

Evaluating the Locational Efficiency of Boreholes in Amper, Plateau State, Nigeria

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Abstract

Many parts of the developing countries of the world face perennial water scarcity problems despite concerted efforts to provide reliable sources of potable water such as boreholes. Some of these problems arise from inefficient location of the boreholes. Amper town in Plateau State, Nigeria is a fast growing area that suffers water scarcity especially in the dry season in spite of the fact that there are numerous boreholes located in it. This study investigates the locational efficiency of boreholes in the town. Four standard measures of locational efficiency of boreholes were investigated: physical accessibility, functional water population density (FWPD), reliability and residents' perception. Imagery of the town was downloaded from Google Earth, georeferenced and digitized, with all discernible housing units. Household numbers were estimated and a structured question was distributed to household heads for data on residents' perception of boreholes location and use. There are 19 boreholes in the town with only 8 of them being functional. Buffer analysis showed that 80% of households are within the acceptable WHO recommended 200m distance, even though only 65% reside within 200m of a functional borehole. The FWPD is poor with more than 1700 persons per borehole for functional boreholes and more than 700 per all boreholes. These are against the recommended 25 persons per borehole. Only four of the functional boreholes operate for 24 hours in a day, which shows unreliability. Residents also have alternative sources of water arranged because of the problem with accessing borehole water due to crowding at borehole locations and unreliability. They claimed they are not involved in borehole location decisions and political interference and poor construction are responsibility for the large number of non-functioning boreholes. The study recommended that better locational decisions be made to ensure functioning of the boreholes.

Keywords: Functional water population density, Locational efficiency, Reliability, Water scarcity

INTRODUCTION

In many parts of the world, Nigeria inclusive, ground water resources have become very important means of meeting the increasing demand for water in both urban and rural areas. Boreholes have become the major means by which these ground water resources are tapped.

A borehole is simply a narrow shaft drilled into the ground, either vertically or horizontally to access ground water stored in aquifers. The borehole is further developed by fixing a hand-pump to it to ensure continuous extraction of the groundwater (Adow, 2013). Boreholes are considered important sources of safe potable water for human use. This is pertinent to note against the background of the fact that less than 30% of Nigerians have access to safe potable water supply (Federal Government of Nigeria, FGN, 2004). Moreover, access to pipe-borne water in Nigeria is abysmally poor at only 6.5% (Dangana, Halilu, Asiribo-Sallau and Kuta, 2015). Against this

backdrop it is easy to understand why the federal, states and local governments in Nigeria are investing large amounts of financial and other resources towards the provision of boreholes in communities across Nigeria. Necessary as the provision of borehole facilities is, it is equally important that the people in the communities where they are constructed have easy access to these facilities. This requires that the boreholes be efficiently located for maximum impact.

There are some important considerations that should be taken into account in the bid to supply water in a community. This includes the quantity and quality of water. These are essential to meet the demand need of the community and health safety of the residents, respectively. Another important aspect of construction of boreholes for water supply in a community is their locational efficiency. Irrespective of the number of boreholes constructed, if they are not efficiently located, water scarcity would persist in some or all parts of the community.

Examining the locational efficiency of boreholes would also help to identify some underlying factors that contribute to the scarcity of water in the area as well. Geographical information system (GIS) has made the determination of the locational efficiency of facilities more effective. It has therefore been employed to measure whether boreholes are efficiently located for more effective water supply in communities. This study therefore employs GIS techniques to examine the locational efficiency of boreholes in Amper town, Kanke LGA of Plateau State. Amper is a fast growing town that continues to experience water scarcity in the dry season despite seemingly large investments in construction of boreholes. Understanding the efficiency of the

distribution of the boreholes may provide insight into why the boreholes do not appear to have solved the problem of water scarcity in the area. This is the challenge that this study explores.

MATERIALS AND METHODS

Study Area

Amper town is the headquarters of Amper district in Kanke local government area of Plateau State. The town is situated on the slopes of the Jos Plateau, often described as the “last step” descending the Jos Plateau to the lowland regions in the south-eastern escarpment. It is located between latitudes 9°20'30" and 9°21'35" and longitudes 9°41'30" and 9°43'. Figs 1 and 2 show the study area.

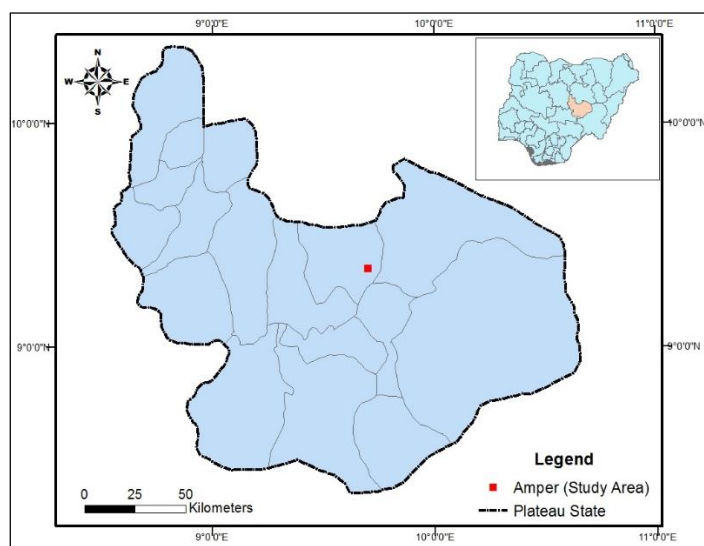


Figure 2 Location of Amper Town (Study Area)

By its location on the south eastern escarpment of the Jos Plateau, Amper appears to be on the leeward side, and therefore experiences less rainfall, estimated at between 900mm and 1100mm annually. The average temperature is about 30 ° C, which is higher in the hot months of March to May. The Harmattan season is short starting in early December till February (Rotdung, 2005).

