Bima Journal of Science and Technology, Vol. 4(1) July 2020. ISSN: 2536-6041

IDENTIFICATION AND MAPPING OF DOMESTIC WATER SUPPLY SOURCES IN GYEL DISTRICT OF JOS, PLATEAU STATE, NIGERIA

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ABSTRACT

The challenges of public water supply in most cities and suburban areas of developing countries are increasing with increase in population, poor operational efficiency of existing waterworks and infrastructure, leakages, low reticulation coverage, poor service delivery and poor cost-recovery. The study is aimed to identify and map the public water supply sources in Gyel District of Jos South Local Government of Plateau State, Nigeria. The study adopted the use of Satellite data, coordinates of various sources of domestic water and their attributes, population data coupled with a structured questionnaire and photographs from field in achieving the objectives of identifying and mapping of water supply sources in the area. Spatial analytical method such as; Density and Proximity analysis were used to identify the water sources with the aid of ArcGIS 10.3 tool in Mapping and Geo-processing, while SPSS and Microsoft software were used for computing the statistical analysis. Thus, the result obtained was; Hand dug well has the highest frequency of coordinates among the public water sources like public bore holes and pipe borne water, in which 60% of the respondents used it as their primary source of domestic water supply. The pattern of the distribution of water supply facilities were found clustered around the city centre and well planned cadastral area, this exert serious pressure on access to the sources especially on those within the unplanned and newly developed area as only 32% of the respondents have access to the public domestic water sources. Most of the built-up areas which constituted the households fall within the basic access and No-access level where the standards for domestic water usage are not met. Therefore, the following recommendations were suggested, which are; Encouragement for the provision of more domestic water sources by the Plateau State Water Board (PSWB), The Jos metropolitan Development Board (JMDB) should ensure built-up areas adopt town planning standard and the PSWB should ensure periodic extension service of water supply facilities in the area.

Keywords: Identification, Mapping, Water Supply, Domestic Sources, Gyel District

INTRODUCTION

Water is increasingly becoming a scarce resource in almost all countries and cities with growing population on the one hand, and fast growing economic, commercial and developmental activities on the other (Ali, 2018). This scarcity makes water both a social and an economic good whose users range from poor households with basic needs to agriculturists, industries and commercial undertakings with their needs for economic activity to rich households for their higher standards of living. Increasing demands for water resulting from economic growth, climate change, pollution and concomitant population growth, therefore work to increase pressure on available resources. Water pollution affects international water bodies, reducing their potability or irrigation potential for wholly innocent populations who don't depend on treated water from the government agencies thereby imposing serious scarcity (FAO, 2012 and Ali, 2018). Most of the world's surface and groundwater systems have been modified from their natural state and water abstractions of any volume have an impact on the health of a system and so have the potential to compromise natural assets and ecosystem processes. It is common knowledge that human influence is so pervasive and has had such significant impacts on rivers, lakes, wetlands, estuaries and aquifers on the entire ecosystem which in turn can affect the health and the economy of the citizens adversely. When water for the environment is not managed or is poorly managed, the impacts on system health can impose additional consequences on all other users of the affected water bodies (Australian Water Partnerships, 2018).

Integrating GIS database can provide utility managers reliable and scientific support decision making on water distribution network management and rehabilitation (Soakodan,*et al.,*2011), GIS is applied in four sections of the water infrastructure sector: asset management, distribution management, customer and outage management (Brussels, 2005). It is ideal to manage infrastructure by integrating all the information systems within a section. GIS is further applied in the entire lifespan of water supply systems from planning to implementation, operation and maintenance to replacement in mapping water resources, tracking water volume supplied and monitoring pipes against bursts and leakages.

GIS provides a variety of support asset inventory (keeping record of pipes, valves, fittings, hydrants and meters together with their characteristics and status); determining and prioritizing repair and replacement works and to be able to excavate and replace a damaged pipe at the exact route and depths required. This has the advantage of preventing waste of resources when buried pipes can be traced, of which Geographical Information Systems(GIS) data can be used to solve it, Moreover, service continuity can be ensured by limiting repair and maintenance time through spatial scenario modeling, locating areas affected by particular problem and informing the affected area (Zhang, 2006).

