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ORIGINAL RESEARCH ARTICLE

PATTERN OF RESIDENTIAL WATER DEMAND ANALYSIS FOR MAIDUGURI METROPOLIS, NORTH-EASTERN NIGERIA

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ABSTRACT

This study investigated the projected 50-year water demand of Maiduguri township from 2006 to 2056. The impact of socio-economic factors on water consumption pattern of the population was also assessed. Data were collected from 200 households using structured questionnaires and analyzed using Statistical Package for the Social Science (SPSS). The results show that on an average, a household in Jere and Maiduguri consumes an estimated 421.85l L/day while areas worst hit are new layouts and those covered by the phase 2 water treatment plant (yet to be completed). In addition, it was found that, gender, education, household size and income were statistically significant predictors of water demand. Furthermore, the results revealed that in 2006, the combined population of Jere and Maiduguri was 749,123, which was later projected to be around 3,618,579 by the year 2056. Similarly, water demand was estimated to rise to approximately 154,443 M^3/day by the year 2056 to meet the water demand of the growing population. However, in 2006, the combined water supplied from Maiduguri water treatment plant and all the functional boreholes (public boreholes) stands at 31,973M^3/day while in 2016 it rose to 43,811 M^3/day. The increase was due to additional supplies obtained from boreholes provided by some Non-Governmental Organization (NGOs) in some locations across the two areas. It is noteworthy that water supplied in the year 2016 to the population was grossly inadequate to meet the household water demand. Therefore, with the projected water demand of about 154,443 M^3/day by 2056, it is recommended that all existing water supply schemes including the proposed phase 2 of the Maiduguri surface water treatment plant designed to cover West end, Wulari, Bulunkutu and Maduganari areas to be completed to increase the supply. Service boreholes in newly established layouts should be put to operate at full capacity including the additional ones drilled. Also, the Dala Alamdari mini water works constructed by International Committee of the Red Cross (ICRC) which is operated below its installed capacity due to poor management to be enhanced.

1.0 Introduction

With the expansion of urban areas, infrastructural development and persistent need for clean drinking water, many urban communities are still faced with the challenge of inadequate water

supply (Adeoye et al. 2013; Ogundobe and Ifabiyi, 2014). Water supplied for domestic and agricultural uses are generally inadequate. However, the supply of clean drinking water to meet the growing population is challenging in many societies (Adeoye et al. 2013; Abubakar et al. 2014). Unsustainable utilization of available water and poverty are other factors that affect water demand and supply (Mbaya, 2008). Overall, lack of access to clean water supply affects the general standards of living of the people. Thus, assessing available water resources and predicting water demand are essential for proper water demand planning and management.

Recently, several studies have been conducted to evaluate the determinants of water demand in various locations in Nigeria (Mbaya, 2008; Sule, 2010; Al-Amin et al., 2011; Ogundobe and Ifabiyi, 2014). However, there are still some gaps to filled because little information is known about the situation in the North eastern Nigeria. Furthermore, some of the literatures which emerged from the Northern region did not cover the intricacy of the unique water demand in this time of incessant influx of people in various towns as a result of insurgency. For instance, Mbaya, (2008) had shown that the water consumption pattern of Gombe state between 1996 and 2020 was as low as 20 l/c/d which was lower than the prescribed minimum of 60 l/c/d by the World Health Organization (WHO) and United Nations Development Program (UNDP) (WHO, 2006; UNESCO 2012,). Similarly, Sule, (2010) found that the average per capita water consumption in Ilorin, Nigeria in low, medium and high-density areas to be 92.24l/c/d, 61.22l/c/d and 71.22l/c/d respectively. The differences were due to discrepancies in socio-economic characteristics of the households, population, and availability of clean water for domestic use. Additionally, this finding agrees with the result obtained by Ayanshola, et al., (2010) in the same location (i.e. Ilorin town). In addition, Arbues and Martinez-Espineira (2003) considered factors such as price of water, income and household composition as the major predictors of domestic water demand. In their study, different tariffs were used with the objectives of identifying the predictors of water demand as previously mentioned. It was reported that the quantity of water consumed by household largely depends on factor such as the socio-economic characteristics of the household, Education, climate and sanitation or hygiene practices. Interestingly, Ifabiyi, et al. (2012) found that the levels of education, income, and marital status were of households were positively correlated to water use while time spent in fetching water and distance to water source were found to be negatively correlated. Conversely, Al-Amin et al. (2011) revealed that, other factors such as cultural habit, settlement pattern, type of supply and water source could be a determinants of water use. Since water use varies according to different factors influenced by people's standard of living, then forecasting is one option which can enhance understanding of the underpinning determinants of water demand (Ifabiyi et al., 2012; Cook et al., 2001). Therefore, information regarding the past, present and future water demand would assist in addressing challenges of water supply in urban and semi-urban centres. It is noteworthy that several methods of forecasting water demand exist in literatures such as per capita and per unit approaches, end-use models, extrapolation methods and structural or casual models (Boumann et al., 1998). Each of these methodologies can be adopted based on intended use and the time frame of the prediction and data set at hand (Galan, et al., 2009). Additionally, (Sule, 2010) argue that the selection of water demand forecast methodologies is a function of planning objective, availability of data and resources availability.