Amper has a population size estimated above 10,000 people. Most of its residents are either full time or part-time farmers. Large number of Kanke local government workers lives in Amper town and commute to work from the town. Most of the teachers (primary and secondary) in schools in the entire district also reside in or near the town. Consequently, there is a large number of civil

servants in the town. Amper also has one of the largest weekly markets (Saturdays) in the Central Senatorial zone of Plateau State. People travel from far and wide to sell and buy agricultural products, cattle and livestock and engage in other commercial activities on a weekly basis.

Methodology

Types and sources of data

The study collected data on locational and spatial characteristics of boreholes, characteristics of residents and their use of boreholes and also their levels of participation in decisions to locate boreholes in the study area. These data were collected from both primary and secondary sources. Data on locational and spatial characteristics of

boreholes, and data on characteristics of respondents and their participation in locational decision of boreholes were collected from primary sources. These include field measurements by the researcher and field assistants, and from residents using a structured questionnaire. Secondary sources include textbooks, journal, articles, geophysical survey documents, Google Earth and other published and unpublished documents.

First, the researchers undertook a reconnaissance survey of the study area. They identified the location of all boreholes in the town. They also identified the extent of the wards in the study area for effective collection of data. There are seven wards (angwas), which were used for effective sampling of respondents and questionnaire administration. The researchers visited all the ward heads and intimated them of the research aim and objectives and sought their support for the study.

Sampling Method

Determining sample size

First, a census was conducted of all boreholes in the study area and information pertaining to their characteristics were collected. In total, there were nineteen (19) boreholes in various stages of development and all are used in analysis. Secondly, the total number of one hundred and seventy-one (171) questionnaires was administered to households in the study area, out of which one

hundred and fifty eight (158) were deemed appropriately filled and used for data analysis.

The sample size was derived using the following formula for unknown population:

$$S = \frac{Z^2 pq}{me^2} \tag{1}$$

Where S = Sample size; Z is Z-score value at the 95% confidence level; p = proportion of household heads (20% or 0.2); q = 1-p (80% or 0.8); and me = margin of error (6% or 0.06).

The margin of error is increased to 0.06 to account for uncertainty about the actual population.

Sampling techniques

For boreholes, all the 19 boreholes identified are used in the analysis. However, a mixed sampling method, the stratified availability sampling technique, was adopted for collection of data from respondents in the community.

The study area was stratified into already existing ward sections called “Angwa.” These are Kapkal, Tomten, Kururuwa, Fyaplak, Chika, Per, and Golten. Number of households were estimated for each ward based of the number of houses in the wards. The questionnaires were therefore distributed on the basis of a proportion of estimated number of households.

Table 3 Questionnaire Distribution

| S/N | Sections | Estimated Number of Households | Number of Questionnaires | Number Returned |
|-----|----------|--------------------------------|--------------------------|-----------------|
| 1 | Chika | 356 | 22 | 18 |
| 2 | Fyaplak | 464 | 29 | 26 |
| 3 | Golten | 302 | 18 | 16 |
| 4 | Kapkal | 298 | 18 | 18 |
| 5 | Kururuwa | 632 | 39 | 36 |
| 6 | Per | 270 | 17 | 16 |
| 7 | Tomten | 446 | 28 | 28 |
| | Total | 2768 | 171 | 158 |

The number of houses are counted from the image of the town downloaded from Google Earth. Anecdotal evidence suggests that for most of the houses, there are at least two households within it.

A household is simply defined as a group of persons who eat from the same pot. In many traditional settlements such as Amper, there are usually several households residing in the same housing unit. Often

several members of the same extended family may live together in one large compound yet they are almost independent of one another as separate households. It is therefore common to find more than one household in most housing units in settlements such as the study area. An average number of two (2) households per compound or house may be considered conservative and minimalist but deemed suitable for the study so as not to overestimate variables.

Method of Data Collection

Location information of boreholes

The coordinate information of each borehole in the study area were collected using GPS device. The coordinate information were collected in UTM which is a projected coordinate system to make it easier for display in ArcGIS. Attribute information regarding each borehole were also collected including the levels of development and functionality of the boreholes.

Locational efficiency of boreholes

First, the image of the study area was downloaded from Google Earth, georeferenced and digitized in ArcGIS 10.3. The area extent of the study area was also carefully demarcated using features identified on ground during the reconnaissance survey. This is

important because some of the analysis depend on the area extent of the study area. For example, the nearest neighbor analysis and mean centre of borehole distribution are sensitive to the size of the study area. Figure 6 presents the demarcation for the study area based on conterminous buildings in the area.

Second, the coordinate information of all boreholes in Amper town were collected using GPS equipment, which were converted and displayed as point features using the “Display XY data” operation and stored in a geodatabase created specially to manage the GIS data for the study.

