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WATER STORAGE INFRASTRUCTURE DEVELOPMENT AND WATER SERVICE DELIVERY: PERSPECTIVES FROM MANDERA COUNTY, KENYA

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ABSTRACT

Purpose of Study: To assess the effect of water storage infrastructure development on the provision of water services in Mandera County.

Problem Statement: The Kenya National Water Policy 2021 was designed to ensure sustainable water resource management and equitable access to clean water. However, key gaps exist in its implementation in Mandera County, where water scarcity remains a persistent challenge. The study was underpinned by Institutional Theory.

Methodology: The study was informed by pragmatism philosophy and employing a descriptive survey research design. The target population comprised 535 participants drawn from various key stakeholders in Mandera County, including the Water Resources Authority, Mandera Office, Mandera County Companies, community leaders, representatives from the Non- Governmental Organization, County Government of Mandera Water Department, and the National Drought Management Authority. The researcher used Slovin’s formula to obtain a sample size of 229 respondents.

Result: Findings revealed that 51.9% of the variation in the provision of water services in Mandera County was attributed to the development of water storage infrastructure, demonstrating strong influence of storage infrastructure on water service delivery.

Recommendation: The county department of water services should investment in the construction, maintenance and security of water storage infrastructure, with specific attention to underserved rural areas.

Keywords: *Water Storage Infrastructure, Water Service Delivery, Infrastructure Development, Rural Water Supply, Mandera County*

INTRODUCTION

Water is a valuable resource when it is available in safe and adequate quantities; however, it can also pose significant risks when it is unsafe or insufficient Buser (2024). The availability of clean and secure water is crucial for survival, as life fundamentally depends on it (Bazaanah & Mothapo, 2024; Lebu, Lee, Salzberg & Bauza, 2024). Both the supply and quality of water influence the prevalence or prevention of infectious diarrhea and other severe waterborne diseases, which are among the leading causes of infant mortality and malnutrition (Fardowsa, 2024). Beyond health concerns, water-related challenges also have economic consequences, such as increased absenteeism in schools and lost productivity in workplaces. As a result, ensuring access to water in a sustainable and equitable manner has become a global priority. This raises concerns for communities and nations facing unreliable, inadequate, or unsafe water supplies (WHO, 2022). Implementation of National Water Policy describe the process of translating a country's water-related goals, strategies, and regulations into actionable plans and concrete measures (Magrini & dos Santos, 2024).

National water policies typically encompass a wide range of issues, including water supply and sanitation, irrigation, hydropower, environmental conservation, and climate change adaptation. The success of implementing a national water policy largely depends on the creation of robust institutional frameworks and governance structures. According to the United Nations Water (UN-Water), effective water governance requires political, social, economic, and administrative systems that influence water use and management (UN-Water, 2021). Sub-Saharan Africa is considered a water-scarce region in terms of access to clean drinking water. By 2022, nearly 400 million people in the region were without basic drinking water services (WHO, 2023). This acute shortage has profound implications for both public health and economic progress. According to Lee and Schwab (2005), unreliable water supply where residents receive water for only a limited number of hours each day creates conditions that promote stagnation and microbial growth. They further observed that fluctuations in hydraulic pressure can cause contaminants to be drawn into pipelines from surrounding polluted areas. Additionally, factors such as aging infrastructure, corrosion, and leaks within water distribution networks contribute to bacterial proliferation along the supply channels (Bazaanah & Mothapo, 2024).

In Brazil, the National Water Resources Policy, established in 1997, focuses on decentralized and participatory management, emphasizing the importance of river basin committees and water agencies (ANA, 2019). Despite Brazil having about 12% of the world's freshwater resources, water distribution remains highly uneven (Scanlon, Fakhreddine, Rateb, de Graaf, Famiglietti, Gleeson & Zheng, 2023). The southeastern region, where major cities like São Paulo and Rio de Janeiro are located, often faces severe water shortages. According to the National Water Agency (2019), approximately 35 million Brazilians lack access to safe drinking water, and over 100 million do not have proper sanitation facilities. Recent efforts have included substantial investments in water infrastructure and initiatives to improve water quality and accessibility. However, challenges persist due to pollution, deforestation, and climate change, which impact water availability and quality (Scanlon *et al.*, 2023).

Singapore, a small city-state in Southeast Asia, has implemented a comprehensive and successful National Water Policy, known as the "ABC Waters Program" (Tortajada, Hartley, Ong & Arora, 2024). The program focuses on the principles of Active, Beautiful, and Clean (ABC) waters, aiming to integrate water resources with urban planning and development. Under the ABC Waters Program, Singapore has transformed its water bodies into clean and attractive assets, while also providing multiple benefits to the community (Linh, Ahmed & Loc, 2023). The policy includes initiatives such as the construction of rain gardens, bioswales, and floating wetlands to enhance water quality and reduce flood risks. These initiatives not only contribute to the beautification of urban areas but also provide natural habitats for wildlife. According to the World Health Organization (2020), approximately 60 million Nigerians still lack access to basic drinking water services, and over 100 million lack access to adequate sanitation. Efforts to improve water provision include the Water, Sanitation, and Hygiene (WASH) program, which focuses on increasing access to clean water and sanitation facilities. However, the implementation has been hindered by issues such as funding shortfalls, governance problems, and climate change impacts, which exacerbate water scarcity in certain regions.

