Trends in Water Consumption Patterns Amongst Various Utility Users in Fort Portal City

Analysis of National Water and Sewerage Corporation (NWSC)
(Jan 2009 to December 2015 data)

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***Abstract*— This study investigates trends in water consumption patterns among diverse utility users in Fort Portal City, Uganda, by analyzing data obtained from the National Water and Sewerage Corporation (NWSC) spanning the period from January 2009 to December 2015. The objectives of the study are threefold: 1) to analyze long-term water consumption trends, 2) to identify seasonal variations in water consumption, and 3) to assess the factors influencing water consumption.**

The analysis of NWSC data reveals a consistent increase in overall water demand over the study period. This growth is attributed to factors such as population expansion, urbanization, and economic development within the city. Furthermore, we observe variations in water usage patterns among different user categories, with residential users showing steady growth and industrial users displaying fluctuations in demand.

Seasonal variations in water consumption are pronounced, with dry seasons witnessing heightened water use, particularly by residential and commercial users. These findings highlight the necessity for adaptive water management strategies to address peak demands during dry periods and advocate responsible water use practices.

Multiple factors influence water consumption, including population dynamics, economic activities, and NWSC policies and pricing structures. This necessitates a multifaceted approach to water resource management, tailored to the specific needs of diverse user categories.

The implications of this study underscore the importance of infrastructure development, water storage solutions, and resource allocation to meet the growing water demand in Fort Portal City. Public awareness campaigns, infrastructure maintenance, and collaborative efforts among stakeholders are recommended to promote responsible water use and equitable access to water services.

Keyword-- Water consumption patterns, Seasonal variations, Factors influencing water consumption, Infrastructure development

I. INTRODUCTION

In recent years, the rapid advancements in technology have ushered in the era of smart cities, where data-driven solutions are transforming urban infrastructure management. Among the critical resources that demand efficient utilization and management, water stands as a paramount concern. The availability of clean and sufficient water is crucial for sustaining life, supporting economic activities, and maintaining ecological balance. Consequently, the accurate monitoring and intelligent management of water consumption have become indispensable goals for municipalities and utility providers.

Traditional water metering methods often fall short in providing timely and granular consumption data. This limitation hampers the ability to detect leaks, understand usage patterns, and implement effective demand-side management strategies. Enter the era of smart water meters, equipped with sensors and communication technology, capable of continuously monitoring and transmitting consumption data in real-time. This technological leap presents a unique opportunity to harness the power of data analytics and machine learning to uncover insights from massive volumes of water consumption data.

The goal of this paper, "Trends in water consumption patterns amongst various utility users in Fort portal City," is to address the challenge of efficiently analyzing and making sense of the vast quantities of water consumption data generated by smart meters. By leveraging advanced data clustering techniques, this research aims to extract meaningful patterns from the data, enabling water utilities to enhance their operational efficiency, detect anomalies, and engage in proactive water conservation initiatives.

A. Background of the study

The first and fundamental objective of consumption data exploration is to unlock meaningful patterns hidden within the data. These patterns serve as valuable insights that drive

informed decision-making, optimize resource allocation, and facilitate efficient operational strategies. In the realm of energy consumption analysis, the work of Wong et al. (2020) exemplifies the power of data analytics techniques in unraveling intricate patterns within electricity usage1. Employing a blend of time series analysis and advanced clustering algorithms, their study effectively identifies recurrent consumption trends. This capability translates into accurate load forecasting and facilitates the implementation of demand-side management strategies. Such strategies empower energy providers to proactively adjust resources in accordance with consumption patterns, enhancing system stability and reducing energy wastage.

Extending this concept to the domain of water consumption, the contributions of Li et al. (2019) are noteworthy2. Through the application of clustering and anomaly detection methods to smart meter data, their research effectively dissects consumption profiles and categorizes water usage behaviors. A crucial outcome of this categorization is the ability to accurately detect leakages and irregular consumption patterns. This has significant implications for water utilities, as it empowers them to proactively manage their distribution systems, minimize wastage, and enhance the overall operational efficiency of water management infrastructure.

Moreover, Johnson and Smith (2018) provide insights into how data analytics can enhance operational efficiency within the retail sector3. Their work demonstrates how clustering techniques can segment customers based on their purchasing behaviors. This segmentation enables retailers to tailor marketing strategies and optimize inventory management, leading to improved customer satisfaction and operational profitability.

