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ASSESSMENT OF POPULATION PRESSURE ON WATER SUPPLY RELIABILITY IN GOMBE METROPOLIS, GOMBE STATE, NIGERIA

[1*]Didams, G., and [2]Lashiko, B. H.

[1]Department of Geography and Environmental Management, Faculty of Science, Gombe State University, Gombe State, Nigeria, orcid: 0000000228460020

[2]Post Primary Schools Management Board, Adamawa State, Nigeria

*Corresponding author: gdamsviva@gsu.edu.ng

Abstract

Water is essential for all forms of life, yet its availability is increasingly threatened by rapid population growth, particularly in urban centres of developing nations. This study assessed population pressure on water supply reliability in Gombe Metropolis, Gombe State, Nigeria. The research employed a mixed-methods approach, utilizing population data from the National Population Commission spanning two decades (2006–2025), water supply records from the Gombe State Water Corporation, and structured questionnaires administered to 400 residents across the metropolis. Time series analysis, Mann-Kendall rank statistics, and Spearman's rank correlation coefficient were used to analyse the relationship between population dynamics and water supply patterns. The findings revealed that Gombe Metropolis experienced a remarkable population increase from 312,467 in 2006 to 630,413 in 2025, representing a 102% growth rate. Conversely, water supply volumes remained erratic and failed to demonstrate any commensurate upward trajectory, fluctuating between 5,122 m³ and 10,123 m³ annually without a clear increasing trend. Spearman's rank correlation coefficient (-0.065) indicated a weak negative correlation between population growth and water supply, confirming that water supply variations are largely independent of demographic changes. The per capita water availability stands at a critically low 10.36 litres per capita per day, far below the Nigerian national target of 60–100 LPCD and the WHO minimum recommendation of 50 LPCD. This severe deficit has forced residents to rely on expensive alternative sources, with households spending upwards of N30, 000 monthly on water procurement. The study concludes that population pressure has significantly compromised water supply reliability in Gombe Metropolis, creating a scenario where demand consistently outstrips supply. The situation is exacerbated by infrastructural deficiencies, operational inefficiencies, and geological challenges that complicate groundwater access. Urgent interventions are required, including expansion of treatment plant capacity, investment in distribution networks, adoption of water conservation strategies, and implementation of integrated water resource management frameworks to ensure sustainable water security for the growing population.

Keywords: Population Pressure, Water Supply Reliability, Per Capita Water Availability, Gombe Metropolis, Gombe State, Nigeria

1. INTRODUCTION

Water is one of the most plentiful resources. Covering more than two-thirds of the Earth, water travels from the sea into the air to the land and back to the sea in a seemingly endless cycle of renewal. Yet water is a finite resource, and the tiny fraction suitable for drinking or irrigating crops is distributed unevenly throughout the world's regions. At the same time, the human need for water is escalating because of rapid population growth and industrialization, especially in the world

regions where water is most scarce. The world's population lives at the mercy of the water cycle. Human innovative talents can make the best possible use of the water that passes through the territory of a country, but technology cannot influence the rate at which water is naturally renewed from the global water circulation system. Further, human activities, such as the clearing of land,

disposal of wastes, and withdrawal of freshwater, introduce disturbances in the water cycle that resonate throughout the Earth's environmental systems. These disturbances are accelerated by the worlds continuing population growth.

Population growth represents one of the most significant global challenges affecting water supply systems, with particularly severe consequences for urban centres in developing nations. As the world's population continues to increase, so does the demand for freshwater, a resource already under considerable strain. With global population projected to reach 9.7 billion by 2050, unprecedented stress on water resources is anticipated, especially in densely populated urban areas (Liu et al., 2024). Nigeria, as the most populous country in Africa, presents a critical case study in this regard, with Gombe State located in the northeastern region experiencing significant demographic pressures that have overwhelmed its water systems (Irene et al., 2025).