Spatial technology provides quick answers to many issues regarding domestic water distribution network such as: provision of service, planning and maintaining network infrastructure, managing existing customers, finding new customers and administering network coverage. MacDonald, Dochartaigh and Welle (2009) mapped water and sanitation in Ethiopia. ArcGIS was used to come up with spatial distribution of water location in the three Wards which are, Woredas, Benishangul and Gumuz in Ethiopia which was subsequently overlaid on vectorized hydro-geological map of the region. The results revealed that hand pumps failure in this region were that of the reduced yield of the aquifer and deep-seated water level during the dry season. The study also informed the planners of the need to channel more funds for the maintenance of the schemes in the affected areas (Matheaus, et al, 2017 and Atser and Udoh, 2014).

Tao and Gregory (2007) studied thespatial analysis of household water supply and demand in a distributed geographic network in the towns of Amherst and Clarence, New York**.** Spatial network models were constructed in Geographic Information Systems environment for simulations. Baseline data of household water consumption per person per day, their population distribution and transportation capacity of water main utility lines was collected for the model simulation in ArcGIS environment. The results indicated that as the network extended eastward, southeast part of the Amherst and three of the four sub-regions in the Town of Clarence encountered the discrepancy of supply capacity in meeting the accumulated household water demand. In recent times, domestic water scarcity was severe in Gyel district area of Jos South Local Government in Plateau State, as the water supply from the source has not kept pace with the population increase, this existing problem has necessitated the study to identify and map domestic water supply sources in the area.Water point mapping databases, generated through surveys of water sources such as wells and boreholes, are now available in many low- and middle-income countries, but often suffer from incomplete coverage (Yu, *et al*., 2019).

MATERIALS AND METHODS

Study Area

Gyel District is located between Latitude 9° 46'0" N and 9° 52'0"N, north of the equator and Longitude 8°48'0"E and 8°52'0"Eand is relatively bounded in the North by Tudunwada and Hwolshe in Jos north LGA, while in the south by Vom district, west by Bassa LGA and in the East by Dadinkowa,Whytt and Raholkanang respectively**,** in Jos South Local Government Area of Plateau state which covers the total land area of 81.9km/sq approximately. Ojo, Gbuyiro and okoloye (2004) asserted that the influence of the oscillation of the Inter Tropical Discontinuity (ITD) is completely modified by the high altitude of the Plateau. The area has more cold weather than most parts of Nigeria on the same latitude**,** it is characterised with an Average monthly temperatures range between 21–25 °C, these cooler temperatures have made it a semi-temperate like area. It receives about 1,400 millimetres rainfall annually between April and October with the precipitation arising from both conventional and orographic sources, owing to the location of the area.

Gyel district is an area of Younger Granite intruded into the older basement complex rocks which covers the entire locality and other neighboring localities. These younger granites are thought to be about 160 million years old. This creates unusual scenery of Jos. There are numerous hilly rocks with gentle slopes, characterized by a long period of weathering and erosion (Iloejo, 1981).Omotosho (2007) asserted that the average elevation of the Jos Plateau is about 1150 meters above mean sea level and the highest peak on the Shere hills which is about 1777 meters above sea level. However, the area is dominated by relief average altitude of 1,217m, with depressions which pave way for drainages adjoining the plain area.

Also, according to Adams (2000), the drainage pattern on the area is in a radial pattern where the many rivers and streams diverge from the top of the plateau and flow away to different directions, some of the streams drain into river Ganawuri and Kaduna. The population the study area was 145,750 from 2006 population census projected to 193,406 as at 2018, it comprises 24communities mostly dominated by the Berom, Hausa, Yoruba, Ibo and other minor tribes from within and outside plateau state which most of them are Christians combined with the Muslims, The area is known for vegetable farming, animal grazing; Rock quarrying, Tin Mining activities and marketing, (Barbour, 1982).

Nature, Types and Sources of Data Used

Data used in the research work and their sources are as contained in Table 1:

Data Pre-Processing

This include geo-referencing, delineating the study area using the data collected to create of geo-database and feature classes which were digitized into map format used for the spatial analysis. All the maps acquired were properly geo-referenced in ArcGIS software and Geo-corrected to a common Projection System (UTM, Clarke 1880), and to a common Geo-TIFF data format. The maps were also geo-coded to a common resolution with the quick bird satellite image at a resolution of 0.6m to ensure both compatibility and data standard.

