Assessment of Water Resource Utilization in Panda Town, Karu Local Government Council, Nasarawa State, Nigeria

Acha Bitrus Omeck, Dogara Adamu Ahmad

Geography Department, Nasarawa state University, Keffi, Nasarawa state, Nigeria.

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ABSTRACT

This study assessed the water resource utilization in Panda town, Karu Local Government Area, Nasarawa State, Nigeria. The research aimed to evaluate the availability, accessibility, and management of water resources in the study area. A mixed-methods approach was employed, combining both quantitative and qualitative data collection and analysis methods. Data were collected through questionnaire administration, interviews, and field observations. The results showed that Panda town relies heavily on groundwater and surface water sources, with 75% of the respondents depending on wells and boreholes for their domestic water needs. However, the water sources were found to be vulnerable to contamination, with 60% of the respondents reporting water-borne diseases. The study also revealed inadequate water management practices, with 80% of the respondents lacking proper waste disposal facilities. The research identified a need for improved water infrastructure, enhanced water management practices, and increased community awareness on water conservation and hygiene. The findings of this study have implications for policymakers, water resource managers, and local communities in Panda town and similar areas. Recommendations are made for sustainable water resource management and utilization in the study area.

Keywords: Water resource utilization; Panda town; Karu Local Government Area; Nasarawa State; Nigeria; Water management; Sustainable development.

BACKGROUND TO THE STUDIES

Water is essential to life, as human survival is intricately linked to it (Molden, 2013). The World Health Organization (WHO, 2015) reports that approximately 173 million people globally rely on untreated surface water, with over 90% of these individuals residing in rural and peri-urban areas. This highlights a significant disparity in the provision of portable water for domestic, agricultural, and industrial purposes (WHO, 2017). In response, the 2030 Agenda for Sustainable Development emphasizes an integrated approach to managing the social, economic, and environmental dimensions of water resources, as outlined in Sustainable Development Goal 6. This goal specifically aims to address all facets of the water and sanitation cycle (Fischer, Hope, Manandhar, Hoque, Foster, Hakim & Bradley, 2020). Target 6.1 of the SDGs focuses on drinking water, urging member states to ensure universal and equitable access to safe and affordable drinking water for everyone by 2030 (Central Statistical Agency of Ethiopia (CSAE), 2017).

The UN uses the "proportion of population with sustainable access to an improved water source" as its primary indicator for progress (Makarigakis & Jimenez-Cisneros, 2019). Lacking access to safe water is a severe deprivation that endangers lives, limits opportunities, and undermines human dignity (Pereira & Marques, 2021). To address this, the UN urges states and international organizations to allocate financial resources, build capacity, and transfer technology, especially to developing countries, to enhance efforts to provide safe, clean, accessible, and affordable drinking water and sanitation for all (Gomez, Perdiguero, & Sanz, 2019). While numerous treaties have acknowledged this necessity, the resolution was critical to make it binding, ensuring that "all means possible" are employed to make access to safe drinking water a reality (Herrera, 2019). Despite these goals, access to safe water remains a significant challenge. Research indicates that around 1.8 billion people rely on water sources contaminated with faecal matter, which can lead to diseases such as cholera, enteric fever, and various other acute and chronic illnesses (Jessoe, 2013).

In Africa, water shortages are largely due to both the underdevelopment of available water resources and their uneven distribution. This issue is exacerbated by a population growth rate of 3% per year, which significantly contributes to ongoing water and sanitation challenges (Boelee, Geerling, van der Zaan, Blauw, & Vethaak, 2019). Currently, the primary cause of water shortages is water pollution, predominantly resulting from human activities, particularly in agriculture. Practices such as bush burning, and the use of fertilizers, pesticides, herbicides, and fungicides, lead to soil runoff into surface waters and leaching into aquifers. These chemicals seep into the water table, contaminating drinking water sources (Kishor, Purchase, Saratale, Saratale, Ferreira, Bilal, & Bharagava, 2021). Additionally, industrial waste is often discharged into nearby waterways or wastewater lagoons, further degrading water quality (Kishor *et al.,* 2021).

In Panda Town, situated in the Karu Local Government Area of Nasarawa State, access to clean and reliable water poses a critical challenge affecting residents across all age groups and genders. The community grapples with severe water shortages, compelling its members to spend considerable time and effort fetching water. This scarcity not only disrupts daily routines but also hinders economic activities, limiting opportunities for income generation and overall development. The urgent necessity for a thorough investigation into water quality, consumption patterns, and their environmental impacts in Panda Town cannot be overstated.

This study aims to meticulously evaluate the current practices of water resource utilization within the community. By pinpointing existing challenges and recommending sustainable management strategies, the research seeks to alleviate the adverse effects on health, livelihoods, and general well-being. Effective management of water resources in Panda Town is crucial for promoting community health, boosting economic productivity, and fostering sustainable development.

Statement of the Research Problem

Access to safe drinking water is a critical target under the Sustainable Development Goals (SDGs), yet the UN identifies population growth as a significant threat to achieving this goal. By 2050, the world's population is projected to increase by 25%, with 75% of this growth expected in urban areas. The rapid urbanization in developing countries has led to the expansion of informal settlements in rural areas, which act as absorbers for individuals unable to afford urban living standards. However, these informal settlements often face water crises, characterized by both supply and quality issues, due to limitations in physical planning and infrastructure provision.

Given the crucial role informal settlements play in accommodating urban expansion, there is a compelling need for systematic investigations into domestic water crises within such settlements. This study aims to contribute to understanding this issue, focusing on Panda Town in Karu Local Government Area (LGA) of Nasarawa State, which is closely situated near Abuja, the Federal Capital Territory.

Several studies were carried out on groundwater potential (Sunkari, Kore & Abioui, 2021) and improved water supply impacts (Abanyie, Ampadu, Frimpong, & Amuah, 2023). These studies provided valuable insights into examining water availability and utilization in Nigeria. Other studies mapped and assessed water sources' quality and contamination risks, as identified by Opaluwa, Muhammad, Madaki, Usman, & Mohammad, (2022), are essential for ensuring safe drinking water access. Understanding community perceptions and attitudes towards water quality, akin to the gaps identified in studies by Locke (2020) and Akawu, Maiwada & Abdulsalami (2020), is vital for designing effective interventions. Moreover, evaluating the impact of local land use practices on water resources, as highlighted by Locke (2020), is critical for sustainable water management strategies. However, there was a dearth of studies on these areas in Panda and other peri-urban and rural areas of Nasarawa state. Addressing these research gaps through localized studies in Panda which is closer to the FCT and similar contexts will provide essential data for policy makers and stakeholders to improve water infrastructure, enhance water quality monitoring, and promote sustainable water management across the region. This study aims to fill this gap by providing a spatial and temporal evaluation of current water sources in Panda Town. It seeks to assess the adequacy and accessibility of these sources to residents, explore residents' perceptions and attitudes towards water quality and reliability, identify main challenges in water resource utilization, and propose measures to enhance water resource management in the community.

Research Questions

1. What are the current sources of water in Panda Town?
2. How adequate and accessible are these water sources to the residents?
3. What are the perceptions and attitudes of residents towards the quality and reliability of water sources?
4. What are the main challenges in water resource utilization in Panda Town?

Objectives of the study

The aim of this research is to assess the current practices of water resource utilization in Panda Town, Karu LGA, Nasarawa State, with the goal of proposing sustainable strategies for water management. This has been achieved through the following objectives:

i. Identify the main sources of water used by residents in Panda Town;

ii. Evaluate the adequacy and accessibility of existing water sources in Panda Town;

iii. Assess the perceptions of the residents towards the quality of water sources in Panda Town;

iv. Assess the challenges of water resource utilization in Panda Town.

Significance of the Study

This research holds significant importance as it addresses the urgent need for enhanced water resource management in Panda Town, which is essential for improving public health, fostering economic activities, and mitigating environmental degradation. By thoroughly assessing current practices and identifying challenges, this study aims to develop effective strategies to ensure sustainable water access for the community. The findings of this research will serve several critical purposes:

i. Inform policymakers about the current state of domestic water in Panda Town and underscore the necessity for infrastructure improvements based on a thorough assessment of available water sources.
ii. Raise awareness among relevant stakeholders about the imperative to implement policies that strengthen weaknesses in water policy, regulation, and implementation.
i. Contribute to meeting the water needs of Panda Town residents and align with the global mandate for safe, affordable, and efficient water supply as outlined in Sustainable Development Goal 6 (SDG6).
ii. Educate the local population of Panda and neighbouring areas about the environmental risks associated with consuming water from untrusted and polluted sources.
iii. Serve as a foundational reference for future research endeavours, providing a basis for further studies by subsequent researchers interested in water resource management and related issues.

By fulfilling these objectives, this study seeks to drive positive change in Panda Town, promoting sustainable development and enhancing the overall well-being of its residents through improved water resource management practices.

Scope of the Study

This study is focused on Panda Town in Karu Local Government Area (LGA), Nasarawa State, Nigeria. Panda Town is located near Abuja, the Federal Capital Territory (FCT), and experiences the socio-economic pressures associated with its proximity to the capital. The study will specifically examine the water resources utilized by the residents of Panda Town, evaluating their accessibility, adequacy, and quality. The findings from this area will provide insights that may be applicable to similar peri-urban and rural communities in Nasarawa State and other areas experiencing rapid urbanization.

The temporal scope of this study covers the period from 2010 to 2024. This timeframe was chosen to capture recent trends and developments in water resource availability, utilization, and management in Panda Town, with a focus on current water-related challenges exacerbated by population growth and urbanization. The data collection and analysis will focus on this period to provide up-to-date insights and recommendations relevant to policymakers and stakeholders.

The conceptual scope of this study encompasses the key concepts of water resource management, including water source identification, adequacy and accessibility of water, water quality perceptions, and water utilization practices among the residents of Panda Town. The study has explored how these concepts influence water consumption patterns and public health, while also considering the socio-economic and environmental factors affecting water resource management in the community. This study has also examined residents' attitudes toward water quality and reliability, as well as the challenges faced in accessing safe drinking water.

Concepts of Water Resource Utilization

In the literature review section of the research proposal on water resource utilization in Panda Town, it is essential to define key terms to ensure clarity and understanding throughout the study. Key terms to define include:

Water Resource Utilization

Water resource utilization refers to the efficient and sustainable use of available water resources to meet the demands of various sectors, including agriculture, industry, and domestic use, while maintaining ecological balance (Zhang & Lin, 2022; Zhu & Cao, 2024; & Long, 2020). It involves maximizing the productivity and benefits derived from water resources while minimizing waste and environmental impact (Zhang & Lin, 2022; Long, 2020).

Key aspects of water resource utilization according to Zhang & Lin, 2022; Zhu & Cao, 2024 & Feng, Gu, Li, Wang, Gui, Zhao, Zhang, 2024 include:

1. Evaluating the quantity and quality of available water resources in a specific region or country, considering surface water and groundwater resources.
2. Assessing the efficiency of water use across different sectors, such as agriculture, industry, and domestic use, to identify areas for improvement.
3. Implementing water conservation measures and promoting the use of water-efficient technologies and practices.
4. Treating and recycling wastewater to reduce the demand for freshwater resources and minimize pollution.
5. Developing and enforcing policies and regulations to ensure sustainable water resource management and equitable allocation among various stakeholders.
6. Encouraging public awareness and participation in water conservation efforts to promote responsible water use by individuals and communities.
7. Fostering collaboration and coordination among different sectors and regions to optimize water resource utilization and address cross-boundary water management issues.

Effective water resource utilization is crucial for ensuring water security, supporting economic development, and maintaining healthy ecosystems (Zhu & Cao, 2024 & Long, 2020). It requires a comprehensive approach that considers the interconnections between water, energy, food, and the environment, and adapts to changing climatic conditions and societal needs (Zhu & Cao, 2024; Feng *et al.* 2024).

Water Quality

Water quality refers to the physical, chemical, and biological characteristics of water that determine its suitability for various uses, such as drinking, agriculture, industry, and recreation. It is a critical factor in ensuring the health and well-being of both human populations and aquatic ecosystems. (Massarelli, 2024; Locke, 2024). Key aspects of water quality include:

Microbiological Contaminants

Pathogenic bacteria, viruses, and protozoa, which can cause waterborne diseases if present in drinking water (Massarelli, 2024; Locke, 2024).

Indicator organisms, such as E. coli and coliforms, which are used to assess the potential presence of harmful microbes (Massarelli, 2024; Locke, 2024).

Water Quality Monitoring and Assessment

Systematic sampling and analysis of water samples to evaluate the physical, chemical, and biological parameters. (Massarelli, 2024; Locke, 2024; WHO, 1997).

Use of water quality indices and aggregators to provide a comprehensive assessment of water quality for different purposes (WHO, 1997).

Identification of pollution sources, such as industrial effluents, agricultural runoff, and improper waste disposal, and implementing measures to mitigate their impact (Massarelli, 2024; Locke, 2024; WHO, 1997).

Importance of Water Quality

Ensuring the safety and suitability of water for human consumption, agricultural irrigation, industrial processes, and recreational activities (Massarelli, 2024; Locke, 2024).

Maintaining the health and biodiversity of aquatic ecosystems, supporting the provision of ecosystem services (Massarelli, 2024; Locke, 2024).

Informing water resource management decisions and policies to promote sustainable water use and conservation (Massarelli, 2024; Locke, 2024; WHO, 1997).

Effective water quality monitoring, assessment, and management are crucial for protecting public health, preserving the environment, and supporting sustainable development. Ongoing research and collaboration among stakeholders, including policymakers, water utilities, and the scientific community, are essential to address emerging water quality challenges and ensure the availability of clean and safe water resources (Massarelli, 2024; Locke, 2024; WHO, 1997; UNICEF & WHO, 2021; WHO & UNICEP, 2017 & Ewuzie, Aku & Nwankpa, 2021).

Sustainability

Water sustainability refers to the maintenance and availability of clean water that can continue to fuel future generations for consumption, agricultural processes, and biodiversity (Jones, 2014). However, our water supply is facing distinct challenges, such as the agricultural industry being the largest consumer of freshwater due to irrigation and livestock needs, and the explosive industrial revolution leading to growing populations and urban centres that negatively impact water availability and pollution rates (Jones, 2014).

