BILINGUAL PUBLISHING GROUP

Journal of Environmental & Earth Sciences

https://journals.bilpubgroup.com/index.php/jees

REVIEW

Indigenous Knowledge and Water Conservation Practices in South Africa: A Systematic Literature Review

Arvind Kumar Sahani [1], ***Garima Gupta*** [2], ***Subhash Anand*** [3*], ***Vishwa Raj Sharma*** [4], ***Rajender Singh*** [5], ***Azka Kamil*** [6], ***Harish Kumar*** [3], ***Alka Gagan*** [3], ***Vinod Kumar Mayala*** [7], ***Arun Pratap Mishra*** [3], ***Sunil Jaiswal*** [3], ***Jasmine Anand*** [8]

[1] *Department of African Studies, University of Delhi, Delhi 110007, India*

[2] *Department of Environment Planning, School of Planning and Architecture Delhi, Delhi 110012, India*

[3] *Department of Geography, Delhi School of Economics, University of Delhi, Delhi 110007, India*

[4] *Department of Geography, Shaheed Bhagat Singh College, University of Delhi, Delhi 110007, India*

[5] *Department of Geography, Shivaji College, University of Delhi, Delhi 110007, India*

[6] *Department of Geography, Kamala Nehru College, University of Delhi, Delhi 110007, India*

[7] *Department of Economics, Hansraj College, University of Delhi, Delhi 110007, India*

[8] *Department of Applied Mathematics, Delhi Technological University, Delhi 110042, India*

ABSTRACT

Water scarcity poses a significant challenge globally, with South Africa exemplifying the severe socio-economic and environmental impacts of limited water access. Despite advances in modern water management systems, the integration of indigenous knowledge (IK) into formal frameworks remains underutilized. This study systematically reviews the role of indigenous water conservation practices in South Africa, analyzing over 50 high-quality sources using the PRISMA methodology. The findings highlight the effectiveness of IK in addressing water scarcity through techniques such as rainwater harvesting, terracing, and wetland management, which are low-cost, environmentally sustainable, and deeply rooted in cultural practices. Indigenous methods also enhance climate resilience by enabling communities to adapt to droughts and floods through practices such as weather prediction and adaptive farming techniques. Furthermore, these

*CORRESPONDING AUTHOR:

Subhash Anand, Department of Geography, Delhi School of Economics, University of Delhi, Delhi 110007, India; Email: sanandpvs@gmail.com

ARTICLE INFO

Received: 5 December 2024 | Revised: 11 December 2024 | Accepted: 16 December 2024 | Published Online: 14 February 2025

DOI: https://doi.org/10.30564/jees.v7i2.7988

CITATION

Sahani, A.K., Gupta, G., Anand, S., et al., 2025. Indigenous Knowledge and Water Conservation Practices in South Africa: A Systematic Literature Review. Journal of Environmental & Earth Sciences. 7(2): 248–261. DOI: https://doi.org/10.30564/jees.v7i2.7988

practices foster social inclusivity and community empowerment, ensuring equitable water access and intergenerational knowledge transfer. The study underscores the potential of integrating IK with modern water technologies to create holistic solutions that are scalable, sustainable, and aligned with South Africa's goal of achieving water security by 2030. Policy recommendations emphasize the need for institutional support, data collection, and financial incentives to sustain and mainstream indigenous approaches. By bridging the gap between traditional and contemporary systems, this research provides a roadmap for leveraging diverse knowledge systems to address water scarcity and build resilient communities.
Keywords: Water Scarcity; Indigenous Knowledge; Water Conservation; Climate Resilience; Sustainable Water Management; South Africa

1. Introduction

1.1. Global and South African Water Scarcity: An Overview

Water scarcity is recognized as one of the most significant global challenges, affecting not only individual communities but also broader social and economic stability worldwide. The United Nations (UN) reports that approximately 2.2 billion people lack safely managed drinking water services, highlighting the extensive and urgent nature of this issue[1]. This is the situation even though the United Nations formally recognized access to safe water and sanitation as a fundamental human right in 2002. According to the United Nations, "the basic human right of access to safe and adequate drinking water is crucial to leading a life with equality and dignity," which is why water and sanitation services should be recognized as fundamental human rights[2]. Also, Goal 6 of the SDGs (Sustainable Development Goals) recognizes access to safe, affordable, and clean drinking water as a basic human right. By 2030, Sustainable Development Goal 6 aspires to "check the equitable access and effective management of clean drinking water and sanitation for all"[3]. According to the UN's 2023 Water Development Report, an estimated 80% of wastewater flows back into ecosystems untreated, contaminating water sources and posing a severe risk to human health and biodiversity, which further worsens the existing issue[4]. These issues underscore the necessity of innovative solutions and sustainable practices in water management.

South Africa exemplifies the complex dynamics of water scarcity due to recurrent droughts, socio-economic disparities, and population growth. Historical inequalities have exacerbated access issues, as disadvantaged communities, especially those in rural regions, experience limited access to clean water despite post-1994 policy changes. The UN indicates that in developing regions such as sub-Saharan Africa, up to 60% of the population remains vulnerable to water scarcity, underscoring the regional disparity in water access and quality[5]. In South Africa alone, an estimated 14 million people—mainly from historically marginalized communities—do not have direct access to safe drinking water, with droughts worsening the situation, as demonstrated by recent water crises in regions like Cape Town[6, 7]. The projected increase in water demand driven by population growth, climate change, and urbanization necessitates sustainable water management practices that consider the needs of vulnerable populations. The UN has highlighted indigenous knowledge as an essential component of resilience-building in regions susceptible to water crises, noting that local and indigenous practices provide tailored, sustainable water management techniques that support both environmental and social well-being[8]. In South Africa, integrating indigenous knowledge with formal water management systems is essential for addressing both immediate and long-term water needs, particularly in light of the country's goal to achieve water security for all by 2030[1].

1.2. The Role and Relevance of Indigenous Knowledge

Indigenous knowledge (IK) refers to the traditional knowledge systems developed by local communities over generations, reflecting their deep understanding of the environment, its cycles, and the natural resources available to them. It is a dynamic system that includes a range of practices, beliefs, and skills passed down through generations and adapted over time to changing environmental conditions[9].

IK is highly localized, as it is deeply rooted in the specific geographic, ecological, and cultural contexts of a community, often linking natural phenomena to spiritual and cultural beliefs[10]. In contrast to scientific knowledge, which tends to be more universal and analytical, indigenous knowledge is holistic and context-specific. It involves an intimate relationship between humans and their environment, where knowledge is often intertwined with cultural practices, including agriculture, medicine, and water management[11]. Indigenous/traditional knowledge systems are also founded on empirical observations, with communities relying on long-term interactions with their surroundings to make predictions and develop strategies for resource management[12].