Interestingly, a lot of literature has been published on water demand analysis but such studies showed different approaches with no consensus on the accuracy of the methods to predict water demand (Mbaya, 2008; Adeoye et al., 2013; Ogundobe and Ifabiyi, 2014). This is because

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every region has its own peculiar water use and socio-economic characteristics influencing water consumption. However, most of the models used in water demand studies are regression models Arbues et al., (2003) with the commonest estimators being ordinary least square (OLS), Two and Three Stage Least Squares (2SLS, 3SLS), and Maximum likelihood depending on the data set the researcher possessed. Therefore, the aim of this study is to predict water demand and supply base on the current supply, water availability and accessibility in Jere and Maiduguri townships. Information regarding current and future domestic water use by households would be evaluated for possible expansion.

2. Materials and Method

2.1 The Study Area

The study was conducted in Jere and Maiduguri metropolitan councils as shown in Figure 1. However, for proper coverage and understanding, Maiduguri town comprises of Jere and Maiduguri urban areas, and is located between latitudes 11° 42' N, 12° 00' N, and longitudes 12° 54' E, 13°14' E. The town has an area of more than 3000km^2 with population of 749,123 people according to National Bureau of Statistics (NBS, 2007) figure. Maiduguri has semi-arid climate, savannah or tropical grasslands vegetation, light annual rainfall ranging from 300mm to 500mm and has average daily temperature of 22 to 35°C with mean maximum temperature exceeding 40°C between March and June before the onset of the rains in July to September (Arku et al., 2011). However, in this study, the town was divided into five Zones namely Kyarimi Park, Bulumkutu, Shehuri, Gwange and Bolori area respectively. This division was adopted from Borno State Water Corporation (BOSWC).

The economic mainstay of residence of Maiduguri includes farming, trading, civil service and other skilled works. Recently, there has been significant increase in population in Maiduguri as a result of insurgency where most Local Government Areas of the state were devastated. This development has increased pressure on the available water resources.

One of the main sources of water supply to Maiduguri is surface water from Alau Dam through the Maiduguri water treatment plant. Alternatively, many residents have their private boreholes to meet their water demand. This has led to proliferation and constructions of private and commercial boreholes to argument the water supply challenges. presently, ground water serves as another main source of water to many households in Maiduguri.