A shape file was created in ArcGIS to delineate the boundary of the study area and to show the extent of features necessary for the research analysis.

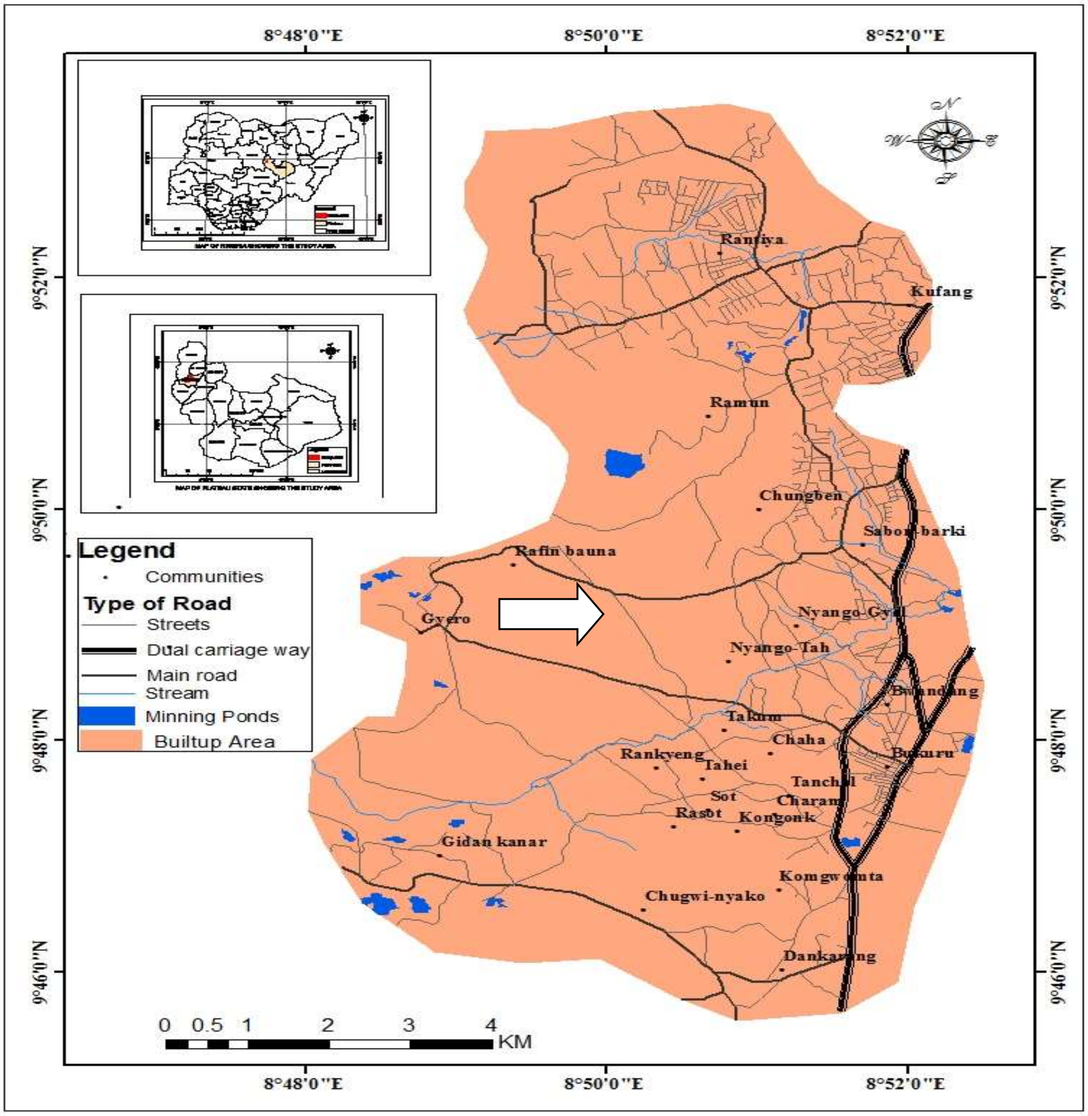

Figure 1: The Study Area

Source: Modified from Quickbird Satellite Image, 2015

Table 1: Data Used

Data used	Data source
Coordinate of Public Reservoirs, hand dug well, water supplying pipes network, bore holes and water hydrants	Field work and plateau state water board, Jos
Quick bird satellite image (0.6 m resolution) of 2015	National centre for Remote sensing, Jos
Population data.	National population commission, Jos
Photographs of the current situation of water supply source	Field work
Statistical data	Questionnaires administered
Journals and other published documents on water supply	Library and Internet