In the context of water conservation, IK plays a crucial role, especially in arid and semi-arid regions, where water scarcity is a persistent challenge. Indigenous communities have developed techniques and technologies over centuries to sustainably manage water resources. These practices include water harvesting, soil erosion prevention, and the sustainable use of available water sources, often ensuring water security during periods of drought[13]. For instance, traditional rainwater harvesting systems, such as the use of stone channels and dams, have been instrumental in enhancing local water storage capacities[14]. The relevance of indigenous knowledge in the modern context of water conservation lies in its resilience and adaptability. Many indigenous techniques have remained effective over time, and they offer sustainable alternatives to the industrial approaches to water management, which may be resource-intensive and environmentally damaging[11]. As climate change exacerbates water scarcity, incorporating indigenous knowledge into national and local water governance can provide valuable insights into sustainable practices and foster resilience in communities facing the growing threat of droughts and water shortages[15].

1.3. Innovative Aspect of the Research

This research innovatively bridges the gap between traditional indigenous practices and contemporary water management strategies by systematically exploring how the two can synergize to enhance water conservation and resilience. By employing a robust methodology, including a systematic review of over 50 high-quality studies, this work highlights the unique strengths of indigenous practices—such as their low-cost, culturally embedded, and ecologically adaptive features—and explores ways to integrate these with modern technologies for greater efficiency. The research also pioneers an interdisciplinary approach, combining ecological, socio-cultural, and technological perspectives to propose holistic, scalable solutions that align with Sustainable Development Goals (SDGs), particularly Goal 6 on water security and equitable access.

1.4. Research Gap

Despite the recognition of water scarcity as a critical issue globally and in South Africa, there is limited systematic research on the integration of indigenous water conservation practices with modern water management systems. Existing studies primarily focus on documenting individual indigenous practices or assessing modern water technologies, often neglecting how these two approaches can complement each other to address the growing water crisis effectively. Furthermore, many studies overlook the socio-cultural dimensions of indigenous knowledge, such as its role in fostering community-based governance and resilience to climate change. Additionally, there is a lack of empirical data evaluating the long-term sustainability and scalability of these practices within the framework of South Africa's national water policies.

2. Methodology: PRISMA Screening and Selection

2.1. Systematic Review Process Using PRISMA

To systematically evaluate the role of indigenous knowledge in water conservation, this study employed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to conduct a thorough review of existing literature. An initial pool of over 1000 articles was identified using keywords such as "indigenous water conservation practices in South Africa," and "traditional water management practices in South Africa". The articles were screened based on relevance, empirical quality, and geographical focus, eventually narrowing the selection to 47 high-quality sources for an in-depth analysis.

2.2. Inclusion and Exclusion Criteria

Articles selected for review were required to meet specific inclusion criteria: they needed to focus on indigenous practices in water conservation, include data or case studies specific to South African contexts, and be published within the last 25 years. Exclusion criteria eliminated studies without empirical data, literature lacking regional specificity, and non-peer-reviewed sources. This careful selection process ensured a robust, focused review of pertinent literature on indigenous water management [14]. A visual representation of this selection process is shown in the PRISMA flow diagram in **Figure 1**, detailing each stage of article screening and exclusion.

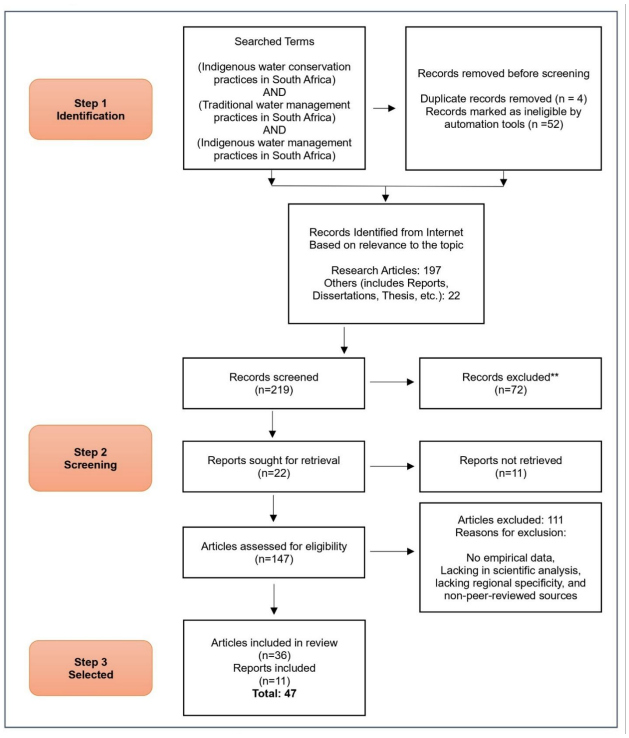

Figure 1. Overview of the screening process.

The articles included in the review were selected based on specific inclusion and exclusion criteria. To be included, the articles had to focus on indigenous knowledge (IK) and water conservation, particularly in South Africa or regions with similar contexts, and provide empirical data or case studies. Only peer-reviewed publications from the last 25 years were considered to ensure relevance and academic rigor. Excluded articles were those without empirical evidence, non-peer-reviewed sources, or those not directly related to water conservation practices. Additionally, articles that lacked geographical relevance to South Africa or similar regions were excluded, ensuring the review was region-specific and focused on the effectiveness of indigenous water management practices. These criteria helped create a focused and reliable review of IK's role in water conservation.

3. Characteristics that Distinguish Indigenous Practices from Modern Approaches

After reviewing the literature, a structured view of the factors that distinguish indigenous practices from modern ones, capturing both the social and ecological dimensions of these traditional methods, has been formulized. Water scarcity can be effectively managed, especially in arid and semi-arid regions, by using indigenous knowledge in methods of water management like rainwater harvesting, "sacred water governance" which emphasizes a spiritual connection with water—and stone-based terracing to retain water [16]. These techniques provide sustainable solutions through practices that are deeply ingrained in local cultural understanding of the environment. The **Table 1** below shows the characteristics of indigenous practices.

Indigenous Knowledge (IK) refers to the cumulative knowledge systems developed by local communities over generations through close interaction with their environment. It reflects a deep understanding of natural cycles and resource management, often rooted in specific ecological, cultural, and spiritual contexts. Unlike modern scientific methods, IK is holistic and adaptive, incorporating empirical observations and cultural traditions to address resource-related challenges. In water management, IK includes practices such as rainwater harvesting, sacred water governance, and stone-based terracing for water retention [11].

Differences between Indigenous and Modern Water Management Practices

Indigenous Knowledge (IK) in water management is rooted in traditions passed down through generations, offering time-tested, resilient practices adapted to local conditions [17]. It integrates cultural and spiritual values, with rituals and taboos emphasizing respect for nature, as seen in the Zulu community's sacred view of water, contrasting with

Table 1. Characteristics that distinguish indigenous practices from modern approaches.