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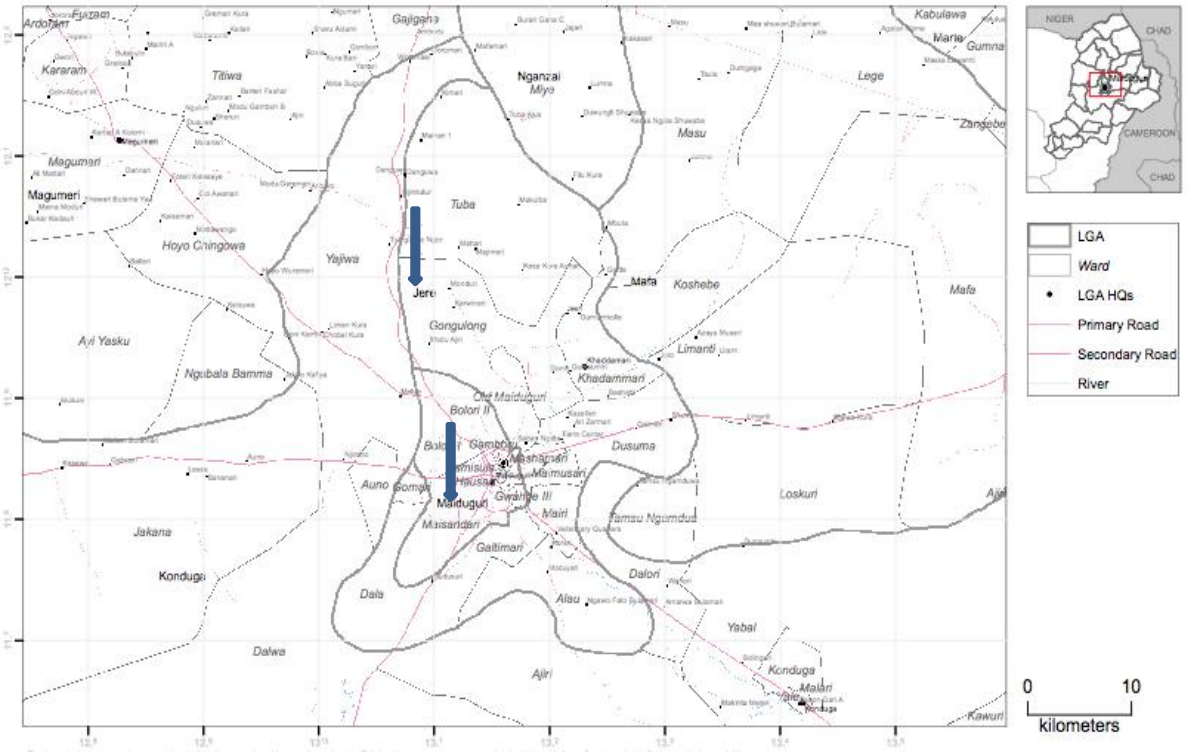

Figure 1. Map showing Maiduguri and Jere Local Government Areas (Source: https://www.unocha.org).

For convenience, Maiduguri town was divided into five different zones where 40 households were selected randomly from each of the five zones to form the coverage area for survey.

Data was collected by administering pretested structured questionnaires designed according to (Dagnew, 2012) with some modifications. This study considered respondents who are 18 years of age and above or household heads to obtain relevant information on domestic water use (Sule et al., 2010). This information includes: level of education of the household heads, household size, occupation, storage facility and other demographic and socio-economic factors affecting water consumption. The data obtained were analyzed using SPSS (IBM version 20) software. Similarly, analysis of variance (ANOVA) was used to determine the level of significance of the parameters and their dependence.

Analytical tools used in this study were based on the objectives of the study. These tools include: descriptive statistics such as frequencies and percentages for socioeconomics and demographic variables and Multiple linear regression models through the origin for factors affecting water stored for daily usage. The regression through the origin or no intercept model means that there is no constant term included in the model. The fitted model in regression through the origin is as follows from Equation 1:

$$Y = \beta_1 X_1 Y \quad (1)$$

This implies that that the constant βo in regression with intercept set to zero shown by Equation 2.

$$Y = \beta_{\circ} + \beta 1 Xi + ei \quad (2)$$

where: β_o is the intercept, β_1 is the slope and ei denotes the ith residual. In equation 1, β_1 is a coefficient and Xi is a predictor variable. It should be clearly noted that, water stored for daily

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usage is the dependent variable used in this study. Water stored for daily usage is a function of available storage facility when there is water scarcity or intermittent supply.