In Kenya, the national water policy outlines clear objectives aimed at enhancing water supply services, ensuring progress toward the realization of water as a fundamental human right (Awandu, Kanda, & Kimokoti, 2024). Its primary goal is to guarantee universal access to safe and clean water for all citizens in Kenya. Additionally, it emphasizes the importance of developing water storage infrastructure, such as reservoirs and dams, to provide a stable water supply, particularly during periods of scarcity. A key focus of the policy is the sustainable management of water resources, ensuring their long-term availability and quality while balancing social, economic, and environmental considerations (Wamucii, Teuling, Ligtenberg, Gathenya & van Oel, 2023). Moreover, it incorporates climate change adaptation strategies and disaster risk reduction measures within the water sector to enhance resilience and sustainability.

The specific details on how the policy measures are being implemented on the ground, the progress made in addressing the identified challenges, and the level of success achieved remain unclear. Further investigation is necessary to determine the level of adoption of the policy by various stakeholders and to evaluate the effectiveness of the coordination mechanisms established to ensure its successful implementation (Musyoka & Deya, 2023). Provision of Water Services Provision of Water Services is the systematic delivery of clean, safe water to households, businesses, and other establishments through a network of infrastructure and management systems (Sisay, Gari & Ambelu, 2024). This essential service encompasses the entire process from water collection, treatment, and distribution to wastewater management and sanitation. The primary goal is to ensure consistent access to potable water for drinking, hygiene, and various domestic and industrial uses while maintaining environmental sustainability (Nel, Simuyaba, Muchelenje, Chirwa, Simwinga, Speight & Bond, 2023). The importance of water services forms the backbone of public health, economic development, and overall quality of life.

STATEMENT OF THE PROBLEM

Ideally, effective implementation of national water policies is expected to enhance the provision of water services by enabling improved water resource management, increased access to clean water, development of water infrastructure, protection of water sources, and enhanced water governance. However, evidence from existing empirical studies suggests that the implementation of national water policies provides mixed results with regard to their effect on water service provision. For instance, there is extensive evidence indicating a positive and significant relationship between national water policy implementation and improved water service provision in Tanzania (Nganyanyuka et al. (2018); Marks and Kumpel (2018) in Kenya; Liddle and Fenner (2017) in Uganda; Koehler et al. (2020) in Kenya, Uganda, and Ethiopia; Oates et al. (2019) in Ethiopia).

The Kenya National Water Policy 2021 was designed to ensure sustainable water resource management and equitable access to clean water. However, key gaps exist in its implementation in Mandera County, where water scarcity remains a persistent challenge (Suda, Sušnik, Masia & Jewitt, 2024). The policy outlines strategies such as decentralized water governance, increased infrastructure investment, stakeholder collaboration, and climate resilience integration, yet these have not been fully realized (Eweet & Muna, 2022). Weak institutional capacity, inadequate funding, and ineffective enforcement mechanisms hinder progress, leaving many communities reliant on unsafe or distant water sources. In Mandera, harsh climatic conditions, coupled with poor water infrastructure and resource mismanagement, makes the crisis worse. Similar challenges are observed in Turkana, Marsabit, and Ethiopia's Afar region, where fragmented policy execution leads to unreliable water access (Hassan, 2025).

The majority of these studies were carried out in diverse geographic locations under different conditions, utilizing distinct methodologies and variables. As a result, this creates contextual, methodological, and conceptual gaps. The current study sought to fill these knowledge gaps by using specific proxies tailored to Mandera's unique challenges, such as the availability and functionality of water infrastructure, stakeholder partnerships, climate change integration, water catmint protection and capacity building. This study therefore sough to assess the effect of water storage infrastructure development on the provision of water services in Mandera County.

RESEARCH OBJECTIVE

To assess the effect of water storage infrastructure development on the provision of water services in Mandera County.

RESEARCH HYPOTHESIS

H_0: There is no significant statistical association between water storage infrastructure developments on the provision of water services in Mandera County.

EMPIRICAL REVIEW

Lee, Mokhtar, Hanafiah, Halim and Badusah (2018) conducted a study to assess the potential of rainwater storage as an alternative water source in Malaysia, investigate related policies and development strategies, and analyse its impact on water services provision. Their mixed-method approach combined qualitative analysis of policy documents and regulations with quantitative assessment of rainwater supply potential. The study revealed that rainwater storage holds significant potential in Malaysia due to favourable rainfall patterns and distribution, particularly for non-potable uses. The researchers identified relevant policies, guidelines, and incentives, emphasizing the importance of integrating rainwater storage infrastructure into urban planning and building design. Successful implementation of rainwater storage systems could alleviate water scarcity issues and enhance the sustainability and resilience of water services in the country.

Rockström and Falkenmark (2015) highlight the importance of water storage infrastructure development in Africa to address water scarcity and provide sustainable water services for agriculture. Through a review of existing literature and data, the authors emphasize the urgent need to invest in water management strategies that can enhance food security and support sustainable development. They find that water scarcity in Africa is exacerbated by climate change and population growth, affecting agriculture and socio-economic development. Increasing water storage capacity is identified as a crucial solution, enabling communities to capture and store rainfall for use during dry periods, reducing vulnerability to climate variability. Integrated water management approaches, policy support, and investment in infrastructure are emphasized to promote sustainable practices and ensure long-term water availability. The authors also highlight co-benefits, including improved access to safe drinking water, resilience to climate change, and income generation opportunities. Overall, the article underscores the significance of water storage infrastructure for addressing water scarcity challenges and fostering sustainable development in Africa.