Factor/Indicator	Indigenous Practices	Modern Practices	References
Historical continuity	Rooted in generations of tradition and are time-tested, developed over centuries within a specific community or region.	Modern practices are often based on recent scientific research, technological developments, and are not necessarily tied to a long history within a specific community.	[17]
Cultural and spiritual significance	Integrated with cultural beliefs, spiritual values, and often governed by taboos or rituals that create a unique relationship with the environment.	Generally, lack a cultural or spiritual dimension; are typically implemented based on functional, technical, or economic considerations rather than traditional beliefs.	[12, 14]
Local ecological knowledge	Draws on intimate knowledge of local ecosystems, weather patterns, and plant and animal behaviors, built up through generations of observation and adaptation.	Relies on scientific data, technological tools, and standardized approaches, often not specific to the local ecosystem but based on generalized scientific knowledge.	[10, 14]
Resource availability and minimal external inputs	Uses readily available natural resources like stones, clay, and native plants, minimizing reliance on external resources or industrial products.	Often requires external inputs such as industrial materials, synthetic chemicals, or advanced technology, which can be costly and may not be locally sourced.	[15, 18]
Community-based management and knowledge transmission	Managed collectively by the community, with knowledge transferred orally or through apprenticeships. Practices are embedded in community responsibility.	Often managed by centralized authorities, and knowledge is documented in formal texts or digital formats, not requiring community transmission.	[13, 15]
Adaptation to natural cycles and climate resilience	Highly adapted to local climate cycles, ensuring resilience against droughts and floods. Designed to align with natural ecological rhythms rather than productivity goals.	Modern practices focus on maximizing productivity and often rely on irrigation or other technology, which may not be ecologically sustainable in the long term.	[10, 11]
Social inclusivity and knowledge sharing	Inclusive in nature, designed for the benefit of the whole community, with knowledge-sharing frameworks that ensure widespread access and participation.	Often focused on efficiency or economic gains, sometimes leading to unequal access or benefits, and knowledge is shared through formal systems, excluding those without formal training.	[17, 18]

the technical focus of modern systems[19]. IK relies on sustainable resource use, employing locally available materials like stones and clay, avoiding the financial and environmental costs of industrial inputs often required in modern methods[18]. It emphasizes community-based management and knowledge-sharing, ensuring inclusivity and strengthening social ties, whereas modern systems are typically centralized and less accessible to marginalized groups[15]. Additionally, IK aligns with natural cycles, fostering resilience against climate extremes through practices like drought-resistant cropping, which modern approaches may overlook in their focus on productivity[14]. Finally, IK promotes equity by benefiting entire communities, ensuring inclusive participation, in contrast to the efficiency-driven and sometimes inequitable nature of modern water management systems[17].

Further, every indigenous practice (cases from the articles/report reviewed) was aligned with the formulized indicators (as mentioned below in the **Table 2**).

4. Impact of Indigenous Water Conservation Practices in South Africa

The effectiveness of indigenous water conservation techniques in South Africa is demonstrated by their ability to promote community-based governance, increase climate change resilience, and manage water resources sustainably. Indigenous water management practices in South Africa have proven to be not only effective in preserving water resources but also crucial for enhancing climate resilience, improving social inclusivity, and fostering community-based water governance. The cases of IK (mentioned below) demonstrate that these practices, which have evolved over generations, offer sustainable solutions for contemporary water challenges. By combining traditional knowledge with modern technology, South Africa can develop more holistic and resilient water management strategies to address the growing pressures of climate change and water scarcity.

Table 2. Indigenous knowledge cases aligned with indicators.

Factor/Indicator	Indigenous Practices	References
Historical continuity	1. Limpopo Province Terracing: Indigenous terracing techniques have been used for centuries to manage soil erosion and water retention. 2. Rainwater Harvesting in Karoo: This practice has been passed down through generations, using locally made containers of stones for collecting rainwater. 3. Grazing Management in Namaqualand: Traditional practices involve controlled grazing to prevent soil erosion and water depletion, based on generational knowledge.	[17]
Cultural and spiritual significance	1. Sacred Water Sites in Limpopo: Sacred water sources are protected and governed by taboos, limiting access to preserve water quality and spiritual integrity. 2. Ritualistic Water Use in Eastern Cape: Traditional rituals tied to water usage are carried out before using water for farming, which emphasizes spiritual respect for the resource. 3. Water-Related Rituals of the Zulu Community: Water is used in purification rituals, which imbue water use with spiritual meaning and align it with broader cultural practices. 4. Rainmaking Ceremonies in the Karoo: Rain dances or prayers are held to invoke rainfall, which reinforces the spiritual connection to water.	[12–14]
Local ecological knowledge	1. Karoo Weather Prediction via Local Indicators: Farmers use behavioral cues from plants and animals to predict rainfall and manage water resources. 2. Indigenous Vegetation Knowledge in KwaZulu-Natal: Knowledge of local plant species that help conserve water and maintain soil fertility. 3. Farming Practices Based on Soil and Water Knowledge in Limpopo: Knowledge of soil water retention based on soil types and their ability to conserve moisture in arid conditions. 4. Seasonal Rain Forecasting in the Eastern Cape: Indigenous farmers use the position of certain stars or birds to predict seasonal rains, ensuring optimal water management for crops. 5. Indigenous techniques for managing bush encroachment to prevent excessive water absorption by the invasive species.	[10, 12, 14, 17]
Resource availability and minimal external inputs	1. Stone-Lined Channels in Mpumalanga: Farmers use locally available stones and clay to create rainwater harvesting channels, avoiding industrial materials. 2. Clay Pits for Water Storage in Limpopo: Clay pits are dug in local areas to collect and store rainwater, using minimal external materials. 3. Bush-based Water Sources in Eastern Cape: Local communities rely on indigenous plants and bushes for water storage, minimizing the need for technology or external inputs. 4. Natural Springs in KwaZulu-Natal: Indigenous communities collect water from natural springs, ensuring sustainable usage without reliance on external inputs.	[13, 15, 17, 18, 20]
Community-based management and knowledge transmission	1. Rainwater Harvesting in Karoo: Knowledge of rainwater harvesting techniques is passed down orally through generations. 2. Mpumalanga Collective Water Management: Water conservation techniques like contour farming are managed collectively by the community. 3. Shared Water Knowledge in Limpopo: Farmers in Limpopo share their knowledge on water management strategies in regular community meetings, fostering collective responsibility. 4. Community-Based Irrigation Systems in KwaZulu-Natal: Smallholder farmers work together to manage irrigation systems, ensuring equitable water distribution.	[11, 13, 15, 17, 18]
Adaptation to natural cycles and climate resilience	1. Shifting Planting Times in KwaZulu-Natal: Farmers adjust planting times based on seasonal shifts, responding to climatic changes and conserving water. 2. Drought-Tolerant Crops in Limpopo/Karoo: Farmers select drought-tolerant crops that are well-suited to arid conditions, conserving water in times of drought. 3. Adaptation to Dryland Farming in Eastern Cape: Indigenous farmers employ adaptive techniques like mulching to maintain soil moisture during dry spells. 4. Indigenous Drought Strategies in Limpopo: Use of indigenous knowledge for managing seasonal droughts, including adjusting farming practices to avoid water depletion.	[10, 11, 14, 17]
Social inclusivity and knowledge sharing	1. Mpumalanga Collective Soil and Water Conservation: Smallholder farmers implement water conservation techniques together, ensuring equitable access to water. 2. Karoo Drought Adaptation Techniques: Knowledge of water conservation is shared through community meetings, ensuring widespread participation in drought preparedness strategies. 3. Water Use Education in Limpopo: Knowledge of water conservation methods is shared with all community members, including elders teaching younger generations. 4. Water Sharing Systems in KwaZulu-Natal: Communities share water resources, with local water sharing practices ensuring that water is accessible to all, irrespective of wealth.	[13, 15, 17, 18]