3. Results

In this study, population projection was based on the 2006 census figure. Table 1 presents the water demand projection for Maiduguri town from 2006 to 2056. The population of Maiduguri in 2006 was 749,123 (NBS, 2007) while the projected population in 2016 was 1,026,479. It is estimated that the population would reach 1,406,254, 1,927,276, 2,640,834 and 3,618,579 by the year 2026, 2036 2046 and 2056 respectively. Water demand is estimated to increase from 31,973M^3/day in 2006 to 154,443 M^3/day in 2056.

Table 1: Projected water demand for Jere and Maiduguri townships for five decades.

Year	Projected population	Service population Per 10 persons	Water Demand(m3/day)
2006	749123	319730	31973
2016	1026479	438107	43811
2026	1406254	600312	60020
2036	1927276	822573	82258
2046	2640834	1127123	112713
2056	3618579	1544430	154443

Table 2 shows that the average household size in Jere and Maiduguri was 10 persons per household. Similarly, the estimated current water demand and supply for these households were 200000 L/day and 84400l/day respectively. Presently, only 42% of household water demand is met by the water utility provider at approximately 422 L/day. However, the future water demand was estimated to be 154,443 M^3/day by the year 2056 as shown in Table 1.

Table 2: Household current demand and access to public water supply (L/day) base on 100 L/c/day

Sample	Average Size	Average water demand	Total water demand	Average water supply	Total water supply	Percentage satisfied
200	10	100	200000	422	84400	42

Figure 2a shows that out of the 200 respondents interviewed, 70 % were heads of the house, 12% are grown up children while 3.5 % are wives of the heads and 9.5% were blood relations and other relatives. In relation to the ages of the respondents in Figure 1b, 2% were between 18 and 23 years, 12.5% were between 24 and 29 and 26% were between 30 and 35 years of age respectively. Also, 20.5% were between 36 and 41 while 17.5% was between 42 and 47 years. Similarly, 17% of the respondents were between 48 and 53 years, and 54 and 59 respectively while 9% were 60 years and above. Considering the gender of the respondents, Figure 1c shows that 88% of the respondents were male, 80% of whom are married while the remaining 20% were not married. With regards to their level of educational, most of the respondents (data not shown), about 69% attended tertiary education whereas 8% and 4% have secondary and primary

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education respectively. Similarly, 19% have attended informal education such as Quranic education. Furthermore, Information regarding the respondent's occupation revealed that more than half (54.5%) of the respondents were civil servants, 21.5% were traders while only 1% are farmers, and the remaining 23% are not working class.