Climate change is also leading to more droughts, storms, and floods, damaging infrastructure and causing unreliable water systems and food shortages (Jones, 2014). Sustainable water systems and practices should ensure that water can meet consistent needs without sacrificing water availability and quality for future generations (Aqua Techtade, 2023). Ideal sustainability practices should aim to hit three primary goals: feasibility, accessibility, and environmental responsibility (Aqua Techtade, 2023).

Sustainable water management means the ability to meet the water needs of the present without compromising the ability of future generations to do the same (Aqua Techtade, 2023). Achieving sustainable water management requires a multidisciplinary and holistic approach in which technical, environmental, economic, landscape aesthetic, societal, and cultural issues are addressed (Aqua Techtade, 2023).

Water sustainability is crucial for inclusive growth, as water belongs to everyone, yet many are excluded from its benefits4. Ensuring that water is equitably and sustainably shared requires an inclusive approach, with women, youth, persons with disabilities, indigenous groups, and other underrepresented and marginalized groups having access and voice in the water sector (World Bank, 2024).

To guide effective climate change adaptation, activities should reflect the importance of water management for reducing vulnerability and building climate resilience, prioritizing actions such as expanding beyond traditional integrated water resources management (IWRM), promoting investment and solutions that incorporate management of "natural infrastructure," and supporting actions at scale to build climate resilience by combining watershed management, sustainable infrastructure, and empowerment and learning through adaptive institutions (World Bank, 2024).

Community Engagement

Community engagement in the context of water resource use and management refers to the active involvement of local residents, stakeholders, and community groups in the planning, decision-making, implementation, and monitoring processes related to the management and utilization of water resources (Arimoro & Musa, 2020; Tantoh, Sieber, Barkmann, & Nkongho, 2021). It encompasses a collaborative approach where the perspectives, knowledge, and needs of the community are integrated into the management strategies to ensure sustainable and equitable access to water.

Key components of community engagement in this context include:

Participation: Encouraging the involvement of community members in discussions, decision-making, and activities related to water resource management (Kema, Semali, Mkuwa, Kiwara, Kilima, Mshana, & Shayo, 2012; O'Donovan, Berrang-Ford, Alison, Gouweleeuw, Lwasa, Namanya, & Harper, 2020).

Collaboration: Working together with local organizations, governmental agencies, non-governmental organizations (NGOs), and other stakeholders to develop and implement water management plans that reflect the community's needs and priorities (Adams & Boateng, 2018; Hassenforder, Smajgl, & Ward, 2020).

Education and Awareness: Providing information and raising awareness about water conservation, water quality, and the importance of sustainable water management practices (Crosby, Jayasinghe, & McNicholl, 2020; Hyun, Ostergren, Leclerc, Macdonald, & Vardhan, 2019).

Capacity Building: Enhancing the skills and knowledge of community members to enable them to effectively participate in water management activities (Arimoro & Musa, 2020; Hovden, Tantoh, & Sieber, 2020).

Inclusivity: Ensuring that all segments of the community, including marginalized and vulnerable groups, have a voice in the water management process (Silvestri, Wittmayer, Schipper, Kulabako, Oduro-Kwarteng, Nyenje, & van Raak, 2018; Nastar, Boda, & Olsson, 2018).

Transparency and Accountability: Establishing clear and open communication channels to keep the community informed about water management decisions, policies, and projects, with accountability mechanisms in place to address community concerns and feedback (Kema *et al.,* 2012; Crosby *et al.,* 2020).

Sustainability: Promoting practices that ensure the long-term availability and quality of water resources (Arimoro & Musa, 2020; Tantoh *et al.,* 2021).

Empowerment: Empowering community members to take ownership of water management initiatives, giving them the authority and resources needed to make decisions and take actions that affect their water supply and quality (Adams & Boateng, 2018; Hassenforder *et al.,* 2020).

Infrastructure

Infrastructure in water resource use and management encompasses the physical and institutional systems essential for the collection, storage, treatment, distribution, and disposal of water resources. Key components

include water supply infrastructure, such as dams, reservoirs, groundwater extraction systems, and water treatment plants (Tumbare, 2015; Zainudeen, 2007; Cosgrove & Loucks, 2015). Wastewater infrastructure comprises sewer systems, wastewater treatment plants, and stormwater management systems to handle runoff and facilitate recycling (Tumbare, 2015; Cosgrove and Loucks, 2015).

Institutional and regulatory infrastructure involves water management policies, laws, governance structures, monitoring systems, and financing mechanisms (Zainudden, 2007; Oyebode & Coker, 2021; USAID, 2021). Additionally, stakeholder engagement infrastructure includes community engagement platforms, capacity-building programs, and collaborative forums for coordination among water sector stakeholders (Oyebode & Coker, 2021; USAID, 2021). Effective water resource infrastructure requires a holistic and integrated approach, considering physical, institutional, and social dimensions to ensure sustainable, long-term availability, quality, and equitable distribution of water resources.

Conceptual Review

The conceptual review will explore frameworks and concepts relevant to understanding water resource utilization and management in rural communities like Panda Town. Key concepts to review include:

Integrated Water Resources Management (IWRM)

Integrated Water Resources Management (IWRM) addresses the complex nature of water resource management by emphasizing the need to balance supply and demand while ensuring sustainable use. Over time, water resource managers have sought methods to exploit water efficiently, considering its uneven distribution and finite nature (Okereke, Udeagu, & Eze, 2000). The potential for global water disasters has driven efforts to secure current supplies while meeting future needs (Okereke *et al.,* 2000; Winpenny, 1994). A major challenge lies in reconciling supply-driven and demand-oriented management to maximize benefits while preserving ecological systems (Okereke *et al.,* 2000). In many developing countries, demand-oriented management is often viewed with suspicion as an imposition by international organizations like the World Bank, WHO, and IMF (Okereke *et al.,* 2000).

The need for sustainable water use gained prominence in the late 20th century. The 1977 UN Conference on Water in Mar del Plata, Argentina, marked a significant step towards integrated water management, highlighting the need for policy and legislative instruments, coordination among water institutions, and public participation (Rahaman & Varis, 2005; Bandaragoda & Babel, 2010). The conference's action plan laid the groundwork for future efforts in IWRM. Subsequently, the 1992 International Conference on Water and Environment in Dublin introduced four key principles: recognizing water as a finite and vulnerable resource, involving all stakeholders in water management, emphasizing the role of women, and viewing water as an economic resource (Rahaman & Varis, 2005).

To provide a clear definition of IWRM, the Global Water Partnership (GWP) described it as "a process which promotes the coordinated development and management of water, land, and related resources, to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP Technical Advisory Committee, 2000). IWRM aims to allocate water and infrastructure efficiently, reducing wastefulness and supporting environmental sustainability. Despite critiques about its practicality in developing countries (Biswas, 2004), IWRM is seen as a viable approach to balancing current demand with future resource security.

Characteristic of IWRM in Nigeria

In Nigeria, political considerations often drive decisions regarding new water schemes, overshadowing the expertise of professionals (Okereke *et al.,* 2000). Consequently, large-scale infrastructure projects are common, while policy and institutional reforms are lacking. Issues such as inadequate cost recovery measures, outdated irrigation processes, absence of water recovery strategies, and stakeholder inequality reflect gaps in water scheme planning, which are critical to achieving the Sustainable Development Goals (SDGs) (Emenike, Tenebe, Omole, Ngene, Oniemayin, Maxwell, & Onoka, 2017; Solomon, 2011).

The centralized approach to water management in Nigeria, with limited private sector involvement, exacerbates the nation's water challenges. Although private enterprises are beginning to enter the sector, significant barriers remain, including the need for equitable resource distribution, political considerations, and the perception of water as a public good. Large capital investments and the interdependence of water uses further deter private sector participation (Okereke *et al.,* 2000; Solomon, 2011).

Integrated Water Resources Management (IWRM) in Nigeria is perceived as an externally imposed concept, focused on demand, supply, and cost recovery without ensuring sustainable environmental practices (Okereke *et al.,* 2000). The National Water Policy restricts River Basin Development Authorities to land control, development, and conservation to enhance agricultural and water supply outputs (Federal Ministry of Water Resources, 2004).

Key characteristics of IWRM include holistic management of all water sources, river basin management, and synergy among water users, planning within a national framework, economic efficiency, equitable distribution, and environmental sustainability (Muller, Schreiner, Smith, Van Koppen, Sally, Aliber, Cousins, Tapela, Merwe-Botha, Van Der, & Karar, 2009).

Assessing the IWRM in Nigeria

The United Nations report indicates that most African countries, including Nigeria, show medium to low progress in IWRM implementation, with only 41% institutionalization of IWRM elements. This suggests that significant efforts are needed to meet global targets (UN Environment, 2018). Despite the widespread adoption of IWRM principles worldwide, its efficacy is questioned due to varying economic, socio-cultural, and environmental contexts (Akpabio, Watson, Ite, & Ukpong, 2007; Biswas, 2004).

IWRM principles in Nigeria began with the establishment of River Basin Development Authorities and the Federal Ministry of Water Resources in 1970. The 2004 National Water Policy highlighted IWRM principles but did not specify implementation strategies (Enyidi, 2017). River Basin Development Authorities are crucial for IWRM, but challenges such as limited resources and technical capacity hinder their effectiveness (Akpabio *et al.,* 2007).

Issues in the northern part of Nigeria include surface water demands exceeding river flow, river blockages, impacts of large dams, declining groundwater levels, and inadequate hydrometric networks (Solomon, 2011). These challenges reflect the need for better-coordinated management approaches and stronger legal frameworks (Akpabio *et al.,* 2007; Mitchell, 1990).

Stakeholder Engagement

Effective water governance necessitates the meaningful participation of diverse stakeholders, including water users, civil society groups, and marginalized communities, in decision-making processes (Lautze, de Silva, Giordano, & Sanford, 2011). Stakeholder engagement is critical in ensuring that water management policies and practices are equitable, sustainable, and responsive to the needs of all users.

Importance of Stakeholder Engagement

Stakeholder engagement is crucial in water governance as it ensures that the voices and concerns of all affected parties are heard and considered (Lautze *et al.,* 2011). This participatory approach enhances the legitimacy and acceptance of water management decisions, as stakeholders are more likely to support and comply with policies they had a hand in shaping (Whaley & Weatherhead, 2014). It also helps identify and address the specific needs and challenges faced by different groups, leading to more inclusive and effective solutions (Pahl-Wostl, 2015).

There are several mechanisms through which stakeholders can participate in water governance. Public consultations allow stakeholders to provide input on proposed water management policies and projects through public meetings, workshops, and online forums (Behnke, Klug, Cronk, Shields, Lee, Kelly, & Bartram, 2017). Advisory committees that include representatives from various stakeholder groups can provide a structured way for stakeholders to contribute to decision-making (Cassava, Dube, & Bangira, 2015). Collaborative planning

processes, such as integrated water resources management (IWRM), ensure that stakeholder perspectives are integrated into the development of water management plans (Merrey, 2008). Community-based management initiatives empower local communities to manage their water resources, enhancing local ownership and stewardship of water resources (Chifamba, 2013).

Despite the benefits of stakeholder engagement, several challenges can hinder effective participation. Power imbalances between different stakeholder groups can affect the inclusivity of the engagement process (Whaley & Weatherhead, 2014). Stakeholders may lack the resources and capacity to engage effectively in water governance, particularly in developing countries (Haider, Boonstra, Akobirshoev, & Schlüter, 2015). Institutional barriers, such as rigid bureaucratic structures and lack of coordination between different levels of government, can impede effective stakeholder engagement (Pahl-Wostl, 2015). Cultural and social factors, such as traditional gender roles, can also limit the participation of certain groups in water governance (Thoradeniya & Maheshwari, 2019).

Case Studies and Examples

In Nigeria, the engagement of stakeholders in water governance is critical given the country's diverse socio-cultural and geographical context. The Federal Ministry of Water Resources (FMWR) has emphasized the need for stakeholder participation in its water policies. However, challenges remain in ensuring meaningful engagement of all stakeholders, particularly marginalized communities (Federal Ministry of Water Resources, 2004).

The Cross River Basin Development Authority (CRBDA) serves as an example of efforts to incorporate stakeholder participation in water management. Studies have shown that while CRBDA aims to involve local communities and other stakeholders in its activities, it faces challenges such as limited resources and capacity constraints (Akpabio *et al.,* 2007).

Globally, the principles of IWRM advocate for the involvement of all stakeholders in water management. The 1992 Dublin Statement on Water and Sustainable Development highlighted the importance of participatory approaches, emphasizing that water development and management should be based on a participatory approach, involving users, planners, and policymakers at all levels (Rahaman & Varis, 2005).

To enhance stakeholder engagement in water governance, several strategies can be adopted

Empowering Marginalized Groups

Special efforts should be made to empower marginalized groups, such as women and indigenous communities, to participate in water governance. This can involve targeted outreach, capacity-building programs, and ensuring their representation in decision-making bodies (Sultana & Loftus, 2012; Thoradeniya & Maheshwari, 2019).

Creating Inclusive Platforms

Developing inclusive platforms for stakeholder engagement, such as multi-stakeholder forums and participatory planning processes, can facilitate meaningful participation. These platforms should be designed to accommodate the diverse needs and capacities of different stakeholder groups (Cassava *et al.,* 2015; Pahl-Wostl, 2015).

Ensuring Transparency and Accountability

Transparent and accountable governance processes can build trust and encourage stakeholder participation. This includes clear communication of decisions, open access to information, and mechanisms for holding decision-makers accountable (Kema *et al.,* 2012; Crossby *et al.,* 2020).

In conclusion, effective stakeholder engagement is essential for sustainable and equitable water governance. By involving diverse stakeholders in decision-making processes, water management policies and practices can better reflect the needs and priorities of all users, leading to more sustainable and resilient water systems (Lautze *et al.,* 2011; Pahl-Wostl, 2015).

Monitoring and Evaluation

Governance frameworks should include systems for monitoring water availability, quality, and use, as well as mechanisms to evaluate the performance and impact of water management policies and programs (Samadi-Foroushani *et al.,* 2022).

THEORETICAL FRAMEWORK

Theoretical perspectives provide frameworks for understanding the dynamics of water resource utilization and management. Relevant theories to review include

Social-Ecological Systems (SES) Theory

Social-Ecological Systems (SES) Theory is a framework that conceptualizes the interactions between social and ecological systems as a coupled, complex, and adaptive system (Ostrom, 2009). This theory emphasizes the interdependence and feedback loops between human societies and their surrounding environment, recognizing that the sustainability of natural resources, such as water, is influenced by both social and ecological factors.

