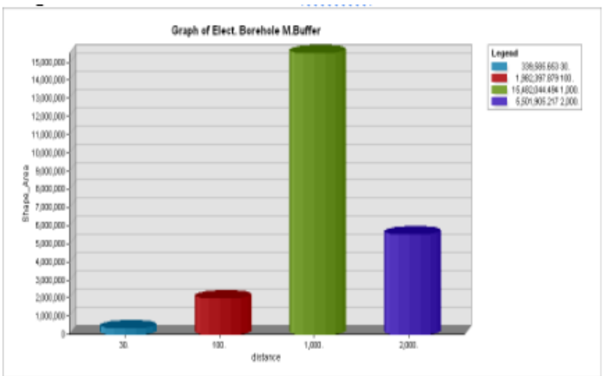


Figure 6: Multiple ring buffer of electric borehole water supply in Fufore Town
Figure 7: Multiple ring buffer of solar borehole water supply.

Accessibility to Solar Borehole
Figure 7 shows the spatial distribution of solar boreholes and its level of accessibility to the built-up area, large area falls within the level of no-access with a coverage area of 12415138.925024 square meters which takes majority of people more than 1000m to reach the solar borehole in Fufore town.



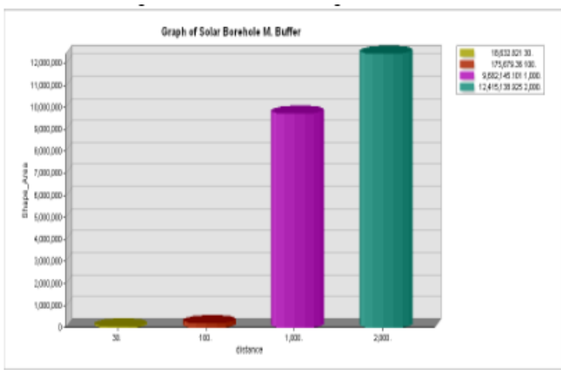


Figure 8: Graph showing Accessibility to Electric Borehole Figure 9: Graph showing Accessibility to Solar Borehole

Accessibility to Hand-Pump Borehole
Figure 10 shows the spatial distribution of hand-pump boreholes and its level of accessibility to the built-up area, large area falls within the level of basic access with a coverage area of 13673625.62273 square meters which takes majority of people 100m-1000m to reach a hand-pump borehole in Fufore town.

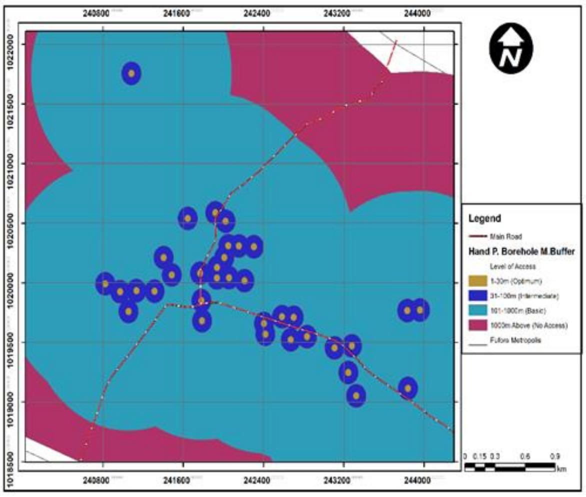


Figure 10: Multiple ring buffer of Hand-Pump borehole water supply.

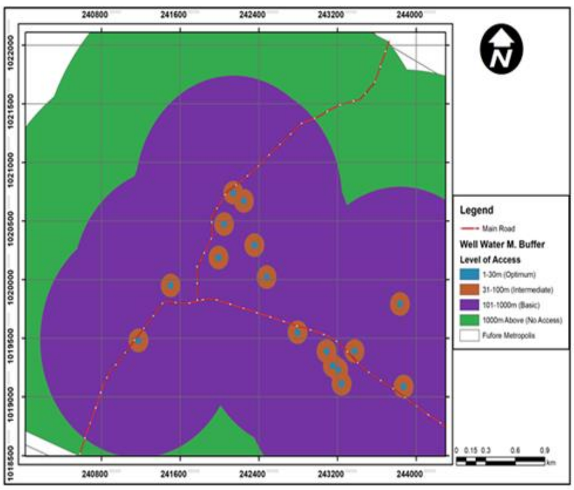


Figure 11: Multiple ring buffer of well water supply in Fufore Town.