Thirdly, several characteristics of locations, including the mean center, the directional distribution and the nearest neighbor statistics were determined using GIS tools in order to determine the spatial pattern of distribution of boreholes in the study area.

Four Measures of locational efficiency of boreholes are used in the study. These are physical accessibility, functional water point density (population-borehole ratio), reliability as defined by the United Nations (UN, UNICEF) and World Health organizations (WHO), and residents’ perceptions on the location of the boreholes. Table 1 presents a summary of these measures of locational efficiency.

Table 4 Measures of locational efficiency of boreholes

| Indicator/Dimension | Standards | Institution |
|--------------------------------|--|---|
| Physical accessibility | 0 -1000 and not more than 30 mins* 0-200m Location with physical security* | WHO/UNICEF WHO (2000) UN Human Rights |
| Functional Water Point Density | 1 water point per 250 persons* | Mwamaso (2015) |
| Reliability | 24 hours per day* | WHO |
| Perceptual Rating | Perceptions on locational factors | Mwamaso (2015) |

*Mwamaso (2015)

Physical accessibility

Two hundred metres is the acceptable recommended distance for residents to travel to a water point for collection of water (WHO, 2000). The Buffer tool in ArcMap 10.3 was used to create a buffer zone of 200 meters around each borehole. The number of houses captured within the 200m buffer zones of the boreholes is counted and

measured against the number of all houses in the study area:

$$H = \frac{n}{N} * 100\% \tag{2}$$

Where H is percentage of houses within 200 m of boreholes; n is the number of houses within 200 m of the boreholes; N is total number of houses in the study area.

Functional water point density (FWPD) or population-borehole ratio

The functional water point density measures the number of people that each borehole serves against the expected. The expected functional water point density, according to Mwamaso (2015), is 1 water point per 250 persons. The formula is represented thus:

$$FWPD = \frac{Np}{Nb} \quad (3)$$

Where FWPD= Functional water point density; Np = total population of the area; Nb = total number of boreholes in the area

To determine the FWPD of the study area, certain steps were taken. First, a buffer of 200 m is constructed around each borehole using the geoprocessing buffer tool in ArcGIS 10.3. Second, the number of houses in the buffer is counted. Third, it is assumed that each house in the community accommodates at least two (2) households. The result therefore will not be an overestimation of the FWPD.

Fourth, an average of five (5) persons per household is adopted, which according to the National Bureau of Statistics (2018) is the average household size in Plateau State. This estimated population is divided by the number of boreholes to give the FWPD, which is a locational efficiency measure of boreholes. The result is measured against the standard, which is one (1) water point per 250 persons (Mwamaso, 2015). Values greater than 250 indicate inefficiency in location of boreholes in the area.

Reliability

Reliability of a water point is defined by WHO as the capacity of the water point to supply or provide

water for twenty-four (24) hours per day (Mwamaso, 2015). This is a much subjective measure of locational efficiency for several reasons. First, some of the boreholes are used only seasonally. During the rainy season when rain water could be harvested, they are locked up. Second, even during the dry season when they are used, they are open for only specified amount of time. The two main reasons provided are that someone is required to monitor the use of the boreholes to ensure that patrons do not misuse and break the pumps (maintenance purposes), and that the water should not be overused for fear of exhaustion even though this threshold has never been reached before. The second reason is therefore more preventive and cautionary. Consequently, the functionality of the boreholes is adopted as a measure of reliability. The non-functional boreholes are already in violation of this measure of reliability since they are never used. The percentage of functional boreholes, therefore, is used to determine the locational efficiency of the boreholes based on the reliability measure, along with seasonality of use.

RESULTS AND DISCUSSION

Location and Characteristics of Boreholes

Of the nineteen boreholes identified (Table 1), eleven are currently not functional as a result of many factors. For example, two of the boreholes were abandoned after they were dug, while three others are incomplete because they have not been fitted with hand pumps, the remaining six are completed but have either never yielded water, or have gone into serious disrepair, and therefore are not being used.

Mean Center of Distribution of Boreholes

Fig 7 presents the mean centre and direction of distribution of boreholes.

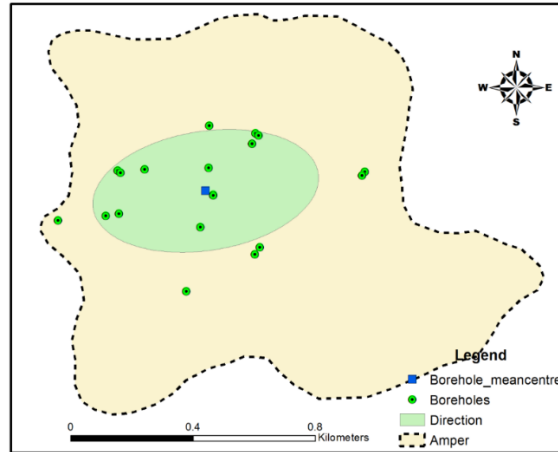


Figure 7 Mean Centre and Direction of Distribution of Boreholes

The mean centre of the distribution is near the centre of the town, which suggests that the boreholes may be evenly distributed around the town. This is not necessarily the situation. Most the boreholes are located around the general area of the centre of the town with only a few at the fringes, especially in the western section of the town. On the balance of other borehole locations therefore, the mean centre is found generally around the centre of the town.

