

Research Article

Indigenous Knowledge Systems and Water Management Practices in Rural Communities of Central Nigeria: Perceptions of Sustainability by Beneficiaries

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Abstract

This research paper explores the significance of Indigenous Knowledge Systems (IKS) in water resources management, specifically within two communities in Central Nigeria: Awe and Ginda B. The two communities were selected due to the unique conditions they present; Awe is popular for salt production from saline groundwater while Ginda B is a community situated on a hill that relies on water from natural springs. It highlights the unique traditional practices developed over centuries that sustain water availability and quality, emphasizing the relationship between indigenous peoples and their environments. The study was conducted through interviews, discussions, and observations in the two communities. The study outlines various indigenous techniques, such as traditional water harvesting (rainwater and the *tafki* system); exploitation of natural springs and hand-dug wells for salt production, domestic and agricultural water needs. The paper also examines the challenges these communities face, including economic pressures and the integration of modern water management systems, which often disrupt traditional practices. By assessing the perceptions of community members regarding the sustainability of their water management practices, the research underscores the importance of blending indigenous knowledge with contemporary approaches to enhance water governance, promote environmental sustainability, and ensure equitable resource distribution. The findings advocate for greater recognition and incorporation of IKS into formal water management strategies to support the resilience and well-being of indigenous communities amidst ongoing environmental changes and socio-economic challenges.

Keywords

Indigenous Knowledge Systems, Water Resource Management, Central Nigeria, Natural Springs, Water Harvesting, Salt Production, Environmental Sustainability

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1. Introduction

1.1. Indigenous Knowledge

Indigenous peoples, estimated to comprise approximately 476 million individuals, constitute more than 6% of the global population. The Asia-Pacific region is home to the largest share, representing 70.5% of the world's indigenous peoples (WHO 2024). Indigenous knowledge systems (IKSs), or indigenous knowledge (IK), refer to the distinctive traditional knowledge and practices that indigenous peoples have cultivated over thousands of years. These systems emerge from the interactions between these communities and their surrounding natural environments, which encompass land, sea, and the sky. The insights, skills, and philosophies developed through these enduring relationships significantly influence decision-making processes related to vital aspects of everyday life.

Warren and Cashman characterize IKS as the collective experience and knowledge of a community that informs its decision-making [1]. Altieri further elaborates that it encompasses knowledge, skills, and technologies that arise from the interaction between humans and their environment [2]. This system includes technical expertise, social structures, decision-making frameworks, resource management practices, and skilled labor. Local populations, such as farmers, are regarded as custodians of this knowledge [3]. IK is inherently dynamic and serves as a foundation for addressing both technical and scientific inquiries. It is specific to societies or ethnic groups, distinguishing it from the international knowledge systems generated by researchers [4].

IK reflects the relationship of indigenous peoples with their environment, encompassing biological, physical, social, cultural, and spiritual dimensions. It is developed over time within a community and can be derived from knowledge holders, historical records, and archaeological findings. Deeply rooted in culture and locality, IK operates outside formal educational frameworks, guiding local decision-making and facilitating development processes [4]. Historically, IKS have been underutilized in development and conservation efforts; however, there is a growing trend to incorporate them into projects, particularly in developing nations such as India. IK offers valuable resource management strategies that can enhance contemporary scientific methodologies.

Community-based monitoring (CBM) is a collaborative approach aimed at observing and addressing the concerns of local communities. Indigenous populations employ CBM to record the effects of resource extraction and environmental alterations. This methodology has been implemented in various regions, including Canada, the United States, Australia, New Zealand, and polar areas, where the impacts of climate change are particularly pronounced. In Siraf, Iran, water management is optimized through a combination of traditional ecological practices and contemporary scientific tech-

niques, which include rainwater harvesting, the utilization of subterranean water sources, and the establishment of underground gardens [5]. The integration of technology with indigenous knowledge is essential for enhancing livelihoods and effectively planning development initiatives. The incorporation of locally accumulated wisdom is crucial for addressing climate change and ensuring sustainable resource management [6].

Indigenous communities across the globe have advocated the integration of traditional knowledge into decision-making frameworks, particularly concerning issues related to land and water management [7]. In response, various indigenous declarations have been formulated and presented at international environmental and sustainable development conferences, underscoring the significance of these knowledge systems [7]. The United Nations recognizes the contribution of indigenous knowledge, culture, and traditional practices to sustainable and equitable development, as well as to environmental stewardship. This acknowledgement paves the way for the recognition, acceptance, and incorporation of indigenous knowledge systems into diverse developmental contexts by nations. To honor and safeguard indigenous knowledge, the South African government enacted the Indigenous Knowledge Bill in 2016, which aims to protect and commercialize these knowledge systems [8]. Additional discussions and analyses of indigenous knowledge can be found in the works of [9-12].

IKS encompasses practices that pertain to the natural environment, culture, and history, aiming to establish a harmonious balance between humans and the environment. Such knowledge is instrumental in promoting environmental sustainability through resource management, conservation efforts, ecological restoration, and the preservation of languages, traditions, and cultural practices. Despite its potential to complement modern practices, the direct application of indigenous knowledge to places other than its origin is questionable and risky. This is due to its local relevance and the fact that it works well at low cost for a specific community under certain natural and social conditions. This knowledge is often seen as inferior to modern science due to a lack of scientific validation, faces threats or is used temporarily where modern technology is unaffordable. However, it offers environmentally friendly solutions on the basis of historical wisdom. Understanding its processes and integrating it with modern science is crucial to realizing its potential and limitations.