Gombe metropolis has witnessed extraordinary population growth, with figures revealing a steady increase from 373,000 in 2006 to a projected 644,000 in 2026, driven by an annual growth rate of 3.87% (Benjamin et al., 2025). This rapid urbanisation has been fuelled by Gombe's role as a political and educational hub, as well as an influx of people fleeing insurgency from neighbouring states. Rabiu, Kolawale, Raheem, Rauf, and Salisu (2025) noted that Gombe State's population has grown from approximately 2.6 million to over 3.6 million, with most of this growth occurring within the Gombe metropolis and surrounding communities. They attributed this phenomenal growth largely to rapid urbanisation and the displacement of populations from Borno, Yobe, and Adamawa states due to the Boko Haram insurgency. This demographic explosion has placed tremendous pressure on the provision of basic social services, with water supply infrastructure originally designed for a much smaller population now stretched far beyond its intended capacity (Benjamin et al., 2025).

The consequences of this supply-demand imbalance are most acutely felt by residents across Gombe metropolis. Residential areas including Tudun Wada, Bolari, Pantami, Herwagana, Kumbiya-Kumbiya, and parts of Jekadafari Quarters have reportedly experienced no water supply from the state water corporation for months (Benjamin et al., 2025). Even highbrow areas like GRA, New GRA, Federal Low Cost, and Buba Shongo rely on commercial water tankers. Newly established residential areas such as Arawa, Kagarawal, Riyal quarters, Bomala, Nayi Nawa, and Tumfure face the most severe challenges, as most are not connected to the Dadin-Kowa water scheme (John and Nggada, 2019). This has forced residents to rely on privately-owned boreholes and water vendors, with ten jerry-cans of water costing as much as N1, 000 or more. Preliminary survey in Gombe metropolis found out that residents in Bolari Quarters spend over N1000 daily on water, amounting to over N30, 000 monthly, a significant portion of a civil servant earning a monthly salary of less than N80, 000. Similarly, a civil servant residing at Arawa Quarters, noted that in his five years of residence, taps had never run even for a single day, forcing his family to rely entirely on private boreholes.

The geological challenges of Gombe present additional complications to water access. Groundwater depth varies dramatically across the metropolis. In areas like Arawa, Bomala, and the eastern districts, the water table lies close to the surface, making drilling easier but exposing shallow aquifers to

contamination from waste sites and soak-away seepage. Conversely, the western axis from GRA through FTH and FCE to Tumfure has groundwater deeper than 200 meters, demanding advanced technology and significant investment for access (Sulaiman, Yusuf, Adamu, Rafi, Akinlotan, and Bello, 2025). It is against this background that this study assessd population preasure on water supply reliability in Gombe metropolis, Gombe State, Nigeria.

2. MATERIALS AND METHODS

Study Area

Gombe metropolis (Figure 1) is located between latitudes 10°15'N and 10°19'N and between Longitudes 11°07'E and 11°15'E. It is bounded by Kwami LGA to the North, Akko LGA to the Southwest and Yamaltu-Deba LGA to the East. Politically, Gombe Metropolis encompasses an area of about 54sqkm. The National Population Commission 2006 data recorded the metropolis population at approaximately 312,467, with current projections estimating it at about 630,413, yielding a density of 11,674 persons per kilometer square. The metropolis is divided into divided into 11 wards with varying population of semiurban and urban areas. It has a tropical continental type of climate, classified as Koppen's Aw, characterized by strong rainfall seasonality with distinct wet and dry seasons. The rainfall is concentrated between the months of May and September with a single maximum in August (Amos, Musa, Abashiya, and Abaje, 2015). The average annual rainfall totals is about 863.2 mm. The bedrock mainly consists of sandstones of cretaceous age, covered by tertiary and quaternary deposits. Gombe metropolis is a low-lying, undulating landscape sloping from Akko escarpment in the west to Liji hill in the east which is the highest point of about 500m. The metropolis is drained by some ephemeral streams and ravines which take their sources from the Akko escarpment and flow eastwards. The soils are highly ferruginous, formed as a result of intensive weathering of the basement rocks. (Amos *et al.*, 2015). The vegetation is of the Sudan savannah type, characterized by shrubs, scattered trees and grasses (Amos *et al*, 2015). The predominant tree species include: Parkia (*Parkia clappertoniana*), Baobab (*Adansonia digitata*), Tamarind (*Tamarindus indica*), date palm (*Phoenix doctylifera) and Neem (Azadirachta indica).*