4.1. Indigenous Water Conservation Practices and Rural Water Security in South Africa

Indigenous water conservation practices have significantly enhanced water security in rural South Africa by providing sustainable and cost-effective solutions. Techniques such as rainwater harvesting and natural storage systems, including clay pits and stone-lined channels, have reduced water stress by up to 30% in areas like Limpopo and the Karoo [10]. In the Eastern Cape, these methods have increased water availability by 20–25% during droughts [20]. Practices such as sacred water site preservation, governed by cultural rituals, and traditional weather prediction further enhance sustainability and resilience to climate change [14, 16]. Moreover, collective governance of water resources promotes equitable access and strengthens community ties, improving agricultural productivity by up to 50% in regions like Limpopo [15]. These approaches are essential for rural areas with limited access to modern infrastructure.

4.2. Improved Water Security in Rural Areas

Indigenous water conservation practices such as rainwater harvesting and the construction of check dams have helped rural communities in South Africa secure their water supplies, especially in areas that lack access to formal water infrastructure. In the Karoo region, for example, indigenous farmers use techniques such as rainwater harvesting pits and small retention dams. These systems help retain and store water during the rainy season, which can be used during the dry months. Ncube in his study provides that communities using indigenous water harvesting methods reported up to 30% less water stress compared to those who depended exclusively on external water sources [10]. Similarly, in the Eastern Cape, indigenous farming communities have seen a 20–25% increase in water availability during dry periods due to the use of traditional water management methods such as rainwater storage pits [20]. Studies also mention that traditional rainwater harvesting techniques have shown to improve water availability by 30% in dry seasons, especially for households and small-scale farms in regions like Limpopo [21, 22]. Also, Mango et al. (2017) document the adoption of traditional rainwater harvesting and soil erosion control methods in the Chinyanja Triangle, which have proven effective in sustaining agricultural productivity in semi-arid regions [23]. Similarly, in the Mbhashe and Mnquma municipalities, indigenous practices like the use of traditional water pits and stone-lined reservoirs have provided sustainable solutions for household water security [24].

4.3. Indigenous Knowledge in Addressing Climate Change and Enhancing Resilience

Indigenous knowledge of local climatic patterns and ecosystems enables communities to adapt to extreme weather events, such as floods or droughts, ensuring that their water systems remain functional during these times. For instance, in KwaZulu-Natal, communities have developed systems that integrate weather prediction with water storage, ensuring they are prepared for rainfall patterns. According to Vilakazi et al., these communities have improved resilience by maintaining water availability in times of extreme drought, with some areas reporting a 40% increase in water conservation efficiency when integrating traditional methods with modern technologies [14]. Similarly, indigenous systems like the "cooling dam" method, which uses natural barriers to reduce evaporation, have enhanced the ability to manage seasonal variations in water flow, contributing to a 15% improvement in water retention in the Karoo and Limpopo province [11]. Further, Reij et al. also highlight that those indigenous practices such as terracing and agroforestry, widespread across Africa, have been pivotal in soil and water retention, enabling agricultural sustainability in arid regions [25]. In the above **Table 2**, under the ecological knowledge understanding the various types of soil and their differing capacities to hold water should be the primary focus of farming practices. Important practices include choosing crops that can withstand drought, using conservation tillage, adding organic matter, putting water harvesting techniques into practice, and using drip irrigation systems to maximize water use on clay-rich soils, which typically retain more moisture than sandy soils [26].

4.4. Preservation of Biodiversity

Many indigenous practices are aligned with the need to protect local biodiversity, which plays an essential role in water conservation. For example, the maintenance of traditional wetlands and river systems helps preserve ecosystems that regulate water flow and quality. Agholor and Nkosi

documented that communities in Limpopo province have preserved wetlands through traditional practices like controlled burning and selective harvesting of aquatic plants. These practices have helped maintain ecosystem services such as water filtration, with evidence showing a 12% increase in the quality of local water sources [19]. Indigenous knowledge plays a crucial role in managing bush encroachment, which impacts groundwater recharge. Practices such as selectively clearing water-intensive species can improve water infiltration and minimize evapotranspiration losses [26]. Aldworth et al. (2023) highlight that those areas with high woody plant density, particularly dense mopane, experience 12% greater evapotranspiration during wetter years compared to cleared areas, leading to reduced groundwater and soil water recharge; however, they don't focus on any indigenous practices [27]. Again, indigenous communities manage wetlands to recharge groundwater sources, which is critical for ensuring water availability during dry periods. This practice not only conserves water but also helps maintain biodiversity and ecosystem health. In regions like KwaZulu-Natal, wetland management by local communities has led to improved groundwater retention and a reliable water source for agriculture and domestic use [9]. This has reduced the reliance on municipal water supplies, which can be scarce or unreliable, especially in remote areas. In addition, some other studies underline the role of traditional ecological knowledge in managing invasive species, such as alien freshwater fisheries and invasive plants, which threaten local biodiversity and water resources [28, 29]. Similarly, the Venda community in the Limpopo Province of South Africa is particularly associated with the protection of sacred groves and springs. These sacred water sources, such as Lake Fundudzi and Phiphidi Waterfalls, hold profound spiritual significance for the Venda people. They are considered sacred spaces connected to ancestral spirits and are preserved through cultural taboos and rituals. These practices not only maintain the sanctity of the sites but also ensure ecological conservation by protecting the surrounding biodiversity and water quality [16].