Accessibility to Well Water

Figure 11 above shows the multiple ring buffer of well water in the study area, the analysis in figure 11 indicated that the level of basic access covers large area (11273340.882623 m^2), which implies that a lot of people will have to move 100m to 1000m to access well water in the study area.

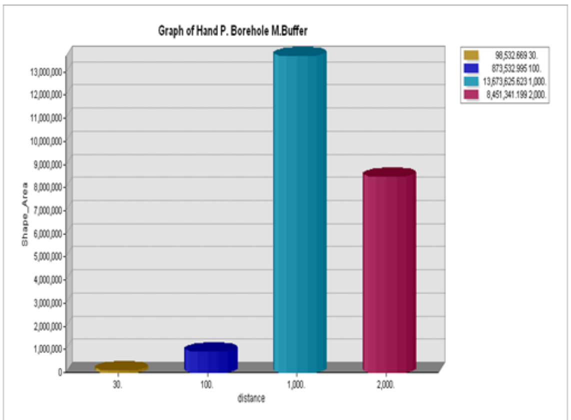


Figure 12: Graph showing Accessibility to Hand-Pump

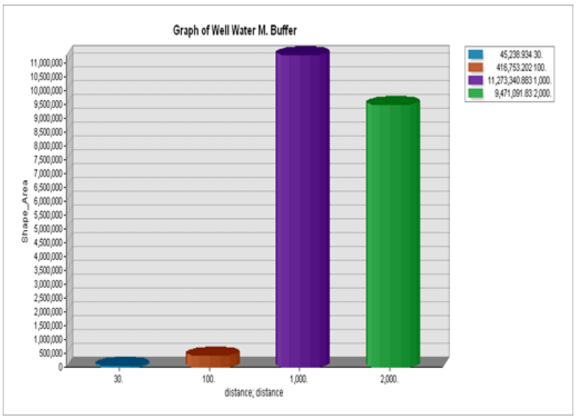


Figure 13: A Graph showing Accessibility to Well Water

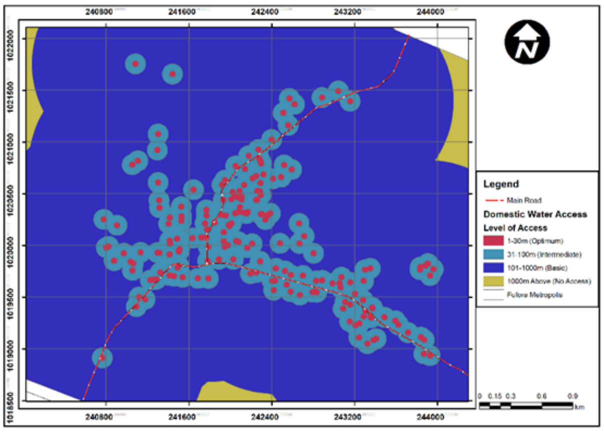


Figure 14: Map showing water supply in Fufore metropolis buffered in meters

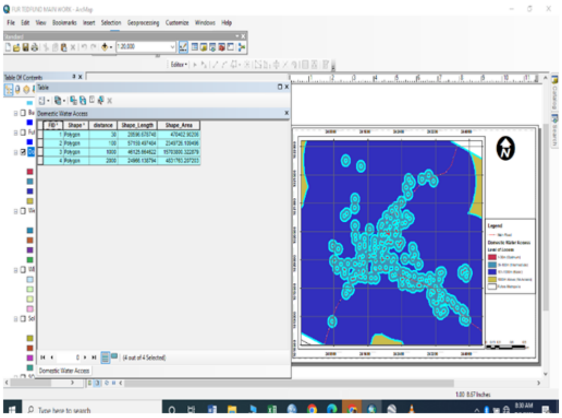


Figure 15: Graphic user interface showing the area (in square meters) of water accessibility

Accessibility to Domestic Water Supply (All Water Sources)

Figure 14 above shows the result of buffer analysis against all criterion, namely Optimum, intermediate, basic and no-access. Figure 15 above shows the area of coverage in square meters of accessibility levels namely, optimum, intermediate, basic and no-access in the study area. Optimum level (1-30 m) covered an area of 470402.9021m^2, intermediate level (30-100 m) covered an area of 2349726.109m^2, basic (100-1000 m) has 15703800.32m^2 and no-access covered 4831763.207m^2.