The challenges faced by IKS include a lack of recognition and respect from nonindigenous peoples, including governments, institutions, and individuals. Documentation and preservation efforts to protect it from loss and erosion. Integration and collaboration with modern science and Western knowledge systems. In Nigeria, IKS have historically been overlooked due to perceptions of primitiveness and a lack of scientific merit, resulting in their marginalization in favour of

Western knowledge. For example, [13] argued that Nigerian IK represents a cultural asset that merits preservation through systematic documentation as part of the national heritage.

1.2. Indigenous Knowledge in Water Resources Management

Water resource management involves planning and managing water quality and quantity for various uses. Effective management should coordinate the development of water, land, and related resources while preventing flood or drought impacts. It includes institutions, infrastructure, incentives, and information systems to support water management. The goal is to ensure adequate water for domestic, industrial, agricultural, and recreational uses while considering climate change, pollution, and rising demand. IK has the potential to offer valuable insights into water management, complementing scientific methods. Recognizing and integrating IK into water resource management can enhance sustainable development, climate change resilience, and cultural preservation. This knowledge includes understanding patterns of the water cycle, seasonal climatic variations, and river flow, which are utilized for informed decision-making on water use and management at the community level. IK emphasizes community-based management of water resources, where local communities take ownership of water management decisions. This approach fosters cooperation, social cohesion, and collective responsibility for water resources. IK recognizes the cultural significance of water, including its spiritual, ceremonial, and recreational values. This holistic understanding helps maintain the integrity of water ecosystems and promotes a sense of stewardship. Indigenous knowledge offers valuable insights into climate change adaptation and resilience. Traditional practices, such as floodplain management and drought coping strategies, can inform modern climate change adaptation efforts. IK can be integrated with modern scientific approaches to enhance water resource management, improved water forecasting and modelling; enhanced water conservation and efficiency; supported climate change mitigation and adaptation; and promoted community engagement and ownership of all resources.

The involvement of local communities in resource governance results in improved environmental and social outcomes. Indigenous communities have historically managed water and related resources [14] through Community-Based Monitoring (CBM), where groups collaborate to monitor, track, and respond to issues of common community concern [15] and to document impacts from resource development and global environmental changes [16]. CBM programs are well established in Canada, the USA, Australia and New Zealand [17, 18]. The Indigenous Observation Network, for example, is the largest indigenous community-based water quality monitoring network led by indigenous groups from Yukon and British Columbia, as well as the Alaskan Native Tribes. The network is coordinated by the Yukon River Inter-Tribal

Watershed Council and the United States Geological Survey.

Indigenous knowledge is fundamental to the development of sustainable water management plans around the world. It combines age-old knowledge with new methods to promote sustainable development [19]. Indigenous communities have developed an understanding of river ecosystems through generations of close interaction with them, incorporating ecological, cultural, and social aspects into their management practices. Indigenous techniques in water management offer valuable lessons for sustainable water management [20]. These techniques face numerous challenges, including climate change, resource degradation, and socioeconomic pressures. To ensure long-term sustainability, it is essential to integrate traditional knowledge with modern practices, among other key factors [21].

IK promotes sustainable water use practices, such as rain-water harvesting and storage; efficient irrigation systems; the conservation of water sources; and the protection of watersheds and aquatic ecosystems. It offers unique insights and approaches that can complement modern scientific methods. Recognizing and integrating IK into water resource management can promote sustainable development, climate change resilience, and cultural preservation. The integration of IK into water resource management enhances sustainability, climate resilience, and cultural preservation by fostering community engagement and promoting traditional practices that effectively address local water challenges. This approach not only improves environmental outcomes but also empowers local communities to take ownership of their water resources, ensuring their long-term viability.

The aim of this study is to examine the experiences and challenges associated with traditional water management practices in two distinct communities in Central Nigeria. One community serves as a case study where water is utilized not only for essential needs but also as a means of economic production, specifically in salt production. The other community exemplifies adaptation to its unique geological and topographical conditions. This study focuses on indigenous practices that promote the sustainable use of water as a critical resource, contrasting them with contemporary methods. Additionally, the research assesses residents' perceptions regarding the sustainability of these traditional practices.

The methodology employed involved multiple visits to the communities, fostering active engagement with residents and local leaders, including elders, to gather historical insights into the significance of water resources and the existing governance frameworks. The data collection methods included interviews, discussions, and observations within each community. In both locations, community elders were consulted to provide information on the historical context of their water systems, the administrative rules governing these systems, and their perspectives on the modernization of water management practices.

2. Water Resources Management in Central Nigeria

2.1. Water Resources Management Statutes

Water resources are an essential element of the ecosystem. The sustainable management of these resources is crucial for societal development, as water is integral to numerous human activities. It supports domestic, commercial, industrial, agricultural, and recreational needs [22]. Nigeria's water resources include 226 billion m³ of surface water and 40 billion m³ of groundwater. This includes over 9,670 miles of rivers and streams, 1,323 lakes, 390 flows, and many acres of wetlands, mostly in the southern regions [23]. Most rivers originate from the North Central Plateau, Western Highlands, Eastern Highlands, and Uri Plateau (Water/Nigeria | Interactive Country Fiches, n.d.).