4.5. Social and Economic Benefits

Indigenous water management practices are often rooted in collective community action and shared responsibility. This inclusivity helps ensure that the benefits of water conservation reach all members of the community, particularly vulnerable groups. The empowerment of women through involvement in water management processes has been a key feature of indigenous systems. In communities where women are integral in managing water resources, there has been a 30–40% improvement in household water access [12]. The shared knowledge transmission helps bridge generational gaps and ensures the long-term sustainability of these practices. In Limpopo, a community-based irrigation system that uses indigenous methods of water distribution has led to a 50% increase in agricultural productivity, which has in turn improved local food security and access to water [15]. Similarly, Richardson and Van Wilgen emphasize on the role of community engagement in managing invasive plants, which threaten water availability and quality. Such practices reinforce the need for community-driven approaches to safeguard both water resources and biodiversity [29]. Furthermore, Harvey and Reed emphasized community-managed water systems, particularly in regions where centralized water distribution is unreliable. These systems are often based on indigenous methods of equitable water sharing, such as the "lekgotla" system, where communities collaboratively decide on water distribution during shortages [30]. The Zulu people hold water as sacred, often associating it with ancestral spirits. Traditional practices include the protection of springs (izigodi) and rivers, viewed as spiritual entities that require ritual offerings to ensure their vitality. These rituals, often led by elders, emphasize collective responsibility in safeguarding water sources for future generations [18].

Indigenous practices often require fewer external inputs and are less reliant on expensive infrastructure. This cost-effectiveness has been especially beneficial in rural areas, where the costs of modern water management systems are prohibitive. Communities employing indigenous methods have reported significant savings compared to those who depend on costly modern water infrastructure. According to a report by WRC (Water Resource Conservation) Report communities in the Eastern Cape saved up to 40% of water management costs by utilizing traditional systems such as gravity-fed water channels and stone-lined water channels for irrigation [13]. Traditional sand dams built by local communities in the Western Cape have shown a 50% reduction in water loss compared to modern, concrete-based dam designs [11]. Postel highlighted that traditional water conservation systems, such as small-scale irrigation channels and

hand-dug wells, are more affordable and easier to maintain compared to large-scale dams and pipelines. In regions with limited financial resources, such as rural South Africa, these methods provide a practical and sustainable alternative[31]. The adoption of indigenous water conservation techniques (WCTs) should not be viewed in isolation; rather, their value lies in their contribution to broader social and economic goals such as human development, poverty alleviation, and environmental sustainability. The use of WCTs is recognized as a key strategy for ensuring sustainable agriculture, which in turn supports sustainable livelihoods, particularly in rural communities. By improving water management, these practices help foster long-term economic growth and enhance the resilience of local communities[32].

4.6. Environmental Sustainability

Indigenous water practices tend to be low-cost and environmentally friendly, relying on locally available materials such as rocks, clay, and native plants. For example, stone terraces used by farmers in Limpopo help control runoff and conserve soil moisture, enhancing crop yields and reducing soil erosion. Such methods decrease the need for expensive irrigation systems, making them accessible for low-income communities[22, 33]. Additionally, the use of natural resources minimizes ecological disruption and promotes biodiversity. Similarly, Basdew, et. al. document the integration of indigenous knowledge in KwaZulu-Natal, where communities use rotational grazing and wetland conservation to bolster water resilience. These practices have ensured sustainable resource use while preserving ecosystem health as well[34]. On the other hand, practices such as conservation tillage and agroforestry not only help in improved water retention by ensuring the long-term sustainability of water resources but also reduce soil degradation[35, 36]. Furthermore, Finn and Jackson in their study challenge the conventional environmental flow assessments, advocating for the inclusion of indigenous values to reflect the cultural significance of water bodies[37]. Such approaches align with studies that call for managing environmental flows to maintain ecological integrity[38]. Among the Xhosa, wells and springs (amanzi sources) are communally maintained and governed by indigenous laws. Elders and traditional leaders allocate water usage rights during dry seasons, ensuring fairness and preventing conflicts. These systems promote water conservation by mandating specific times and methods for drawing water, aligning with sustainable resource management principles[18, 39].

4.7. Water Conservation through Traditional Knowledge of Weather Prediction

Indigenous knowledge systems incorporate weather prediction and seasonal planning based on natural indicators. By interpreting animal behavior, plant growth, and celestial observations, communities can predict weather patterns, adjust water usage, and prepare for possible droughts. This knowledge has reduced crop failures by up to 15% in areas that depend heavily on rain-fed agriculture, as seen in case studies across the Eastern Cape[40]. The KwaZulu-Natal communities use natural indicators such as tree blooming cycles and animal behavior to predict rainfall patterns, allowing farmers to plan their planting and irrigation schedules accordingly[34]. Furthermore, Bryan et al. and Ziervogel et al. note that integrating these practices into national climate adaptation frameworks can enhance resilience to droughts and extreme weather events, which are becoming more frequent due to climate change[41, 42]. Similarly, in their study Edgar et.al. provide that in Limpopo Province the Venda and Pedi communities, have long relied on indigenous knowledge for predicting weather patterns and managing water resources. These communities, residing in regions like Thohoyandou and surrounding rural areas, used specific natural indicators such as; bird migration, flowering cycles, and animal behavior[16].

4.8. Reduction in Waterborne Disease

Proper water management and traditional filtering techniques using locally available materials, such as sand and specific plant roots, have been reported to reduce waterborne diseases. Communities utilizing such techniques in rural South Africa report fewer cases of water-related illnesses, which supports public health while providing a safe, drinkable water supply[43]. Indigenous water purification techniques, such as the use of moringa seeds and sand filtration, have reduced waterborne illnesses in communities by up to 30%, as noted by Naidoo et al. in their study[22].

4.9. Integration of Modern Technology with Indigenous Knowledge

Recent efforts have focused on combining indigenous knowledge with modern water management technologies to enhance the overall effectiveness of water conservation efforts. Alexander et al. advocate for linking indigenous and scientific knowledge to combat the adverse effects of climate change, citing the value of traditional water-sharing systems and natural resource stewardship [44]. Similarly, Muller advocated for blending these traditional practices with urban planning strategies to ensure resilience in rapidly urbanizing areas. For example, green roofs and rain gardens inspired by traditional water-harvesting designs have been integrated into urban water management plans [45]. Further, a study highlighted the successful integration of indigenous rainwater harvesting methods with modern weather forecasting systems in several South African communities. This hybrid approach resulted in a 35% increase in water conservation rates and has been widely adopted in community-driven water management programs [46]. In KwaZulu-Natal, the integration of traditional water storage techniques with digital water tracking systems has led to more efficient water management, reducing water wastage by 25% [14].