The direction of the distribution of boreholes shows a clear East-West alignment. Boreholes are stretched across the town across the eastern and western sections. Most areas in the north and south of the town do not have boreholes.

Nearest Neighbour Analysis

Figure 9 presents the result of the average nearest neighbor statistics of the boreholes.

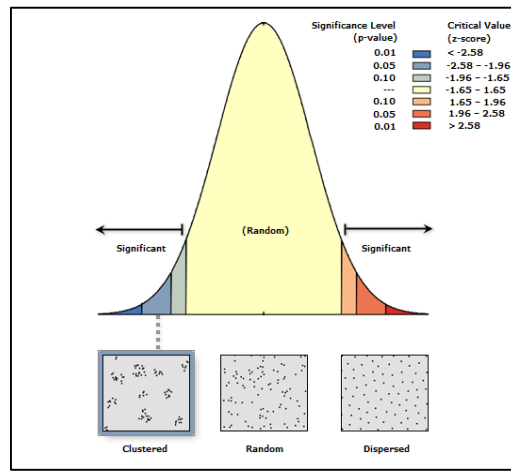


Figure 9 Nearest Neighbor Statistics of Boreholes

The result of the nearest neighbor analysis shows that the boreholes are clustered. The Z value is -2.231589 with a p-value of 0.025642 , which is significant at 0.05 level of significance. The locations of the boreholes in Figs 6 and 7 show that the boreholes are located close to one another around the centre of the town. This may account for why the mean centre is close to the geographic centre of the town.

The implication of such distribution is that those who are not close to the center of the town may not be well served by the location and distribution of boreholes in the town. If the concentration of people in the town is at the centre as the case may be with nucleated settlements, then such a locational pattern maybe viewed as largely efficient because it would serve the largest number

of people in the town and the distances to borehole location for most people may be minimal.

Analysis of Locational Efficiency

Locational efficiency of boreholes is measured using several parameters. These include distances to boreholes, population, and borehole ratio.

Physical accessibility to Borehole

The World health Organization (WHO)/UNICEF Joint Monitoring Programme (JMP) for water-supply and sanitation suggests that the distance to

water sources such as a borehole should be less than 1000m and/or should take not more than 30 minutes to collect water from the source. According to the Nkemdirim, Nwobi and Okoroigwe (2017) the United Nations and WHO have indicated that the minimally acceptable distance to access abundant drinking water should not exceed 200m. The study adopts this standard to test the efficiency of the location of boreholes in Amper. A buffer of 200m was created around each borehole (Fig 10).

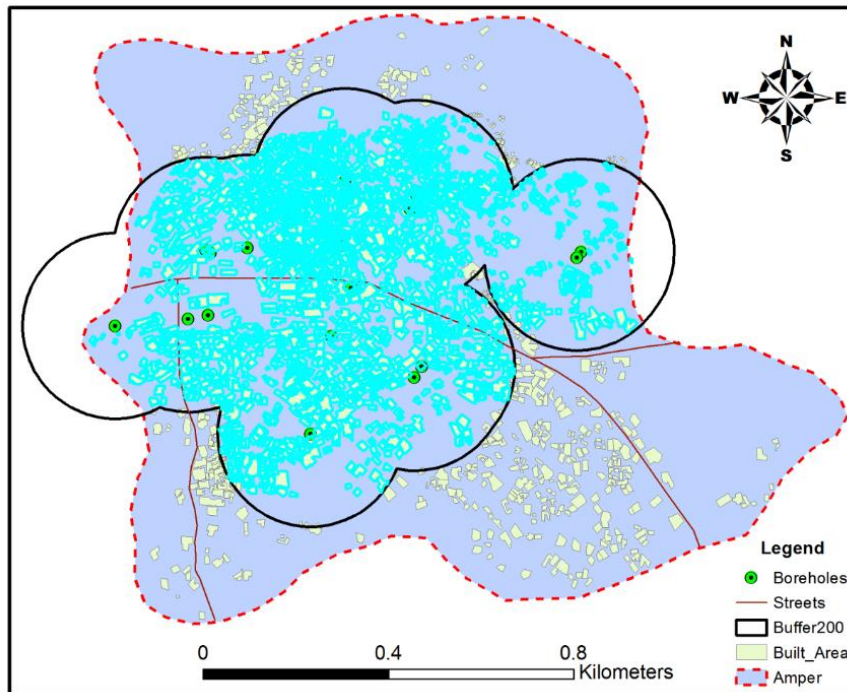


Figure 10 Borehole Buffers at 200m for all Boreholes

Of the 1384 dwelling units digitized, from Google Earth, 1115 houses representing 80.56% fall within 200m of a borehole. This appears to be a high level of efficiency in the location of boreholes with

regards to physical accessibility. However, when only functional boreholes are considered, the level of efficiency is much lesser. Figure 11 presents the result.