GhaffarianHoseini *et al.* (2016) investigate the current status of rainwater storage systems and their role in advancing sustainable water management and green-built environments. Through a comprehensive review of the literature, the study examines system design, technology, performance, water quality, and environmental impact. Key findings highlight the diverse design options and technologies available for rainwater storage, emphasizing the importance of proper system design, maintenance, and treatment methods for optimal performance and water efficiency. The review also underscores the need to address water quality concerns and highlights the positive environmental impact of rainwater storage systems in reducing strain on traditional water resources and mitigating storm water runoff. Overall, the study emphasizes that while rainwater storage systems offer an alternative water source, successful implementation requires careful planning and consideration of various factors to promote sustainable water management practices in built environments.

Baba *et al.* (2018) conducted a study to explore the historical advancements in water dams and water storage systems and their impact on water service provision. Using an interdisciplinary approach, the authors conducted an extensive review of literature, archaeological findings, historical documents, and scientific studies to gather information on water systems from various civilizations. The study revealed common features and techniques employed by ancient civilizations, highlighting the use of terracotta pipes, aqueducts, cisterns, and reservoirs for water collection and storage. The findings emphasized the importance of water storage infrastructure in mitigating water scarcity and managing resources effectively. Additionally, the study discussed the cultural, social, and technological factors that influenced the design and functionality of these systems. By drawing lessons from historical water management practices, the study provided insights for modern-day approaches to ensure sustainable provision of water services and improve water management strategies.

Fernandes, Terêncio and Pacheco (2015) conducted a study to explore the efficacy of rainwater storage systems in providing alternative water sources for low-demanding applications and their impact on water services provision. The study combines theoretical analysis, literature review, and field experiments to assess the feasibility of these systems. The findings indicate that rainwater storage systems are feasible and can enhance water availability for non-potable uses such as irrigation and toilet flushing. They offer environmental benefits by conserving water resources and reducing strain on existing infrastructure while also demonstrating economic viability through potential cost savings. Overall, implementing rainwater storage systems for low-demanding applications can contribute to sustainable water management practices, alleviate water scarcity, and provide an alternative water source for various purposes.

Campisano *et al.* (2017) conducted a study to explore urban rainwater storage systems, their research, implementation, and future perspectives, with a focus on their impact on water service provision. Through a comprehensive review of existing literature and case studies, the authors evaluated the benefits of rainwater storage, including reduced pressure on water sources, increased availability during droughts, and improved water quality. They examined different technologies and systems, such as rooftop and surface runoff collection, and emphasized the importance of integration with existing water infrastructure. The study also highlighted the need for supportive policies, regulations, and institutional frameworks to promote widespread adoption, while addressing challenges such as initial costs and lack of awareness. Future perspectives discussed included decentralized systems and considering climate change impacts. Overall, this research provided valuable insights into rainwater storage, informing future development and policy in the field of water services.

Ammar, Riksen, Ouessar and Ritsema (2016) aimed to comprehensively review the identification of suitable sites for rainwater storage structures in arid and semi-arid regions and assess the impact of water storage infrastructure development on the provision of water services. The researchers conducted a thorough literature search, gathering relevant studies from various sources. They found that factors such as rainfall patterns, topography, soil characteristics, and hydrological conditions need to be considered when identifying suitable sites. The study highlighted the potential benefits of rainwater storage infrastructure, including increased water availability, improved groundwater recharge, and reduced erosion and flooding risks. The technical considerations encompassed various types of structures and water treatment methods. Moreover, the review explored the socio-economic and environmental implications, emphasizing positive impacts on livelihoods, income generation, and food security. It also stressed the importance of environmental sustainability, community involvement, and governance aspects. The findings contribute valuable insights that can inform decision-making processes and support the provision of water services in arid and semi-arid regions.

In Kenya, Ondieki, Akunga, Warutere and Kenyanya (2022) investigated the socio-demographic and water handling practices affecting the quality of household drinking water in Kisii Town, Kisii County, Kenya. The study examined how various factors, including the source of water, transportation, storage, and handling practices, influenced water contamination and the prevalence of waterborne diseases. Using questionnaires, data were collected from 422 sampled households across four main zones: Mwembe, Jogoo, Nyanchwa, and the Central Business District (CBD). Qualitative data for the study were collected through Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) with public health officers. The results indicated a strong correlation between household size and the presence of total coliforms in drinking water, suggesting that larger households faced a higher risk of water contamination. Several hygiene and sanitation factors were identified as critical in influencing the presence of E. coli in drinking water, including the water source, type of transportation container, whether water was covered during transport, storage container type, method of retrieving water from storage, as well as feces and garbage disposal practices. The study concluded that inadequate water handling practices played a major role in water contamination, increasing the prevalence of waterborne diseases, which rank as the second leading cause of mortality in Kisii County.