Methods

The data needs for this study includes the following; population data of Gombe metropolis for the past two decades (2006-2025), responses of people based on their satisfaction as it concerns water supply adequacy or otherwise, publications from different sources especially as it relates to population growth and supply of water in Nigerian cities, information on the reservoir capacity of the water treatment Plant in Gombe metropolis. Information on the population variation of Gombe metropolis for the past two decades was obtained from the National Population Commission (NPC). The twenty years population data is was used in order for the authors to get a clearer view of the population growth of the metropolis for better analysis. The reservoir capacity of the water treatment plant in the Gombe was taken for the past twenty years. This helped the research to determine if there has actually been an improvement in the water supply situation of the metropolis in the past years

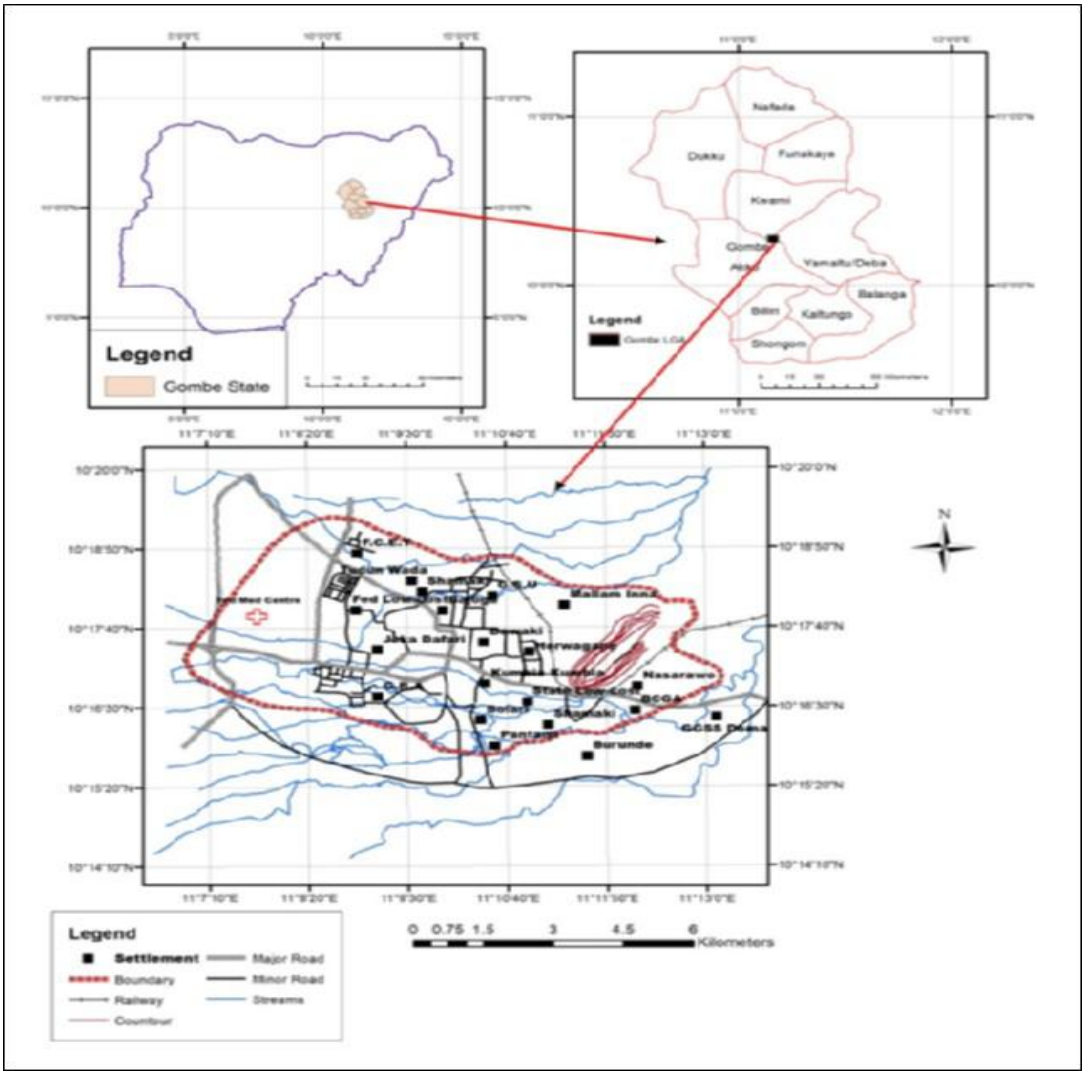

Figure 1. Gombe Metropolis
Source: Adapted from Ministry of Lands and Survey, Gombe State