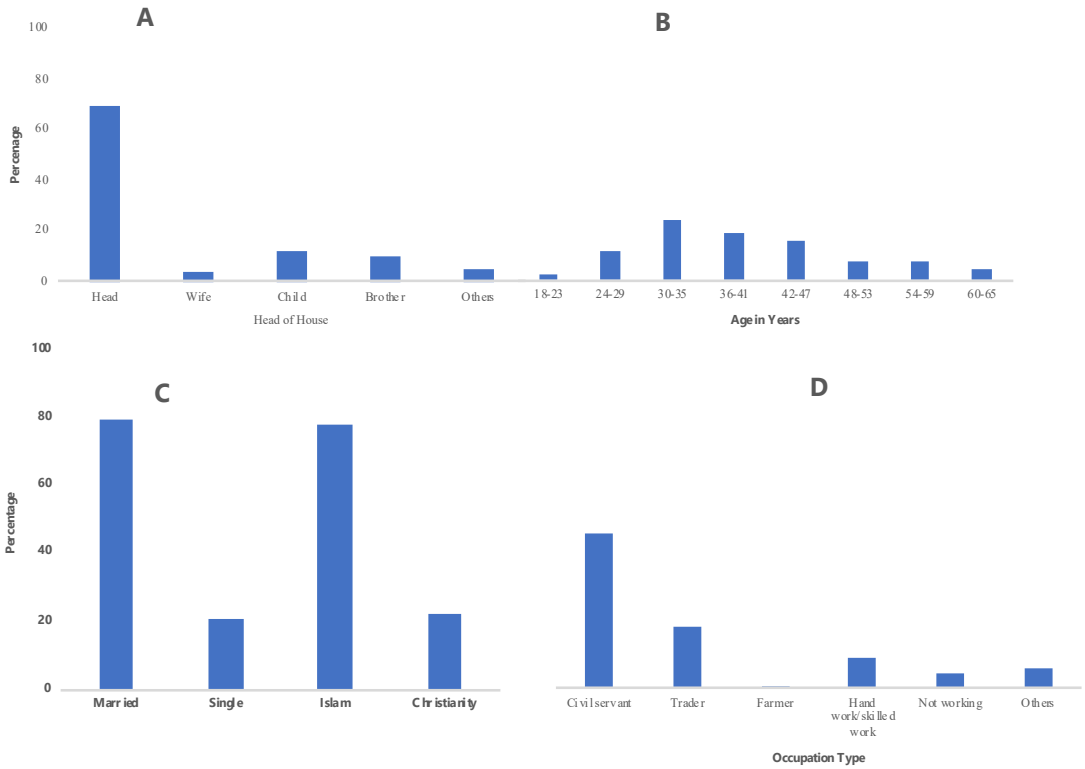

Figure 1: Demographic characteristics of respondents as head of house (A), respondents Age (B), marital and religious inclination (C); and occupation of respondents (D).

On the other hand, Figure 2a showed that 18% of the household surveyed reported that they are connected to public water supply while 8.5% used water from public standpipes. In addition, 58.5% get their water from water vendors. Furthermore, 13.5% of the respondents have their own boreholes and the remaining use to fetch from their neighboring houses. Figure 2b showed that all the respondents used different storage facilities to store their water. Approximately 51% of the respondents used drums or plastic jerry cans as storage facilities. While others, 21% used clay pots, 15% had overhead plastic tanks and 13% had underground cemented reservoirs. Regarding the distance to the primary sources of water, Figure 2c showed 37% collect water at a distance of between 50 and 99 meters away from their homes, 14% travel 100-199 meters, 13.5% travel between 200-500 meters away while 13% fetch water from a source over 500 meters from their residence while the remaining have taps in their compounds. The sanitation system revealed that 70% of the respondents used flush toilet while 28% used pit latrine as in Figure 2d