Iradukunda and Bwambale (2021) examined reservoir sedimentation and its impact on storage capacity in Murera Reservoir, Kenya. The study aimed to assess sediment deposition and evaluate its effects on storage loss, recognizing that lakes and dams in sediment-laden rivers gradually infill over time, reducing storage capacity and affecting aquatic ecosystems. Anthropogenic activities in the Murera watershed were identified as major contributors to sediment accumulation, which in turn affected both water quality and aquatic life. The study utilized a Bathymetric Survey System (BSS) with a dual Jon-boat navigation system equipped with an integrated Global Positioning System (GPS) to gather spatial data. A multi-frequency acoustic system operating at 200, 50, and

12 kHz was employed to assess the reservoir bed level, sediment layers, and accumulated sediments relative to pre-impoundment levels. Data analysis was conducted using Depthpic 5.0.2, Surfer 15.5, and ArcGIS 10.3 software. The results showed that reservoir depth increased from the northern section toward the south, reaching a maximum depth of 7.78 meters, with an overall water storage capacity of 707,862.03 m³. Sediment accumulation was predominantly concentrated in the southern region, with sediment thickness ranging from 0 m to a maximum of 0.8 m. The total volume of stored sediment was calculated at 117,683.39 m³, indicating a 14% reduction in the reservoir's original storage capacity. The study concluded that sedimentation significantly threatens the sustainability of water storage and recommended that policymakers develop and implement strategies to mitigate sedimentation in Kenya's water resources.

THEORETICAL FRAMEWORK

The study was underpinned by Resource-Based View (RBV). The theory was introduced by Barney (1991). RBV states that an organization's ability to achieve and sustain a competitive advantage depends on how effectively it acquires, develops, and utilizes its resources. For a resource to contribute to long-term success, it must meet four key criteria: it must be valuable, rare, difficult to imitate, and non-substitutable (VRIN). This theory underscores the significance of internal resources in driving superior organizational performance. This resource heterogeneity serves as a foundation for sustained competitive advantage, provided the resources fulfill specific conditions. Barney (1991) introduced the VRIN framework to describe these conditions, which was later refined into the VRIO model, replacing "non-substitutable" with "organized to capture value" (Barney & Wright, 1998; Barney, 1995; Kraaijenbrink *et al.*, 2010).

The RBV challenges the traditional structure-conduct-performance paradigm of industrial organization economics, which focused primarily on external factors determining firm performance. Instead, the RBV emphasizes the importance of firm-specific factors in explaining performance differences among firms in the same industry (Peteraf & Barney, 2003; Lockett et al., 2009; Newbert, 2007). This change in focus from industry structure to firm resources marked a significant change in the field of strategic management. Resources in the RBV are broadly defined to include tangible and intangible assets, as well as capabilities. Critics of the RBV have pointed out several limitations of the theory. These include its tautological nature, the difficulty in empirically testing its propositions, and its limited applicability in dynamic environments (Priem & Butler, 2001; Kraaijenbrink et al., 2010; Foss & Knudsen, 2003). However, proponents have responded to these criticisms by refining the theory and developing more sophisticated methodologies for empirical testing (Barney, 2001; Peteraf & Barney, 2003; Armstrong & Shimizu, 2007).

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In the context of this study, the RBV was adapted to understand how public organizations leverage their unique resources and capabilities to achieve policy goals (Bryson *et al.,* 2007; Matthews & Shulman, 2005; Hansen, 2007). This theory provides a framework for understanding how Mandera County can develop and leverage its unique resources - such as local knowledge, community networks, and environmental assets - to improve water service provision (Wachira, 2014; Ogendi & Ong'oa, 2009; Nyanchaga, 2016). Moreover, the concept of dynamic capabilities is particularly relevant in addressing challenges related to climate change integration and adapting water management practices to changing environmental conditions.

CONCEPTUAL FRAMEWORK

A conceptual framework serves as a theoretical model that defines and categorizes the key constructs of a study while illustrating their relationships (Mugenda & Mugenda, 2003). Figure 1 shows the conceptual framework.

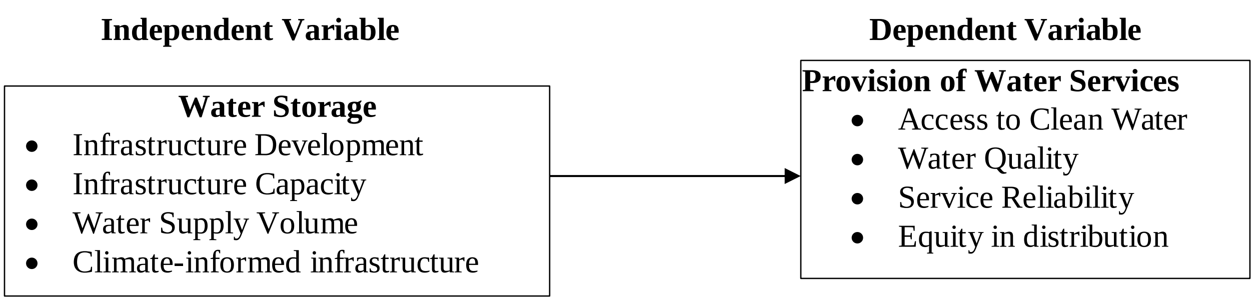

Figure 1: Conceptual Framework

Source: Author (2025)

METHODOLOGY

The study adopted the pragmatism philosophy due to the nature of the research questions. The study investigated climate change integration. This required methodological approach to thoroughly understand their impact on water provision. Applying a pragmatic approach allows the researcher to employ both qualitative and quantitative methods, thereby leveraging the strengths of each (Crossan, 2003). This mixed- method approach is important in providing a comprehensive understanding of the relationship between the independent variables and the dependent variable of water provision. According to assertions by Goldkuhl (2012), the flexibility of pragmatism philosophy emphasizes practical solutions and the usefulness of findings, bridging the gap between positivism and interpretivism. Pragmatism philosophy acknowledges the value of both objective, measurable data (consistent with positivism) and subjective information (in line with interpretivism).