5. Discussion

5.1. Policy Implications and Recommendations

Research highlights the potential benefits of integrating indigenous water conservation practices into South Africa's national water policies to enhance water security. Integrating indigenous knowledge into South Africa's formal water management systems could bridge existing policy and infrastructure gaps. Collaborative programs between governmental agencies and indigenous communities could ensure that traditional practices are recognized and supported. Research has shown that indigenous knowledge can complement technological solutions by adding a layer of social and environmental adaptability. Recognizing and supporting these methods can empower communities and promote resilience against water scarcity [9, 22, 40, 47]. Singh et al. and Zvobgo et al. further suggest that providing financial incentives for traditional approaches, such as rainwater harvesting, could sustain these practices and reduce reliance on centralized water infrastructure [33, 34, 40]. Similarly, Briggs and Sharp underscore the need to integrate indigenous knowledge into policy-making, ensuring socio-cultural inclusivity and equitable water access [48]. The WRC Report in the year 2011 also emphasizes the need for innovative water conservation and management approaches that integrate local knowledge [49]. However, to effectively implement these interventions, policies should mandate the systematic collection of data on indigenous practices to assess their impact. This data would enable policymakers to evaluate their effectiveness and scale up successful approaches accordingly [21, 43].

5.2. Integration with Modern Water Management Practices

Research suggests that the traditional indigenous water practices should be integrated with contemporary water management frameworks in order to achieve maximized efficiency, resilience, and sustainability. If integrated thoughtfully, this combined approach can leverage the ecological sensitivity of indigenous practices with the technological advancements of modern systems. For example, indigenous rainwater harvesting and aquifer recharge methods can be enhanced through modern storage systems and distribution networks, offering a reliable water source in arid or drought-prone areas [33, 40]. Moreover, indigenous water practices emphasize the conservation and equitable distribution of water resources within communities, which aligns with contemporary goals for sustainable resource management and inclusive governance [22, 43]. This integrated approach can provide resilience against climate-induced water shortages, as both systems together offer adaptive strategies that respond to variable rainfall, groundwater levels, and ecosystem needs [9]. Furthermore, Bakker underscores the ethical dimension of water as a common resource, advocating for indigenous perspectives that prioritize collective welfare over privatization. By integrating indigenous and scientific approaches, South Africa can build robust, inclusive water management systems that address its unique socio-ecological challenges while ensuring resilience in the face of climate change [50].

5.3. Potential Challenges in Integrating Indigenous Knowledge with Modern Technology

Integrating indigenous knowledge (IK) with modern technology presents several challenges that need to be care-

fully navigated. These include cultural and epistemological differences, as IK is holistic and context-specific, while modern technology is analytical and standardized [18]. The oral, localized nature of IK also makes it difficult to document and standardize, conflicting with the formal documentation required by modern technology [15]. Additionally, the integration of IK with modern technology risks creating dependency on costly, external technologies that may not be accessible in rural communities, threatening the sustainability of IK practices. Institutional resistance to incorporating IK into policy, combined with its lack of formal recognition, can hinder its integration with modern systems [50, 51]. Furthermore, modern technologies may struggle to account for the intricate, localized understanding of climate variability embedded in IK, particularly in the face of non-linear climate impacts [52]. Lastly, the exploitation of IK without proper consent or benefit-sharing mechanisms poses risks to cultural heritage and community empowerment. However, a collaborative approach in which the modern technology respects and incorporates the IKS is required to successfully integrate both systems, leading to more context-specific and sustainable solutions for climate change and water management [53].

5.4. Major Findings

- Effectiveness of Indigenous Practices: Indigenous water conservation techniques, such as rainwater harvesting and community-based irrigation, have significantly improved water security, reducing water stress by up to 30% in rural areas with limited infrastructure.
- Contribution to Climate Resilience: Indigenous practices like weather prediction, drought-tolerant cropping, and adaptive planting schedules help communities build resilience to climate change, improving water retention and agricultural productivity during extreme weather events.
- Environmental Sustainability: These practices promote minimal ecological disruption, conserve soil and water, and protect biodiversity. Sacred water sites and the management of wetlands and invasive species contribute to ecosystem conservation.
- Social Inclusivity and Community Empowerment: Indigenous practices foster social equity by involving the entire community in water management, promoting knowledge sharing, and empowering women, thus enhancing the sustainability of water systems and social cohesion.
- Cost-Effectiveness: Indigenous methods are low-cost and require minimal external inputs, making them accessible to economically disadvantaged communities, particularly in rural South Africa.
- Integration with Modern Technology: Integrating indigenous knowledge with modern water management technologies improves efficiency and creates adaptive solutions, such as combining traditional rainwater harvesting with digital tracking systems for enhanced water conservation.

5.5. Future Research Directions

Further research is needed to systematically document indigenous water management practices across different regions. Understanding the mechanisms and ecological principles underlying these practices could enhance their adaptation to contemporary challenges, such as urbanization and climate change. Additionally, exploring indigenous perspectives on wastewater treatment and reuse could broaden sustainable water management approaches [22].

6. Conclusions

In conclusion, indigenous water conservation practices provide valuable, sustainable solutions that align with modern water management goals and address pressing environmental challenges. These practices—rooted in centuries of localized knowledge—contribute to sustainable resource use, community resilience, and environmental stewardship. As highlighted in recent studies, indigenous practices such as rainwater harvesting, aquifer recharge, and community-based water governance have shown measurable effectiveness in conserving water resources, reducing vulnerability to drought, and sustaining ecological balance. Integrating these traditional methods with modern technologies can offer a holistic approach to water management that balances innovation with respect for cultural heritage and ecological knowledge. However, there are still shortcomings in integration of IKS with the modern technology. Such integration calls for policy recognition, research support, and community involvement to ensure that indigenous knowledge remains a central, respected component of sustainable development

efforts. Embracing this synergy between indigenous and modern water practices represents a promising path toward achieving water security and resilience in South Africa and beyond, fostering sustainable development that honors and utilizes diverse knowledge systems.

Author Contributions

All the Authors contributed equally to write this article. All authors have read and approved the final manuscript.

Funding

This work received no external funding.

Institutional Review Board Statement

There is no requirement of any approval from any institution because it is "Not applicable" for studies not involving humans or animals.

Informed Consent Statement

This manuscript is based on the secondary data so it is not required any consent from anyone. Not applicable for this study.

Data Availability Statement

We are publishing our article first time in your journal and we have not created any data so it is not applicable for us.

Conflicts of Interest

There is no conflict of interest among all the authors.

References

[1] UN, 2021. The United Nations world water development report 2021: Valuing water. ISBN NO. 978-92-3-100434-6, 21 Mar 2021. Available from: https://www.unwater.org/publications/un-world-water-development-report-2021

[2] UN, 2010. UN water. Available from: https://www.unwater.org/water-facts/human-rights-water-and-sanitation (cited 22 November 2024).