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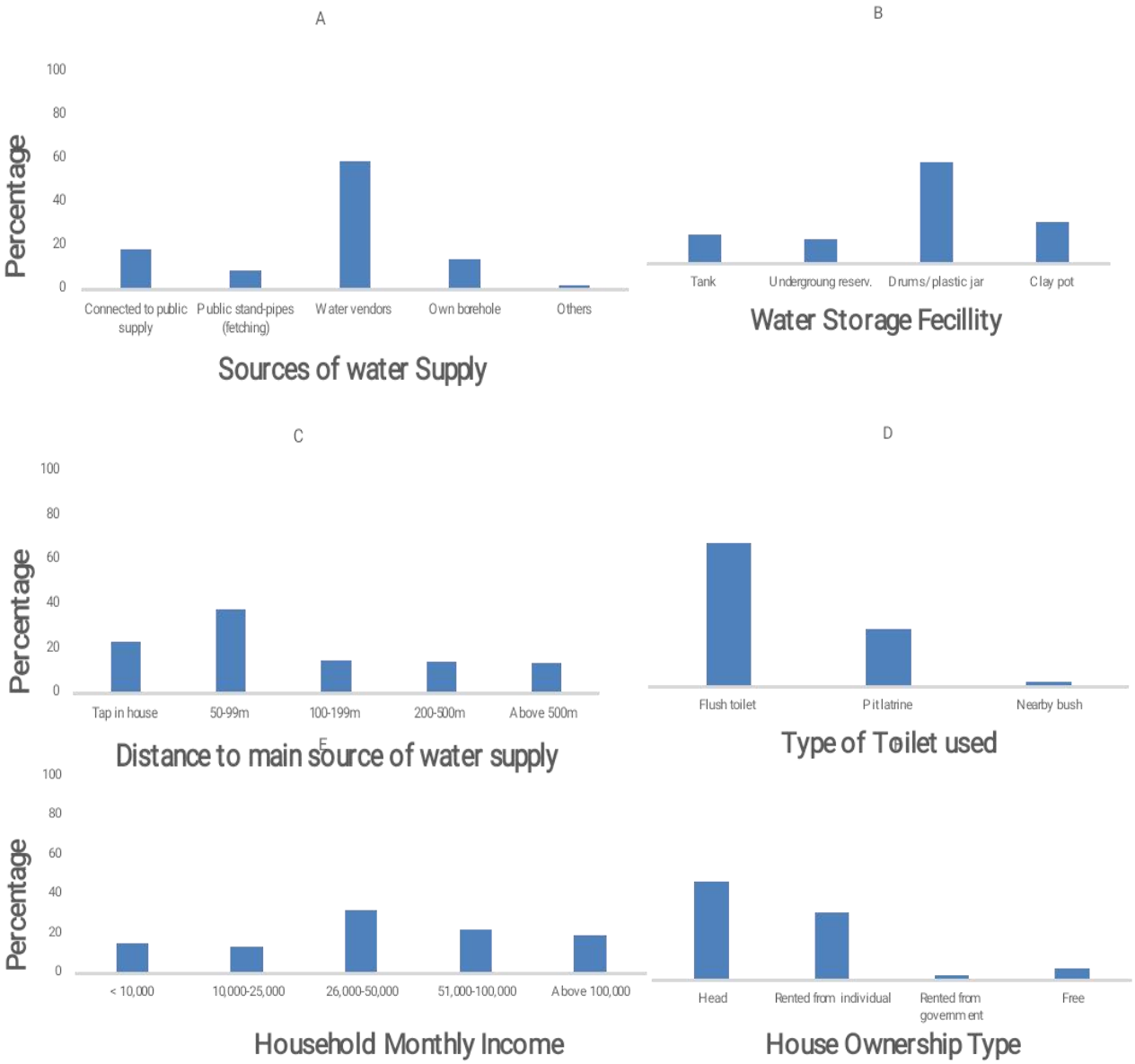

Figure 2 Water supply and sanitation condition of respondents: household main water supply (a), water storage facilities (b), distance covered by respondents to water sources (c), type of toilet used by the respondents (d), monthly income of households (e) and type of house owned (f).

Figure 2e showed that 31.5% of the respondents earns between ₦26,000 and ₦50,000 monthly, 21.5% earns between ₦51,000 and ₦100,000 monthly while 13%, earns less than ₦10000 while 15% collect between ₦ 10000 and ₦25,000 respectively. Additionally, only 19% of the respondents earned above ₦100,000 per month. Private residential ownership indicated in Figure 2f that 53% own the houses, whereas only 36.5% and 3.5% rented from individual and government respectively.

The study found the mean water stored for daily usage (demand) in Maiduguri to be approximately 421.85 l/h/d (i.e. 44 l/c/d), which is not in agreement with 86.22 l/c/d reported by (Ayanshola, Sule and Salami 2010). Similarly, a value of 150/c/d was reported for Ijebu (Coster and Otufale 2014). According to the procedure of stepwise multiple linear regression analysis technique, a model with high value of R2 (or adj R2) and a lower value of both standard error and mean square error, with a good P-value of less than 0.05 which test the significance of both

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regression coefficients and the regression model is considered to be the best. Factors used in this study include: respondent as head of household (X_1), gender (X_2), age (X_3), educational years completed (X_4), household size (X_5), occupation (X_6) and monthly income of the household (X_7) For each type of demand model, the researchers take a number of factors which are considered as important because of their reliable impacts on that demand. The result of multiple regressions analysis (Table 3) shows a high coefficient of determination R^2 (0.674) and adjusted R^2 (0.662). This means that 66.2% of proportion of the variability in quantity of water stored for daily usage, (daily consumption or demand) per household.