Despite advancements since the first waterworks in Lagos in 1915, many Nigerians still lack access to water supplies. Water shortages are frequent in major towns and rural areas throughout the year [24]. Like other scarce resources, water is protected globally by laws, policies, and regulations to prevent misuse [25]. Effective environmental control is necessary to improve living conditions and health. Environmental policies aim to maintain, manage, and protect our environment. However, the inefficient application of these regula-

tions has led to current issues such as poor infrastructure, inadequate water supply, corruption, poor governance, and a lack of facility maintenance [26]. The key regulations governing water resources in Nigeria include the following:

- 1) National Water Resources Policy, which outlines the framework for water resources management.
- 2) The Water Resources Act is responsible for regulating water use, management, and conservation.
- 3) Environmental impact assessment, which requires environmental assessments for projects affecting water resources.

Salami et al. reported that despite policy documents aimed at addressing this issue, water resource management continues to be a challenge in Nigeria [27]. Organized water management in Nigeria dates to colonial times, with rainwater harvesting practiced since 1849. This evolved to stream intake, and by the 1950s, a water services unit existed within the public works department. Table 1 lists the statistics defining water resource management in Nigeria.

The sustainable management of water resources in Nigeria is critical for societal development, yet challenges such as inadequate infrastructure, poor governance, and ineffective policy implementation hinder access to clean water for many citizens. Addressing these issues through improved regulatory frameworks and environmental policies is essential for enhancing living conditions and ensuring the responsible use of this vital resource.

Table 1. Primary Water Resources Management Statutes in Nigeria and their functions (modified from: [22]).

Statute	Year enacted
The Water Resources Act	1976, 1993
Minerals and Mining Act	1990
The River Basin Development Authority (RBDA) Act	1990
Nigeria Hydrological Services Agency (NIHSA) Act	2010
The Nigerian Meteorological Agency (NIMET) Act	2003
State Water Edicts	Diffuse
The National Inland Waterways Authority (NIWA) Act Cap N47	2004

2.2. Indigenous Techniques of Water Management

Indigenous techniques of water management in the Central Region of Nigeria have been developed and refined over centuries, reflecting the resourcefulness and adaptability of local communities. There are several water management techniques used by households and farmers, including traditional water harvesting techniques, indigenous irrigation

systems, and water storage and conservation techniques. [19] asserted that historical evidence indicates that indigenous communities have utilized various methods, including traditional irrigation systems, rainwater harvesting, and natural indicators, to manage water resources sustainably. These techniques are essential for maintaining water availability, quality, and sustainability in the region. [28] identified two main water harvesting techniques in Jama'are, LGA, Bauchi State: microcatchments and roof collection. Microcatchments trap runoff via embankments or pits, like practices in Central

Nigeria, where rainwater is collected from various surfaces into storage containers. Additionally, floodwater harvesting involves building canals, channels, or reservoirs to store water from rivers and streams.

For water storage and conservation techniques, local communities utilize clay pots and jars to store water for domestic purposes, thereby minimizing evaporation and contamination. Additionally, underground water storage methods involve farmers constructing underground tanks or cisterns to collect rainwater or runoff for irrigation and domestic use. To conserve water, farmers implement practices such as mulching, crop rotation, and early planting to reduce water losses and optimize water usage.

3. Case Studies



Figure 1. Case studies from Ancient Awe and Ginda B Towns, Nasarawa State, Central Nigeria.

This research presents two case studies of the ancient Awe and Ginda B settlements in Nasarawa State, Nigeria (figure 1). In Awe, water management is linked to economic activities, particularly salt production, which has historical significance. The traditional and modern practices of water management for domestic and industry purposes are examined. In Ginda B, the community relies on natural springs for water because of its unique geological features. This review highlights traditional water management practices and their perceived effectiveness and sustainability. Both communities maintain strong traditional systems that are considered effective over time.

3.1. Ancient Settlement of Awe

The first case study is from an ancient rural settlement, Awe town, Nasarawa State, Central Nigeria. It is geologically situated in the middle Benue Trough of Nigeria with a succession of sedimentary rocks, including the Asu River Group,

which was deposited directly on the basement complex, and the Albian Awe Formation, which is overlain by the Keana Formation. The youngest rock unit in the area is the Ezeaku Formation [29]. Awe is known for the occurrence of brines (TDS up to 64,000mg/l), which are produced from the shale unit of the Awe Formation [30, 31]. These brines are locally mined for salt production, which is an important economic activity. Brines have contaminated both surface and groundwater resources. Past government intervention led to the construction of a water supply scheme more than 6 km away from the main settlement. This likely motivated the expansion of the community towards water in search of non-saline water, an area now known as New Awe Town. Areas of saline groundwater have been identified via geophysical parameters determined from vertical electrical sounding resistivity data [32].