[3] UNGA, 2016. The human rights to safe drinking water and sanitation: Resolution adopted by the General Assembly. Available from: https://digitallibrary.un.org/record/821067?v=pdf (cited 25 November 2024).

[4] UN, 2023. UN world water development report 2023: Partnerships and cooperation for water. ISBN No. 978-92-3-100576-3, 15 Mar 2023. Available from: https://www.unwater.org/publications/un-world-water-development-report-2023

[5] UN, 2018. Water for sustainable development 2018–2028: An international decade for action. Available from: https://www.un.org/en/events/waterdecade/ (cited 25 November 2024).

[6] Muyambo, F., Jordaan, A., Bahta, Y., 2017. The role of indigenous knowledge in drought risk reduction: A case of communal farmers in South Africa. Jàmbá: Journal of Disaster Risk Studies. 9(1), 1–6.

[7] Calverley, C., Walther, S., 2022. Drought, water management, and social equity: Analyzing Cape Town, South Africa's water crisis. Frontiers in Water. 4, 910149. DOI: https://doi.org/10.3389/frwa.2022.910149

[8] UNESCO, 2017. Local and Indigenous Knowledge Systems (LINKS). Available from: https://www.unesco.org/en/links (cited 25 November 2024).

[9] Olokesusi, F., 2006. Survey of indigenous water management and coping mechanisms in Africa: Implications for knowledge and technology policy. ATPS SPECIAL PAPER SERIES No. 25. Available from: https://atpsnet.org/wp-content/uploads/2017/05/special_paper_series_25.pdf (cited 25 November 2024).

[10] Ncube, B., 2018. Insights into indigenous knowledge strategies for coping and adapting to drought in agriculture: A Karoo scenario, South Africa. Indilinga African Journal of Indigenous Knowledge Systems. 17(1), 92–108. Available from: https://hdl.handle.net/10520/EJC-fe65c371a

[11] Budeli, A., 2021. An exploration of african indigenous knowledge methods of water conservation and management in the Limpopo Province of South Africa [Master's thesis]. Limpopo, South Africa: University of Venda. pp. 85–155.

[12] Swatuk, L., 2010. The state and water resources development through the lens of history: A South African case study. Water Alternatives. 3(3), 521–536. Available from: https://www.water-alternatives.org/index.php/allabs/114-a3-3-4/file

[13] WRC, 2009. Indigenous water harvesting and conservation practices: historical context, cases and implications. TT 392/09, April 2009. Available from: https://www.wrc.org.za/wp-content/uploads/mdocs/TT%20392-09%20Agricultural%20water%20management.pdf

[14] Vilakazi, B., Zengeni, R., Mafongoya, P., 2019. Indigenous strategies used by selected farming communities in KwaZulu Natal, South Africa, to manage soil, water,

and climate extremes and to make weather predictions. Land Degradation & Development. 30(16), 1999–2008. DOI: https://doi.org/10.1002/ldr.3395

[15] Thakur, R., Rane, A., Harris, G., et al., 2020. Government initiatives and policies for water conservation and wastewater treatment in South Africa and indigenous knowledge. In: Singh, Yulia Milshina, Kangming Tian, Deepak Gusain, João Paulo Bassin (eds.). Water Conservation and Wastewater Treatment in BRICS Nations. Elsevier: Amsterdam, Netherlands. pp. 285–293. DOI: https://doi.org/10.1016/B978-0-12-818339-7.00014-X

[16] Edgar, B., Eva, M., Lee, K., 2022. Disappearance of African indigenous knowledge of water conservation and management in Limpopo Province of South Africa: An IKS perspective. African Journal of Development Studies. 12(2), 49–73. Available from: https://hdl.handle.net/10520/ejc-aa_affrika1_v12_n2_a3

[17] Denison, J., Wotshela, L., 2012. An overview of indigenous, indigenised and contemporary water harvesting and conservation practices in South Africa. Irrigation and Drainage. 61, 7–23.

[18] Agholor, A., Nkosi, M., 2020. Sustainable water conservation practices and challenges among smallholder farmers in Enyibe Ermelo Mpumalanga Province, South Africa. Journal of Agricultural Extension. 24(2), 112–123. DOI: https://doi.org/10.4314/jae.v24i2.12

[19] Basu, M., Dasgupta, R., 2023. Exploring indigenous water knowledge, values, and practices: Insights and examples. In: Basu, M., Dasgupta, R. (eds.). Indigenous and Local Water Knowledge, Values and Practices. Springer: Singapore. pp. 1–9. DOI: https://doi.org/10.1007/978-981-19-9406-7_1

[20] Fanteso, B., Yessoufou, K., 2022. Diversity and determinants of traditional water conservation technologies in the Eastern Cape Province, South Africa. 194(3), 161. Environmental Monitoring and Assessment. 194(161), 1–14. DOI: https://doi.org/10.1007/s10661-022-09848-2

[21] Chisenga, J., 2002. Indigenous knowledge: Africa's opportunity to contribute to global information content. South African Journal of Libraries and Information Science. 68(1), 16–20. Available from: https://hdl.handle.net/10520/EJC61124

[22] Naidoo, N., Longondjo, C., Vrdoljak, M., 2013. Investigating operational indigenous knowledge of water and waste management, and establishing ways to integrate them into water services management. Report number 1941/1/13, October 2013. Available from: https://www.wrc.org.za/wp-content/uploads/mdocs/1941-1-131.pdf

[23] Mango, N., Makate, C., Tamene, L., et al., 2017. Awareness and adoption of land, soil and water conservation practices in the Chinyanja Triangle, Southern Africa. International Soil and Water Conservation Research. 5(2), 122–129. DOI: https://doi.org/10.1016/j.iswcr.2017.04.003

[24] Mapuka, F., Nel, W., Kalumba, A., 2024. Exploring household water conservation methods in rural South Africa: A case of the Mbhashe and Mnquma local municipalities. Sustainable Water Resources Management. 10(4), 145. DOI: https://doi.org/10.1007/s40899-024-01127-x

[25] Reij, C., Scoones, I., Toulmin, C., 2013. Sustaining the soil: Indigenous soil and water conservation in Africa. Routledge: London, UK. pp. 181–188 DOI: https://doi.org/10.4324/9781315070858

[26] WRC, 2023. Woody encroachment: Understanding its impact on water resources. Water Wheel, May–June 2023. pp. 8–28. Available from: https://www.wrc.org.za/wp-content/uploads/mdocs/WW%20May%20-%20June%202023_WOODY%20ENCROACHMENT.pdf