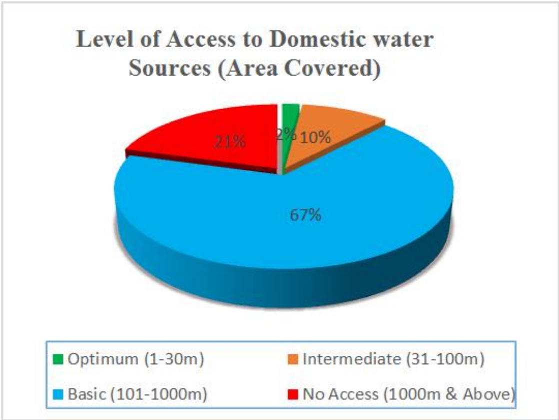


Figure 16: pie chart showing the percentage of water accessibility levels in Fufore town

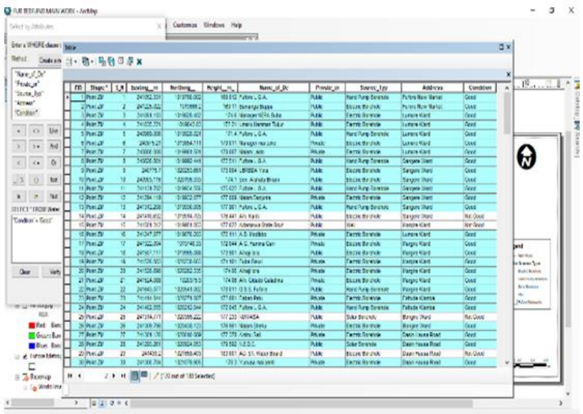


Figure 17: database showing the query result of 170 water source that are in good working

Geodatabase Creation

A geodatabase for both the spatial and attributes data of the water sources was created from which, queries were made to answer other research questions and manipulations, such that updates and retrievals can be easily made with time. The coordinates and their attributes were copied into Microsoft Excel 2013 environment from the DGPS device and then was saved as CSV (comma delimited) format. This was then imported into ArcGIS 10.5 from which queries were made. The figure 17 above shows one of the queries carried out to test the efficacy of the database.

VI. Discussions of Results

This research project aimed at examining the spatial analysis of access to domestic water supply source in Fufore town of Adamawa state. In the course of the study, the location of the existing water sources and water supply type were identified and mapped namely, electric borehole, solar borehole, hand-pump borehole, and well water. The locations collected were then subjected to proximity analysis in ArcGIS 10.5 using four different buffer distances namely 1-30 m, 30-100 m, 100-1000 m, and 1000 m and above that corresponds to the four-criterion tested as optimum, intermediate, basic and no-access levels to the built-up area respectively.

Figure 16 above, depicted that, in Fufore town only 2% of the built-up area have optimum access to water supply. consequently, 10% of the built-up area are at intermediate level of water accessibility. Basic level takes the larger proportion covering 67% and no access level takes 21%. A whooping percentage of 67 in the built-up area of Fufore town has basic access to water, and a cumulative percentage of 88% of the built-up area have to go as far as 100 to more than 1000 meters to access water. This is similar to the findings by George and Jacob (2010) in accessibility of water services in Kisumu and Meshach Omada (2018) in spatial analysis of access to domestic water supply in Gyel district, Jos South Local Government Area, Plateau State, Nigeria.

VII. Research Findings

From the results obtained in this study, the following findings were obtained.

i. The study identified a total of 188 existing water supply locations within the study area (Table 1). Out of the 188 locations 130 (69.15%), 16(8.51%), and 35 (18.62%) are electric boreholes, well water and hand-pump borehole respectively and its level of accessibility to the built-up area, shows that large area falls within the level of basic which takes people 100 to 1000 meters to reach these source types. However, solar borehole, 7 (3.72%), cover large area within the level of no-access which takes people more than 1000 meters to reach this source type.

ii. 67% of the built-up area in Fufore metropolis has basic access to water, this implies that majority of people living in the built-up area of Fufore town will have to move more than 100 meters to access water for domestic use.

iii. Out of the 188 water sources in Fufore town, 170 are in good working condition while 18 are not working.

iv. The number of water sources within Fufore town are adequate to cater for the water demand of the populace but despite that, the water supply is not steady due to the fact that most of the water sources are electric boreholes which depend solely on limited power supply from the national grid.

v. Water sources in Fufore town share a close proportion of ownership i.e. public 98 (52.13%) while private 90 (47.87%).

vi. In addition to bore holes and wells, there is river Beti located on the southern end of Fufore town, the river extends from east to west and pours its content in to river Benue located about 20km west of the town. The river is occasionally used for domestic purposes too.