Ancient settlements have traditionally relied on indigenous knowledge systems for water management. Water management techniques have been instrumental in guiding water supply projects implemented by the government and non-governmental organizations (NGOs). The salinity of groundwater from natural springs in Awe was recognized by early settlers, leading to its utilization for economic purposes. Historical records indicate that between 1975 and 2012, approximately 82 to 116 salt production units operated in Awe Town [33].

Salt production has been a traditional occupation of the people of Awe; by the 13th century, it had developed into an organized industrial complex [33]. This development facilitated commercial exchanges with other civilizations, enhancing the economic prosperity of Awe Town. By the mid- to late 1800s, salt marketing became a focal point of the trans-Saharan trade. Awe Town continued to benefit from the salt trade because of an organized system of governance. Recognizing the importance of this commodity in economic sustainability led to the establishment of a governance structure.

In many communities, these brines (saline groundwaters) are surrounded by traditional restrictions and rituals [31]. Typically, access to saline water is granted exclusively to women, whereas nonindigenous individuals or men are either entirely prohibited or permitted only after undergoing an initial traditional ritual. Generally, the salt-making industry is predominantly managed by women and has served as a primary source of income for a significant proportion of these rural women, albeit at a subsistence level.

Saline water has traditionally been used for medicinal purposes. For example, wound care is performed with saline water. In terms of interactions, residents appreciate the potential of saline water and its effectiveness as a disinfectant that can reduce infections.

Traditionally, water management by indigenous communities focuses on two primary purposes, agriculture and domestic consumption, with salt production being an additional purpose in places such as Awe. Indigenous water management techniques have evolved over time, particularly in arid

and mountainous regions. In many African countries, surface water bodies (including groundwater-sourced springs) are considered common property resources, granting all community members equal rights to access and use water [34]. During the wet season, rainfall supplies water for domestic and agricultural uses. Rainwater harvesting is common during this

period but is typically limited to households with corrugated metal roofs. In the dry season, most available water sources, including some modern supply systems, may dry, necessitating significant community efforts to secure water. To address this scarcity, most communities have resorted to the use of groundwater through hand-dug wells.