Sampling Technique and Size Determination

Stratified random sampling techniques was adopted for the administering of the questionnaire for the study, A total number of three hundred and eighty four (384) questionnaires were distributed, in which the entire 24 communities within the study area covering both the urban and rural area were randomly and proportionally represented with the total population of 145,750, using the formula by Krejcie and Morgan (1970);

$$n^1/n \quad x \quad N = N^1/N \quad x \quad Q \qquad (1)$$

Where n^1: Sampled population for individual community

n : Sum total for the population of the whole sampled communities

N^1: Sampled proportion for individual community

N: Proportion of the sample size which is 100%

Q: Total Questionnaire Administered 384

Data Collection, Creation of Geo-Database and Data Analysis

This involve reconnaissance survey, the use of questionnaire, during the field work, in which 384 questionnaires were distributed to households and 263 retrieved back, personal observation was also conducted to gain more insight on domestic water supply in the study area also the use of GPS receiver to collect the coordinates of various water facilities and digital camera for photographs. The coordinates of the following public water supply source were collected from the field, which include; pipe-borne taps, hand dug wells, boreholes, reservoirs and water supplying pipes which were transformed in excel sheet and imported to ArcGIS 10.3 environment to create the geo-database.

ArcGIS 10.3 version was used to create a file geo-database for this research work, which consist of Built-up area, Road network, water supplying pipe network, public reservoir, taps, boreholes, hand dug well, water hydrant, stream and ponds feature classes within Gyel district area and their necessary attributes such as location, diameter, condition, function and distance covered which was conceptually organized.

Integrated approach was used to achieve the objective the objective of identifying and mapping water supply sources in Gyel which includes both the GIS and Statistical analysis, thus; The GIS analytical techniques involve the use of ArcGIS 10.3 in achieving the research objectives includes; A handheld GPS receiver (Garmin CX 76) was used to collect coordinate points of the public domestic water source such as pipe-borne taps, boreholes, hand dug well, water hydrants, reservoirs, traced water supply pipes and their attributes and was transformed into ArcGIS environment using Microsoft excel which was used to create a file geo-database containing the feature classes which were digitized and compiled into a digital map which form the basis for the analysis.

The pattern of distribution and density of public hand dug wells and boreholes and line density for the distribution of water supplying pipes were used respectively to describethe pattern of domestic water source distribution and concentration depicting the area of high, moderate and low concentration within the study area. Proximity analysis using multiple rings buffering of distance in metres to standard was adopted, this depicts four level of accessibility which includes; optimum, intermediate, basic and no-access levels were used with the following distance interval which were; 1-30m, 30-100m, 100-1000m and 1000m above to analyse the level of accessibility to domestic water source within the study area(Enoch and Issaka, 2015).The statistical analysis includes the use of results from a structured questionnaire administered on the field with the use of statistical packages for social science (SPSS) in computing simple percentage and statistical diagram for the following variables which are the source, pattern and level of accessibility to domestic water supply source in the study area.

RESULTS

Sources and Uses of Domestic Water Supply

Table 2 shows the various sources of domestic water supply in Gyel district area, which were the public water supply source that the coordinate points were taken on the field to create geo-database for the spatial analysis.Also,from Table 2, hand dug well was the dominant domestic water source which was 60% of the source of water for the respondent followed by pipe borne water which was just 28%, borehole 4% and stream 8%, which indicated, that hand dug wells are the primary source domestic water supply in this area, while from figure 2 and plate 1, the source of domestic water supply in this area includes Hand dug well, Boreholes, and water supply pipes, Stream and ponds**.**

Table 2: Sources of domestic water

Sources of domestic water	**Number of respondents**	**Percentage**
Pipe borne	73	28
Hand dug Well	157	60
Borehole	11	4
Stream and ponds	22	8
Total	**263**	**100**

Source: Field survey, 2019

Table 3 shows that the water supply in this area is being used for all the domestic purpose, as indicated the highest percentage of the respondents from the households used water for various domestic purpose such as drinking, cooking, bathing, washing and general sanitation which proved the necessity of domestic water supply to the area.Figure 2 shows the map compiled from the geo-database created from the coordinates of public water supply source in the study area, while plate 1 show the types of water source in the area.