VIII. SUMMARY

Having carried out the office and field reconnaissance survey, the DGPS equipment was used to determine the spatial data i.e. X,Y,Z coordinates of all the water sources and their attribute data was obtained through social interview administered on the residents where those water sources are located. To process the field data, the base map of the study area was extracted from Environmental Systems Research Institute (ESRI) in ArcMap 10.5 environment and the digital map was created by downloading satellite image of the study area at a maximum resolution of 8192 x 4639 pixels from Google Earth Pro, the image was geo-referenced and digitized on-screen to create the digital map of the study area necessary for the geospatial analysis. The domestic water sources data base was created by importing the spatial and the attribute data in CSV format from Microsoft excel to Arc Catalog where Geo data base was created. Data analysis was performed in ArcMap 10.5 to obtain level of accessibility of various water sources. Multiple ring buffer tool of the Arc tool box was used to create buffer distances of 1-30m, 31-100m, 101-1000m and 1000m above around each source type that corresponds to the four-criterion tested as optimum, intermediate, basic and non-access levels to the built-up area respectively.

The study identified a total of 188 existing water supply locations within the study area. Out of the 188 locations 130 (69.15%), 16(8.51%), and 35 (18.62%) are electric boreholes, well water and hand-pump borehole respectively and its level of accessibility to the built-up area shows that large area falls within the level of basic which takes people 100 to 1000 meters to reach those source types. However, solar borehole, 7 (3.72%), cover large area within the level of no-access which takes people more than 1000 meters to reach this source type. From the analysis it is also clear that in Fufore town only 2% of the built-up area have optimum access to water supply. Consequently, 10% of the built-up area are at intermediate level of water accessibility. Basic level takes the larger proportion covering 67% and no access level takes 21%. A whooping percentage of 67% in the built-up area of Fufore town has Basic access to water, and a cumulative percentage of 88% of the built-up area have to go as far as 100 to more than 1000 meters to access water. Out of the 188 water sources in Fufore town, 170 are in good working condition while 18 are not working and the water sources share a close proportion of ownership i.e. public 98 (52.13%) while private 90 (47.87%).

IX. CONCLUSION

The analysis of distribution of domestic water sources in Fufore town was conducted successfully. In the course of the study, a total of 188 water sources were identified and mapped as presented in figure 5. Out of the 188 water sources, 130(69.15%) are electric boreholes, 35 (18.62%) are hand pump boreholes and 16(8.51%) are well water. According to the analysis carried out, 170 are in good working condition and only 18 are not working. Their level of accessibility shows that 67% of the built-up area in Fufore metropolis has basic access to water. However, 7(3.72%) are solar boreholes which covers large area within the level of no access which takes people more than 1000 meters to reach those sources type, and in general, area coverage of $4831763.207m^2$ has no access to water in the town. From the study it is clear that the number of water sources within Fufore town are adequate to cater for the water supply demand of the populace. However, the water supply within the town is not steady due to the fact that most of the water sources are electric boreholes which depend solely on limited power supply from the National grid.

Contribution to Knowledge and Scientific Break Through

All the literature reviewed indicated that the analysis of the accessibility of water sources supply was made manually base on the distribution of water supply sources on the base maps of their study areas. However, in this research, proximity analysis was carried out to create buffer maps using multiple rings to show the level of accessibility of various domestic water sources supply with the standard of distance 1-30, 31-100, 100-1000 and 1000 above.

X. RECOMMENDATIONS

Having successfully completed the study and base on the findings made, the following recommendations has been made: -

1. Government and non-governmental organizations should sink more boreholes in no access water areas.
2. Electric boreholes should be incorporated with solar panels as an alternative to power failure from the national grid.
3. More researches should be carried out periodically to review the situation on ground.

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