In the context of water resource utilization in rural and peri-urban areas of Nigeria, SES theory is highly relevant for several reasons:

Acknowledging the complexity of water resource management

SES theory recognizes that water resource utilization is influenced by a multitude of interacting factors, including biophysical conditions, infrastructure, institutions, and user groups (Pahl-Wostl, 2015). This perspective is crucial for understanding the challenges faced in rural and peri-urban areas of Nigeria, where water resources are often scarce and unevenly distributed.

Emphasizing the role of institutions and governance

SES theory highlights the importance of institutions and governance structures in shaping the use and management of natural resources (Ostrom, 2009). In the context of water resources, this includes formal and informal rules, norms, and decision-making processes that govern access, allocation, and use. Analyzing these institutional arrangements is essential for identifying barriers and opportunities for sustainable water resource utilization in rural and peri-urban Nigeria.

Recognizing the diversity of stakeholders and their interactions

SES theory acknowledges the presence of multiple stakeholders, such as water users, policymakers, and community organizations, and their interactions in shaping the dynamics of the system (Pahl-Wostl, Lebel, Knieper & Nikitina, 2012). In rural and peri-urban Nigeria, understanding the roles, interests, and power relations among these stakeholders is crucial for designing inclusive and equitable water resource management strategies.

Promoting adaptive management and learning

SES theory emphasizes the need for adaptive management approaches that can respond to changing conditions and new information (Folke, Hahn, Olsson, & Norberg, 2005). In the context of water resource utilization, this is particularly relevant given the uncertainties posed by climate change, population growth, and socio-economic transformations in rural and peri-urban Nigeria. Adopting an adaptive management approach can help stakeholders learn from experience and adjust their strategies accordingly.

Fostering cross-scale interactions and linkages

SES theory recognizes the importance of cross-scale interactions and linkages between different levels of governance and management (Berkes, 2002). In the case of water resources, this includes understanding how decisions and actions at the local, regional, and national levels influence water resource utilization in rural and

peri-urban areas of Nigeria. Considering these cross-scale interactions is crucial for developing coherent and coordinated water resource management policies.

In conclusion, Social-Ecological Systems (SES) theory provides a comprehensive framework for analysing the complex interactions between social and ecological systems in the context of water resource utilization. Its emphasis on institutions, stakeholder interactions, adaptive management, and cross-scale linkages makes it a highly relevant and valuable approach for assessing and improving water resource utilization in rural and peri-urban areas of Nigeria.

Institutional Theory and Water Resource Utilization in Peri-Urban and Rural Nigeria

Institutional theory is a widely-used framework in the social sciences that examines how institutions, defined as the formal and informal rules, norms, and structures that guide and constrain human behaviour, shape organizational and societal outcomes (Scott, 2013). This theory is highly relevant in understanding water resource utilization in peri-urban and rural areas of Nigeria.

Core Concepts of Institutional Theory

Institutional theory focuses on how institutions influence the behaviour of individuals and organizations. Institutions can be formal, such as laws and regulations, or informal, such as cultural norms and social expectations. They provide stability and meaning to social life by creating predictable structures within which individuals and organizations operate (Scott, 2013). Key concepts within institutional theory include:

Application to Water Resource Utilization in Nigeria

In the context of water resource utilization in peri-urban and rural areas of Nigeria, institutional theory helps explain how various formal and informal institutions influence water management practices and outcomes.

Formal Institutions

These include national and local water policies, regulations, and governance structures. For example, the Federal Ministry of Water Resources (FMWR) and River Basin Development Authorities (RBDAs) are formal institutions responsible for water resource management. The National Water Policy outlines the regulatory framework and objectives for water management in Nigeria (Federal Ministry of Water Resources, 2004).

Informal Institutions

These encompass cultural norms, traditional practices, and social networks that shape water usage and management. In many Nigerian communities, traditional leaders and local customs play a significant role in governing water resources. Informal institutions often determine access to water, conflict resolution, and community participation in water projects (Whaley & Weatherhead, 2014).

Challenges and Implications

Understanding the interplay between formal and informal institutions is critical for effective water resource management in Nigeria. Some of the challenges and implications include:

Institutional Fragmentation

There is often a lack of coordination between different levels of government and between formal and informal institutions. This fragmentation can lead to overlapping responsibilities, inefficiencies, and conflicts in water management (Pahl-Wostl, 2015).

Capacity Constraints

Both formal and informal institutions may face capacity constraints in terms of resources, technical expertise, and enforcement capabilities. These limitations can hinder the implementation of effective water management

strategies (Haider *et al.,* 2015).

Adaptation and Compliance

Local communities may resist formal water management policies if they conflict with traditional practices and norms. Ensuring community buy-in and compliance requires aligning formal policies with local contexts and involving community leaders in the planning and implementation processes (Whaley & Weatherhead, 2014).

Institutional Change and Innovation

Promoting institutional change and innovation is essential for improving water resource management. This involves fostering collaboration between formal and informal institutions, encouraging adaptive management practices, and building institutional capacity through training and resource allocation (Pahl-Wostl, 2009).

Diffusion of Innovation Theory and Adoption of Sustainable Water Management Practices in Nigeria

Diffusion of Innovation Theory, developed by Everett Rogers (2003), provides a valuable framework for understanding how new technologies, practices, or ideas spread through a social system over time. In the context of water resource utilization, this theory can help explain the adoption of sustainable water management practices within peri-urban and rural communities in Nigeria.

Adaptive Management in Water Resource Utilization in Nigeria

Adaptive Management is a systematic approach to environmental management that emphasizes learning from experience and adjusting strategies based on ongoing monitoring and evaluation of outcomes (Holling, 1978). In the context of water resource utilization, this approach is particularly relevant as it allows for flexibility in responding to changing environmental, social, and economic conditions, such as climate change, population growth, and evolving community needs.

The key principles of Adaptive Management include:

a) Acknowledging uncertainty and complexity in social-ecological systems (Pahl-Wostl, 2007).

b) Promoting iterative decision-making and learning through experimentation and monitoring (Walters, 1986).

c) Involving diverse stakeholders in the management process (Pahl-Wostl *et al.,* 2007).

Political Ecology and Water Resource Utilization in Nigeria

Political Ecology examines the political, economic, and social factors that influence access to and control over natural resources, such as water (Robbins, 2012). In the context of water resource utilization in peri-urban and rural Nigeria, this theory can help unpack the power dynamics and structural inequalities that shape water access and governance.

Key aspects of Political Ecology that are relevant to water resource utilization in Nigeria include:

i. Unequal power relations: Political Ecology highlights how power imbalances between different social, economic, and political groups can lead to the marginalization of certain communities in terms of water access and decision-making processes (Sultana, 2013).

ii. Politicization of water resources: Water resources are often politicized, with different actors, such as government agencies, private companies, and community groups, competing for control and access (Nastar *et al.,* 2018).

iii. Socio-economic and cultural factors: Political Ecology emphasizes how socio-economic status, cultural norms, and traditional practices can influence water access and management, particularly in peri-urban and rural areas (Whaley & Weatherhead, 2014).

iv. Environmental degradation and water scarcity: Political Ecology examines how environmental degradation, such as pollution and overexploitation of water resources, can exacerbate water scarcity and disproportionately impact marginalized communities (Sultana & Loftus, 2012).

By applying a Political Ecology lens, researchers and policymakers can better understand the complex interplay of power, politics, and social dynamics that shape water resource utilization in peri-urban and rural Nigeria. This can inform the development of more equitable and inclusive water governance frameworks that address the root causes of water insecurity and empower marginalized communities.

Environmental Justice and Water Resource Utilization in Nigeria

Environmental Justice addresses the equitable distribution of environmental benefits and burdens, including access to clean water and exposure to water-related hazards, among different social groups (Schlosberg, 2013). In the context of water resource utilization in peri-urban and rural Nigeria, this theory can help identify and address disparities in water access and quality among communities.

Key aspects of Environmental Justice that are relevant to water resource utilization in Nigeria include:

1. Equitable access to water: Environmental Justice emphasizes the importance of ensuring that all members of society, regardless of their socio-economic status, race, or geographic location, have fair and equal access to clean and safe water (Schlosberg, 2013).
2. Disproportionate exposure to water-related risks: Environmental Justice examines how certain communities, often the most marginalized, may be disproportionately exposed to water-related hazards, such as flooding, water-borne diseases, and water pollution (Sultana & Loftus, 2012).
3. Participatory decision-making: Environmental Justice advocates for the meaningful involvement of affected communities in the decision-making processes related to water resource management and the equitable distribution of environmental benefits and burdens (Schlosberg, 2013).
4. Addressing structural inequalities: Environmental Justice seeks to address the underlying structural inequalities and power imbalances that contribute to the unequal distribution of water resources and water-related risks (Sultana & Loftus, 2012).

By applying an Environmental Justice framework, researchers and policymakers in Nigeria can identify and address the disparities in water access and quality among peri-urban and rural communities. This can inform the development of more inclusive and equitable water governance policies and interventions that prioritize the needs of marginalized groups and ensure that the benefits and burdens of water resource utilization are fairly distributed.

Empirical Review of Related Literature

Assessment of Water Sources, Quality, Adequacy and Accessibility of Water Sources to Residents

Samaila, Baba & Aliyu (2023) aimed to explore factors affecting the performance of local industries in Nasarawa State, Nigeria, and identify remedial measures. Using focus groups, the researchers identified 113 performance-impacting factors grouped into seven categories and classified 82 remedial measures into internal (for construction firms) and external (for government and stakeholders). Critical factors included financial indiscipline, lack of experience, poor banking policies on SMEs, corruption, globalization effects, multiple taxation, stringent prequalification criteria, poor design, lack of entrepreneurship skills, and payment delays. Recommendations focused on implementing management practices and support measures to improve performance. The study's reliance on qualitative data from focus groups may limit generalizability, suggesting the need for quantitative validation across a broader sample of local industries.

The Study by Bello, Ortese & Mohammed (2022) analyzed the utilization, demand, and supply of domestic water in Akwanga Local Government Area, Nasarawa State, Nigeria. Using GIS techniques and questionnaires administered to 399 households (332 completed), the study applied SPSS for descriptive statistics, regression, and correlation analysis. Findings indicated that women and children were primarily responsible for water

collection, with household size, distance to water sources, and infrastructure significantly affecting water demand and supply. The high positive correlation between water demand and supply pointed to participatory approaches and expanded pipe-borne water networks as solutions. The study's focus on a single local government area limits the applicability of findings, warranting broader comparative studies across different regions and seasons.

Heavy metal contamination in borehole water across 12 Local Government Areas in Nasarawa State, Nigeria, was assessed by Tukura, Ayinya, Ibrahim, & Onche (2014) through analysing water samples from 52 boreholes using atomic absorption spectrometry (AAS) during the dry season. Findings revealed high levels of Zn and Fe in Keana, with Pb and Cr levels exceeding WHO limits in several areas. ANOVA indicated significant differences in Zn levels, with Fe, Pb, and Cr contamination attributed to anthropogenic and geological sources. The study's limitation to the dry season suggests a need for wet season sampling and broader geographical coverage to provide a comprehensive contamination profile.

Suleiman, Sangari, & Ogah (2021) investigated the impact of the distance between soakaways and boreholes on groundwater quality in Karu LGA. Utilizing both primary and secondary data, the research specifically focused on the bacteriological quality of groundwater samples from boreholes in the area. The findings indicated that the proximity of groundwater sources to pollution sources significantly affects the degree of contamination. Based on these findings, the researchers recommended collaboration between environmental management agencies, the provision of piped water and sewerage services by the Ministry of Water Resources and Nasarawa State Urban Development Board, and careful site selection for boreholes to prevent groundwater pollution and protect public health.

Magaji & Abimbola (2020) assessed and compared the water quality from various sources in Masaka, Nasarawa State. Water samples from streams, sachet water, boreholes, and wells were analyzed for physicochemical and biological properties using standard equipment and procedures as prescribed by APHA (2005). The results indicated high turbidity and conductivity levels, with bacteriological properties exceeding WHO limits. Statistical analysis revealed significant differences in water quality between concrete wells with and without covers. The study recommended public enlightenment on water sanitation, regular monitoring by NAFDAC, and the covering of wells to improve water quality.

The study by Ihuma, Adogo, Malgwi, Maikenti, & Koggie, (2016) aimed to determine the bacteriological properties of surface water from the Uke River in Karu LGA. Water samples were collected from five points over five weeks and analyzed for heterotrophic bacteria, fecal coliforms, and total coliforms. Six bacterial genera, including Escherichia coli, were identified, indicating significant bacterial contamination. The findings suggest that the water is not fit for consumption without proper treatment. The study highlights the need for continuous monitoring and proper water treatment to ensure safety.

Aremu, Opaluwa, Nghargbu, & Yahuza, (2012) focused their research on assessing and comparing water quality from different sources in Masaka, Nasarawa State. Water samples from streams, sachet water, boreholes, and wells were analyzed for various physicochemical and biological properties. The findings showed high turbidity and conductivity levels, with significant bacteriological contamination. The study recommended public awareness campaigns, regular monitoring by regulatory agencies, and proper covering of wells to improve water quality and public health.

Solihu & Bilewu (2020) examined the availability, coverage, and access to potable water supply in Oyo State, Nigeria. Using data from the Federal Ministry of Water Resources, the analysis revealed that while water supply is available, it is inadequate, with groundwater being the primary source. Coverage and access to potable water were found to be 27.3% and 62.74%, respectively. The study recommended improving water supply from alternative sources, especially major surface water schemes, to prevent overexploitation of groundwater.

Idusere, Abbas, Izunobi, Ogedegbe, & Ogbonna, (2020) investigated the sources of water supply and challenges faced by urban and rural dwellers in Zaria, Nigeria. Using descriptive statistics and AMS techniques, the study found that urban residents travelled longer distances for water, with sources varying seasonally. Wells and water

vendors were the predominant sources. The study recommended improved water purification methods, public education on water hygiene, and government support for sustainable water supply solutions.