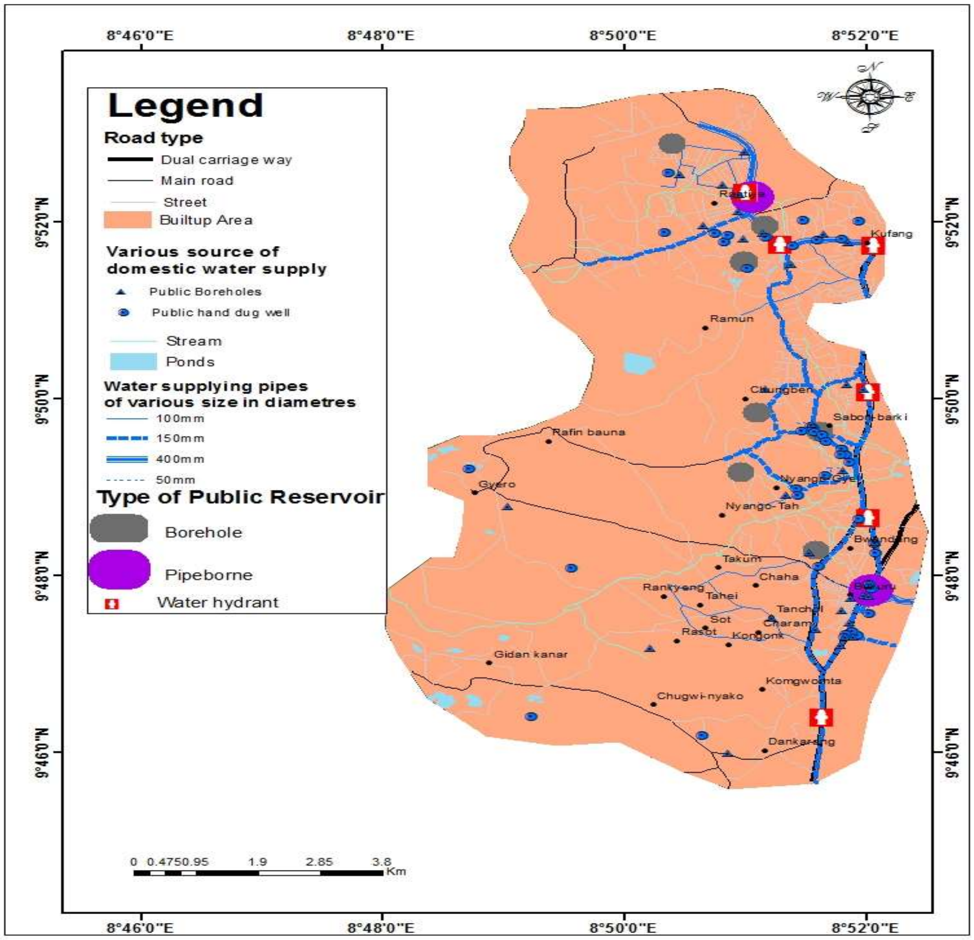

Figure 2: Map showing various sources of public domestic water supply

Plate 1(A – D): Various sources of Public domestic water supply in the area.
Source: Field Survey, 2019

Table 3: Uses of domestic water

Uses of the water supply	Number of respondents	Percentage
Drinking	36	14
Cooking	52	20
Bathing	61	23
Washing and sanitation	48	18
All of the above	66	25
Total	**263**	**100**

Source: Field Survey, 2019

Domestic Water Supply Sources Used for the Creation of Geo-Database

The area was provided with 41 public wells with ten located in Bukuru carrying the highest number followed by Rantya which has eight wells. NyangoGyel has five wells drilled by the government for their use while Kufang and Tanchol have four respectively, the areas having one as the least in the bucket are Gyero and Dankarang. Out of the number of wells provided by the government for the communities, thirty are not seasonal implying that these wells have water all the year round minimizing the issues of acute water scarcity in the area. Eleven others are seasonal which resulted possibly from inappropriate location of the wells as shown in Table 4.