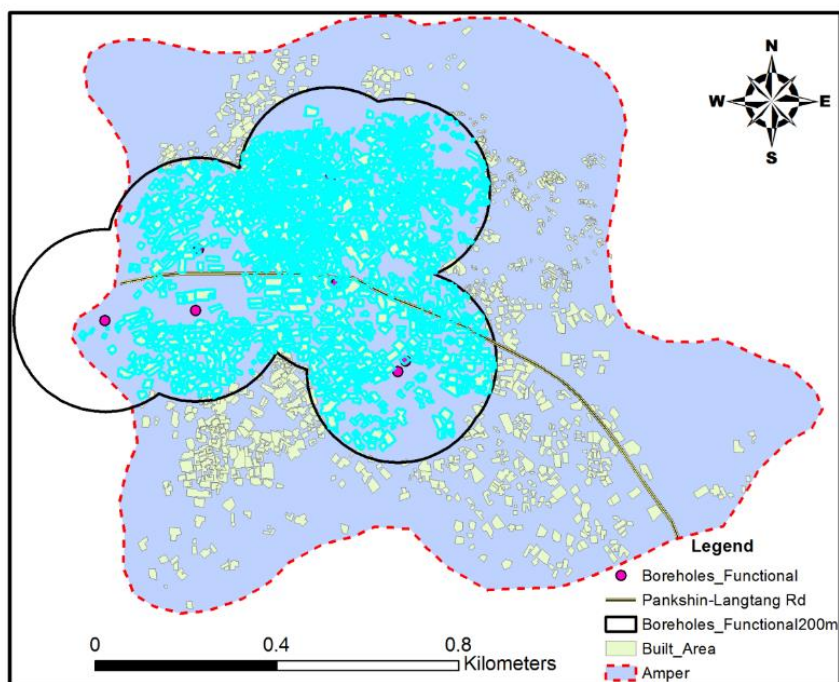


Figure 11 Borehole Buffers at 200m for only Functional Boreholes

Using only the eight (8) functional boreholes, there are only 894 houses out of 1384 that fall within 200m of a borehole. This is about 64.60%.

Functional water point density (FWPD) or population–borehole ratio

According to Mwamaso (2015) the acceptable functional water point density is one water point per 250 people. This standard is adopted for the study area. In total, there are 1384 housing units clearly determined and digitized in the study area. Preliminary data collected during the reconnaissance survey indicated that on average, there are two households per housing unit. Based on this preliminary data therefore, it was estimated there would be about 2768 households in the study area. The Nigerian National Bureau of Statistics (2018) points out that there are approximately five persons per household in Plateau state. Using this data, therefore, the population of the study area is estimated as 13840 (2768 households*5 persons/household). Using Eq. 3 for FWPD, the locational efficiency of boreholes relative to population therefore is calculated as 728.42. This means that each boreholes serves an estimated 728 persons as against the 250 persons recommended (Mwamaso, 2015). This shows a high level of

inadequacy in the number of boreholes in the study area. The population borehole ratio in the study area is grossly inadequate and the locational distribution is greatly inefficient. This inadequacy becomes even more acute when only the functional boreholes are considered. The FWPD becomes 1730 persons per borehole. This number is simply unacceptable. It shows that though many households may be close to boreholes (physical accessibility), accessing water from the boreholes may be more difficult than the physical accessibility measure suggests.

Reliability of boreholes

According to Mwamaso (2015), reliability of a water point is defined by WHO as the ability of the water point to supply or provide water twenty-four hours per day. Technically, only eight boreholes out of nineteen are currently functional. This represents about 42%. However, some of these are not operational in the rainy season due to availability of rain water. And in the dry season, four of these boreholes are open for only eight hours in a day (6am-10am and 2pm-6pm) to protect them from overuse and possible exhaustion. With regards to reliability therefore, boreholes in the study area are below average for all boreholes. It may be safe to assume that the remaining eleven (11)

nonfunctional boreholes may not have found water and that is why they were either abandoned. This may result from bad locational decision making.

Perception of Location of Boreholes by Residents

Locational efficiency of boreholes deals with access of people to the water source. The technical measures of efficiency of boreholes such as a spatial distribution and pattern, physical accessibility, water point ratio and reliability do not account for the users' perception of locational efficiency. It is therefore necessary to examine what residents of Amper town think about the location of boreholes in the study area. This is important because their perception of the efficiency of location may

influence the use of the boreholes. They also may throw light on how the boreholes are located and explain the pattern of borehole distribution.

Characteristics of respondents

Table 5 Presents data on the characteristics of respondents. The age distribution shows that 58% are less than 40 years old, which makes it a young population. About 57% of respondents are male and about 52% are married. 68% are engaged in the civil service, farming and business. More than 92% of respondents have Secondary school education or a higher qualification. About 59% have tertiary educational qualification which shows that the respondents are well educated and informed.

Table 5 Characteristics of respondents

| | Characteristics | Freq | % |
|--|-------------------|------------|---------------|
| Age | <20 | 14 | 08.86 |
| | 20-29 | 24 | 15.19 |
| | 30-39 | 52 | 32.91 |
| | 40-49 | 28 | 24.05 |
| | 50+ | 30 | 18.99 |
| | Total | 158 | 100.00 |
| Sex | M | 90 | 56.96 |
| | F | 68 | 43.04 |
| | Total | 158 | 100.00 |
| Marital Status | Single | 64 | 40.51 |
| | Married | 82 | 51.90 |
| | Divorced | 04 | 02.53 |
| | Widowed | 08 | 05.06 |
| | Total | 158 | 100.00 |
| Occupation | Unemployed | 50 | 31.65 |
| | Civil service | 64 | 40.51 |
| | Farming | 18 | 11.39 |
| | Business | 26 | 16.46 |
| | Total | 158 | 100.00 |
| Highest Educational Qualification | Non formal | 08 | 05.06 |
| | Primary Education | 04 | 02.53 |
| | Secondary | 52 | 32.91 |
| | OND/NCE | 58 | 36.71 |
| | Degree & Above | 36 | 22.78 |
| | Total | 158 | 100.00 |

Need for boreholes in study area

Table 6 presents data on residents' perception of whether there is the need for boreholes in the study area. All but two respondents agree that the study area needs boreholes. This is because there is a large deficit in water supply especially in the dry season.