Ewuziea, Akub, & Nwankpad (2021) reviewed the data collection, analysis, and reporting techniques used in water quality research in Nigeria over the past 20 years. Analysing 123 published articles, the study identified shortcomings in data analysis and reporting methods. It recommended improved techniques for analysing and visualizing water quality data and highlighted the need for continuous evaluation of methodologies to ensure reliable and accurate water quality assessments.

Kana (2022) assessed heavy metal contamination of groundwater in Karu, Central Nigeria. Using heavy metal evaluation indices, the study found significant contamination with heavy metals exceeding WHO limits, particularly near poultry farms, dumpsites, and quarry areas. The study attributed the contamination to anthropogenic activities and recommended improved waste disposal practices and continuous environmental monitoring to control pollution and protect groundwater quality.

Ngene, Christiana, Gideon, Adebanji, Jacob & Victor (2021) reviewed the state and limitations of water resources management in Nigeria and explored the feasibility of adopting integrated water resources management (IWRM). The literature review highlighted the slow progress in IWRM implementation due to poor water governance and unclear frameworks. The study recommended an iterative approach to IWRM tailored to specific water problems in Nigeria and emphasized the need for empirical studies on current IWRM efforts.

Sunkari *et al.* (2021) conducted this study in the Federal Capital Territory (FCT), Abuja, Nigeria, using eighteen vertical electrical sounding (VES) data points to delineate potential groundwater development areas. Using the ABEM Terrameter with Schlumberger array, the researchers categorized the geo-electric sections into topsoil, clay, fractured/weathered basement, and fresh basement. Groundwater predominantly resides in the fractured/weathered basement, flowing irregularly from NW to SE, influenced by aquifer depth variations. Nine VES points in the NE and SE peripherals showed groundwater development potential at depths of 40-80 m and resistivity values of 80-680 Ωm, whereas the SW and central parts lacked promising groundwater prospects due to the absence of fractured/weathered zones. Communities like Bwari, Kuje, IduCITEC, Sherete, and GTSSC in the northern and SE zones are optimal for water well drilling, though southern areas like Gwagwalada and Gugugu also exhibit potential.

Study by Abanyie *et al.* (2023) assessed the impacts of improved water supply on rural livelihoods in Doba and Nayagnia communities, Upper East Region, Ghana. Through structured questionnaires and statistical analyses, the study highlighted positive effects on health, hygiene, time-saving, productivity, food supply, nutrition, school performance, reduced stress (particularly for women), and health expenditure. Significant correlations were found between household income and access to improved water ($P = 0.001$), as well as water tariff and potable water access ($P = 0.010$). The study observed a decline in water-related diseases post-improvement in water supply, emphasizing the need for sustainable operation and maintenance schemes to uphold these benefits.

Locke (2020) reviews the impact of land use/land cover (LULC) on water quality, highlighting how activities like agriculture, urban development, mining, and commercial forestry contribute to diffuse pollution, whereas natural vegetation can act as a protective buffer. The review stresses the importance of maintaining un-fragmented natural vegetation in riparian zones and catchment areas to safeguard water resources. However, gaps in knowledge remain regarding the specific types and amount of vegetative cover needed to mitigate pollution effectively, and the impact of landscape fragmentation on vegetation's protective capacity warrants further context-specific research.

Perceptions and Attitudes of Residents towards the Quality and Reliability of Water Sources

Gevera, Dowling, Gikuma-Njuru, & Mouri (2022) assessed the local population's knowledge and perceptions of drinking water quality in Makueni County, Kenya, focusing on health impacts associated with high salinity and fluoride levels in groundwater. Methods included questionnaires and focus group discussions with 115 individuals. Findings revealed dissatisfaction with water taste due to salinity, low daily consumption rates, and health issues like diarrhoea linked to water quality. The study highlighted a lack of awareness regarding fluoride's

health effects, suggesting a need for public health education. Limitations include the small sample size and potential bias in self-reported health impacts.

Benameur, Benameur & Saidi (2022) investigated public perception and awareness of drinking water quality in Biskra, Algeria, using a survey-based cross-sectional study. The study identified preferences for tank and tap water sources, with low awareness of water quality standards and inadequate communication about preventive measures. Education level significantly influenced satisfaction with water quality and trust in water safety, underscoring educational disparities in water perception. Limitations include potential response bias and the need for broader geographic representation.

Ayiwulu & Edache, (2015) assessed households' perceptions of domestic water quality in Nassarawa Eggon Local Government Area, Nigeria, using questionnaires and descriptive statistics. Findings highlighted hand-dug wells, boreholes, and streams as primary water sources, with concerns over water taste, colour, and odour. The study underscored the prevalence of water-related diseases and emphasized the need for improved water treatment and education. Limitations include potential recall bias and limited generalizability beyond the study area.

Ojo (2011) developed and tested a customer satisfaction framework for public water utilities in the Federal Capital Territory, Nigeria. The study utilized qualitative and quantitative methods to assess service quality perceptions and priorities for improvement among 1,045 customers. Findings indicated reliability and water quality as critical factors influencing satisfaction, with recommendations for enhanced communication and service delivery. Limitations include sampling bias and potential biases in self-reported satisfaction levels.

Sridhar, Okareh & Mustapha (2020) evaluated knowledge, behaviour, and practices related to water, sanitation, and hygiene (WASH) in Kaduna State, Nigeria, through spot checks and questionnaires with 854 participants. The study revealed widespread reliance on surface waters and inadequate treatment practices, despite moderate awareness of hygiene practices. Findings underscored the need for improved WASH infrastructure and education to mitigate health risks. Limitations include self-reporting bias and regional specificity.

Challenges in Water Resource Utilization

Emenike *et al.* (2017) aimed to assess water access in Ado-Odo Ota, Ogun State, Nigeria, focusing on accessibility, availability, affordability, and acceptability of water sources. They employed a stratified sampling technique and distributed 700 structured questionnaires. Findings revealed heavy reliance on private water sources due to concerns over government facilities' quality and accessibility. Recommendations included revisiting policies to incorporate subsidies, cost recovery mechanisms, and rainwater harvesting to improve equitable water access. Limitations may include potential biases in self-reported data and challenges in verifying water quality claims from private sources. Further research could explore the socio-economic impacts of recommended policy changes on vulnerable communities.

Akawu, Maiwada & Abdulsalami (2020) explored determinants of portable water demand in Nasarawa State using multinomial logit models and data from 400 respondents across six local government areas. Their study identified household head income, location, and dwelling ownership as primary factors influencing water demand patterns. They underscored the urgent need for expanding piped water infrastructure to rural areas to enhance access. Limitations may include sampling biases and the challenge of accurately capturing socio-economic factors influencing water demand. Future studies could focus on the differential impacts of water supply improvements on various demographic groups within rural communities.

Ezekiel & Dominic (2015) examined domestic water sources and demand challenges in Nassarawa Eggon, Nasarawa State, Nigeria, focusing on the prevalence of hand-dug wells amidst population growth. They recommended infrastructural upgrades to meet growing water demand and mitigate health risks associated with inadequate water supply. Limitations may include the need for more extensive spatial analysis of water source distribution and potential biases in self-reported water consumption data. Future research could explore the socio-economic impacts of water infrastructure investments on community health outcomes and livelihoods.

Gyang, Uzoigwe, Ayim, Ombugadu & Ahmed (2017) evaluated parasitic contamination in drinking water sources in Lafia, Nasarawa State, finding high rates of Giardia lamblia and emphasizing the need for water treatment to prevent waterborne diseases. The study highlighted significant differences in contamination rates across different water sources and underscored the importance of regular water quality monitoring and treatment. Limitations may include the seasonal variability in parasite prevalence and the challenge of establishing causal relationships between water contamination and health outcomes. Future research could focus on longitudinal studies to track changes in parasite prevalence and assess the effectiveness of water treatment interventions in reducing disease transmission.

Each of these studies contributes valuable insights into various aspects of water management and quality in Nigeria. However, common research gaps include the need for more comprehensive community perceptions studies, integrated policy responses, and assessments of long-term sustainability impacts of interventions. Future research efforts should aim to address these gaps to inform targeted interventions and achieve sustainable development goals related to water access and quality.

SUMMARY OF LITERATURE REVIEW

In examining water availability and utilization in Panda, Karu LGA of Nasarawa State, insights from recent studies provide valuable context. Studies by Sunkari, Kore & Abioui (2021) delineated groundwater potential in nearby regions, highlighting fractured/weathered basement areas conducive to groundwater development. Conversely, areas lacking such geological formations suggest potential limitations in water availability. Abanyie *et al.* (2023) underscored the transformative impacts of improved water supply on rural livelihoods, correlating enhanced access with health benefits and economic improvements, findings pertinent for assessing water interventions in Panda. Locke's (2020) review on land use/land cover impacts emphasized the protective role of natural vegetation in preserving water quality, signaling a need to evaluate how local land practices in Panda influence water resources.

Despite these insights, a noticeable research gap exists regarding specific water sources, quality, and local land use effects in Panda, Karu LGA. Understanding these dynamics is crucial for sustainable water management and community resilience. Filling this gap requires spatially explicit research to map out water sources, assess their contamination risks, and gauge the impact of land use practices on water availability and quality. Addressing these factors can inform targeted interventions to improve water infrastructure, mitigate pollution risks, and enhance water security in Panda and similar communities across Nasarawa State.

Numerous studies have explored water quality, availability, and community perceptions across diverse regions of Nigeria. For instance, Lock (2020) and Ayiwulu & Edache (2015) focused on household perceptions and water quality in various Nigerian contexts. In Nasarawa State specifically, studies by Ihuma *et al.* (2016) in Karu LGA, Solihu & Bilewu (2020) in Masaka, and Aremu *et al.* (2012) in Masaka assessed water quality from different sources but did not comprehensively address community perceptions. The absence of similar studies in Panda Town and other parts of Nasarawa State is noteworthy for several reasons. Firstly, understanding local perceptions and attitudes towards water quality and reliability is pivotal for designing targeted interventions that meet community concerns and preferences. Secondly, such studies can inform policy formulation and infrastructure development to enhance water management and ensure equitable access to safe drinking water. Thirdly, local insights are crucial for fostering community engagement and promoting adherence to water conservation and hygiene practices. Therefore, conducting studies in Panda Town and similar locales would bridge critical knowledge gaps, improve public health outcomes, and contribute to sustainable water resource management in the region.

The studies reviewed highlight various challenges and insights into water management across Nigeria, with implications for areas like Panda, Karu LGA, and Nasarawa State. Emenike *et al.* (2017) identified a reliance on private water sources due to concerns over government facilities in Ado-Odo Ota, underscoring issues of water quality and accessibility. Similarly, Akawu, Maiwada & Abdulsalami (2020) emphasized the need for expanded piped water infrastructure in Nasarawa State, driven by factors such as household income and location. Opaluwa *et al.* (2022) found elevated levels of heavy metals in River Adema, suggesting contamination sources needing regulation, relevant to understanding similar risks in Nasarawa State.

Ohwo (2016) highlighted policy gaps and infrastructure deficiencies impacting public water provision in Nigerian cities broadly, pertinent to challenges in urban areas of Nasarawa State like Karu LGA. Acinwu, Abenu & Kevin (2023) identified cultural beliefs and inadequate infrastructure as barriers to water use efficiency in Abuja, reflecting potential barriers in Panda and similar regions. Ezekiel & Dominic (2015) discussed the prevalence of hand-dug wells and population pressures affecting water sources in Nassarawa Eggon, relevant for understanding similar dynamics in Nasarawa State. Gyang *et al.* (2017) focused on parasitic contamination in Lafia's water sources, underscoring the importance of water treatment and sanitation practices, applicable to health concerns in Panda and across Nasarawa State. These insights collectively highlight the need for localized studies in Panda, Karu LGA, and throughout Nasarawa State to address specific water management challenges, inform policy interventions, and achieve Sustainable Development Goal targets for universal access to safe drinking water and sanitation.

Based on the review summary provided, several research gaps can be identified, particularly concerning water management in Panda Town and similar peri-urban and rural settings in Nasarawa State:

Specific Water Sources and Quality Assessment

There is a lack of detailed studies that explicitly map out and assess the quality of water sources in Panda Town. Understanding the types of water sources available (e.g., boreholes, wells, rivers) and their contamination risks (e.g., heavy metals, microbial contamination) is crucial for ensuring safe drinking water access.

Community Perceptions and Attitudes

While some studies in Nasarawa State have assessed water quality from different sources, there remains a gap in understanding local perceptions and attitudes towards water quality and reliability in Panda Town. This knowledge is essential for designing effective interventions that address community concerns and promote sustainable water use practices.

The Study Area and Methods

Study Area Description

Panda Town is a rural community located in Karu LGA, Nasarawa State, Nigeria. It is characterized by a mix of residential and agricultural land use, with a growing population facing challenges in water supply and management.

Panda Town is a rapidly growing rural community with a mix of residential and agricultural land use. The population has been increasing in recent years due to migration from urban areas and natural growth, putting pressure on the available water resources and infrastructure (National Population Commission, 2019).

Panda Town is located in Karu Local Government Area (LGA) of Nasarawa State, Nigeria. The GPS coordinates of the town are approximately 8°52'N, 7°05'E (Google Maps, 2023). The town covers an area of around 10 square kilometres and is situated along the Abuja-Keffi highway, about 20 kilometres from the Federal Capital Territory (FCT) Abuja (Nasarawa State Government, 2021). Figure 1 is the Map of the Study Area.

Climate

Panda Town experiences a tropical climate with distinct wet and dry seasons. The rainy season typically lasts from April to October, while the dry season is from November to March. The average annual rainfall is around 1,500 mm, with the highest rainfall occurring in August (Nigerian Meteorological Agency, 2022). The average annual temperature ranges from 25°C to 35°C, with the hottest months being March to May (Nigerian Meteorological Agency, 2022).

Water Resources

Panda Town relies on both surface and groundwater resources for domestic and agricultural use. The main surface water sources include seasonal streams and ponds, which are often contaminated during the rainy season

(Nasarawa State Water and Sewerage Corporation, 2021). Groundwater is accessed through hand-dug wells and boreholes, but the water quality and quantity are variable (Adamu *et al.,* 2015).

Soils

The soils in Panda Town are predominantly sandy loams and clay loams, which are generally fertile and suitable for agriculture. However, soil erosion and degradation are becoming increasingly common due to unsustainable farming practices and overgrazing (Nasarawa State Ministry of Agriculture, 2019).