Table 3 (coefficient of variation) reveals that five of the independent variables are strong predictors of water demand. These are: gender (β=-0.91, P=0.047), educational years completed (β=0.403, 0.004), household size (β=0.273, 0.001), occupation (β=-0.18, 0.009), and monthly income of the household (β=0.403, 0.008). The table also shows both the standardized and unstandardized coefficients. To compare the effects of different variables, it is appropriate to use the standardized coefficients rather than the unstandardized ones. Standardized means that the values of the coefficients correspond to the expected change in the dependent variable given a change in the independent variable equal to its standard deviation. Thus, in logical term, each of the coefficients has been converted to the same scale so that comparison between them is possible. According to this analysis, the mean of the dependent variable (water stored for daily usage per household or water demand) is 421.85l/day.

An ANOVA results showed that the entire model could predict a better than 0% (R2 value). The model reaches statistical significance value of 0.000 (i.e. p<.05). Each of the variables included in the model were also examined to see which of them contributed to the prediction of the dependent variable. The linear regression model through the origin was formulated from Table 3 and regression equation with coefficient presented by equation 2.

Table 3: Multiple linear regression result of determinants of water demand (water stored for daily usage)

Model	Coefficients				
	Unstandardized Coefficients		Standardized Coefficients		Sig
	B	Std. Error	Beta	T	(P-values).
Respondent as head of house	-42.534	47.884	-0.045	-0.888	0.375
Gender	141.973	71.171	0.091	1.995	0.047
Age	0.654	1.479	0.052	0.442	0.659
Educational years completed	15.615	5.322	0.403	2.934	0.004
Household size	13.089	3.781	0.273	3.462	0.001
Occupation	-36.400	13.778	-0.180	-2.642	0.009
Monthly income of household (N)	42.154	15.685	0.268	2.687	0.008

$$Q_s=0.091X_2+0.403X_4+0.273X_5-0.180X_6+0.268X_7 \quad (2)$$

where:

Q_s is the quantity of water stored for daily usage (daily household water demand).

X_2=Gender,

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X_4 =Educational years,

X_5= Household size,

X_6= Occupation and

X_7 = Monthly income of the household head.

4. Discussion

This study presents the population projection and water demand of Maiduguri from 2006 to 2056. To our knowledge, this is the first study where water demand and supply was holistically studied in Maiduguri. It was evident that most of the areas worst hit by water scarcity are new layouts and areas proposed to be covered by the phase 2 of the Maiduguri surface water treatment plant. Currently, there is no sign of Government intention to commence work on this project after the commissioning of the phase 1 in 1993. Although, the number of households having access to water has increased, yet the population without access has doubled over the year due to population expulsion in the city. However, this result agrees with that of Mbaya, (2008) who observed that an increase in service population is attributed to the increase in water supply from the regional water scheme in Gombe state. Conversely, over the years there has been a gap between water supply and demand. Interestingly, more than 57% of household water requirement in Maiduguri town is not met by the public water supply (PWS) due to poor funding, maintenance, and mismanagement of the available finances. Additionally, even the completed phase one is not operating at full installed capacity due to lack of power supply and water treatment chemicals. It is noteworthy that most of the boreholes in the study area also operates below their design yields. The total average water demand was estimated to be 200000 L/day while only 84400 L/day was being supplied by 2016. Similarly, such observation has been reported by Mbaya, (2008) where an average water demand of 18000 l/day was estimated but only 9000 L/day was supplied in Gombe State. This was reported for Gombe metropolis with population of 235,687 (NBS, 2007). Household without access to PWS is left with no options than to sink their private borehole or buy water from vendors, which are usually unsafe and costly. Furthermore, majority of the respondents are traders and civil servants whose earnings hardly sustain their family, thus, resorted to the purchase of water storage containers at the expense of many household needs.