The wells do not have the capacity to meet the deficit and there are no surface water supply sources (e.g. dams) to meet the demand. Tapping ground water through boreholes becomes a necessary and logical strategy to obtain enough water to meet the demand.

Table 6 Residents' perception of need for boreholes

| | Freq | % |
|-------|-------------|----------|
| Yes | 154 | 97.44 |
| No | 04 | 02.56 |
| Total | 158 | 100.00 |

Proximity of boreholes to residents

Table 7 present data on proximity of boreholes to residents. About half of the respondents (52%)

indicated that the boreholes are near to their residences. This may be a reflection of the fact that these residents live around the centre of town.

Table 7 Boreholes proximity to residents

| Nearness | Freq | % |
|-----------------|-------------|----------|
| Yes | 82 | 51.90 |
| No | 76 | 48.10 |
| Total | 158 | 100.00 |

In the same token the other half of the respondents may not feel inclined to the idea that the boreholes are efficiently located. Generally, residents would consider the boreholes more efficiently located if

they are nearer to them than if they are not. Table 8 shows that while half the number of respondents indicated they have a borehole close to their residences, some of them are non-functional.

Table 8 Functionality of boreholes

| Functionality | Freq | % |
|----------------------|-------------|----------|
| Yes | 28 | 17.72 |
| No | 130 | 82.28 |
| Total | 158 | 100.00 |

Slightly more than 80% of respondents claimed that the boreholes closest to them are not functional, which may explain why a large number of residents thinks that the boreholes are not near enough to them. This is quite understandable. There is no point in having a borehole close by if it does not work. Residents are still compelled to go farther distances than are acceptable to get water for their uses from functional boreholes. Table 9 presents data on residents' perceived reasons for this large number of non-functional boreholes in the community.

Bad locations and poor construction are regarded as the most important factors (87%) why most boreholes in the community are non-functional. Many boreholes are located in places that do not have any high prospects of yielding water (bad location) or the contractors did not dig deep enough to reach the water table or aquifer (bad construction). In both cases the result was a dry borehole, many which litter the community.

Table 9 Reasons why boreholes are non-functional

| Reasons | Freq | % |
|-------------------|-------------|---------------|
| Bad location | 68 | 43.04 |
| Poor construction | 72 | 45.57 |
| Poor maintenance | 14 | 08.86 |
| Others | 04 | 02.53 |
| Total | 158 | 100.00 |

In other cases, poor maintenance (about 9%) is the culprit. The borehole yielded water that the community used but along the line it fell into disuse because of faulty parts. The community has not been able to restore the faulty parts to proper use therefore they have become non-functional. An example is the borehole in Fyaplak. It is one of only three well developed borehole sites, with an

overhead water tank and a generator house. It was one of two most productive boreholes in the town. Unfortunately, the generator was vandalized in 2019 and has not been repaired. Consequently, the borehole has not been in use.

Table 10 presents data on distances of residents housing units to the nearest functional borehole location.

Table 10 Distances to borehole locations

| Distances | Freq | % |
|------------------|-------------|---------------|
| Less than 100m | 56 | 35.44 |
| 100-200m | 48 | 30.38 |
| 200-300m | 24 | 15.19 |
| 300m & Above | 30 | 18.99 |
| Total | 158 | 100.00 |

Nearly 68% of residents claim that their residences are within 200m of a borehole location, which is close to the results for the physical accessibility (65%). Only 18% reported that they are more than 300m away from a borehole location.

Alternative sources of water supply

All respondents indicated that they have alternative sources of water supply to the boreholes. Table 11 presents the data

Table 11 Alternative sources of water

| Alternative Sources | Freq | % |
|----------------------------|-------------|---------------|
| Well | 120 | 75.95 |
| Rain | 18 | 11.39 |
| Water Tanker | 02 | 01.27 |
| Water carriers | 18 | 11.39 |
| Total | 158 | 100.00 |

Wells are by far the most common (about 80%) alternative to boreholes as source of water supply. Many respondents contended that it was imperative

to have alternative sources of water to the boreholes for several reasons as presented in Table 12.

Table 12 Reasons for alternatives to boreholes

| Reasons | Freq | % |
|--|------|--------|
| Borehole is too far | 34 | 21.52 |
| Getting water from borehole is too difficult | 32 | 20.25 |
| Non-functional boreholes | 86 | 54.43 |
| Poor water quality of boreholes | 06 | 03.80 |
| Total | 158 | 100.00 |

The most common complaint against the boreholes is the non-functionality of most of them. More than half of the respondents (54%) identified this factor as the main reason for sourcing other alternatives to boreholes for water supply. About 42% claimed that the boreholes are too far away for their convenience or too difficult to get water from, probably either from the large number of persons using them at a time (poor water point density or population-borehole ratio) or the fact that it takes much time to collect water from them. This is a special indictment of the locational efficiency of boreholes in the study area in regards of distance, time and population/borehole ratio.