Well-structured questionnaires were distributed to some of the inhabitants of the metropolis especially those that have access to the municipal water supply. A total of 400 questionnaires were administered in the course of this study in order to get across to a certain percentage of the people in the metropolis. Simple Random Sampling was used in the distribution of questionnaires in this study. The data is presented in tables, charts and line graphs, Time Series statistical tool was used in the analysis of data on population increase over the twenty-year period. Mann-Kandall Rank Statistics (Ţ) was used to establish if between the beginning and the end there is a monotonic increase or decrease in the values of time series, and the Spearman's Rank Correlation was used to establish the type of relationship that exist between the independent variable (water) and the dependent variable (population).

3. RESULTS AND DISCUSSION

Population Trend in Gombe Metropolis

Table 1 presents the population of Gombe metropolis for the past two decades and also the deviation from the mean (453,349) of the population data.

Table 1. Population trend of Gombe metropolis and the deviation from the mean 2006 - 2025

S/No	Year	Population	Deviation from the mean

1	2006	312,467	-140,882
2	2007	324,341	-129,008
3	2008	336,646	-116,708
4	2009	349,399	-103,950
5	2010	362,616	-90,733
6	2011	376,315	-77,034
7	2012	390,516	-62,833
8	2013	405,235	-48,114
9	2014	420,494	-32,855
10	2015	436,312	-17,037
11	2016	452,712	-637
12	2017	469,715	16,366
13	2018	487,345	33,996
14	2019	505,624	52,275
15	2020	524,579	71,230
16	2021	544,234	90,885
17	2022	564,613	111,264
18	2023	585,744	132,395
19	2024	607,664	154,315
20	2025	630,413	177,064

Sum = 9,066,973

Mean = 453,349

Note: Population fluctuates based on census interpolations, but the trend shows a consistent 3.8-4.0% annual growth.

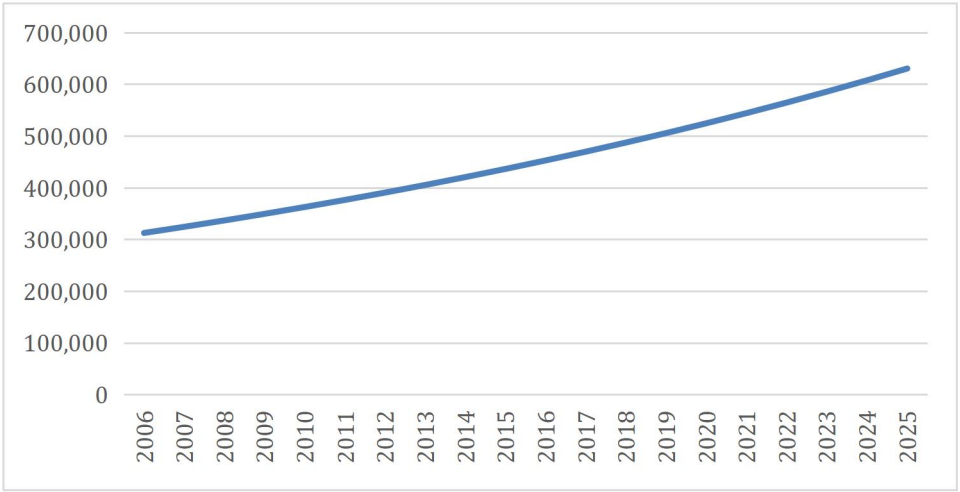

Figure 2. Population Trend of Gombe Metropolis (2006-2025)

In order to understand the trend in the moving time series of the data set on the population of the study area, the smoothing or filtering in time series was used in order to remove the unnecessary fluctuations in the data sequence of the population data collected. This filtering was done using the moving average of five (5), after which the result gave the moving averages and a monotonically increasing population as shown in table 2 and figure 3 respectively.