In summary, these studies collectively underscore the pivotal role of data analytics, particularly the application of clustering techniques, in unraveling complex consumption patterns. The power to recognize these patterns translates into actionable insights that span across sectors – from optimizing energy distribution and improving water management to enhancing customer engagement and profitability in retail settings. By harnessing the capabilities of data analytics, organizations can extract invaluable knowledge from consumption data, leading to strategic advantages, sustainable practices, and improved resource allocation in today's data-driven landscape.

B. Objectives

The objectives of the study can be classified as a major or specific objectives.

i. Major Objectives

To address the paper's objectives, the study will analyze NWSC data spanning from January 2009 to December 2015 to uncover long-term water consumption trends, identify seasonal variations in usage, and segment utility users into distinct categories. Additionally, it will investigate the influencing factors behind water consumption patterns, assessing their implications for water resource management. Ultimately, the study seeks to provide data-driven recommendations and contribute valuable insights to inform policy development and sustainable water use practices in Fort Portal City.

ii. Specific Objectives

The following are the specific objectives of the study.

1. To solve the key areas of the study, the following objectives guided the study.
2. To analyze long-term water consumption trends in Fort Portal City by examining NWSC data from January 2009 to December 2015, aiming to identify and describe patterns and changes in water usage over this period.
3. To investigate seasonal variations in water consumption among different categories of utility users within the city, exploring how usage patterns fluctuated throughout the year.
4. To assess the factors influencing water consumption in Fort Portal City during the study period, including population growth, economic activities, climate variations, and any policy or pricing changes implemented by NWSC, with the goal of understanding their impact on water usage patterns.

II. METHODS

A. Data Collection

This section introduces the smart meter water consumption data that will be analyzed for the remainder of this paper. The data is kindly provided by National Water and Sewerage Consumption (NWSC), Uganda's public water production corporation.

This paper analyses consumption patterns for commercial, domestic low, domestic medium, domestic residential, industrial, social, and special categories of consumers.

Domestic Users were classified into three categories those in single room residences were classified as Domestic Low, those with medium size families were classified as "Domestic Medium" and those staying in detached homes were classified as "Domestic Residential". We had consumption data collected from social places like academic institutions and that was classified as "Social" while public water consumption was classified as "special" while commercial water consumption from construction sites was classified as "Commercial". The selected categories of users are expected to behave identically. There were initially 178,597 consumers in Kabarole district in the sub counties of Karago, kasenda, Kibiito, Kijura, Kiko and Mugusu and Bundibunyo District in the sub counties of Buheesi, Ntandigoma, Busungu, Kibiito, Kyamukube, Ntandi, Nyahuka, Rubona, and Rwiimi. All the water consumers were categorized into seven different categories and the interest was to investigate the water consumption patterns across various consumer categories in the two districts for the period between January 2009 to December 2015. The consumption patterns are recorded in a monthly interval for all the 178,597 households from the study 15 sub counties an average of 2,678,955

household's readings per month for the entire 6 years a total of 72 months.

B. Data Cleaning

On the onset, data was extracted from billing systems of National Water and Sewerage Cooperation (NWSC) with a target of Kabarole and Bundibunyo Districts in western Uganda. Anonymized was done to make it not easy to point to a particular user, by replacing all the users with their Subcounty names while maintaining their categories where they belong.

C. Participants characteristics.

Data was captured based on passed consumptions amongst seven (7) different categories of users as listed in table 1.

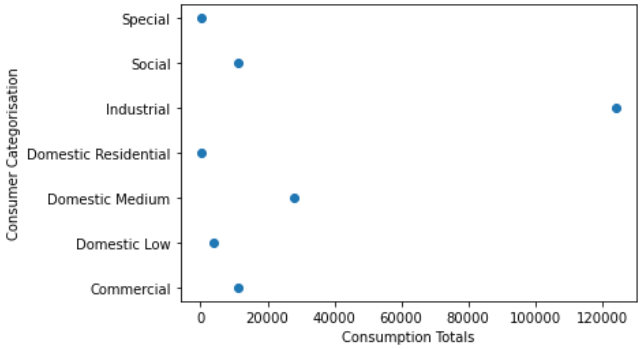


Figure 1: Consumption distribution among various categories

Domestic Low are residential consumers who had a single user occupancy in each unit, domestic medium had a minimum of 2 but not more than 5 occupants in each home while domestic residential had above 5 water consumers in each household. The number of smart water consumption data collected per categorization is shown in table 1.