Economic Activities

The main economic activities in Panda Town include:

Informal sector

Many residents, especially women and youth, engage in informal economic activities, such as petty trading, handicrafts, and casual labour (National Bureau of Statistics, 2020). The lack of access to reliable water supply and management is a significant challenge for the economic development of Panda Town, particularly for agriculture and small-scale businesses (Nasarawa State Water and Sewerage Corporation, 2021). Addressing these water-related issues is crucial for improving the livelihoods and well-being of the community.

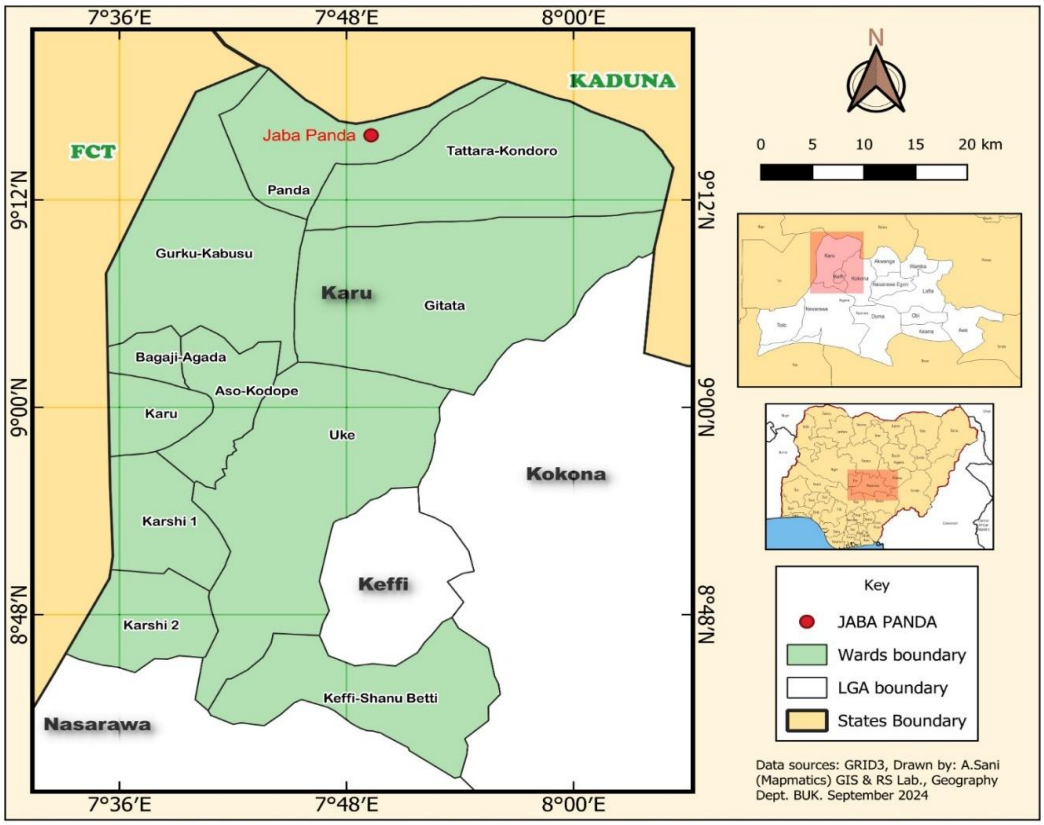


Figure 1: Map of the Study Area 3.3.

RESEARCH METHODS

Research Design

This study employed the mixed-methods approach to comprehensively assess water resource utilization in Panda Town. Mixed-methods research combines qualitative and quantitative techniques, allowing for a more holistic understanding of the research problem by triangulating different sources of data.

Types and Sources of Data

Primary Data:

i. **Surveys**
Structured questionnaires was administered to households in Panda Town to gather quantitative data on water sources used, perceptions of water quality, accessibility issues, and socio-demographic information.

ii. **Interviews**
In-depth interviews was conducted with key informants such as community leaders, local water management authorities, and representatives from NGOs or government agencies involved in water supply.

Secondary Data:

Government reports, academic publications, and NGO records provided secondary data on historical trends in water supply, infrastructure development, and previous interventions in Panda Town.

Sample Size Determination

The 2022 Projected Population for Karu LGA was estimated to be 333, 800 people (NPC & NBS, 2023). This number was entered into a Raosoft, an online sample size calculator which provided 384 as the appropriate sample size for this study under a significance level of 95% and a margin of error of 5%.

Selection of Study Locations

Study locations within Panda Town was selected using a stratified random sampling technique to ensure representation across different demographic groups and geographical areas. This approach helped capture variations in water availability and utilization patterns within the community. Water samples was collected from three (3) hand dug wells, and three (3) boreholes and the samples undergone water quality assessments.

Sampling Techniques

A stratified random sampling method was employed:

- **Stratification:** Panda Town was divided into strata based on factors such as residential density, proximity to water sources, and socio-economic status.
- **Random Sampling:** Within each stratum, households was randomly selected to participate in the survey, ensuring that the sample is representative of the entire community.

For this study, where the sample size is 384, the sample were allocated between the questionnaire survey (household-level respondents) and key informant interviews (KII) (stakeholders involved in water management and governance). A common approach is to prioritize the larger proportion for household surveys, while reserving a smaller portion for key informants.

Questionnaire Survey (Household Respondents)

326 respondents (85% of the total respondents) were allocated to households since they will provide insights on the daily water usage, access, challenges, and perceptions of water quality.

Key Informant Interviews (KII)

The remaining 58 respondents (15%) was allocated for key stakeholders (local government officials, water resource managers, community leaders, etc.) who can provide more specialized information on water governance, infrastructure, and policy challenges.

Stratification for Questionnaire Survey (Households)

The 326 household respondents was stratified based on residential density, proximity to water sources, and socio-economic status as follows:

a) High-density residential areas – 40% of 326 = 130 respondents;
b) Medium-density residential areas – 35% of 326 = 114 respondents;
c) Low-density residential areas – 25% of 326 = 82 respondents

Stratification for Key Informant Interviews (KII)

For the 58 key informants, the sample was stratified based on different stakeholder groups involved in water management and governance as follows:

i. Local government officials (e.g., water resource department) – 30% of 58 = 17 respondents;
ii. Community leaders – 25% of 58 = 15 respondents;
iii. Water resource managers (e.g., operators of water infrastructure) – 20% of 58 = 12 respondents;
iv. NGO representatives or water-related civil society groups – 15% of 58 = 9 respondents;
v. Health or environmental officers (who deal with water quality) – 10% of 58 = 5 respondents

This proportion ensures that you cover a comprehensive range of perspectives from both the community and stakeholders involved in water management.

Data Collection Procedure

a) **Surveys**

Surveys was administered face-to-face by trained enumerators who explained the purpose of the study and obtained informed consent from participants.

Questions covered topics such as sources of water used (e.g., boreholes, piped water), frequency and reliability of water supply, perceptions of water quality, and challenges faced in accessing water.

b) **Interviews:**

Key informant interviews was conducted with stakeholders involved in water management and governance in Panda Town.

Semi-structured interview guides was used to explore issues related to infrastructure, policy frameworks, community perceptions, and challenges in water resource management.

Data Analysis

Quantitative Data Analysis

Quantitative data collected from surveys and water quality tests was analysed using appropriate statistical methods to address the research objectives.

Descriptive Statistics:

Descriptive statistics was used to summarize and present the characteristics of the study population, water sources, and key variables related to water resource utilization in Panda Town. Measures such as frequencies, percentages, means, and standard deviations was calculated to describe the distribution and central tendencies of quantitative data. Statistical software such as SPSS (Statistical Package for the Social Sciences) or R was used for data entry, cleaning, and basic descriptive analysis.

Qualitative Data Analysis

Qualitative data from interviews and open-ended survey responses was analysed thematically to identify patterns, themes, and narratives related to water resource utilization and management in Panda Town.

Thematic Analysis

Thematic analysis aimed to identify and interpret patterns of meaning within qualitative data, allowing for a nuanced understanding of community perspectives and experiences. The following steps guided thematic analysis:

i. **Data Familiarization:** Reading and re-reading transcripts to become familiar with the data.
ii. **Coding:** Coding data segments into meaningful categories and themes.
iii. **Theme Development:** Identifying overarching themes that emerge from the coded data.
iv. **Data Interpretation:** Interpreting themes in relation to the research objectives and theoretical framework.

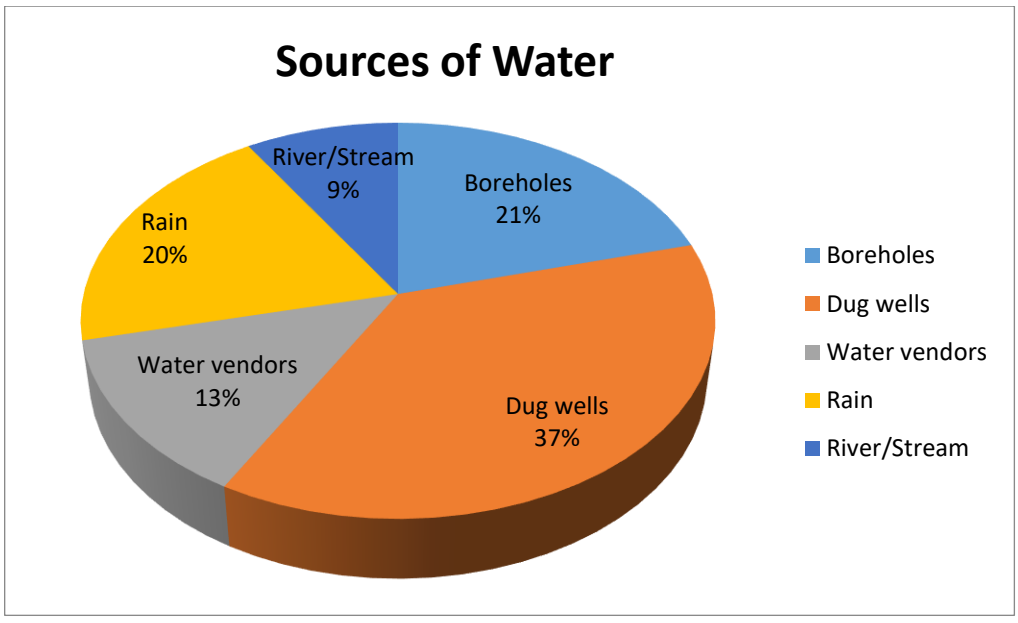
Qualitative analysis software such as NVivo or Atlas.ti was used to facilitate the coding and analysis process, though manual coding and analysis techniques were also employed as needed.

RESULTS AND DISCUSSION

The main sources of Water used by the residents in panda town

Responses from survey, interviews and observations by the author revealed that Panda Town does not have pipe-borne water and they rely solely on both surface (rivers and streams) and groundwater (dug wells and boreholes) resources for their domestic and agricultural water uses. As shown in table 4.1, about half (49.5%) of the respondents identified dug wells as the major source of water supply in Panda Town as well as the most accessible, available and reliable in terms of meeting up with the water need of the people compared to other sources. There are boreholes in the study area which people from far and near come to fetch water. This is similar to study Dada (2023), which revealed boreholes (69.1%) and wells (17.6%) as main water sources, with water scarcity leading to high rates of open defecation and poor sanitation. The distribution of boreholes and wells are not sufficient to meet up with water demand and accessibility of the people, as such the existence of push cart water vendors moving from place to place selling water from house to house, acting as supplementary source of domestic water suppliers. For agricultural uses, farmers majorly obtained water from river/stream for irrigational purpose.

Figure 4.1: Sources of Water



Water Availability from Various Sources

The availability of water is seasonal and there is high scarcity of water from various sources, especially during the dry season. As shown in table 4.1, while some of the respondents agreed to always (27.6%) have borehole water available regardless of the season, most of them don't always (60.0%) have borehole water. Again, while some said dug wells always (31.7%) have water available regardless of the season, most of dug wells don't always (60.9%) have water. Also, few of the river/stream always (11.1%) has little water available regardless of the season; while most (53.5%) don't usually have water during the dry season. As regards water vendors, few of the water vendors are always (14.5%) available regardless of the season, while some are sometimes (49.8%) available during the rainy season and most are not (49.8%) usually available during the rainy period. This is similar to a study by (Opaluwa *et al.,* 2022) which asserted that "due to seasonal variation in water access, water vending is usually seasonal with few water vendors often found during the rainy season. The demand for water during rainy season is generally low because most sources have enough water as well as rain water. While during dry season, water vending is high with many water vendors distributing water to their customers".

Table 4.1: Availability of Water from Various Sources

Sources	Availability/Frequency Always	Sometimes	Not	Percentage (%)		
Borehole	37	178	82	12.5	59.9	27.6
Dug wells	94	181	22	31.7	60.9	7.4
Rivers/Streams	33	105	159	11.1	35.4	53.5
Water vendors	43	106	148	14.5	35.7	49.8

Source: Field Survey (2024)

The adequacy and acceptability of existing Water sources in the study area

Responses from respondents indicated that most (39.4%) of the boreholes are located very far from them, while

some (32.3%) highlighted that the boreholes are far from their residents, but few (28.3%) said boreholes are located close to them see table 4.2. This means that most of the respondents spend considerable time and efforts accessing water for their daily use. This finding contrast a study by Bello *et al.* (2022), where most of the boreholes are located close to various households, hence accessibility to water is easy. Generally, dug wells are often constructed by individual household hence, most of the respondents said dug wells are close (56.6%) to them. In that regard, there is less effort accessing water from the dug wells. However, despite the closeness of the wells, some people from upland often trek a significant (29.0%) distance to obtain water from the wells of those downward, especially during dry period.

Table 4.2: Accessibility of Water to Various Households

Sources	Proximity/Frequency V. Far	Far	Close	Percentage (%)		
Borehole	117	96	84	39.4	32.3	28.3
Dug wells	43	86	168	14.5	29.0	56.6
Rivers/Streams	149	83	65	50.2	28.0	21.9

Source: Field Survey (2024)

Perceptions of the Residents towards the Quality of Water

The physiochemical characteristics of water often define its quality. Water quality data are important for water supply planning projects and aesthetics among others. The major parameters that define water quality are Total Hardness, Total Dissolved Solids (TDS), alkalinity, chloride, taste, odour, colour, microorganisms and other

toxic elements (Gevera *et al.,* 2022). But generally, colour, turbidity, hardness, taste and odour are the quality parameters mostly used by households to determine the quality of water sources (Tukura *et al.,* 2014).