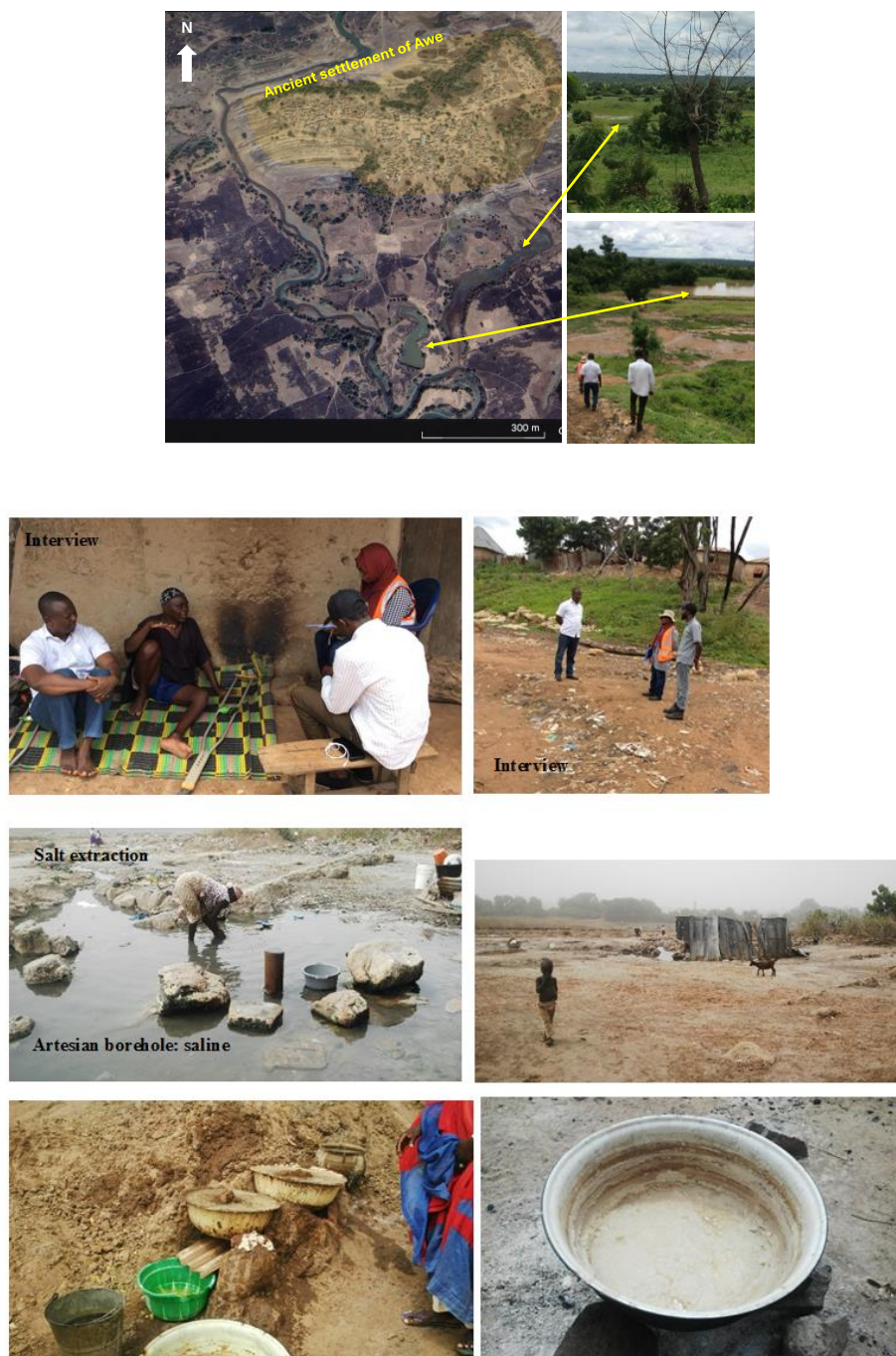


Figure 2. (top) Google image of the ancient town of Awe showing the outlines of water retention structures. (bottom) Awe in pictures.

In the ancient settlement of Awe, indigenous water management practices included tafki, natural springs, rijiya (hand-dug wells), and rainwater harvesting (Figure 2). In

contemporary times, water management has evolved to include concrete-lined hand-dug wells and boreholes (both hand-pumped and motorized), which are privately owned or

provided through government and nongovernmental interventions. Additionally, numerous private wells and boreholes have been established by residents to ensure a sustainable supply of water for domestic use.

In the structure of water governance, the Emir of Awe holds the position of supreme leader and appoints two title holders: *Sarkin Ruwa* (manager of water) and *Sarkin Gishiri* (manager of salt). These individuals are tasked with the management of their respective resources. While all inhabitants have equal access to water for necessities, the activities of fishing and salt production are regulated and overseen by *Sarkin Ruwa* and

Sarkin Gishiri, respectively.

Salt processing is conducted locally, beginning with the collection of brines from springs or from areas where these brines have crystallized on the ground surface (Figure 3a). The collected salts are then diluted with water from the river to dissolve the salt and remove sand particles (Figure 3b). The brines are subsequently evaporated using firewood (Figure 3c). After crystallization, the salt is collected, bleached (the specific bleaching agent could not be determined during the field visit), and packaged for sale (Figure 3c).



Figure 3. Salt production in Awe settlement. (a) Evaporated salts collected and dissolved to remove sand; (b) filtering of saltwater, leaving behind the sandy particles; (c) evaporation hut, producing and bleaching salt image of the ancient town of Awe showing the outlines of water retention structures.

Indigenous Practices of Water Management in Awe Tafki

Tafki refers to a constructed structure involving the excavation of the ground to a specific depth and width and is used to collect runoff water. It is typically developed in areas with gentle slopes, usually not too deep, and is elongated in form, with varying sizes depending on the capability of its developers and the available space. The structure is surrounded by earthen bunds to prevent the loss of trapped water obtained from the runoff or diversion of the River Asuku. This practice has been in existence for at least 100 years, as confirmed by an in-depth interview (Sarkin Ruwa Awe, 2024). During the interviews, three tafkis were visited, each varying in size. The use of water for irrigation and domestic purposes, sourced from the diversion of the River Asuku and trapped rainfall during the wet season, was common. To ensure quality, this structure is isolated from grazing cattle and human interference. Despite ongoing use, one observed that tafki had almost

dried up during a recent visit and interaction with the community. The largest of these tafkis have an outline circumference of 451.8m and an area of 5,796.24m². Development and maintenance usually commence during the first days of the rainy season to enable adequate trapping of runoff water from gentle slopes.

1. Rijiya – hand dug well

In Awe town, hand-dug wells serve as an essential traditional method for accessing groundwater. In the Old Town region, however, this water is characterized by high salinity levels (TDS up to 64,000mg/l), which restricts its use for drinking and certain domestic activities. Despite the relative simplicity of constructing these wells, there are only 3 such wells in the Old Town region, some of which are over 100 years old. This can be attributed to the poor quality of groundwater and the reliability of traditional Tafki in terms of water availability throughout the year.

2. Rainwater harvesting

Rainwater harvesting is a common practice in Awe and is conducted primarily during the rainy season for immediate use. The technique is not well developed and lacks infrastructure for storage. Residents collect rainwater in small containers when it rains, which helps reduce the need to collect water from tafkis or hand-dug wells. During discussions, residents were asked about practices to ensure the quality of the rainwater. They indicated that domestic use or drinking of harvested rainwater is usually limited to later episodes of rainfall after the first rains have cleaned the roofs. Residents also acknowledge the benefits of boiling water to prevent the consumption of pathogen-infested water and are aware of waterborne diseases such as cholera and enteric fever. The study further revealed that rainwater harvesting is not organized in a way that maximizes collection; instead, inclined aluminum roofs are used with containers placed on the ground directly under the eaves to catch water. The quantity of collected water depends on the intensity of rainfall, which can be influenced by the wind velocity during the rainy season. The maximum discharge from the springs is $648\text{cm}^3\text{s}^{-1}$.

3. Natural springs

Saline groundwater emerges from natural springs around a geological structure known as the Awe anticline, with these springs dispersed along the limbs of the anticline. These saline springs constitute the primary water source for salt production. The use of this water is unrestricted, and women frequently collect it for salt production. When groundwater seeps to the surface, evaporation results in the formation of salt crystals, which are subsequently collected by women for salt production. Some physicochemical properties of spring water are shown in Table 2.