A total of 35 boreholes were provided by the government to support the supply of water from the pipe borne water system of the Plateau State Water Board. Out of the thirty-five of the sources, only five are dysfunctional.Bukuru has thirteen boreholes scattered across all locations, followed by Kufang with eight while Bwandang, Rasot, Dankarang and Rantya having only one borehole each, see Table 5. Different types, length and sizes of pipes convey water either as main or service lines from the treatment plants and borehole to the municipalities and the households as shown in Table 6. They are all functional and made of cast iron and plastic with the main conveying water from the various sources like dams, reservoirs and or the ground water source such as wells and borehole.

DISCUSSION

In the study area, both public and private water sources exist that cater for the needs of the inhabitants of the area. Streams, private wells, private boreholes, public wells and public boreholes that are spatially distributed which complement the public pipe borne water system in the area as shown in Plate 1(Odafivwotu and Abel, 2014).Ali (2018) found that due to combination of factors of age and type of pipes, they are not able to withstand high water pressure resulting to burst and leaks leading to high level Non-Revenue Water of 58%.

Table 4: Number of Public Wells and their coordinates

S/N	Latitude	Longitude	Location	Condition
1	9º52′33.602″	8º50′21.883″	Kufang	Not seasonal
2	9º51′53.718″	8º50′20.234″		Not seasonal
3	9º51′52.729″	8º50′45.615″		Not seasonal
4	9º51′51.081″	8º50′51.218″		Not seasonal
5	9º51′46.796″	8º50′49.900″	Rantya	Not seasonal
6	9º51′28.338″	8º51′01.437″		Not seasonal
7	9º51′50.422″	8º51′10.336″		Not seasonal
8	9º51′44.159″	8º51′23.850″		Not seasonal
9	9º52′01.299″	8º51′29.124″		Not seasonal
10	9º50′47.785″	8º51′36.046″		Not seasonal
11	9º51′48.444″	8º51′56.812″		Not seasonal
12	9º52′00.970″	8º51′56.812″		Not seasonal
13	9º49′41.542″	8º51′33.409″	SabonBarki	Seasonal
14	9º49′40.223″	8º51′34.728″		Not seasonal
15	9º49′37.586″	8º51′35.387″		Not seasonal
16	9º49′39.235″	8º51′27.806″	Nyango-Gyel	Not seasonal
17	9º49′35.279″	8º51′39.342″		Not seasonal
18	9º49′33.631″	8º51′37.694″		Seasonal
19	9º49′30.005″	8º51′40.661″		Seasonal
20	9º49′26.050″	8º51′48.572″		Seasonal
21	9º49′22.424″	8º51′47.583″	Tanchol	Not seasonal
22	9º49′21.765″	8º51′50.879″		Not seasonal
23	9º49′17.150″	8º51′52.197″		Not seasonal
24	9º49′08.251″	8º51′40.002″		Not seasonal
25	9º48′59.351″	8º51′25.828″	Bwandang	Not seasonal
26	9º48′54.407″	8º512′5.828″		Not seasonal
27	9º48′38.585″	8º51′57.142″	Bukuru	Seasonal
28	9º48′21.115″	8º52′04.723″		Not seasonal
29	9º48′15.842″	8º52′04.393″		Seasonal
30	9º48′06.283″	8º51′36.046″	Bwandang	Seasonal
31	9º47′53.757″	8º50′02.086″	Bukuru	Seasonal
32	9º47′50.791″	8º52′04.064″		Seasonal
33	9º47′33.980″	8º52′01.756″		Seasonal
34	9º47′22.444″	8º51′53.186″		Not seasonal
35	9º47′19.148″	8º515′6.153″		Not seasonal
36	9º47′21.125″	8º51′49.890″		Not seasonal
37	9º47′18.488″	8º51′49.890″		Seasonal
38	9º49′12.865″	8º48′43.327″	Gyero	Not seasonal
39	9º48′04.635″	8º49′34.088″	Gidankanar	Not seasonal
40	$9^0$46′24.102″	$8^0$49′13.982″		Not seasonal
41	$9^0$46′11.247″	$8^0$50′38.693″	Dankarang	Not seasonal