The poor water quality of some boreholes probably deserves some mention here even though the least number and percentage of respondents

(about 4%) deem it important enough for them to require alternative sources of water. All the six (6) respondents who made this claim are located around two (2) specific boreholes, one at Kururuwa ward area and the other in Chika ward area. The water from these two boreholes is salty and used only for some domestic purposes other than cooking and drinking such as washing of clothes and dishes. The respondents also claimed that the water is hard and requires the use of detergent rather than regular soap to even take a bath.

Public participation in location of boreholes

Table 13 presents data on level of public participation with borehole locations in the study area.

Table 13 Level of public participation with borehole locations

| | Freq | % |
|--------------------------|------|--------|
| None | 106 | 67.09 |
| Geophysical survey Stage | 18 | 11.39 |
| Identifying locations | 24 | 15.19 |
| Implementation Stage | 10 | 06.33 |
| Total | 158 | 100.00 |

Most respondents (67%) claimed that the community is never involved at any stage of selection of site for borehole locations. This is a low level of public participation. This may also influence their perception of the locations of boreholes and their choice and use of the resource.

Most respondents (59%) believe that political factor is the most important factor that has determined the location of most boreholes in the community. This is the reason why most of them are not functional because the geophysical surveys that should have guided locations of boreholes are either not conducted because decisions on where to

located them have already been taken in advance or were discarded to appease political agents in the community. They alleged that some boreholes were located close to the residences of government officials and community political representatives and agents rather than at locations that possessed greater promise for substantial amount of ground water. Consequently, these boreholes did not supply any water and were abandoned. An interesting case is that of three boreholes, barely 50 m or less apart, which were all abandoned. One of the three, was constructed directly in the yard of a government official for their convenience.

Table 14 Factors of Borehole Locations

| Reasons | Freq | % |
|-------------|------|--------|
| Political | 93 | 58.86 |
| Geophysical | 41 | 25.95 |
| Convenience | 17 | 10.76 |
| Others | 07 | 04.43 |
| Total | 158 | 100.00 |

Geophysical considerations were thought to be the main factor of determining location of boreholes by about 26% of respondents. Usually, it is expected that a geophysical survey of the area precedes the construction of the borehole to enable the identification of possible locations with high promise of water availability. Some of the boreholes benefitted from such a survey in the town. In most of the cases that benefitted from geophysical survey, the boreholes, some of which are still being used, yielded water.

Other factors are the convenience (11%) of contractors and other influential members of the community. It is claimed that some of the contractors were not interested in doing an effective work and just needed to sink boreholes wherever they wanted in order to claim their money. They therefore did not bother to conduct a geophysical survey or consult with the community. They just dug boreholes where they thought was convenient. An example given is the salty water borehole at Kururuwa, which is the site of a longstanding well that is referred to in the Ngas local dialect as “*am neshel*”, translated as salty water.

Respondents claimed that a borehole sunk in such a location would yield nothing other than salty water, which is not a desirable quality of water. They believed that the contractor was sure that a borehole dug in the area would yield water and that was all they wanted. Whether the community would be able to use the water is immaterial to them. It was a matter of convenience for them.

A few people (4%) thought that there was a deliberate policy to sink some of the boreholes at well-known water holes in the community. Unfortunately, only a few of such cases worked. One of the boreholes constructed in Tomten area is close to a well that has provided water for the area and beyond for more than half a century. Close to it (about 20 meters) is a depression that used to retain water during the rainy season and part of the dry season but is now silted and marshy. It is at this depression that the borehole was sunk, with the expectations that it would yield much water. This particular borehole is one of the developed ones with an overhead tank and a generator house. Unfortunately, it has never been used because it did not yield water beyond the day of construction. Two such other cases of boreholes dug near traditional waterholes or longstanding wells but are now dry and non-functional were cited at Kapkal and Per wards.

Two other ones (the one mentioned at Kururuwa and another at Fyaplak ward areas) yielded water. The one at Fyaplak area was particularly productive but has become temporarily incapacitated due to the vandalisation of the generator.

Discussion

Table 15 shows the summary of the findings on the locational efficiency of boreholes in Amper.

Table 15 Summary of locational efficiency indicators/measures

| Indicator/Dimension | Standards/Institutions | Efficient | Inefficient |
|--------------------------------|---|-----------|-------------|
| Physical accessibility | 0 – 200m (WHO, 2000) | √ | |
| Functional Water Point Density | 1 water point/250 persons (Mwamaso, 2015) | | √ |
| Reliability | 24 hours per day (WHO, 2000) | | √ |
| Perceptual Rating | Perceptions on locational factors | | √ |

WHO (2000) recommends that water sources should be within 200 m of the dwellings of residents of a community to be regarded as efficiently located. This study found out that at least 65% of residential units in the study area are within 200 m of a functional borehole. Moreover, about 68% of respondents claimed that they are within 200m of a borehole in the area. In regards of distance to borehole therefore, the locational efficiency in the community is reasonably high and acceptable. Mwamaso (2015) found that with regards to physical accessibility in Kiromo and Zonga wards of Tanzania, the full coverage of water access by boreholes is at 188%, which means that the area is generally over-served. He however cautioned that this did not mean that all houses and therefore people were covered within the acceptable limit for physical access to water. A significant number of houses and people were still out of the 400m limit he used. In parts of Niger State, Nigeria, Dangana et al. (2015) found that about 60% of residents of Lapai, Bida and Edati local government areas travel not further than approximately 100 meters to access water (well, boreholes, vendors and streams). Similarly, in Amper there is a significant number of houses and people outside the 200 m buffer zone considered acceptable for access to water. The second technical measure however falls grossly short of acceptable limits.