Table 2. Properties (mg/l) of saline groundwater from springs and an artesian borehole (drilled in 1976) in Awe.

	TDS	Ca	Mg	K	Fe
Spring	64000.00	1180.00	0.72	65.70	0.76
Borehole	55000.00	935.00	0.70	63.40	0.67
	Mn	Cl	HCO ₃	SO ₄	NO ₃
Spring	0.76	0.03	960.00	11.60	0.71
Borehole	0.67	0.07	825.00	6.20	1.41

3.2. Ginda B Community

Ginda B is a small community in Central Nigeria with a population between 500 and 800 people. The settlement dates back 100-150 years and is associated with a network of fracture springs that provide water for the population. The village is located on a hilltop at an elevation of 450 m above mean sea level, as measured by GPS at primary healthcare center (figure 4). The primary economic activity is farming. The community is situated on rocks of the Nigerian Basement Complex terrain, particularly gneisses, which are characterized by a series of fracture springs along the slopes and at the base of the hill. Ginda B's geological and topographic conditions make groundwater difficult to access, which is further complicated by the low-income levels of its residents. There is no public water supply, so springs serve as the main water source for domestic purposes such as drinking, hygiene, and sanitation (plates 3 and 4). Although some households and primary healthcare centers practice rainwater harvesting, not all residents can afford to set up such facilities.



Figure 4. Google Earth image of Ginda B showing the location and quality of water from springs.

Indigenous knowledge regarding water sources involves locating springs on hillsides and protecting them from contami-

nation. Residents knew the locations and yields of these springs. They safeguarded the sources from human activities that could

affect water quality by redirecting cattle grazing routes.

Open defecation was prevalent but conducted away from the springs. Water governance was informal, with access granted on a first-come, first-served basis. Women and children (girls) devoted half of their day to collecting water from the springs. The village faces various socioeconomic chal-

lenges due to an inadequate water supply. Women and children spend considerable time fetching water, involving trips to the network of springs, some of which are seasonal. This situation has affected the educational attainment and economic status of villagers.



Figure 5. Ginda B in pictures.

In 2008, Ginda B received a Primary Healthcare Centre through the Conditional Grant Scheme of the Millennium Development Goals MDGs-CGS (figure 5). However, a solar-powered borehole project with the same scheme failed because of deep water levels, poor access to drilling equipment, and inadequate drilling technology. Indigenous knowledge of water sources was further exploited through discussions with the leadership of the community. Residents knew the quality, quantity, and seasonality of water from the springs. This knowledge led the MDGs-CGS to develop the most productive springs for the community water supply, establishing a spring-sourced water scheme (figure 7). Spring development was proposed as an alternative to provide water to the primary healthcare center and the village. The scheme

thus proposed and constructed consisted of a collection point, an infiltration gallery, a reservoir/ground tank, a pump house and, finally, an overhead tank adjacent to the Primary Healthcare Center (figure 6). Water from the springs is filtered in the gallery and then stored in a ground reservoir from which a 3hp submersible pump powered by a diesel generator pumps the water to the overhead adjacent to the healthcare center. A reticulation network from the overhead tank was also set up to provide water to the households in the village. Once the reservoir is filled, 2 hours of pumping are needed to fill the overhead tank, which has a capacity of 20,000 litres. At the time the scheme was set up, pumping is performed thrice a week, which consumes approximately 32 litres of diesel (at the cost of ₦8,000~22 USD; now ₦38,000~25 USD). Basic

training on routine maintenance of the scheme (such as service of the generator) was provided, after which the project was handed over to the village via the village head. The scheme was managed by the community, and all residents had access to the water but at a minimum cost. Payment and running of the scheme were performed through the Youth Council set up by the village Council under the leadership of the village head.

The scheme ran successfully for a while; however, unfortunately, it was not sustainable for several reasons, especially the economic hardship exacerbated by the rising cost of

maintaining the diesel-powered submersible pump. The community has since reverted to the indigenous practice of collecting water from springs.

Household surveys reveal that residents see the need to improve sustainability efforts. While borehole technology and access routes have improved, funding remains a challenge. Constituency projects are seen as potential sources of funding. Spring water becomes scarce in the dry season, requiring collection at lower altitudes. Residents acknowledge the importance of protecting drinking water sources and understanding good siting practices.