Perceptions on Water Colour

As shown in table 4.3, most (64.7%) of the respondents agreed that the borehole source has very clean water, while 35.4% believed that some borehole has clean water. Again, most (58.9%) of the dug wells are perceived to have clean water, while few (19.9%) has very clean water. But despite the cleanliness, some (24.6%) of the respondents asserted that well water are perceived to be cloudy or brownish colour in some area. In addition, while most (56.6%) of the households agreed that the water supplied by vendors is clean and few (11.8%) said it is very clean, some (31.7%) perceived that the colour of water is questionable – as it is the case in other parts of the state. It was also found that most (56.9%) agreed that the river/stream has dirty water and some (29.0%) very dirty. But few (14.1%) said the river/stream also have clean water. Therefore, the concern colouration of water at various sources often affects people's perception on their choice of domestic water use.

Table 4.3: Household Responses on Water Colour

Sources	Quality/Frequency				Percentage (%)			
	v. clean	clean	dirty	v. dirty				
Boreholes	192	105	0	0	64.7	35.4	0	0
Dug wells	59	175	73	0	19.9	58.9	24.6	0
Rivers/Streams	0	42	169	86	0	14.1	56.9	29.0
Water vendors	35	168	94	0	11.8	56.6	31.7	0

Source: Field Work (2024)

Perceptions on Water Taste

Taste of water can be influenced by various factors, such as the source of the water, the presence of dissolved minerals and gases, contaminants and even treatment used in purification processes. Hence, water from various sources can have distinct tastes based on their mineral contents and treatment methods.

Regarding the taste of water from various sources, it was discovered that most (54.6%) of the respondents are satisfied with the taste of water from boreholes, saying it has a very good (36.4%) taste see table 4.4. But few (8.8%) are not satisfied saying that water from some boreholes has poor taste. Again, most (45.5%) responded that water from the dug wells has poor taste. While some perceived that well water has good (38.1%) taste. Also, respondents expressed satisfaction with water supplied by water vendors as most (48.5%) said the water taste (36.4%) very good. But few (15.8%) also expressed dissatisfaction with the taste of water, saying it has a poor taste. Water obtained from the rivers/streams is not usually used for drinking by the respondents as such there was no sufficient information on taste of water from rivers/streams

Table 4.4: Water Taste

Sources	Quality/Frequency			Percentage (%)		
	V. Good	Good	Poor			
Boreholes	108	162	26	36.4	54.6	8.8
Dug wells	49	113	135	16.5	38.1	45.5
Rivers/Streams	0	0	53	0	0	17.9
Water vendors	106	144	47	35.7	48.5	15.8

Source: Field Work (2024)

Perceptions on Water Turbidity and Hardness

Water turbidity and hardness are two critical parameters in assessing water quality, affecting both environmental health and human use. High water turbidity levels can indicate potential problems in water supply such as the presence of pathogens or pollutants. While hard water is not typically considered harmful, very hard water can impact the taste of water, beverages, pipes, soap and detergent efficiency.

Table 4.5 revealed that most of the households expressed satisfaction with borehole water saying it is soft (45.1%). But some perceived that it is hard (32.0%), while others perceived it to be hazy (22.9%). Again, it was found that most perceived the dug well water to be soft (54.9%). But some also perceived that it is hard (29.0%), while others felt it is cloudy/hazy (16.2%). Just like the wells and boreholes, water supplied by vendors is mostly soft (63.3%). But some perceived it as hard (31.3%) and hazy (5.4%). Again, most of the responses revealed that water from the rivers/streams is cloudy/hazy (41.1%) and hard (32.7%). While others said it is soft (26.3%). Generally, water bodies like rivers, streams, ponds, lakes etc., often have high water turbidity and hardness due to the presence of pathogens and pollutants (Magaji & Abimbola, 2020).

Perceptions on Water Odour

Water itself is generally odourless, but scent can arise from various sources. Some of the factors that contribute to odour in water includes: chlorine, sulphur, organic matter, microbial growth, iron rust and contaminants from industries. Table 4.6 revealed that most (93.9%) borehole water is perceived to have no odour. But some asserted that few (6.1%) of the boreholes have little odour. Similarly, most (86.2%) of the dug well water is perceived to have no odour, while some perceived that few (13.8%) of the dug wells have little odour. Again, most (72.1%) of the water supplied by water vendors have no odour. But some (19.55) asserted that the vended water sometimes have bad odour, while others said it has little (8.4%) odour. The odour from vended water can arise as a result of microbial growth and the long period of time water stayed in the gallons (Kjellen & Mcgranahan, 2020). As regards the rivers/streams, most (59.3%) perceived that the water has no odour. But some asserted that the water has bad odour (19.5%), while others perceived that the water has little odour (12.5%).

Table 4.6: Water Odour

Sources	Quality/Frequency			Percentage (%)		
	Little	Bad	No Odour			
Boreholes	18	0	279	6.1	0	93.9
Dug wells	41	0	256	13.8	0	86.2
Rivers/Streams	37	84	176	12.5	28.3	59.3
Water vendors	25	58	214	8.4	19.5	72.1

Source: Field Work (2024)

Challenges of the residents on water resources utilization in the study area

Despite having abundant water resources in Nigeria, Nassarawa State is facing a serious challenge in improving access to this water resource due to the rapid increase in demand driven by high population growth, urbanization and rise in standard of living. This demand surge is causing water shortages in both urban and rural areas with competing water uses, lower levels of irrigation potential, degrading watersheds and water courses, fragmented and uncoordinated water resources development, poor data and lack cooperation on co-riparian use of national water bodies (Ayiwulu & Edache, 2015).

In Panda Town, increasing water scarcity (32.3%) and widespread water borne diseases (23.9%) are the compounding problems of water resource utilization. Deteriorating water quality (22.2%), structural inequality (12.8%), high water cost (8.1%) and lack of proper implementation of water conservation practice are also increasing the challenge of water scarcity in the area see table 4.7. Interviews with key stakeholders revealed that inadequate management and coordination of the Nation's water resources has resulted in numerous threats to water sources in various areas of Panda Town. Water-related diseases such as malaria, cholera, diarrhea, schistosomiasis, and ring worm are also posing serious threats to public health. This scarcity has threatened Panda developments with rapid rise in prolonged droughts, floods and increased cost of water for irrigation. As

such, since water consumption and shortages keeps increasing without any decrease, it therefore means that both domestic and agricultural water efficiency is relatively low.

Table 4.7: Challenges of Water Resource Utilization

Challenges	Frequency	Percentage (%)
Increasing water cost	24	8.1
Increasing water scarcity	96	32.3
Increasing water borne disease	71	23.9
Structural inequality	38	12.8
Deteriorating water quality	66	22.2
Water Conservation Practice		
Yes	106	35.7
No	191	64.3

Source: Field Work (2024)

CONCLUSION AND RECOMENDATIONS

Conclusion

Rapidly, increasing economic and population growth in urban and rural areas has generated corresponding increase in demand for augmentation of water supplies. Irrigation, by far the largest water use, remains a mainstay of some local and state economies. This increasing demand for this finite resource continues to increase as populations grow and expand. Sound management depends on reliable information about the quantity and quality of water available and how this availability varies in time and from place to place. It is important to enhance the understanding of all elements of the water cycle and how human activities affect it, so that water resources can be protected and developed sustainably.

In conclusion, results from survey shows that both domestic and agricultural water efficiency in Panda Town is poor and this underline the urgent need to increase investments in sustaining and expanding access to water to various households and this should include partnership with government, NGOs, World Bank, WHO and UNICE, so as to provide a clear roadmap on where exactly there is need to put resources for maximum impact. Also, domestic and agricultural sustainable water use awareness and programs should be conducted on regular basis so as to educate the people on the various ways to save and store water, in order to ensure efficiency.

Recommendation

The observed potentials of water resources in Panda Town are worthy of effective improvement and management for ensuring the sustainable use and conservation of water resources. Despite the numerous challenges of water resource utilization from various sources, there are also ways of improving these sources that can make an appreciable difference on the well-being of the urban poor. As such, it was on these bases that the following recommendations were made;

i. Source Protection: protect water sources such as rivers, lakes and aquifers from pollution by implementing buffer zones, land use regulations monitoring programmes.
ii. Water Quality Monitoring: establish monitoring networks and protocols to assess water quality parameters regularly and identify potential sources of pollution.
iii. Water Allocation Policies: develop water allocation policies and mechanisms to ensure equitable distribution of water resources among competing users and sectors.
iv. Climate Change Adaptation: incorporate climate change considerations into water management planning and infrastructure design to build resilience against drought, floods, and other extreme weather events.
v. Stakeholder Consultation: engage stakeholders including local communities, NGOs, businesses and government agencies in the decision-making process for water management.

vi. Capacity Building: provide training and education programs to empower communities with the knowledge and skills needed to participate effectively in water governance and management.
vii. Further study can be conducted on "Water Resource Utilization Based on Climatic Conditions", so to further improve the knowledge gap in relation to water challenges experienced in Panda Town.

FINDINGS

- High Groundwater Dependence: Residents rely almost entirely on private boreholes, hand-dug wells, and local streams due to a complete lack of functional municipal public water infrastructure.
- Severe Dry Season Scarcity: Groundwater tables drop sharply between November and April, causing shallow wells to dry up and forcing high economic reliance on informal water vendors ("Mai Ruwa").
- High Microbial Contamination: Water testing consistently reveals unsafe levels of coliform bacteria in open wells and streams, driven by proximity to pit latrines and poor waste disposal.
- Agricultural Water Stress: Small-scale farmers face critical water shortages for dry-season irrigation and livestock watering, limiting local food production and income.
- Failed Infrastructure Projects: Many public solar-powered boreholes and hand pumps are abandoned or non-functional due to a lack of community ownership and maintenance funding.

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REFERENCES

1. Abanyie, S.K., Ampadu, B., Frimpong, N.A. & Amuah, E. E. Y. (2023): Impact of improved water supply on livelihood and health: Emphasis on Doba and Nayagnia, Ghana. Innovation and Green Development 2 (2023) 100033
2. Acinwu, E. R., & Abenu, A. (2022): Water Demand Management in the Federal Capital Territory, Abuja-Nigeria: A Survey of Public Attitudes towards Water Conservation.
3. Acinwu, E. R., Abenu, A., & Kevin, O. K. (2023). Practices and Barriers of Water Use Efficiency in the Federal Capital Territory, Abuja, Nigeria. Journal of Applied Sciences and Environmental Management, 27(5), 959-964.
4. Adams, E. A., & Boateng, G. O. (2018). Are rural communities ready for community-led total sanitation? Experiences from Ghana's CLTS program. GeoJournal, 83(4), 715-728.
5. Adamu, G. K., Adamu, H., & Mohammed, A. (2015). Groundwater quality assessment using multivariate statistical techniques in Karu, Nasarawa State, Nigeria. Journal of Geosciences and Geomatics, 3(3), 73-85.
6. ADI. (2023): Community Engagement in Water management: Empowering Individuals for Collective Impacts. Integrated Water Resource Management. Retrieved on the 25th June, 2024 from https://www.adi-international.org/community-engagement-in-water-management-empowering-individuals-for-collective-impact/#

7. Afolabi, A.S. (2021): Investigating Source Identification and Quality of Drinking Water in Piwoyi Community of Federal Capital Territory, Abuja. Research Square, https://doi.org/10.21203/rs.3.rs-736140/v1
8. Akah, L., Alawa, D., Apie, M., Ogabor, J. & Ekuri, P. (2021). Analysis of the accessibility of Portable Water among Urban and Rural Poor. Turkish Online Journal of Qualitative Inquiry. 12520-12529.
9. Akamani, K. (2016), Adaptive Water Governance: Integrating the Human Dimensions into Water Resource Governance. Journal of Contemporary Water Research & Education, 158: 2-18. https://doi.org/10.1111/j.1936-704X.2016.03215.x
10. Akawu, F. A., Maiwada, J. I., & Abdulsalami, O. (2020). Analysis of the determinants of demand for portable water and sanitation in Nasarawa State, Nigeria. International Journal of Innovative Research and Advanced Studies, 7(12), 27-36.
11. Akpabio, E. M. (2007). Assessing integrated water resources management in Nigeria: Insights and lessons from irrigation projects in the Cross River Basin. Water Policy, 9(2), 149–168.
12. Akpabio, E. M. (2008). Integrated water resources management in the Cross River basin, Nigeria: How can we reconcile institutional boundaries and interests? International Journal of River Basin Management, 6(3), 267–276.
13. Akpabio, E. M., Watson, N. M., Ite, U. E., & Ukpong, I. E. (2007). Integrated water resources management in the Cross River basin, Nigeria. International Journal of Water Resources Development, 23(4), 691–708.
14. Ananga, E.O., Naiga, R., & Agong', S.G. (2021): Examining the contribution of community participation in water resource production and management: perspectives from developing countries. SN SocSci 1, 37 (2021). https://doi.org/10.1007/s43545-020-00050-0
15. Aqua Techtrade. (2023): Sustainable Water: Our Essential Guide To Sustainable Water Resource Management Solutions & Strategies. Retrieved on the 25th June, 2024 from https://www.aquatechtrade.com/news/water-treatment/sustainable-water-essential-guide
16. Aremu, M.O., Opaluwa, O.D., Nghargbu, K. & Yahuza, A.H. (2012): Analysis of Ground–Water and Stream for Physico–Chemical Parameters in Doma Local Government of Nasarawa Stare, Nigeria.
17. Arimoro, A. O., & Musa, J. J. (2020). Community engagement in water resources management: Empowering individuals for collective impact. ADI International. https://www.adi-international.org/community-engagement-in-water-management-empowering-individuals-for-collective-impact/
18. Armah, F.A., Ekumah, B., Yawson, D.O., Odoi, J.O., Afitiri, A. & Nyieku, F.E. (2018): Access to improved water and sanitation in sub-Saharan Africa in a quarter century. Heliyon 4 (2018) e00931. doi: 10.1016/j.heliyon.2018.e00931
19. Ayiwulu, E., & Edache, M. (2015). Household's perception on the quality of domestic water in NassarawaEggon LGA of Nasarawa State, Nigeria. International Journal of Research in Social Sciences, 5(1), 35-50.
20. Bandaragoda, D. J., & Babel, M. S. (2010). Institutional development for IWRM: An international perspective. International Journal of River Basin Management, 8(3), 215-224.
21. Behnke, N. L., Klug, T., Cronk, R., Shields, K. F., Lee, K., Kelly, E. R. & Bartram, J. (2017). Resource mobilization for community-managed rural water systems: Evidence from Ghana and Peru. Journal of Cleaner Production, 156, 437-444.
22. Bello, I. E., Ortese, A. S., & Mohammed, S. (2024): Utilization Analysis of Water Demand and Supply in Akwanga Local Government Area of Nasarawa State, Nigeria.
23. Benameur, T., Benameur, N. & Saidi, N. (2022): Predicting factors of public awareness and perception about the quality, safety of drinking water, and pollution incidents. Environ Monit Assess 194, 22 (2022). https://doi.org/10.1007/s10661-021-09557-2
24. Berkes, F. (2002). Cross-scale institutional linkages: perspectives from the bottom up. Pages 293-321 in E.T. Ostrom, T. Dietz, N. Dolsak, P.C. Stern, S. Stonich, and E. U. Weber, editors. The Drama of the Commons. National Academy Press, Washington, DC.
25. Biswas, A. K. (2004). Integrated water resources management: A reassessment. Water International, 29(2), 248-256.
26. Boelee, E., Geerling, G., van der Zaan, B., Blauw, A., & Vethaak, A. D. (2019). Water and health: From environmental pressures to integrated responses. Actatropica, 193, 217-226.