Mwamaso (2015) pointed out that the UN and WHO acceptable standard is that the population-borehole ratio should be 250 persons per 1 functional water point. In the study area, however, there is an incredibly high population-borehole ratio of more than 1700 persons per one functional borehole. This is unacceptable by any standard. If all the boreholes (functional and non-functional) are used, the ratio is still unacceptably high at more than 700 persons per borehole. Other parts of Nigeria appear to fare much better than Amper. For example, Dangana et al. (2015) found that Enagi, Edati LGA of Niger state, one borehole facility served only 91 people, while in Sakpe, 100 people on average were served per borehole. In Lape town, one borehole served about 87 people and in Gulu, one borehole served 110 people. In Mapaworo community however, there is only one borehole to 300 persons. It may be important to state that since the population and land area sizes of these

communities are not known, it is difficult to make a useful comparison with Amper. Suffice it to state that the acute water scarcity in Amper is due to many factors.

The simple reason is that the number of boreholes is grossly inadequate and therefore their locations would definitely be inefficient in regards of this standard. This may explain why many respondents (20%) claimed that collecting water at boreholes is too difficult for them. With such a high population-borehole ratio it is best imagined how much difficult it may be to collect water and how much time it would take to wait in line for one's turn at the pump. Additional 54% of respondents claimed that the nearest borehole to their residences is non-functional, which adds to their difficulty of getting water at other locations, which may be within 200 meters but still perceptually far considering the fact that the non-functional borehole would have provided them with the closer alternative. The poor FWPD index value also means that the functional boreholes will be crowded with people from other areas with non-functional boreholes. This fact makes it difficult for those within the 200m acceptable buffer zone to access water.

The measure of reliability of supply of borehole is average at best. Out of 19 boreholes in the community, only 8 (42%) are functional. Some of the reasons adduced for the large number of non-functionality of boreholes in the area include bad locations of boreholes (43%) and poor construction (45%). Political factors (58%) rather than geophysical factors (25%) is responsible for the location of boreholes in the town and are partly responsible for their non-functionality. Some of these boreholes, according to residents, are used only during the dry season because they are locked up during the rainy season. Access to reliable supply of water from these boreholes is therefore seasonal. Often because of breakdown of equipment, the boreholes do not supply water all the time. Consequently, there are hardly any guarantees that the boreholes would meet the 24-hour supply of water as standard measure of reliability. All respondents have also indicated that because of gross unreliability of supply from most of the boreholes they have acquired other alternative sources of water to the borehole to ensure steady

water supply to the households. The study therefore finds that in terms of 24-hour reliability of water supply, only four of the boreholes can be relied on throughout the year. Unfortunately, two of these yield salty water only all year round. Location of boreholes is therefore inefficient.

CONCLUSION

Boreholes in the study area have a high degree of locational efficiency based on physical accessibility. However, based on population-borehole ratio (functional water point density), reliability and perceptual measures, the boreholes' locational efficiency is scored low. Overall, therefore, the location of boreholes in the study area is inefficient. The benefit of physical accessibility by most residents is nullified by a poor population-borehole ratio, which means that boreholes are overcrowded and even those within the acceptable 200m physical distance compete with the larger population for access to borehole water. The fact that all respondents indicated that they have arrangements for alternative sources of water further illustrates the fact of the inefficient location of the boreholes and their unreliability. Arrangements for alternative sources of water may be due to residents' perceptions of the difficulty of reaching, collecting and reliability of these boreholes, even though there are apparently many boreholes in the town. If the boreholes were efficiently located, they would all be yielding water all day and all year round. This would have provided the needed relief and the alternatives may not have been necessary.

The study makes the following recommendations. There is a need to complete and restore all the 11 boreholes that are currently non-functional in the study area. This will greatly improve the physical accessibility and water point density measures of locational efficiency. There is also need to increase the number of boreholes in the study area to cater for population-borehole ratio (functional water point density) to improve this measure of locational efficiency.

There is need to have boreholes that are well constructed to ensure reliability in supply of water. There is also need to have public participation in the decisions governing borehole location and construction. This will greatly aid perceptual measure of locational efficiency.

Studies should be conducted on locational decision making processes especially of boreholes at communities to ensure that the people take ownership of the resource. The procedures and processes for location of boreholes should be strictly adhered to. This includes extensive geophysical surveys and other complementing surveys that would increase the prospects of obtaining the required quantity of water from the boreholes. This is important considering that each borehole, within the last two years cost N400,000 per borehole. This is separate from the cost of other accessories such as the hand pump, generator, overhead tank, and others including labour. Studies of locational efficiency of boreholes in other communities are recommended to determine the level of inadequacy or water supply gap required to meet the water demand in those communities. Other studies should also include water yield ratio of boreholes, and how borehole water could be harnessed to increase efficiency in distribution of water to communities.

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