Table 2. Population trend check for Gombe Metropolis

S/No	Year	Population	MA

1	2006	312,467	-
2	2007	324,341	-
3	2008	336,646	337,094
4	2009	349,399	349,863
5	2010	362,616	363,098
6	2011	376,315	376,816
7	2012	390,516	391,035
8	2013	405,235	405,774
9	2014	420,494	421,054
10	2015	436,312	436,894
11	2016	452,712	453,316
12	2017	469,715	470,342
13	2018	487,345	487,995
14	2019	505,624	506,299
15	2020	524,579	525,279
16	2021	544,234	544,959
17	2022	564,613	565,367
18	2023	585,744	586,534
19	2024	607,664	-
20	2025	630,413	-

To fit the moving average the number of data point's k was calculated, after which the graph for the moving average should start. This is due to the fact that the number of moving average (16) is less than the number of the raw data (20), so the data points should be in equilibrium with the moving average, hence the calculation of the number of data points away from the beginning of the data sequence at which the moving average should begin. Therefore, according to the result, the moving average of the data in the graph started from 2008 to 2023. The graph of the result is plotted below.

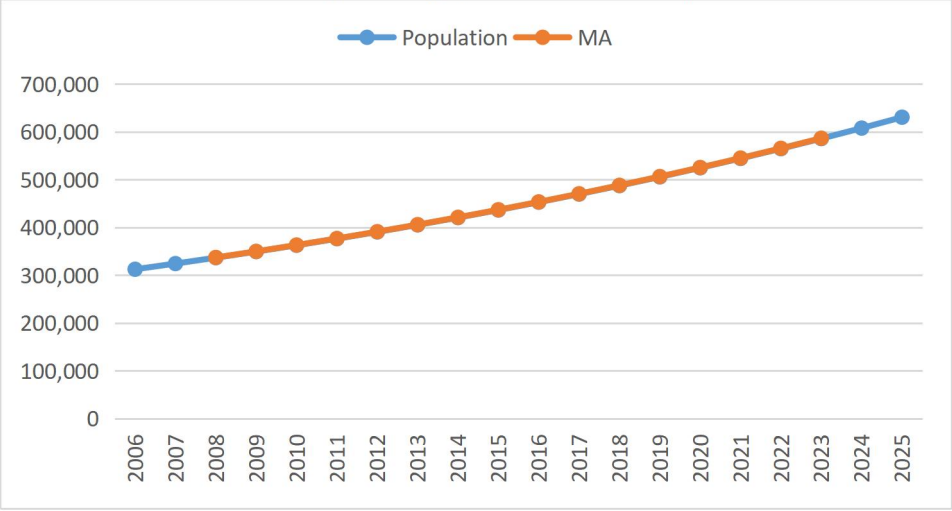

Figure 3. The movement of the population of Gombe Metropolis and the Mas

Analysis of the results in Table 3 and Figure 3 indicates that the population exhibits a steady and consistent upward trend. Over the twenty-year period, the population increased from 312,467 in 2006 to 630,413 in 2025, representing a near doubling of the total number of residents. This growth is remarkably linear, with each successive year adding between approximately 12,000 and 21,000 new inhabitants, reflecting a compound annual growth rate that is both stable and sustained. Such a demographic

trajectory is typical of rapidly urbanizing cities in developing regions, where natural increase and rural-to-urban migration combine to produce a continuously expanding urban population (Uttah, Akeh, Awan, and Obiefuna, 2022). The absence of any year-on-year decline or stagnation in the population figures further underscores the fact that Gombe Metropolis has been experiencing uninterrupted demographic pressure, which has profound implications for infrastructure, housing, employment, and essential services such as water delivery.

Water Supply in Gombe Metropolis

Findings revealed that Gombe Metropolis depends almost entirely on the Dadin Kowa Water Treatment Plant fed by Dadin Kowa Dam (Figure 4) located 37- 41.6 km east of the metropolis, on the River Gongola. Othe sources of water supply are through groundwater (boreholes and wells) distributed around. At inception the Dadin Kowa treatment plant was designed for 30 MLD. Subsequently, after rehabilitation in 2019, design capacity increased to 50 MLD (Gombe State Water Corporation, 2025). Despite the 50MLD design capacity, actual production and supply is constrained by energy and operational issues. Table 3 presents the actual water supply to Gombe Metropolis.