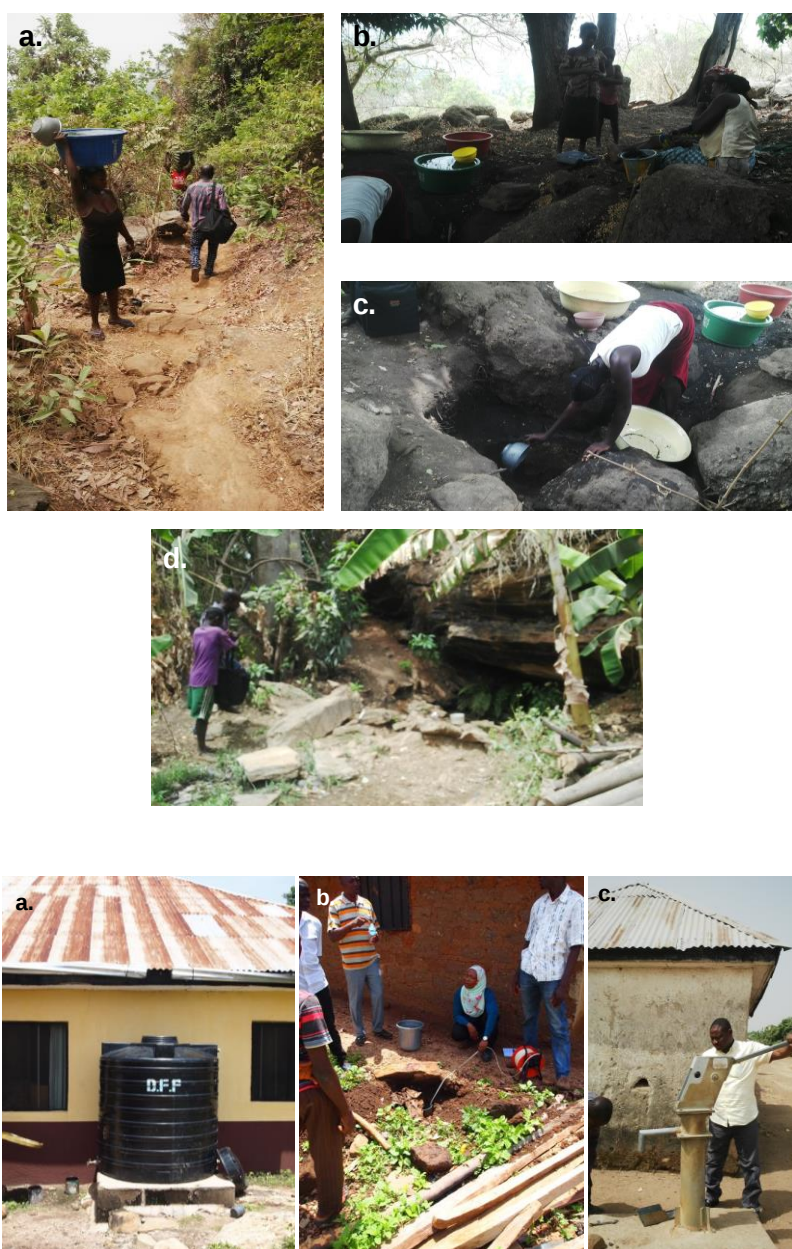


Figure 6. (top) Images of indigenous practices of water management. (a) The journey downhill to access water from springs; (b), (c) and (d) springs and water collection points. (bottom) Millennium Development Goals – Conditional Grants Scheme intervention: Primary healthcare center (a) rainwater harvesting; (b) and (c) failed attempts to drill boreholes for the Center.

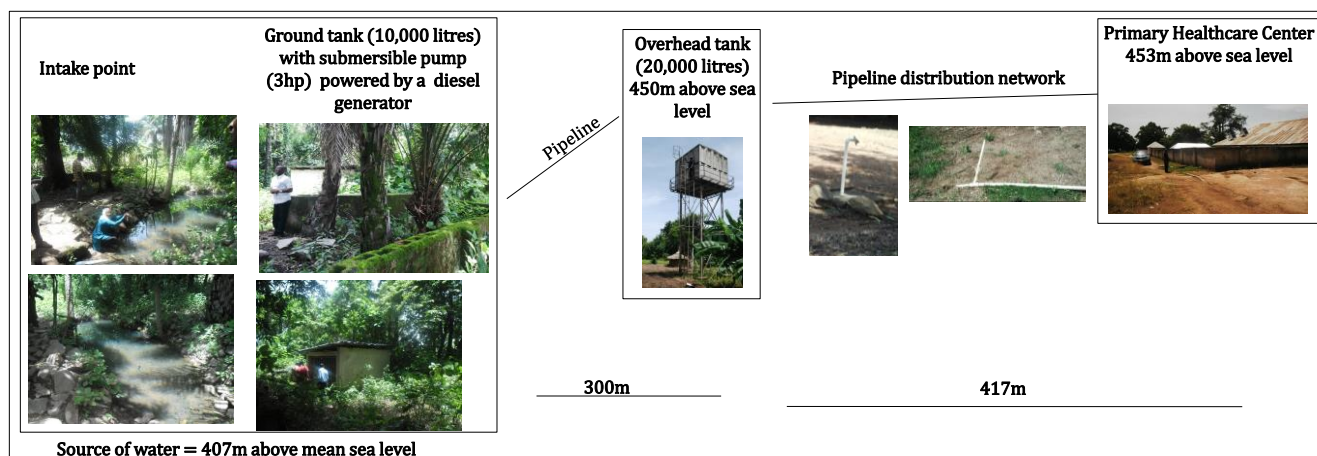


Figure 7. Spring-based water supply scheme for Ginda B.

4. Perceptions of Sustainability

The indigenous communities in Central Nigeria have developed and refined traditional water management techniques over centuries, reflecting their deep cultural, spiritual, and ecological connections to water resources. These practices not only ensure sustainable water availability for agriculture and domestic use but also highlight the importance of integrating ancestral knowledge and community-based approaches into contemporary water management strategies.