27. Boretti, A., & Rosa, L. (2019). Reassessing the projections of the world water development report. NPJ Clean Water, 2(1), 15.
28. Buonomo, V. (2017). Water and Human Rights: Considerations and Challenges under International Law. Water and Human Rights, 13.
29. Cassava, S., Dube, T., & Bangira, C. (2015). Stakeholder participation in water resources management: The case of Mzingwane Catchment, Zimbabwe. Physics and Chemistry of the Earth, Parts A/B/C, 79, 112-119.
30. Cheesman, J., Benneth, J & Son, T.V.H. (2008). Estimating household demand using revealed and contingent behaviour. Evidence from Viet Nam. Water Resource Research. 44, 11-42.
31. Chifamba, E. (2013). Stakeholder participation and management of water resources in Masvingo, Zimbabwe. Journal of Sustainable Development in Africa, 15(1), 1-16.
32. Cosgrove, W. J., & D. P. Loucks (2015), Water management: Current and future challenges and research directions, Water Resour. Res., 51, 4823–4839, doi:10.1002/2014WR016869.
33. Crosby, L., Jayasinghe, D., & McNicholl, D. (2020). Community engagement for programme design: A case study from Sierra Leone. Waterlines, 39(2-3), 116-132.
34. Dada, A. A. (2023). An Evaluation of Domestic Water Quality, Consumption Management and Its Environmental Implications in Mararaba, Nasarawa State, Nigeria (Doctoral dissertation, University of Abuja (Nigeria)).
35. DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. American Sociological Review, 48(2), 147-160.
36. Emenike, C. P., Tenebe, I. T., Omole, D. O., Ngene, B. U., Oniemayin, B. I., Maxwell, O., & Onoka, B. I. (2017). Accessing safe drinking water in sub-Saharan Africa: Issues and challenges in South–West Nigeria. Sustainable Cities and Society, 30, 263–272.
37. Enyidi, U. (2017). Potable water and national water policy in Nigeria (A historical synthesis, pitfalls and the way forward). Journal of Agricultural Extension and Rural Development, 3, 105–111.
38. Ewuzie, U., Aku, N. O., & Nwankpa, S. U. (2021). An appraisal of data collection, analysis, and reporting adopted for water quality assessment: A case of Nigeria water quality research. Heliyon, 7(9), e07950. https://doi.org/10.1016/j.heliyon.2021.e07950
39. Ezekiel, A., & Dominic, A. (2015). Sources, demand and problems of domestic water in NassarawaEggon Town, Nigeria. Pollution, 1(1), 55-65.
40. Fadairo, Olushola, Adelakun, Olufolake, Adetunji, & Aderonke. (2020). Promoting Community-led Water, Sanitation and Hygiene Interventions in Rural Settlements in Oyo State, Nigeria: Lessons from Agele and Mogba Communities of Ibarapa-East Local Government Area.
41. Federal Ministry of Water Resources. (2004). National Water Policy. Federal Republic of Nigeria.
42. Feng, J., Gu, C., Li, S., Wang, L., Gui, F., Zhao, S., & Zhang, B. (2024): Assessment of Water Resource Utilization and Analysis of Driving Factors in Zhoushan City Based on Water Footprint Theory and LMDI Model. Water 2024, 16, 385. https://doi.org/10.3390/w16030385
43. Fentie, M.; Assefa, E.; Aklog, D.; Tadesse, A. & Janka, E. (2024): Assessment of Drinking Water Quality in Northern Ethiopia Rural Area: A Case Study of Farta District, South Gondar Zone. Water 2024, 16, 1651. https://doi.org/10.3390/w16121651
44. Fischer, A., Hope, R., Manandhar, A., Hoque, S., Foster, T., Hakim, A. & Bradley, D. (2020). Risky responsibilities for rural drinking water institutions: The case of unregulated self-supply in Bangladesh. Global Environmental Change, 65, 102152.
45. Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. Annual Review of Environment and Resources, Vol. 30, 441-473. https://doi.org/10.1146/annurev.energy.30.050504.144511
46. Gain, A. K., Giupponi, C., & Wada, Y. (2016). Measuring global water security towards sustainable development goals. Environmental Research Letters, 11(12), 124015.
47. Gevera, P. K., Dowling, K., Gikuma-Njuru, P., & Mouri, H. (2022). Public knowledge and perception of drinking water quality and its health implications: an example from the Makueni County, South-Eastern Kenya. International Journal of Environmental Research and Public Health, 19(8), 4530.
48. Global Water Partnership Technical Advisory Committee. (2000). Integrated Water Resources Management. TAC Background Paper No. 4. Global Water Partnership.

49. Google Maps. (2023). Panda Town, Nasarawa State, Nigeria. Retrieved from https://www.google.com/maps/place/Panda+961106,+Nasarawa/@9.2638378,7.7941609
50. Gu, Q., Chen, Y., Pody, R., Cheng, R., Zheng, X., & Zhang, Z. (2015). Public perception and acceptability toward reclaimed water in Tianjin. Resources, Conservation and Recycling, 104, 291-299.
51. Gurría, A., & Secretary-General, O. E. C. D. (2017). Putting water at the centre of the global agenda. Lecture at the Centre for Foreign relations, New York City, 24.
52. Gyang, P. R., Uzoigwe, N. R., Ayim, J. O., Ombugadu, A., & Ahmed, H. O. (2017). Evaluation of local drinking water sources to determine their possible contamination with parasite in Lafia Local Government Area Nasarawa State, Nigeria. European Journal of Basic and Applied Sciences Vol, 4(1).
53. Haider, L. J., Boonstra, W. J., Akobirshoev, G., & Schlüter, M. (2015). Tracing the water-energy-food nexus: The potential of an ethical approach. Current Opinion in Environmental Sustainability, 16, 49-56.
54. Hassenforder, E., Smajgl, A., & Ward, J. (2020). The water governance challenge. Environmental Science & Policy, 107, 23-35.
55. Herrera, V. (2019). Reconciling global aspirations and local realities: Challenges facing the Sustainable Development Goals for water and sanitation. World Development, 118, 106-117.
56. Holling, C. S. (1978). Adaptive environmental assessment and management. John Wiley & Sons.
57. Hopewell, M. R., & Graham, J. P. (2014). Trends in access to water supply and sanitation in 31 major sub-Saharan African cities: an analysis of DHS data from 2000 to 2012. BMC Public Health, 14, 1-12.
58. Hovden, A. K. S., Tantoh, H. B., & Sieber, S. (2020). Exploring the role of traditional ecological knowledge in water resource management in Northwest Cameroon. Sustainability, 12(7), 2907.
59. Hurlimann, A., & Dolnicar, S. (2018). Public acceptance and perceptions of alternative water sources: a comparative study in nine locations. In Water Reuse Policies for Potable Use (pp. 151-174). Routledge.
60. Hyun, C., Ostergren, D. M., Leclerc, A., Macdonald, G. K., & Vardhan, M. (2019). Community-led total sanitation: A mixed-methods study from rural Mali. Journal of Water, Sanitation and Hygiene for Development, 9(2), 349-360.
61. Iduseri, E. O., Abbas, I.I., Izunobi, J.U., Ogedegbe, S.O. & Ogbonna, D.O. (2020): Access to Safe Drinking Water in Developing Countries: A Comparative Analysis of the Urban and Rural Areas of Zaria, Kaduna State, Nigeria. J. Appl. Sci. Environ. Manage. Vol. 25 (11) 1869-1878 November 2021, Electronic ISSN 1119-8362. DOI: https://dx.doi.org/10.4314/jasem.v25i11.4
62. Ihuma, J. O., Adogo, L. Y., Malgwi, D. T., Maikenti, J. I., & Koggie, A. Z. (2016). Bacteriological analysis of surface water obtained from Uke River in Karu, Nasarawa State, Nigeria.
63. Jessoe, K. (2013). Water pollution and health outcomes. Journal of Environmental Economics and Management, 66(2), 424-442.
64. Jones, J.A.A. (2014): Water Sustainability: A Global Perspective, 1st Edition, Routledge, 2014, ISBN 1444128655, 9781444128659.
65. Jones, S. (2013). How can INGOs help promote sustainable rural water services? An analysis of WaterAid's approach to supporting local governments in Mali. Water Alternatives, 6(3).
66. Kana, A.A. (2022). Heavy metal assessment of groundwater quality in part of Karu, Central Nigeria. Water Practice & Technology Vol 17 No 9, 1802 doi: 10.2166/wpt.2022.102.
67. Karu LGA. (2022). Karu Local Government Area: Economic Activities. Retrieved from https://www.karulga.gov.ng/economic-activities
68. Kema, K. M., Semali, I., Mkuwa, S., Kiwara, A. D., Kilima, S., Mshana, C., & Shayo, E. H. (2012). Factors affecting the utilization of improved ventilated latrines among communities in Mtwara rural district, Tanzania. BMC Public Health, 12(1), 1-8.
69. Kishor, R., Purchase, D., Saratale, G. D., Saratale, R. G., Ferreira, L. F. R., Bilal, M. & Bharagava, R. N. (2021). Ecotoxicological and health concerns of persistent colouring pollutants of textile industry wastewater and treatment approaches for environmental safety. Journal of Environmental Chemical Engineering, 9(2), 105012.
70. Kjellén M., & McGranahan, G., (2006). Informal water vendors and the urban poor, IIED, Human Settlements Discussion Paper Series, Theme: water -3, 26.
71. Kulkarni, S. (2011). Drinking water, sanitation and handwashing practices: Recent trends in selected states of India. International Journal of Environmental Research and Public Health, 8(8), 3316-3330.

72. Lautze, J., de Silva, S., Giordano, M. & Sanford, L. (2011): Putting the cart before the horse: Water governance and IWRM. Natural Resources Forum, 35: 1-8. https://doi.org/10.1111/j.1477-8947.2010.01339.x
73. Locke, K.A. (2024): Impacts of land use/land cover on water quality: A contemporary review for researchers and policymakers. Water Quality Research Journal 1 May 2024; 59 (2): 89–106. doi: https://doi.org/10.2166/wqrj.2024.002
74. Long, M. (2020): Explore the role of sustainable utilization of water, IOP Conf. Ser.: Earth Environ. Sci. 560 012057.
75. Magaji, J. Y., & Abimbola, T. A. (2020). Comparative analysis of water quality from different sources in Masaka, Nasarawa State, Nigeria. Australian Journal of Science and Technology, 4(3), 303-311.
76. Makarigakis, A. K., & Jimenez-Cisneros, B. E. (2019). UNESCO's contribution to face global water challenges. Water, 11(2), 388.
77. Massarelli, C. (2024): Water Quality - Recent Technologies and Methodologies for Water Resources Monitoring, National Research Council, Italy. ISBN: 978-0-85466-973-8, ISSN: 2754-6713 Part of the Book Series "Environmental Sciences".
78. Mehrazar, A., MassahBavani, A. R., Gohari, A., Mashal, M., & Rahimikhoob, H. (2020). Adaptation of water resources system to water scarcity and climate change in the suburb area of megacities. Water Resources Management, 34, 3855-3877.
79. Merrey, D. J. (2008). Is normative integrated water resources management implementable? Charting a practical course with lessons from Southern Africa. Physics and Chemistry of the Earth, Parts A/B/C, 33(8-13), 899-905.
80. Meyer, J. W., & Rowan, B. (1977). Institutionalized organizations: Formal structure as myth and ceremony. American Journal of Sociology, 83(2), 340-360.
81. Mitchell, B. (1990). Integrated Water Management: International Experiences and Perspectives. Belhaven Press.
82. Molden, D. (2013). Water for food water for life: A comprehensive assessment of water management in agriculture. Routledge.
83. Muller, M., Schreiner, B., Smith, L., Van Koppen, B., Sally, H., Aliber, M., Cousins, B., Tapela, B., Merwe-Botha, M. Van Der, & Karar, E. (2009). Water security in South Africa. 12, Midrand, South Africa.
84. Nasarawa State Government. (2021). Nasarawa State at a Glance. Retrieved from https://www.nasarawastate.gov.ng/about-nasarawa/
85. Nasarawa State Ministry of Agriculture. (2019). Nasarawa State Agricultural Development Programme. Retrieved from https://www.nasarawaagric.gov.ng/
86. Nasarawa State Ministry of Environment. (2020). Nasarawa State Environmental Action Plan. Retrieved from https://www.nasarawaenvironment.gov.ng/
87. Nasarawa State Ministry of Livestock and Fisheries. (2021). Nasarawa State Livestock Development Programme. Retrieved from https://www.nasarawalivestockfisheries.gov.ng/
88. Nasarawa State Water and Sewerage Corporation. (2021). Water Supply and Sanitation in Nasarawa State. Retrieved from https://www.nasarawawater.gov.ng/
89. Nastar, M., Boda, C. S., & Olsson, L. (2018). The social dynamics of degradation of local ecosystem services: A case of beach sand mining in South Africa. Ecological Economics, 143, 166-177.
90. National Bureau of Statistics. (2020). Nigeria Living Standards Survey 2018-2019. Retrieved from https://www.nigerianstat.gov.ng/nada/index.php/catalog/64
91. National Population Commission. (2019). Nigeria Demographic and Health Survey 2018. Retrieved from https://dhsprogram.com/pubs/pdf/FR359/FR359.pdf
92. Ngene, B.U., Christiana O. Nwafor, C.O., Gideon O. Bamigboye, G.O., Adebanji S. Ogbiye, A.S., Jacob O. Ogundare, J.O. & Victor E. Akpan, V.E. (2021). Assessment of water resources development and exploitation in Nigeria: A review of integrated water resources management approach. Heliyon 7 (2021) e05955.
93. Nigerian Meteorological Agency. (2022). Climate Data for Nasarawa State. Retrieved from https://www.nimet.gov.ng/climate-data