Figure 4. Dadin Kowa Reservoir

Table 3. Water Supplied to Gombe Metropolis from 2006 - 2025

S/No	Year	Volume of Water supplied in m³
1	2006	10,123
2	2007	8,567
3	2008	10,122
4	2009	9132

5	2010	9,562
6	2011	7,666
7	2012	5,122
8	2013	8,221
9	2014	7,453
10	2015	8551
11	2016	6123
12	2017	7,564
13	2018	7,023
14	2019	8,124
15	2020	7,521
16	2021	6,567
17	2022	6,022
18	2023	7,222
19	2024	8,892
20	2025	6,534

In glaring contrast to the population trend, the volume of water supplied annually to Gombe Metropolis has not followed any clear or consistent pattern of growth. The figures fluctuate widely from year to year, with values ranging from a low of 5,122 m³ in 2012 to a high of 10,123 m³ in 2006, and no discernible long-term increase to match the rising population. For instance, while the population grew by over 100% during the study period, the water supply in 2025 (6,534 m³) was actually lower than the supply recorded in 2006 (10,123 m³), and many intervening years show similar variability without any sustained upward trajectory. Years such as 2011, 2012, 2016, and 2022 registered particularly low volumes, while others like 2008 and 2024 saw moderate recoveries, yet these were never enough to establish a reliable upward trend. This erratic supply pattern suggests that water delivery is heavily influenced by factors such as infrastructure breakdowns, seasonal climatic variations, operational inefficiencies, or even policy changes, rather than by any planned expansion to keep pace with population growth.

Based on a daily water supply of 6,534 m³ and a population of 630,413, the per-capita supply is 10.36 liters per capita per day (LPCD). This is critically below the Nigerian National Water Supply Policy target of 60–100 LPCD for urban areas, and far short of the WHO minimum recommendation of 50 LPCD for basic health and hygiene (United Nations, 2020). At 10 LPCD, water is only sufficient for bare minimum drinking and cooking, leaving no provision for handwashing, bathing, laundry, or sanitation (African Development Bank (AfDB), 2020).

Relationship between Population Growth and Water supply in Gombe Metropolis

To statistically assess the relationship between population growth and water supply, Spearman's rank correlation coefficient was computed to test the hypothesis that there is no significant relationship between the population growth and the water supply in Gombe Metropolis.

Table 4. Correlation Analysis of Population and Water Supply

S/No	Year	Population (Y)	Water supplied in m³	Rank Y	Rank X	D	d²
1	2006	312,467	10,123	1	20	-19	361
2	2007	324,341	8,567	2	16	-14	196

3	2008	336,646	10,122	3	19	-16	256
4	2009	349,399	9132	4	18	-14	196
5	2010	362,616	9,562	5	17	-12	144
6	2011	376,315	7,666	6	12	-6	36
7	2012	390,516	5,122	7	1	6	36
8	2013	405,235	8,221	8	14	-6	36
9	2014	420,494	7,453	9	9	0	0
10	2015	436,312	8551	10	15	-5	25
11	2016	452,712	6123	11	3	8	64
12	2017	469,715	7,564	12	10	2	4
13	2018	487,345	7,023	13	6	7	49
14	2019	505,624	8,124	14	13	1	1
15	2020	524,579	7,521	15	11	4	16
16	2021	544,234	6,567	16	4	12	144
17	2022	564,613	6,022	17	2	15	225
18	2023	585,744	7,222	18	7	11	121
19	2024	607,664	8,892	19	17	2	4
20	2025	630,413	6,534	20	5	15	225
							Σd^2 = 1,416

According to the table 3 above the value of Σd^2 = 1,416 and the value of n = 20. Substituting for spearman's rank correlation formula as:

$$r_{\S} = 1 - \frac{6\Sigma d^2}{n(n^2-1)}$$

$$r_{\S} = 1 - \frac{6(1{,}416)}{20(20^2-1)}$$

$r_{\S}$ = -0.065.

Given the scale of correlation, this resulting correlation coefficient is very close to zero and negative, indicating a weak and inverse relationship between population size and water supply volume. In practical terms, this means that as the population of Gombe Metropolis has grown over the years, the volume of water supplied has not increased correspondingly; in fact, there is a slight tendency for water supply to decrease as population rises, though the correlation is so weak that it is essentially negligible. This near-zero correlation confirms visually what the raw data suggest, that water supply variations are largely independent of demographic changes and are driven by other non-demographic factors.