This study employed a descriptive survey research design. This design was suitable because it allowed for the systematic collection of data from key stakeholders involved in water services, providing required information regarding the influence of climate change integration (Aquino Lee, Spawn & Bishop-Royse, 2018). The study was carried out in Mandera County, located in the northeastern part of Kenya. The county experiences low and erratic rainfall, with an average annual precipitation of only 255mm, making it one of the driest regions in Kenya (Mandera County Government, 2018). This scarcity of water resources has a profound impact on the lives of its approximately 867,457 residents (Kenya National Bureau of Statistics, 2019).

The study targeted 535 participants drawn from various key stakeholders in Mandera County, including the Water Resources Authority (WRA) Mandera Office, Mandera County Companies, community leaders, representatives from the Non- Governmental Organization (WESCOORD), County Government of Mandera Water Department, and the National Drought Management Authority (NDMA). The study, however excluded the general citizenry of the county as direct respondents, as it focused on policy implementation and institutional effectiveness, which required input from key stakeholders directly involved in water governance and service provision.

The study used Slovin's formula to estimate the sample size (Slovin, 1960) as shown below:

$n = N / (1+Ne^2)$.

Where:

n = no. of samples N = total population

e = error margin/margin of error which is approximated at $\alpha=0.05$ $n = 535 / [1+535 (0.05^2)]$

n = 535 / [1+535 (0.0025)]

n = 535 /[1+1.33 5]

n = 535/2.335

n = 228.877 ~229

To select the study sample, the researcher utilized a probability sampling technique. This method guaranteed each member of the population an equal chance of being selected (Quatember, 2019). Questionnaires and key informant interviews were adopted as a means of collecting data from the study participants. Semi-structured questionnaire allowed for both standardized data collection and flexibility, enabling respondents to provide more useful information on specific water policy implementation issues in Mandera County. This approach ensured that important topics are covered while allowing for in-depth responses on complex challenges. Further, they can be administered directly or through representatives where people can read and write (Pandey & Pandey, 2021).

Primary data was collected through the administering of structured questionnaires to the selected officers. The questionnaire was self-administered but in cases where clarification was needed the researcher or research assistants assisted. The researcher obtained a letter of introduction from the Department of Development Studies at Kenyatta University and sought a research permit from the National Commission for Science, Technology, and Innovation of the Republic of Kenya (NACOSTI). Two research assistants were recruited and trained and participated in the pretesting before commencing the data collection exercise. The questionnaires was administered from respective offices on a face-to-face survey and drop- and-pick approach. The study conducted diagnostic tests including multicollinearity, normality, heteroscedasticity, and linearity tests before performing regression analysis. These tests ensured the validity and accuracy of the model assumptions.

Upon collecting the questionnaires, the researcher reviewed them for completeness, accuracy, and consistency. Responses from structured questions were coded and entered into SPSS, a statistical software chosen for its flexibility in handling diverse data formats. Descriptive statistics such as mean, variance, and standard deviation summarized the dataset, while qualitative data was coded and analyzed using the same software. The study applied both Pearson's correlation and linear regression analyses to examine relationships between independent variables and water service provision. Correlation analysis assessed the direction and strength of associations, while regression analysis evaluated the combined influence of stakeholder partnerships, watershed protection, and climate change integration. This approach allowed for controlling external factors and determining the collective and individual effects of each independent variable on the dependent variable.

This study used simple linear regression models to link the independent variable to the dependent variable. The following linear regression model was used to link independent variablewith dependent variable:

$$\mathbf{Y = \beta_0 + \beta X + \varepsilon}$$

Whereby Y = Provision of Water Services in Mandera County

X= water storage and storage infrastructure development, β_0 =Constant, β= Coefficient.

ε = Error Term.

Ethical integrity was maintained through adherence to confidentiality, anonymity, and the exclusive academic use of collected data. Respondents' identities were protected, and findings would be shared with relevant stakeholders to promote transparency. Data collection occurred in safe, accessible areas with the support of local authorities, and participation was voluntary, with the option to withdraw at any time. Sensitive data to be securely stored and encrypted, and all safety protocols including travel precautions were followed due to Mandera County's security context.

FINDINGS AND DISCUSSION

A total of 229 participants were sampled from the target population comprising staff from Water Resources Authority (WRA) Mandera Office, Mandera County Companies, community leaders, Non-Governmental Organization (WESCOORD), County Government of Mandera Water Department, and National Drought Management Authority (NDMA). Out of the 229 distributed questionnaires, 211 were successfully filled, representing a response rate of 92.1 percent. Therefore, the data collected was considered representative and reliable for drawing valid conclusions on the effect of National Water Policy 2021 implementation in Mandera County.

Demographic results revealed that study sample was predominantly male (66.8%) and largely composed of young to mid-career professionals aged between 31 and 45 years. Most respondents possessed college or bachelor's qualifications, with a few holding master's or PhD degrees, indicating strong educational diversity. Majority of the respondents had 6–10 years of work experience in Mandera's water sector and had lived in the County for a similar period, reflecting both institutional familiarity and local understanding. The demographic profile suggests a knowledgeable and experienced group well-positioned to inform climate-integrated water policy implementation in Mandera County.