94. O'Donovan, J., Berrang-Ford, L., Alison, L., Gouweleeuw, L., Lwasa, S., Namanya, D. B., ...& Harper, S. L. (2020). Spatial and temporal changes in freshwater provision in the Rwenzori Mountains, Uganda. Climatic Change, 163(1), 1-21.
95. OECD. (2015). OECD Principles on Water Governance. OECD.
96. Ohwo, O. (2016): Challenges of public water provision in Nigerian cities: a review. Journal of Water, Sanitation and Hygiene for Development 1 March 2016; 6 (1): 1–12. doi: https://doi.org/10.2166/washdev.2016.071
97. Ojo, V. O. (2011). Customer satisfaction: A framework for assessing the service quality of urban water service providers in Abuja, Nigeria (Doctoral dissertation, © Ojo, VO).
98. Okereke, P. A., Udeagu, E. I., & Eze, E. U. (2000). Water Supply Management in Nigeria (Examples in Some States). M. Cajec Publications, Owerri.
99. Okyere, C. Y., Pangaribowo, E. H., & Asante, F. A. (2017). Adoption of water purification methods among urban households in Ghana. Environment, Development and Sustainability, 19(6), 2323-2344.
100. Onyango, L., Awiti, A., Calvert, G., & Wakhungu, J. (2018). Rainwater harvesting technology adoption and uptake determinants in semi-arid Tharaka North, Kenya. African Journal of Environmental Science and Technology, 12(4), 123-135.
101. Opaluwa, O. D., Muhammad, A. I., Madaki, K. S., Usman, A., & Mohammad, I. A. (2022). Water Quality Assessment of River Adema, Nasarawa, Nasarawa State, Nigeria. Journal of Applied Sciences and Environmental Management, 26(8), 1433-1442.
102. Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. Science, 325(5939), 419-422.
103. Oyebode O.J. & Coker, A.O. (2021): Management of Infrastructure in Water Sector: A veritable Tool for Healthcare and Sustainable Development in Nigeria, IOP. Conf. Ser. Sci. Eng. 1038, 012008.
104. Pahl-Wostl, C. (2007). Transitions towards adaptive management of water facing climate and global change. Water Resources Management, 21(1), 49-62.
105. Pahl-Wostl, C. (2015). Water governance in the face of global change: From understanding to transformation. Springer.
106. Pahl-Wostl, C., Craps, M., Dewulf, A., Mostert, E., Tabara, D., & Taillieu, T. (2007). Social learning and water resources management. Ecology and Society, 12(2).
107. Pahl-Wostl, C., Lebel, L., Knieper, C. & Nikitina, E. (2012): From applying panaceas to mastering complexity: Toward adaptive water governance in river basins, Environmental Science & Policy, Volume 23, 2012, Pages 24-34, ISSN 1462-9011, https://doi.org/10.1016/j.envsci.2012.07.014. (https://www.sciencedirect.com/science/article/pii/S1462901112001104)
108. Pahl-Wostl, Claudia. (2009). A Conceptual Framework for Analysing Adaptive Capacity and Multi-Level Learning Processes in Resource Governance Regimes. Global Environmental Change. 19. 354-365. 10.1016/j.gloenvcha.2009.06.001.
109. Pereira, M. A., & Marques, R. C. (2021). Sustainable water and sanitation for all: are we there yet? Water Research, 207, 117765.
110. Popoola, A., Magidimisha-Chipingu, H., Chipungu, L., Adeleye, B., Akogun, O., & Medayese, S. (2021, February). Household water stress, adaptation and resilience in some selected peri-urban and rural communities of Oyo State, Nigeria. In IOP Conference Series: Earth and Environmental Science (Vol. 654, No. 1, p. 012006). IOP Publishing.
111. Rahaman, M. M., & Varis, O. (2005). Integrated water resources management: Evolution, prospects and future challenges. Sustainability: Science, Practice and Policy, 1(1), 15-21.
112. Rakotomanana, H., Komakech, J. J., Walters, C. N., & Stoecker, B. J. (2020). The WHO and UNICEF Joint Monitoring Programme (JMP) indicators for water supply, sanitation and hygiene and their association with linear growth in children 6 to 23 months in East Africa. International Journal of Environmental Research and Public Health, 17(17), 6262.
113. Robbins, P. (2012). Political ecology: A critical introduction (Vol. 16). John Wiley & Sons.
114. Rogers, E. M. (2003). Diffusion of innovations (5th ed.). Free Press.
115. Saleth, R. & Dinar, A. (2004): The Institutional Economics of Water: A Cross-country Analysis of Institutions and Performance. 10.4337/9781845421496.00001.
116. Samadi-Foroushani, M., Keyhanpour, M.J., & Musavi-Jahromi, S.H. (2022): Integrated Water Resources Management Based on Water Governance and Water-food-energy Nexus through System Dynamics and

Social Network Analyzing Approaches. Water Resour Manage 36, 6093–6113 (2022). https://doi.org/10.1007/s11269-022-03343-6

117. Samaila, B., Baba, E., & Aliyu, I. U. (2023). Assessment of Water Quality in Mararaba, Lafia, Nasarawa State, Nigeria. Tropical Journal of Environment & Earth Science (Tjees), 20.
118. Saraswat, C., & Gupta, A.K. (2024). Water Governance Transitions Pathway: Adaptive Water Governance. In: Gupta, A.K., Gupta, A., Acharya, P. (eds) Disaster Risk and Management Under Climate Change. Disaster Resilience and Green Growth. Springer, Singapore. https://doi.org/10.1007/978-981-99-4105-6_16
119. Schlosberg, D. (2013). Theorising environmental justice: The expanding sphere of a discourse. Environmental Politics, 22(1), 37-55.
120. Scott, W. R. (2013). Institutions and organizations: Ideas, interests, and identities. Sage Publications.
121. Silvestri, G., Wittmayer, J. M., Schipper, K., Kulabako, R., Oduro-Kwarteng, S., Nyenje, P. M., & van Raak, R. (2018). Transition management for improving the sustainability of WASH services in informal settlements in sub-Saharan Africa–an exploration. Sustainability, 10(11), 4052.
122. Solihu, H. & Bilewu, S. O. (2020): Availability, coverage, and access to the potable water supply in Oyo State Nigeria. Environmental Challenges 5 (2021) 100335.
123. Solomon, S. (2011). Water: The Epic Struggle for Wealth, Power, and Civilization. HarperCollins, New York.
124. Sridhar, M. K. C., Okareh, O. T., & Mustapha, M. (2020). Assessment of knowledge, attitudes, and practices on water, sanitation, and hygiene in some selected LGAs in Kaduna State, Northwestern Nigeria. Journal of Environmental and Public Health, 2020(1), 6532512.
125. Suleiman, A. O., Sangari, D. U., & Ogah, A. T. (2021). Effect of distances between soakaway and borehole on groundwater quality in Mararaba, Karu LGA, Nasarawa State, Nigeria. Journal of African Sustainable Development, 23(2), 73-84.
126. Sultana, F. (2013). Water, technology, and development: Transformations of development technonatures in changing waterscapes. Environment and Planning D: Society and Space, 31(2), 337-353.
127. Sultana, F., & Loftus, A. (2012). The right to water: Prospects and possibilities. Routledge.
128. Sunkari, E.D., Kore, B.M., & Abioui, M. (2021): Hydrogeophysical appraisal of groundwater potential in the fractured basement aquifer of the federal capital territory, Abuja, Nigeria. Results in Geophysical Sciences 5 (2021) 100012.
129. Tantoh, H. B., Sieber, S., Barkmann, J., & Nkongho, R. N. (2021). Community participation in rural water supply: Evidence from Northwest Cameroon. Water, 13(4), 532.
130. Thoradeniya, B., & Maheshwari, B. (2019). Stakeholder participation in water governance: A case study from Sri Lanka. Water Policy, 21(1), 1-18.
131. Triplett, R., Chatterjee, C., Johnson, C. K., & Ahmed, P. (2019). Perceptions of quality and household water usage: A representative study in Jacksonville, FL. International Advances in Economic Research, 25, 195-208.
132. Tsekleves, E., Braga, M.F., Abonge, C., Santana, M., Pickup, R., Anchang, K.Y., de Pippo, T., Semple, K. & Roy, M. (2022): Community engagement in water, sanitation and hygiene in sub-Saharan Africa: does it WASH? Journal of Water, Sanitation and Hygiene for Development 1 February 2022; 12 (2): 143–156. doi: https://doi.org/10.2166/washdev.2022.136
133. Tukura, B. W., Ayinya, M. I., Ibrahim, I. G., & Onche, E. U. (2014). Assessment of heavy metals in ground water from Nasarawa State, Middle Belt, Nigeria. American Chemical Science Journal, 4(6), 798-812.
134. Tumbare, M. J. (2015). Infrastructure for Water Resource Management in Southern Africa. Journal of Infrastructure Development, 7(2), 116-135. https://doi.org/10.1177/0974930615611574
135. UN Environment. (2018). Progress on Integrated Water Resources Management. Global Baseline for SDG 6 Indicator 6.5.1: Degree of IWRM Implementation.
136. UNICEF, WHO (2021): The measurement and monitoring of water supply, sanitation and hygiene (WASH) affordability: A missing element of monitoring of Sustainable Development Goal (SDG) targets 6.1 and 6.2. New York, United Nations Children's Fund and World Health Organization. https://washdata.org/sites/default/files/2021-05/unicef-who-2021-affordability-of-wash-services-full.pdf

137. United Nations Children's Fund (UNICEF). (2012). Progress on drinking water and sanitation: 2012 update. New York: UNICEF.
138. USAID. (2021): Water Resource Management: Technical Brief II. USAID Water and Development Technical Series. Retrieved on the 25th June, 2024 from https://www.globalwaters.org/sites/default/files/usaid_water_wrm_tb_11_508_3.pdf
139. Velleman, Y., Blair, L., Fleming, F., & Fenwick, A. (2023). Water-, Sanitation-, and Hygiene-Related Diseases. In Infectious Diseases (pp. 189-219). New York, NY: Springer US.
140. Walters, C. J. (1986). Adaptive management of renewable resources. Macmillan Publishers Ltd.
141. WaterAid (2018): The Water Gap Report: State of the World's Water. Retrieved on the 22nd June, 2024 from https://www.wateraid.org/in/publications/the-water-gap-the-state-of-the-worlds-water-2018
142. Whaley, L., & E. K. Weatherhead. (2014). An integrated approach to analyzing (adaptive) comanagement using the "politicized" IAD framework. Ecology and Society 19(1): 10. http://dx.doi.org/10.5751/ES-06177-190110
143. WHO (1997): Guidelines for drinking-water quality, 2nd ed. Vol. 3. Surveillance and control of community supplies. Geneva, World Health Organization. https://www.who.int/publications/i/item/9241545038
144. WHO, UNICEF (2017): Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines. Geneva, World Health Organization and United Nations Children's Fund. https://www.who.int/publications/i/item/9789241512893
145. Winpenny, J. (1994). Managing Water as an Economic Resource. Routledge, London.
146. World Bank. (2024): Water Overview: Development News, Research Data. Retrieved on the 25th June, 2024 from https://www.worldbank.org/en/topic/water/overview
147. World Health Organization. (2014). UN-Water global analysis and assessment of sanitation and drinking-water (GLAAS) 2014 report: investing in water and sanitation: increasing access, reducing inequalities.
148. World Health Organization. (2015). Water, sanitation and hygiene in health care facilities: status in low and middle income countries and way forward. World Health Organization.
149. World Health Organization. (2017). UN-Water global analysis and assessment of sanitation and drinking-water (GLAAS) 2017 report: financing universal water, sanitation and hygiene under the sustainable development goals.
150. World Health Organization. (2023). Burden of disease attributable to unsafe drinking-water, sanitation and hygiene, 2019 update. World Health Organization.
151. Wulan, D., Sintawardani, N., Marganingrum, D., Triyono, T., Barid, V., Santoso, H. & Yulianto, E. (2023). Water sources, consumption, and water-related sanitation on Pari Island, Indonesia: a mixed-focus group discussion and survey study. AQUA - Water Infrastructure Ecosystems and Society. 72. 10.2166/aqua.2023.137.
152. Zainudeen, M. (2007). Infrastructure for Sustainable Development and Management of Water Resources. Engineer: Journal of the Institution of Engineers, Sri Lanka. 40. 41. 10.4038/engineer.v40i2.7138.
153. Zhang, H.X. (2023). Introduction to Water Sustainability. In: Zhang, H.X. (eds) Water Sustainability. Encyclopedia of Sustainability Science and Technology Series. Springer, New York, NY. https://doi.org/10.1007/978-1-0716-2466-1_1100
154. Zhang, X., & Lin, Z. (2022). Evaluation of Water Resource Utilization Efficiency in Provincial Areas of China Based on the Unexpected Output SBM Model. Journal of Environmental and Public Health, 2022, 9554730. https://doi.org/10.1155/2022/9554730 (Retraction published J Environ Public Health. 2023 Dec 6;2023:9760810. doi: 10.1155/2023/9760810)
155. Zhu, Q., & Cao, Y. (2024): Research on provincial water resources carrying capacity and coordinated development in China based on combined weighting TOPSIS model. Sci Rep 14, 12497 (2024). https://doi.org/10.1038/s41598-024-63119-3