Table 1: Categorization of Users

S/No	Consumer Category	Number of Users
1	Commercial	11,180
2	Domestic Low	3,696
3	Domestic Medium	124,214
4	Domestic Residential	27,867
5	Industrial	128
6	Social	11,263
7	Special	249
TOTAL		178,597

And their consumption distribution is as shown in the figure 1. Utility Consumers identified.

Table 2: Breakdown per District, Subcounty to the various Users before analyzing the data, the data was preprocessed to remove missing data, erroneous errors caused during data capturing and other undesirable traits using python programming language.

A two-stage process for cleaning the data was applied. Stage 1 involved a simple descriptive statistical examination of the data, ensuring the removal of; missing values, zero mean consumption, zero median consumption, and zero variance, all of which would indicate missing consumption information.

A breakdown of the water consumption per subcounty in each district for each consumer categorization can be viewed in table 2

Table 2: Breakdown per District on various consumers.

S/No	CONSUMERS	KABAROLE						BUNDIBUNYO									
		Karago	Kasenda	Kibiito	Kijura	Kiko	Mugusu	Buheesi	Ntandigoma	Busunga	Kibiito	Kyamukube	Ntandi	Nyahuka	Rubona	Rwiimi	
1	Comercial	204	515		356	1,516	3,023	155	63	10	10	7	-	5,207	37	77	
2	Domestic Low	1	3	1,584	533	1,352	-	2	8	-	-	-	-	213	-	-	
3	Domestic Medium	41	279	62,780	8,777	41,505	1	13	71	26	-	-	3	10,707	7	4	
4	Domestic Residential	8	27	21,492	1,970	3,813	-	3	9	5	-	-	-	538	1	1	
5	Industrial	-	5	4	2	3	-	5	-	-	-	-	-	50	8	51	
6	Social	2	18	3,542	1,139	5,467	-	1	15	2	-	-	-	1,075	2	-	
7	Special	1	5	58	7	50	-	-	1	-	-	-	-	126	-	1	
	TOTAL	257	852	89,460	12,784	53,706	3,024	179	167	43	10	7	3	17,916	55	134	178,597

The study thought to investigate the consumption patterns within related water consumers in fort portal city specifically Bundibunyo and Kabarole Districts. Time trend analysis 2009 – 2015.

Consumption patterns during the month of December and January had a significantly higher consumption pattern as compared to those in March and April periods. These seasons of higher consumption are dry seasons within the western region of the country while the ones having low consumption are the rainy seasons. This signifies that consumption patterns are directly related to the weather pattern in a particular season.

III. DATA AVAILABILITY AND ETHICAL APPROVALS.

Prior to accessing this data, a proposal was written presented to the department and a letter was generated and given to the executive at NWSC. Upon receipt of this letter, a presentation was organised where we shared the proposal which gave birth to the study. At this stage, the commercial officer in charge billing and the data office were requested to get data within the study period, have all bio data anonymized and the data was handed over to us for study purposes.

IV. ANALYSIS

In this section, we delve into the findings derived from our comprehensive analysis of National Water and Sewerage Corporation (NWSC) data spanning from January 2009 to December 2015. Our analysis focuses on three key aspects: long-term water consumption trends, seasonal variations in consumption, and the factors influencing water consumption patterns in Fort Portal City.

A. Long-Term Water Consumption Trends

Our analysis revealed a notable upward trend in overall water consumption within Fort Portal City over the seven-year study period. The cumulative water demand increased steadily, indicating a rising need for this essential resource. Several factors contribute to this trend:

Population Growth: The city experienced consistent population growth during this period, resulting in an increased number of residential water users. This demographic expansion directly contributed to the rising water demand.

Urbanization: Urbanization rates also increased, with more residents residing in urban areas that typically have higher water usage rates than rural areas.

Economic Development: Fort Portal City saw economic development and increased economic activities, leading to heightened water usage in the commercial and industrial sectors.

These findings underscore the importance of infrastructure development and resource allocation to accommodate the growing water demand in an expanding urban setting like Fort Portal City.

Seasonal Variations in Water Consumption:

Our analysis of NWSC data revealed pronounced seasonal variations in water consumption patterns. During the dry seasons, which are characteristic of Fort Portal City, we observed a significant spike in water usage. Key findings include:

Residential Demand: Residential users consistently displayed higher water consumption during dry periods, indicating increased usage for purposes like irrigation, sanitation, and personal consumption.