Descriptive Statistics

Water Storage Infrastructure Development

The study examined how improvements in water storage facilities have influenced the volume, reliability, and accessibility of water supply across the county. Ten statements were formulated to gather respondents' opinions on various aspects of water storage infrastructure, including its capacity, efficiency, maintenance, impact on groundwater recharge, and ability to mitigate water scarcity during dry periods. Table 1 presents the descriptive statistics results on water storage infrastructure development.

Table 1: Descriptive Statistics on Water Storage Infrastructure Development

Statement	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)	Mean	Std. Dev.
Our organization has significantly improved water storage infrastructure.	5.0	8.0	19.0	46.0	22.0	3.72	1.06
The capacity of our water storage facilities has increased substantially.	3.0	7.0	18.0	50.0	22.0	3.81	0.98
Infrastructure development has increased water supply volume.	4.0	6.0	17.0	48.0	25.0	3.84	1.02
Water use efficiency has improved due to better harvesting and storage.	2.0	5.0	15.0	49.0	29.0	3.98	0.93
Storage methods have improved groundwater recharge.	6.0	9.0	21.0	42.0	22.0	3.65	1.09
Storage infrastructure has enhanced water availability during dry seasons.	3.0	6.0	14.0	51.0	26.0	3.91	0.95
Water storage techniques have reduced water losses.	4.0	6.0	16.0	47.0	27.0	3.87	1.01
Infrastructure development has improved distribution efficiency.	2.0	5.0	15.0	52.0	26.0	3.95	0.90
Water storage systems are well maintained.	5.0	7.0	20.0	44.0	24.0	3.75	1.04
Infrastructure development has reduced water scarcity in the county.	4.0	6.0	19.0	48.0	23.0	3.80	0.99
Overall Mean						**3.83**	

Source: Field Data, 2025

The results in Table 1 show that respondents generally held positive perceptions about the contribution of water storage infrastructure development to improved water service delivery in Mandera County. The highest level of agreement was recorded for the statement “Infrastructure development has improved distribution efficiency,” where 78 percent of respondents agreed or strongly agreed. This item recorded the highest mean of 3.95 and standard deviation of 0.90, indicating a strong consensus that improvements in storage infrastructure are enhancing the effectiveness of water distribution networks across the county. Similarly, water use efficiency was widely acknowledged as an outcome of improved harvesting and storage systems, with 78 percent of respondents affirming this, resulting in a mean of 3.98 and a standard deviation of 0.93. This suggests that water storage infrastructure not only increases quantity but also optimizes use, especially in regions prone to scarcity.

The statement “Storage infrastructure has enhanced water availability during dry seasons” also attracted strong support, with 77 percent agreement and a mean of 3.91. This implies that infrastructure development is significantly contributing to climate resilience and year-round water availability in an otherwise arid and semi-arid region. Furthermore, water loss reduction due to improved storage techniques was supported by 74 percent of respondents (mean = 3.87). The consistency in this response is notable and reflects a shared recognition of infrastructure’s role in reducing leakage, spillage, and evaporation losses. These findings align with the objectives of the

National Water Policy (2021), which emphasizes efficiency and sustainability in water management systems.

However, relatively lower agreement was observed for "Storage methods have improved groundwater recharge," where only 64 percent agreed or strongly agreed. The mean score for this statement was 3.65 with a slightly higher standard deviation of 1.09, indicating more variation in opinion. This suggests that while infrastructure development may aid surface storage, its effects on subsurface recharge may not be as uniformly perceived or may require longer-term observation to assess. The perception of system maintenance was moderately positive, with 68 percent of respondents agreeing that "Water storage systems are well maintained." The corresponding mean of 3.75 and a standard deviation of 1.04 reflect mild variability in the quality of operation and maintenance practices across different organizations or sub-counties.

On whether infrastructure development had reduced water scarcity, 71 percent of respondents agreed, yielding a mean of 3.80. This indicates that while progress is evident, full mitigation of water scarcity has not been achieved, and continued investment in infrastructure remains necessary. The combined average mean score for the ten items was 3.83, suggesting a strong collective agreement that water storage infrastructure development has positively influenced the provision of water services in Mandera County. The standard deviations across most items were below or slightly above 1.00, indicating relatively consistent responses. These findings highlight the importance of continued infrastructural investment, with attention to maintenance, recharge systems, and capacity expansion to ensure sustainable water access in the county.

Thematic Analysis

This section presents responses from key informants at WRA and NDMA on how investment in water storage infrastructure has influenced water availability and distribution in Mandera County. It also captures organizational challenges in developing and maintaining such infrastructure.

Respondents emphasized that investments in water storage infrastructure such as elevated tanks, earth pans, subsurface dams, and solarized boreholes have significantly improved water availability, particularly in remote and drought-prone areas. These investments have contributed to more equitable distribution of water across different settlements and reduced reliance on emergency trucking. Interviewee M1 noted:

> *"The construction of high-capacity tanks in urban centers like Mandera Town and Banisa has allowed for consistent water flow, even during dry spells. Before, supply would run dry in days, but now these tanks act as buffers during distribution downtime or drought."*

Respondent M2 added:

> *"Water pans and rock catchments in rural divisions like Arabia and Dandu have extended water access to communities who previously had to walk for hours. These storage systems collect and retain rainwater effectively, reducing pressure on boreholes and increasing coverage."*

Additionally, the introduction of solarized pumping systems was mentioned as a game-changer, particularly in ensuring round-the-clock water access while reducing operational costs. As Interviewee M3 explained:

> *"Solar-powered pumping linked to elevated storage tanks means water can now be supplied consistently without fuel interruptions. This has enabled us to maintain stable water pressure and improve hygiene and sanitation, especially in schools and health centers."*

Despite the positive impact, respondents revealed a range of persistent challenges that hinder the effective development and sustainability of water storage infrastructure. These include logistical, technical, financial, and environmental barriers. Respondent M4 observed:

> *"Transporting materials like concrete rings, steel, or roofing sheets into remote areas such as Guba or Warankara is extremely costly and time-consuming. Poor roads and insecurity in some regions delay projects or increase costs beyond budget."*

Interviewee M5 pointed to design and durability issues:

> *"Many older water pans suffer from high seepage rates due to poor lining or siltation. Without proper maintenance budgets, these structures degrade quickly. A pan may be full during the rainy season but dry within two weeks due to leakage and evaporation."*

Additionally, budget constraints and inconsistent funding cycles were identified as major operational barriers. Respondent M6 explained:

> *"We often get partial funding for construction, but no allocation for maintenance. This means that after installation, there's no budget for desilting or repairs. Communities try to help, but they lack the technical capacity or tools needed."*

Further, there was concern about vandalism and lack of community ownership. As Interviewee M7 stated:

> *"Some of the elevated tanks and borehole solar panels have been vandalized or misused. In some cases, political interference hinders community ownership, and when breakdowns occur, no one takes responsibility until it escalates into a full crisis."*

The interviews clearly indicate that investment in water storage infrastructure has enhanced water security and improved distribution equity in Mandera County. Facilities such as elevated tanks, water pans, and solarized systems have buffered communities against recurrent droughts and reduced dependency on emergency interventions. Nonetheless, the full potential of these investments is constrained by several challenges. These include logistical difficulties in construction, technical deficiencies in design, maintenance neglect, and limited community engagement. High evaporation, siltation, and infrastructure vandalism were recurrent concerns, highlighting the need for more sustainable, community-centered maintenance frameworks.

The findings suggest that even though infrastructure investment is key, it must be complemented by proper planning, capacity building, and consistent funding for maintenance. Community participation in design and management, use of durable materials, and integration of climate-resilient technologies (like tank lining and evaporation shields) are essential to ensure long-term impact. Strengthening local technical teams and clarifying roles among partners will be critical in addressing these systemic bottlenecks.

Provision of Water Services

The dependent variable in this study was provision of water services in Mandera County. This variable was used to assess the outcomes associated with the implementation of the National Water Policy (2021) in relation to access, quality, reliability, affordability, and overall satisfaction with water service delivery. Table 2 presents the descriptive statistics results for the provision of water services.

Table 2: Descriptive Statistics on Provision of Water Services

Statement	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)	Mean	Std. Dev.
Access to clean water has significantly improved in our service area.	3.9	7.5	18.6	44.2	25.8	3.81	1.07
The quality of water provided has improved over time.	5.0	9.0	19.3	43.1	23.6	3.71	1.10
Water services are reliable and consistent.	6.4	10.1	21.7	41.0	20.8	3.60	1.12
There is equity in the distribution of water services across different areas.	8.7	12.9	23.1	38.0	17.3	3.42	1.17
Our water infrastructure adequately meets community needs.	5.5	9.3	20.6	42.7	21.9	3.67	1.09
Water service coverage has expanded significantly in recent years.	4.2	6.1	16.8	46.5	26.4	3.85	1.01
Water services are affordable for most community members.	7.1	11.6	22.0	39.0	20.3	3.54	1.15
Water quality meets all relevant health and safety standards.	6.3	9.4	18.9	43.3	22.1	3.65	1.08
Water services have improved community health outcomes.	3.5	6.7	20.2	47.1	22.5	3.79	1.01
Customer satisfaction with our water services has increased.	4.1	8.0	19.7	45.6	22.6	3.75	1.05
Overall Mean						**3.68**	

Source: Field Data, 2025

The descriptive findings revealed a generally positive perception of water service provision in Mandera County, with an overall mean of 3.68, indicating moderate satisfaction among respondents. The highest agreement (72.9%, M = 3.85, SD = 1.01) was for the statement that water service coverage had expanded significantly in recent years, followed by 70.0% affirming improved access to clean water (M = 3.81, SD = 1.07) and 69.6% recognizing better community health outcomes (M = 3.79, SD = 1.01). Increased customer satisfaction was also noted by 68.2% of respondents (M = 3.75, SD = 1.05), suggesting visible service improvements though with variations across locations. On water quality, 65.4% of participants agreed that quality had improved (M = 3.71, SD = 1.10), and a similar proportion felt that water met safety standards (M = 3.65, SD = 1.08), reflecting progress but with lingering inconsistencies linked to local treatment and maintenance.

However, challenges persist in affordability, reliability, and equity of distribution. Only 59.3% agreed that water services were affordable (M = 3.54, SD = 1.15), while just 55.3% believed that water distribution was equitable (M = 3.42, SD = 1.17), indicating disparities across sub-counties. Reliability was also moderate, with 61.8% agreeing that services were consistent (M = 3.60). These results highlight that while Mandera County has made notable strides in water access, coverage, and quality, significant gaps remain in ensuring affordability, fairness, and reliability of services. The findings call for strengthened infrastructure, equitable allocation of resources, and enhanced quality monitoring to sustain progress and ensure inclusive water service delivery across all communities.