The sustainability of a water management system for indigenous people means a system that is complete and integrates cultural, spiritual, environmental, social and economic considerations to ensure the long-term health and well-being of the people and the environment. Among these factors, social and economic considerations were a priority for the two case studies presented.

The case study of Awe Town highlights the importance of indigenous water management practices and the economic role of salt production in the community, illustrating how traditional knowledge has shaped resource governance. The interplay between historical practices and contemporary interventions underscores the importance of sustainable management of both water and saline resources for the community's economic and social well-being. The indigenous water management practices in Awe, including tafki structures, hand-dug wells, rainwater harvesting, and the utilization of natural springs, demonstrate a resourceful adaptation to local environmental conditions, although challenges such as water quality and infrastructure limitations persist. These methods reflect a deep-rooted cultural heritage and highlight the community's ongoing efforts to secure water for irrigation and domestic use amidst varying water availability.

Ginda B, a small community in Central Nigeria, faces significant challenges in accessing sustainable water sources, which primarily rely on fracture springs for their water needs. Despite initial efforts to implement a spring-sourced water

scheme, economic hardships and rising maintenance costs have led the community to revert to traditional water-fetching practices, highlighting the urgent need for improved sustainability measures and funding to enhance their water supply system. The community currently views natural springs as a more sustainable water source, leading to a return to obtain water from these springs.

These communities use both indigenous and modern water management methods but rely heavily on traditional systems, especially among older residents. Modern systems are effective but are often disrupted by failures, economic issues, or resource stress. These projects are typically planned and executed centrally by the government, NGOs, or development partners. The perception of sustainability expects that the indigenous community has a water management system in which:

- 1) builds on traditional water management practices,
- 2) involves and engages the indigenous community in decisions regarding the management of water resources,
- 3) promote equality in the distribution of water and associated resources across the community,
- 4) enables the indigenous community to control and manage water resources at affordable costs,
- 5) considers water a sacred and spiritual entity essential for life, emphasizing the need to preserve its sanctity and quality.

5. Conclusions

Indigenous knowledge systems (IKSs) play crucial roles in sustainable development and resource management, particularly in the context of water resource management. Representing the invaluable insights and practices of approximately 476 million indigenous peoples, IKSs are dynamic, culturally specific systems shaped by long-standing interactions with their environments. They encompass a holistic understanding that integrates the technical knowledge and community-based management principles essential for addressing local and

global challenges such as climate change and resource degradation. Despite facing challenges such as marginalization and a lack of recognition from modern science, the integration of indigenous knowledge with contemporary methods can enhance decision-making processes, promote environmental stewardship, and foster resilience. Effective initiatives such as community-based monitoring illustrate how indigenous communities actively engage in resource governance, demonstrating the benefits of local ownership and participation. This article investigated traditional water management practices in two communities in Central Nigeria, emphasizing indigenous strategies that ensure sustainable water use tailored to local conditions, in contrast with modern practices.

In conclusion, the integration of indigenous knowledge (IK) in water resource management is essential for fostering sustainable practices and climate resilience in communities, particularly in Central Nigeria's Awe and Ginda B settlements. Both case studies illustrate how traditional water management techniques, shaped by historical and environmental contexts, effectively address local challenges related to water supply and quality. In Awe, traditional practices such as Tafki, hand-dug wells, and natural saline springs development sustain the community by maximizing available water for both domestic and economic needs, notably salt production. The informal governance structure also promotes equitable access among residents. Conversely, Ginda B relies heavily on seasonal springs, with residents employing their knowledge of local water sources to adapt to socioeconomic challenges; however, their reliance on these springs have impacted educational and economic stability. While modern interventions, such as the spring-sourced water scheme, have been attempted, they often face sustainability issues due to economic hardships and maintenance costs. Ultimately, recognizing and valuing IK not only empowers local communities by enhancing their ownership of water resources but also aids in preserving cultural practices and ecosystems. Combining IK with contemporary scientific methods can lead to improved water management strategies that prioritize community needs and promote long-term viability. Hence, fostering partnerships between indigenous practices and modern environmental governance is critical to achieving sustainable water management objectives.

Abbreviations

IKS	Indigenous Knowledge Systems
IK	Indigenous Knowledge
WHO	World Health Organization
CBM	Community Based Monitoring
USA	United States of America
RBDA	River Basin Development Authority
NIHSA	Nigeria Hydrological Services Agency
NIMET	Nigerian Meteorological Agency
NIWA	National Inland Waterways Authority
LGA	Local Government Area

TDS	Total Dissolved Solids
NGO	Non-governmental Organization
GPS	Global Positioning Systems
MDG	Millenium Development Goals
CGS	Conditional Grants Scheme

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Author Contributions

Aisha Abubakar Kana: Conceptualization, Project administration, Data curation and analysis, Processing of field sheets, Writing original drafts plus review and Resources

Ahmad Abubakar Kana: Funding, Conceptualization, Field visits

Mahmud Abdullahi Modibbo: Data curation and analysis, Processing of field sheets, Writing original drafts plus review and Resources

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Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript. Supplementary data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography



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Sunday Yusuf Kpalo: Climate Change, Renewable energy, Waste management, Sustainable Development, Socioeconomic Studies.