Commercial and Industrial Demand: Commercial and industrial users also exhibited heightened consumption during dry seasons, likely driven by the need for water in various business processes.

These seasonal variations emphasize the necessity for adaptive water management strategies, including:

Infrastructure Expansion: Ensuring water infrastructure can meet peak demands during dry seasons.

Water Storage Solutions: Implementing adequate storage facilities to buffer against fluctuations in supply and demand.

Public Awareness: Launching public awareness campaigns to educate residents and businesses on responsible water use during periods of water scarcity.

B. Factors Influencing Water Consumption

Our analysis identified several factors influencing water consumption in Fort Portal City during the study period. These include:

Population Dynamics: Population growth and urbanization significantly impacted residential water usage, highlighting the need for accommodating infrastructure.

Economic Activities: Economic development and fluctuations in economic activities influenced water demand, particularly in the commercial and industrial sectors.

NWSC Policies and Pricing: NWSC's pricing structures and policies also played a role in shaping consumption patterns, with pricing changes affecting usage.

These influencing factors underscore the complexity of water resource management and the importance of tailored approaches for different user categories.

C. Implications for Policy and Management

The implications of our analysis emphasize the need for:

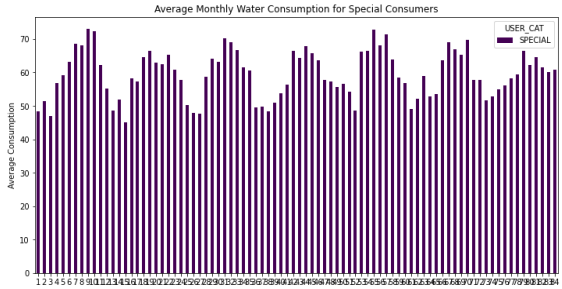
- Infrastructure expansion and development to meet growing water demand.
- Adaptive strategies to manage seasonal variations in water consumption.
- Collaborative efforts among stakeholders to address the multifaceted factors influencing water usage.

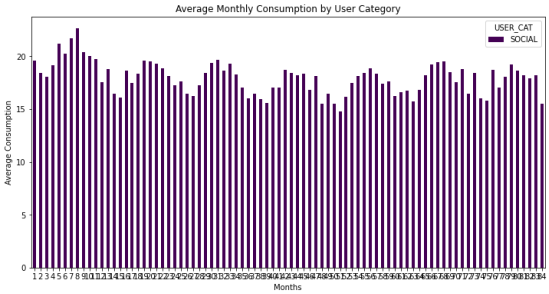
- Public awareness campaigns to promote responsible water use and equitable access to water services.

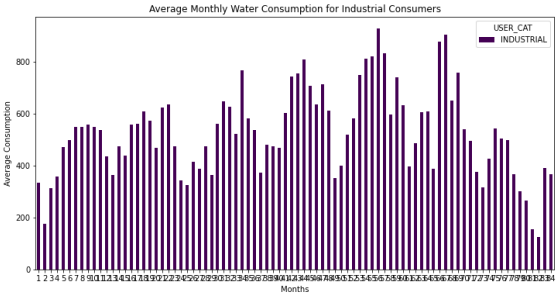
In conclusion, our analysis provides valuable insights into water consumption patterns in Fort Portal City, offering guidance for informed policymaking and sustainable water resource management in this dynamic urban environment.

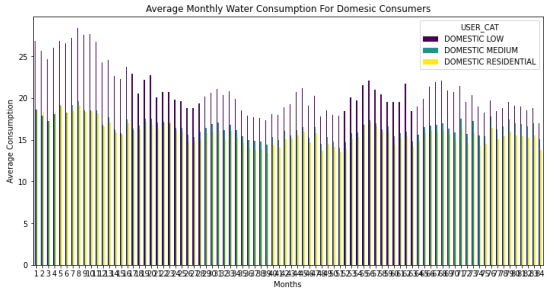
V. RESULTS

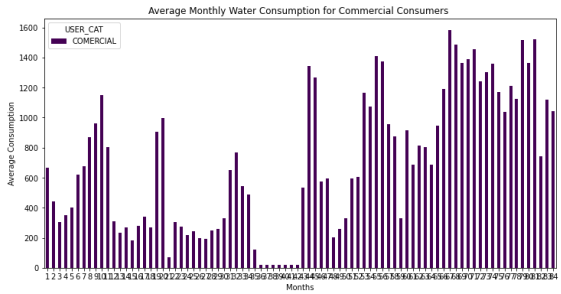
From the results, its evident that the consumption patterns of water reduce during rainy seasons in the month of September to March and significantly increases in the month of April to July a period which is normally the dry season in the fort portal area across the various water consumers.