The study also found that women are the ones who bears the burden of fetching water which could affect their educational future (Ogunbode and Ifabiyi, 2014). With low level of education of the respondents, water demand by households could be affected (Ayanshola, Sule and Salami 2010) resulting in poor hygiene practice thereby translating into loss of water demand priority. Most respondents prefer to fetch water from a nearby sources irrespective of water quality. The percentage of the respondents (37%) who have their primary source of water at a distance of between 50-99 meters was not in agreements with study reported by Coster and Otufale (2014) who argued that 93.1% of the respondents in Ijebu Ode local government of Osun State Nigeria trek for more than 30 minutes to fetch water. Conversely, Ogunbode and Ifabiyi (2014) observed that 69% of the respondent in Osun state had to trek for only 10 minutes to get their drinking water. Furthermore, because most of the respondents are low-income earners they depend largely on water vendors for water supply. In addition, these are people in most cases engaged in illegal water connections on public water supply mains.

Total households water demand in Maiduguri town was observed to be 421.85 L/h/d (ie. 44 L/c/d) for a family of 10 people, lower than 86.22 L/c/day as reported by Ayanshola, et al., (2010)

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for Ilorin. However, the results of this study is higher than 150 l/h/d reported by Coster and Otufale (2014) and 20 L/c/d by Mbaya (2008) for Ijebu and Gombe town respectively.

As expected, gender is statistically significant ($p<0.05$) in explaining water demand. Women requires more water than their male counterparts for their daily activities. This study agrees with Ayanshola, et al., (2010) who studied water supply use in Ilorin town. The result also indicates that household size is positively and statistically significant variable in explaining household water demand in the study area. It was found that, a 1% increase in household size increases water demand by 23.7%. As expected, households with higher number of people used more water, especially families with many children in their care. The larger the household size, the higher the volume of water needed for domestic uses. This finding is similar to the 17% obtained in Iwo Osun State (Ogunbode and Ifabiyi 2014).

Furthermore, respondent's occupation is statistically significant ($p<0.05$) in determining water demand because trader and skilled worker are paid daily and thus could spend more than civil servants who are on a monthly payroll. The regression result also shows that income of households is positively and statistically significant in explaining water demand. A 1% increase in income increases water demand by 26.8%, and this is significant at 5% confidence interval. Generally, the living standard and income level of the people are directly related. People with higher income could satisfy their basic needs than low-income groups. It is clear that households with higher monthly income are more likely to obtain sufficient water at whatever cost. This is probably because they can pay the service and connection charges required by BOSWB as reported by Juryilla (2015). They could also afford to drill their private borehole when in need. It is noteworthy that the head of the house and age of respondent were not significant ($p>0.05$) in determining water demand and use which is not in agreement with the results reported by Ayanshola et al. (2010) where head of the house and age of the respondents were found to be significant.

5. Conclusion

An investigation into the determinants of domestic water consumption by households in Jere and Maiduguri was conducted. It is evident that gender, education, household size and socio-economic status play an important role in determining water consumption by the populace. Although, in most of the communities, water supply was grossly inadequate, the quantity of water supplied has increased in recent time due to intervention in the sector by some NGOs in the provision of boreholes. While the UNDP, (2006) stipulated 60 L/c/day as the daily minimum for water consumption in developing countries, most residents consumes approximately 44 l/c/day which is grossly inadequate. Furthermore, most households are not connected to public water supply. Additionally, there were evidence of intermittent supply from those who are connected to public water supply. This has caused many residents to depend on water vendors for water supply. Interestingly, Areas worst hit by water scarcity are areas not currently covered by the surface water treatment plant and New layouts. Therefore, the study identified the need for water supply system expansion in Maiduguri to meet the growing population. BOSWC should ensure that all existing water supply schemes are operated at full capacity and also provide public taps across the city to give easy access to water for people who could not afford to pay for the charges. Finally, accurate data collection processes should be enhanced for proper management and planning. Again, water metering system should be adopted to avoid wastage at household level.

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