Population Pressure on Water supply reliability in Gombe Metropolis

Population pressure connotes that as more people live in an area, they demand more water, while simultaneously degrading the very resources that supply it. On the other hand, reliability in the context of urban water systems, implies the ability to consistently meet the demand of the population with adequate quantity and quality throughout the year. Given that the population of Gombe Metropolis has more than doubled while the water supply has not only failed to increase but has also shown extreme volatility, it is evident that the system is under severe stress. The per capita water availability, which can be roughly estimated by dividing the annual supply by the population, has almost certainly declined dramatically over time, leading to frequent shortages, rationing, and inequitable access. The wide interannual swings, for example, a drop from over 10,000 m^3 in 2008 to just over 5,000 m^3 in 2012, and another drop from over 8,000 m^3 in 2019 to

around 6,000 m³ in 2022, point to a system that is highly sensitive to disruptions, whether they be technical, financial, or climatic. Such unreliability not only affects daily household consumption but also undermines public health, economic productivity, and social stability. Without major investments in new water sources, storage infrastructure, distribution networks, and demand management strategies, the water supply situation in Gombe Metropolis is likely to worsen as the population continues its relentless growth, making the already weak correlation between supply and demand even more problematic in the future.

4.CONCLUSION AND RECOMMENDATIONS

The study concludes that Gombe Metropolis is experiencing a critical water supply crisis driven largely by sustained demographic pressure that has overwhelmed the existing water infrastructure. Over the two-decade study period, the population more than doubled while water supply volumes remained erratic and stagnant, creating a widening gap between water demand and availability. The weak negative correlation between population growth and water supply confirms that water delivery systems have not kept pace with demographic changes, resulting in severe per capita water deficits that fall far below National and International standards. The current per capita availability of approximately 10.36 litres per day is grossly insufficient to meet even the most basic domestic needs, forcing residents to resort to expensive alternative sources including boreholes and commercial water vendors, with significant financial implications for households, particularly civil servants and low-income earners. The situation is further compounded by geological variations across the metropolis, where some areas have accessible shallow groundwater while others require costly deep drilling, creating spatial inequalities in water access. The study underscores that without deliberate and sustained interventions, the water supply situation will continue to deteriorate as the population grows, with dire consequences for public health, economic productivity, and social stability.

Based on these findings, the following recommendations are proffered. First, the Gombe State Government, through the State Water Corporation, should urgently expand the Dadin-Kowa Water Treatment Plant capacity beyond the current 50 MLD design capacity and ensure that actual production consistently meets operational targets. This expansion should include investment in modern treatment technologies, backup power systems to mitigate energy-related disruptions, and regular maintenance schedules to minimize breakdowns. Second, there is an imperative need to rehabilitate and extend the distribution network to cover newly developed residential areas that are currently disconnected from the municipal supply, including Arawa, Kagarawal, Riyal Quarters, Bomala, Nayi Nawa, and Tumfure. Third, the government should explore alternative water sources, including groundwater development in areas with viable aquifers, rainwater harvesting systems, and possibly inter-basin water transfer schemes to diversify the water supply portfolio and reduce over-reliance on the Dadin-Kowa reservoir. Fourth, a comprehensive water demand management strategy should be implemented, incorporating public awareness campaigns on water conservation, metering of all connections to reduce wastage and illegal usage, and revised tariff structures that promote efficiency while ensuring affordability for vulnerable populations. Fifth,

the government should strengthen regulatory frameworks to protect water sources from contamination, particularly shallow aquifers that are vulnerable to pollution from waste sites and soak-away seepage, through enforcement of environmental sanitation laws and promotion of sustainable waste management practices. Sixth, there is a critical need for investment in research and data collection to establish a robust evidence base for water planning, including regular monitoring of groundwater levels, water quality assessments, and demand forecasting models that account for population projections. Finally, public-private partnerships should be explored to attract investment in water infrastructure, improve operational efficiency, and expand service coverage, while ensuring that the interests of low-income residents are protected through appropriate subsidy mechanisms. The implementation of these recommendations requires sustained political will, adequate budgetary allocation, and institutional capacity building to transform the water sector in Gombe State and ensure reliable water supply for present and future generations.

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