Correlation Analysis

Correlation analysis aimed to determine the degree of association between the implementation of National Water Policy (2021); climate change integration and the provision of water services in Mandera County. SPSS software was used to compute the Pearson correlation coefficients, and the results are presented in Table 3.

Table 3: Correlation Matrix

		Provision of Water Services
Provision of Water Services	Pearson Correlation	1.000
	Sig. (2-tailed)	
Water Storage Infrastructure	Pearson Correlation	.720**

Source: Field Data, 2025

The correlation coefficient for water storage infrastructure was ($r = 0.720$, $p < 0.01$), showing a strong positive and significant association with the provision of water services. This suggests that investment in dams, tanks, and reservoirs significantly influences water access and reliability, especially in arid areas like Mandera County. This finding reflects the findings of Ruiters and Matji (2016) who stressed the importance of infrastructure in municipal-level water provision. However, while their research was rooted in South African municipalities, the lessons on infrastructure-led service delivery are directly applicable to Mandera's context under the National Water Policy (2021).

Regression Analysis

To evaluate this relationship, a simple linear regression analysis was carried out with water storage infrastructure as the predictor variable and provision of water services as the outcome variable. Table 4 presents the model summary for this regression analysis.

Table 4: Model Summary

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.720a	0.519	0.516	0.42502

a Predictors: (Constant), Water Storage Infrastructure

Source: Field Data, 2025

The results in Table 4 indicate that the coefficient of determination (R^2) was 0.519, indicating that approximately 51.9% of the variation in the provision of water services in Mandera County is attributed to the development of water storage infrastructure. This demonstrates a strong influence of storage infrastructure on water service delivery. The adjusted R^2 of 0.516 suggests that, even after accounting for additional variable sin the model, the explanatory power of the predictor remains significant, indicating good model generalizability. Table 5 shows the ANOVA results.

Table 5: ANOVA Results

Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	45.884	1	45.884	253.969	0.000[b]
1	Residual	42.497	209	0.203		
	Total	88.381	210			

a. Dependent Variable: Provision of Water Services

b. Predictors: (Constant), Water Storage Infrastructure

Source: Field Data, 2025

The ANOVA results in Table 5 depicts that the model was statistically significant in explaining how water storage infrastructure influences the provision of water services. The F-value of 253.969 with a p-value of $0.000<0.05$ indicates that the predictor significantly accounts for the changes observed in the dependent variable. Regression coefficient results are shown in Tale 6.

Table 6: Regression Coefficient Results

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.011	0.113		8.949	0.009
	Water Storage Infrastructure	0.678	0.043	0.720	15.933	0.004

a. Dependent Variable: Provision of Water Services

Source: Field Data, 2025

$Y = 1.011 + 0.678X$

Where:

Y = Provision of Water Services

X = Water Storage Infrastructure Development

The coefficient table (Table 6) demonstrates a positive and statistically significant relationship between the development of water storage infrastructure and the provision of water services ($\beta = 0.678$, $p = 0.004 < 0.05$). This suggests that for every one-unit improvement in storage infrastructure, the provision of water services is expected to rise by 0.678 units, holding other factors constant. The t-statistic of 15.933 confirms the strength and reliability of this predictor. These findings are consistent with the out of a study by Lee et al. (2018), who explored rainwater harvesting in Malaysia and concluded that proper integration of storage infrastructure especially rainwater tanks significantly influenced the resilience and sustainability of water services. They indicated that predictable rainfall patterns and supportive policies, when aligned with effective infrastructure, greatly improve service reliability.

CONCLUSION

Water storage infrastructure development has significantly enhanced the reliability, accessibility, and efficiency of water service delivery in Mandera County. In regions characterized by erratic rainfall and prolonged dry spells, the construction and maintenance of water storage facilities such as elevated tanks, water pans, and rock catchments are indispensable. These infrastructures not only increase the volume of stored water but also reduce the frequency and severity of shortages, particularly during drought periods. The introduction of solar-powered systems has further improved operational efficiency and reduced dependency on costly fuel sources. Stakeholders across institutions acknowledge that infrastructure investments have enabled more equitable water distribution, especially in previously underserved areas. However, sustainability challenges remain, especially in terms of maintenance, community ownership, and security. Limited budgets for upkeep, transport challenges in remote locations, and occasional vandalism threaten the longevity of these assets. Therefore, it is essential to integrate infrastructure development with preventive maintenance planning, community education, and financing strategies that ensure long-term functionality.

RECOMMENDATIONS

The county department of water services should upscale investments in the construction, maintenance, and security of water storage infrastructure, with specific attention to underserved rural areas. This should include budgetary allocations for the rehabilitation of existing tanks and water pans, installation of tamper-proof solar pumping systems, and procurement of durable piping and control equipment. Public-private partnerships can be explored to finance large-scale infrastructure such as elevated tanks and community-level reservoirs. Additionally, the department should develop a county-wide maintenance and servicing schedule, assigning clear roles to sub-county water officers, community-based organizations, and water users associations.

Mechanisms such as infrastructure audit reports and public scorecards can be introduced to ensure transparency, community oversight, and long-term operational sustainability. Infrastructure development policies should also put in place climate-resilient and community-owned water storage systems, more so in arid and semi-arid counties like Mandera. Policy instruments should in addition mandate that all publicly funded water infrastructure projects include climate vulnerability assessments and long-term maintenance plans. Moreover, national policies should establish irreducible minimum standards for the design, sustainability, and safety of storage systems, and compel implementing agencies to conduct post-construction audits.

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