Source: Field Survey, 2019

Table 5: Number of public boreholes and their coordinates

S/N	Latitude	Longitude	Location	Condition
1	9^{0}52′48.985″	8^{0}50′57.589″	Rantya	Functioning
2	9^{0}52′26.016″	8^{0}50′46.105″		Functioning
3	9^{0}52′20.716″	8^{0}50′56.706″	Kufang	Functioning
4	9^{0}52′04.814″	8^{0}50′55.822″		Functioning
5	9^{0}51′58.631″	8^{0}50′38.154″		Functioning
6	9^{0}51′52.447″	8^{0}51′08.190″		Functioning
7	9^{0}51′49.796″	8^{0}50′57.089″		Functioning
8	9^{0}51′51.563″	8^{0}51′36.459″		Functioning
9	9^{0}51′47.146″	8^{0}51′49.710″		Functioning
10	9^{0}51′30.362″	8^{0}51′20.558″		Functioning
11	9^{0}50′10.855″	8^{0}51′48.827″	Chungben	Functioning
12	9^{0}50′06.438″	8^{0}51′56.777″		Functioning
13	9^{0}50′07.321″	8^{0}51′09.073″		Functioning
14	9^{0}49′43.469″	8^{0}51′31.159″	Sabonbarki	Functioning
15	9^{0}49′11.667″	8^{0}51′47.060″	Nyangogyel	Functioning
16	9^{0}48′56.649″	8^{0}51′19.674″		Not functioning
17	9^{0}48′48.698″	8^{0}49′00.096″	Gyero	Functioning
18	9^{0}48′23.963″	8^{0}52′02.078″	Bwandang	Functioning
19	9^{0}48′15.129″	8^{0}51′30.275″		Functioning
20	9^{0}47′53.927″	8^{0}51′00.311″	Bukuru	Not functioning
21	9^{0}47′45.976″	8^{0}51′59.428″		Not functioning
22	9^{0}47′44.572″	8^{0}51′57.889″		Functioning
23	9^{0}47′46.285″	8^{0}52′00.973″		Not functioning
24	9^{0}47′44.572″	8^{0}51′52.064″		Functioning
25	9^{0}47′36.348″	8^{0}51′46.925″		Functioning
26	9^{0}47′28.467″	8^{0}51′51.036″		Functioning
27	9^{0}47′23.670″	8^{0}51′34.247″		Functioning
28	9^{0}47′17.846″	8^{0}51′53.435″		Functioning
29	9^{0}47′18.188″	8^{0}51′49.323″		Functioning
30	9^{0}47′12.363″	8^{0}51′46.239″		Functioning
31	9^{0}47′22.985″	8^{0}51′34.590″		Functioning
32	9^{0}47′31.209″	8^{0}51′12.123″		Not functioning
33	9^{0}47′10.650″	8^{0}50′12.698″	Rasot	Functioning
34	9^{0}45′59.723″	8^{0}50′50.731″	Dankarang	Functioning
35	9^{0}48′16.437″	8^{0}51′31.163″	Bwandang	Functioning

Source: Field Survey, 2019

Table 6: Number of water supply pipes

Number of pipes	Material used	Condition	Diameter	Function	Length in meters
1	Cast iron	Functioning	150mm	Service	1132.326094
2	Cast iron	Functioning	150mm	Service	1306.379297
3	Cast iron	Functioning	150mm	Service	71.65548874
4	Ductile	Functioning	100mm	Service	742.3806331
5	Ductile	Functioning	50mm	Service	63.29385871
6	Ductile	Functioning	50mm	Service	10.72278771
7	Ductile	Functioning	50mm	Service	23.9328508
8	Cast iron	Functioning	400mm	Main	425.3764532
9	Ductile	Functioning	100mm	Service	490.3843581
10	Cast iron	Functioning	150mm	Service	254.6020263
11	Ductile	Functioning	100mm	Service	111.5196158
12	Ductile	Functioning	100mm	Service	165.4405924
13	Ductile	Functioning	100mm	Service	84.41770679
14	Cast iron	Functioning	400mm	Main	118.0467738
15	Ductile	Functioning	100mm	Service	68.77533874