[27] Aldworth, T.A., Toucher, M.L.W., Clulow, A.D., et al., 2023. The Effect of Woody Encroachment on Evapotranspiration in a Semi-Arid Savanna. Hydrology, 10(1), 9. DOI: https://doi.org/10.3390/hydrology10010009

[28] Cambray, J.A., 2003. Impact on indigenous species biodiversity caused by the globalisation of alien recreational freshwater fisheries. Hydrobiologia. 500(1), 217–230. DOI: https://doi.org/10.1023/A:1024648719995

[29] Richardson, D., Van Wilgen, B., 2004. Invasive alien plants in South Africa: How well do we understand the ecological impacts? Working for water. South African Journal of Science. 100(1), 45–52. Available from: https://hdl.handle.net/10520/EJC96214

[30] Harvey, P., Reed, R., 2007. Community-managed water supplies in Africa: sustainable or dispensable?. Community Development journal. 42(3), 365–378. DOI: https://doi.org/10.1093/cdj/bsl001

[31] Postel, S., 2000. Entering an era of water scarcity: The challenges ahead. Ecological applications. 10(4), 941–948. DOI: https://doi.org/10.1890/1051-0761(2000)010[0941:EAEOWS]2.0.CO;2

[32] Knox, A., Meinzen-Dick, R., 1999. Property rights, collective action and technologies for natural resource management. Policy Brief no. 1, October 1998.

[33] Singh, P., Milshina, Y., Tian, K., et al., 2020. Water conservation and wastewater treatment in BRICS nations: Technologies, challenges, strategies and policies. Elsevier: Amsterdam, The Netherlands. pp. 353–363.

[34] Basdew, M., Jiri, O., Mafongoya, P., 2017. Integration of indigenous and scientific knowledge in climate adaptation in KwaZulu-Natal, South Africa. Change and Adaptation in Socio-Ecological Systems. 3(1), 56–67. DOI: https://doi.org/10.1515/cass-2017-0006

[35] Mrabet, R., 2002. Stratification of soil aggregation and organic matter under conservation tillage systems in Africa. Soil and Tillage Research. 66(2), 119–128. DOI:

https://doi.org/10.1016/S0167-1987(02)00020-X

[36] Andersson, J., D'Souza, S., 2014. From adoption claims to understanding farmers and contexts: A literature review of Conservation Agriculture (CA) adoption among smallholder farmers in southern Africa. Agriculture, Ecosystems & Environment. 187, 116–132. DOI: https://doi.org/10.1016/j.agee.2013.08.008

[37] Finn, M., Jackson, S., 2011. Protecting indigenous values in water management: A challenge to conventional environmental flow assessments. Ecosystems. 14(8), 1232–1248. DOI: https://doi.org/10.1007/s10021-011-9476-0

[38] Dyson, M., Bergkamp, G., Scanlon, J., 2003. Flow: The essentials of environmental flows. IUCN: Gland, Switzerland & Cambridge, UK. pp. 1–136.

[39] Jacob, D., Nelson, I., Izah, S., 2024. Indigenous water management strategies in the Global South. In: Izah, S.C., Ogwu, M.C., Loukas, A., et al. (Eds.). Water Crises and Sustainable Management in the Global South. Springer: Singapore. pp. 487–525. DOI: https://doi.org/10.1007/978-981-97-4966-9_16

[40] Zvobgo, L., Johnston, P., Williams, P., et al., 2022. The role of indigenous knowledge and local knowledge in water sector adaptation to climate change in Africa: A structured assessment. Sustainability Science. 17, 2077–2092. DOI: https://doi.org/10.1007/s11625-022-01118-x

[41] Bryan, E., Deressa, T., Gbetibouo, G., et al., 2009. Adaptation to climate change in Ethiopia and South Africa: options and constraints. Environmental Science & Policy. 12(4), 413–426. DOI: https://doi.org/10.1016/j.envsci.2008.11.002

[42] Ziervogel, G., New, M., van Garderen, E., et al., 2014. Climate change impacts and adaptation in South Africa. Wiley Interdisciplinary Reviews: Climate Change. 5(5), 605–620. DOI: https://doi.org/10.1002/wcc.295

[43] Prins, F., Etale, A., Ablo, A., et al., 2022. Water scarcity and alternative water sources in South Africa: Can information provision shift perceptions?. Urban Water Journal. 20(10), 1438–1449. DOI: https://doi.org/10.1080/1573062X.2022.2026984

[44] Alexander, C., Bynum, N., Johnson, E., et al., 2011. Linking indigenous and scientific knowledge of climate change. BioScience. 61(6), 477–484. DOI: https://doi.org/10.1525/bio.2011.61.6.10

[45] Muller, M., 2009. Adapting to climate change: Water management for urban resilience. In: Muller, M. (ed.). Adapting Cities to Climate Change. Routledge: London, UK. pp. 291–307. https://doi.org/10.1177/0956247807076726

[46] Viljoen, G., van der Walt, K., 2018. South Africa's water crisis-an interdisciplinary approach. Tydskrif vir Geesteswetenskappe. 58(3), 483–500.

[47] Anderson, E., Jackson, S., Tharme, R., et al., 2019. Water scarcity and alternative water sources in South Africa: can information provision shift perceptions?. Wiley Interdisciplinary Reviews: Water. 6(6), e1381. DOI: https://doi.org/10.1002/wat2.1381

[48] Briggs, J., Sharp, J., 2004. Indigenous knowledges and development: A postcolonial caution. Third World Quarterly. 25(4), 661–676. DOI: https://doi.org/10.1080/01436590410001678915

[49] Middleton, B., Bailey, A., 2011. Water resources of South Africa. Report number TT 513/11, Nov 2011. Available from: https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/TT%20513-11.pdf

[50] Bakker, K., 2007. The "commons" Versus the "commodity": Alter-globalization, anti-privatization, and the human right to water in the Global South. Antipode. 39(3), 430–455. DOI: https://doi.org/10.1111/j.1467-8330.2007.00534.x

[51] DWS, 2021. Strategic Report number RP83/2021, 9 March, 2021. Available from: https://www.dws.gov.za/documents/Other/Strategic%20Plan/2021/Revised2020-21To2024-2025StrategicPlan_09March2021.Rev01.pdf

[52] Madzivhandila, T.S., 2024. Integrating Indigenous Knowledge Systems (IKS) to Climate Change Adaptation in South Africa: Lessons from the "Past". South African Journal of Higher Education. 38(5), 159–168. DOI: https://doi.org/10.20853/38-5-6417

[53] Richter, B., Mathews, R., Harrison, D., et al., 2003. Ecologically sustainable water management: managing river flows for ecological integrity. Ecological Applications. 13(1), 206–224. DOI: https://doi.org/10.1890/1051-0761(2003)013[0206:ESWMMR]2.0.CO;2