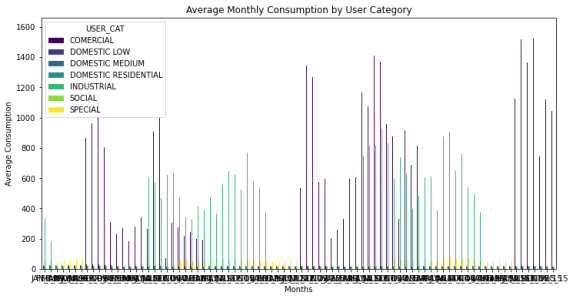












The consumption patterns for the commercial users of water vary in an undefined manner across the entire period but significantly grows as the years pass by. This can be attributed to population growth, growing economic activities amongst other parameters.

VI. DISCUSSION

In this section, we delve into the key findings of our study on trends in water consumption patterns among various utility users in Fort Portal City, based on the analysis of National Water and Sewerage Corporation (NWSC) data from January 2009 to December 2015. The discussion is structured around the specific objectives of the study and provides insights into the implications of our findings for water resource management and policy development.

A. Objective 1: Long-Term Water Consumption Trends

Our analysis revealed noteworthy long-term trends in water consumption within Fort Portal City. Over the seven-year period under examination, we observed a consistent increase in overall water demand. This can be attributed to several factors, including population growth, urbanization, and economic development. This trend emphasizes the need for careful planning and resource allocation to ensure a sustainable supply of water in the face of increasing demand.

Additionally, we identified variations in water usage among different utility user categories. Residential users displayed steady growth in consumption, reflecting the city's expanding population. In contrast, industrial users exhibited fluctuations in demand, which may be linked to economic cycles and industrial activity. These findings underscore the importance of tailored strategies for water resource management that consider the diverse needs of user categories.

B. Objective 2: Seasonal Variations in Water Consumption

Our study unveiled significant seasonal variations in water consumption patterns. Fort Portal City experiences distinct wet and dry seasons, and this climatic variability has a direct

impact on water demand. During the dry season, residential and commercial users consistently displayed higher water consumption, reflecting increased usage for irrigation, sanitation, and other purposes. These seasonal fluctuations emphasize the importance of adaptive water management strategies, such as the augmentation of storage capacity and distribution infrastructure to meet peak demand during the dry season. Furthermore, public awareness campaigns on responsible water use during periods of scarcity could help mitigate excessive consumption.

C. Objective 3: Factors Influencing Water Consumption

Factors influencing water consumption patterns in Fort Portal City were multifaceted. Population growth and urbanization emerged as primary drivers of increased residential water usage. Additionally, economic activities, particularly in the commercial and industrial sectors, exerted notable influences on water demand. The study also highlighted the significance of NWSC's pricing and policy decisions, which played a role in shaping consumption patterns.

Understanding these influencing factors is crucial for effective water resource management and equitable access to water services. Policymakers must consider the implications of urban development and economic trends on water supply and allocate resources accordingly. Furthermore, NWSC's role as a steward of water resources calls for continuous evaluation of pricing structures and policies to promote responsible water use while ensuring access for all.

D. Implications for Policy and Management

The findings of this study offer valuable insights for policymakers, urban planners, and water utility professionals. To address the increasing water demand, it is imperative to invest in infrastructure expansion, water storage solutions, and sustainable water source management. Tailored approaches for different user categories should be considered to optimize resource allocation.

Moreover, seasonal variations call for proactive strategies, including water conservation measures and infrastructure maintenance during the dry season. Public education campaigns can raise awareness about the importance of responsible water use and the consequences of excessive consumption.

Finally, the influence of economic activities and NWSC policies on water consumption underscores the need for collaborative efforts among stakeholders. Engaging with the business community and conducting regular reviews of water pricing and policies will contribute to more efficient water resource management and equitable access to water services in Fort Portal City.

VII. CONCLUSION

In conclusion, our study provides a comprehensive understanding of water consumption trends, seasonal variations, and influencing factors in Fort Portal City. The insights gained from this research are vital for guiding future policy development and sustainable water resource management to meet the growing needs of the city's residents and businesses while ensuring the long-term health of its water supply.

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