Source: Field Survey, 2019

Table 7: Number of Public Reservoirs and their coordinates

S/N	Latitude	Longitude	Location	Type	Condition
1	$9^{0}52'18.582$	$8^{0}51'02.815$	Rantya	Pipe-borne	Functioning
2	$9^{0}47'50.354$	$8^{0}52'02.788$	Bukuru	Pipe-borne	Functioning
3	$9^{0}52'53.511$	$8^{0}50'23.273$	Rantya	Bore-hole	Functioning
4	$9^{0}51'56.834$	$8^{0}51'10.724$	Kufang	Bore-hole	Functioning
5	$9^{0}51'33.767$	$8^{0}50'59.520$	Rantya	Bore-hole	Functioning
6	$9^{0}49'50.299$	$8^{0}51'05.451$	Chungben	Bore-hole	Functioning
7	$9^{0}49'37.777$	$8^{0}51'36.426$	SabonBarki	Bore-hole	Functioning
8	$9^{0}49'10.097$	$8^{0}50'57.543$	Bukuru	Bore-hole	Functioning
9	$9^{0}48'16.056$	$8^{0}51'34.499$	Tanchol	Bore-hole	Functioning

Source: Filed Survey, 2019

This major infrastructure of Plateau State Water Board is in dire need of replacement and rehabilitation to enable them perform optimally in delivering exceptional services to the consumers. In the same It is evident that some of the pipes have spent seventy (70) years, some Twenty-three (23) years, while others Twenty (20) and Thirty (30) years. This contradicts the current result which states that all pipes are functional which with the factor of time would have been fixed.

The Plateau State Water Board has up to 9 functional reservoirs in different locations within the area (Table 7) drawing water from both dams and ponds. Rantya settlement has three reservoirs which sources of water are two boreholes and one pipeborne water supply source respectively as shown in Table 6. Bukuru has two reservoirs with their water sources from pipeborne and borehole respectively. These number of reservoirs are seen to be grossly inadequate compared to the rate of population of these locations and their growing economic activities except for the fact that they are being complimented by other water sources (Ali, 2018). Ali, Eziashi and Olorunleke (2018) identified eight (8) water reservoirs of different capacities with a daily combined capacity of 87100m^3. These reservoirs are constructed mostly on hilltops of relatively high altitude and receive water from the designated treatment plants which is eventually distributed into households through gravity. Two overhead tanks were built in year 1981 and 1975 in Jos and Bukuru areas. The tanks constructed by the state government for water distribution easily into households through gravity. Due to long years of mismanagement, neglect and lack of attention, these overhead tanks are left in a state of disrepair and are dysfunctional and need to be brought back to use to enhance the capacity of the Plateau State Water Board to increase service coverage to unserved areas within Jos metropolis (*Marson andSavin, 2015)*.

CONCLUSION

The application of Spatial analytical tool such as; Density and Proximity analysis using ArcGIS with the aid of Satellite, Global Positioning and Population data has been proved important in Spatial analysis of access to domestic water supply source in identification and mapping the pattern of it distribution and examining the effect on the accessibility in terms of distance and time travelled in related to the quantity of water used in the area. This gives the Planners and decision makers from both The Plateau State Water Board, Private sectors and Individual households, Idea on how to solve the complex problem of domestic water supply in the study area.

Recommendations

Based on the findings of this study, the following recommendations were proposed which include;

i. Encouraging the provision of more domestic water source by the Plateau State Water Board, Private Sectors and Individual household as this will boost water supply, also creating awareness on the importance of various source of domestic water supply as they complement each other's especially during dry season in the area.
ii. The Jos Metropolitan Development Board should ensure that built-up areas adopt town planning standard rules to ease laying of water supplying pipes and other public water supply facility extensions, especially in the newly developing built-up area.
iii. Plateau State water Board should engage in periodic pipeline extension services to be able to cover the newly developed areas, regular replacement of damaged

facilities to enhance the supply of water in the area.

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