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Water security in Southern Africa: addressing climate change, governance failures, and infrastructure challenges through adaptive solutions

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Water security is a major challenge in Southern Africa where climate change, weak governance, and aging infrastructure threaten sustainable water access. The paper aims to assess the state of water security in Southern Africa and highlight adaptive strategies for sustainable management. Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020), the paper synthesize existing research on water availability, climate change, infrastructure, and governance focusing on Botswana, Mozambique, Namibia, South Africa, Zambia, and Zimbabwe. Findings reveal significant inequalities in water access: rural households face unreliable and unsafe supplies, while urban systems are strained by population growth. Climate-induced droughts and floods intensify scarcity, threatening agriculture, energy, and health. Poor institutional coordination and limited investment further constrain effective water management. Women in rural areas bear unequal water collection burdens, deepening inequities. The paper calls for sound water governance and investment in climate-resilient infrastructure. It also advocates for regional cooperation and gender-inclusive policies to ensure fair and sustainable water access. By consolidating fragmented literature, it contributes actionable insights for policy and resilience planning. Its implications extend to guide policymakers in developing adaptive, fair, and long-term water management strategies in response to growing climate and socio-economic pressures.

KEYWORDS

climate change, governance, infrastructure, Southern Africa, water security

1 Introduction

Water security is one of the main global challenge of the 21st century. The growing population exacerbates pressure on resources, while climate variations intensify extreme weather. As a result, water scarcity is becoming widespread across many region of the world. According to UNESCO (2019), about two-thirds of the population live under conditions of high water stress. The situation is expected to worsen in the already problematic regions, such as Latin America, the Middle East, North Africa, and some parts of South Asia. Several countries in Latin America are already facing droughts with severe rationing affecting millions of people (Associated Press, 2025). Middle Eastern and North African (MENA) countries are naturally deficient in water resources. This is due to arid climates and further problems caused by human activities, such as overexploitation and groundwater pollution (Hazarika and Kar, 2024). In South Asia, about 74% of the

population is presently in conditions of very high water stress and from unsustainable sources where the supply does not meet their demand (Amparo-Salcedo et al., 2025; Kuzma et al., 2023). The global water crisis accentuates the imperative of integrated, sustainable water management solutions that address environmental and governance challenges. This implies that gaining a good understanding of these global challenges is a prerequisite for comprehensively addressing water security.

In Africa, water shortages and infrastructure deficits heighten the crisis. Some of the driest regions are located on the African continent, comprising the Sahel and East and Southern African regions. A combination of factors, such as rapid population growth, urbanization, and climate change has increased the pressure on already limited water resources (Center for Strategic and International Studies (CSIS), 2025; Isaacman and Musemwa, 2021; Mokone and Gumede, 2024, 2025), thus presenting a large number of clean water deprivation among millions across this continent to create a challenge for most countries meeting United Nation's water target set under its Sustainable Development Goal 6. The Goal aimed to achieve universal access to water and sanitation by 2030 (UNICEF, 2023). Access to resources is uneven, with some people achieving a lot while others especially those in rural areas or from disadvantaged groups, face greater risks during times of insecurity. Ethiopia, Kenya, and Somalia are among the nations categorized as extremely water-stressed, where rainfall patterns are increasingly perturbed, threatening agriculture, health, and energy production. Hydropower accounts for much of Kenya's energy, making the country vulnerable to changes in precipitation and river flows that are becoming increasingly uncertain with climate change. Despite much research, in Africa, there remain significant gaps in understanding how the interacting dynamics of rising population pressures, climate change, and infrastructural inadequacies coalesce into problems of inequality in access to water.

The Southern African region is the most vulnerable to water scarcity in arid and semi-arid conditions. Though it lies within the African continent, this particular sub-region shares the country's climate variability among the most extreme worldwide, with prolonged droughts interspersed by periods of generally below-normal rainfall (Siderius et al., 2018). Already one of the driest regions in the world, these factors intensify an already formidable problem by increasing evaporation and decreasing precipitation, resulting in more frequent and intense droughts and floods (Kusangaya et al., 2014; Petja et al., 2022). This is the situation that Botswana, Namibia, and South Africa have mostly faced. In South Africa, for example, the city of Cape Town almost ran out of water during its 2018 "Day Zero" crisis, highlighting the country's vulnerability to water shortages, even when it has comparatively good supplies (Calverley and Walther, 2022). In Zimbabwe, increasingly frequent droughts result in acute water shortages, particularly in rural areas where there are no systems to rely on and households depend heavily on rain-fed agriculture (Tanyanyiwa and Kanyepi, 2021). Most existing research on water security in Southern Africa has focused on one of the three core dimensions—climate change, or governance, or infrastructure—without adequately addressing how these dimensions interact. Despite the long-standing vulnerability of water scarcity, a significant lacuna remains in understanding how the intersection of climate change, governance, and infrastructure worsens the water stress in the Southern African region (Siderius et al., 2018; Kusangaya et al., 2014; Petja et al., 2022; Tanyanyiwa and Kanyepi, 2021). The lack of research on climate change, governance, and infrastructure, suggests that the broader impacts of water insecurity have not been fully addressed, especially for rural and vulnerable communities. Therefore, an integrated approach that consider and addresses all three dimensions: climate, governance, and infrastructure—remains a significant gap in the existing literature.

The existing research on water security across the Southern African region has focused mostly on governance, identifying inadequacies and ensuring that water resource management is sound. For example, the Republic of South Africa (1998) became a progressive participatory governance not only to distribute water equitably but also to implement integrated water resource management (IWRM). On paper, the act appears to have a comprehensive framework, but in practice, it does not work, leaving a gap between the policy's intention and actual outcomes. Implementation has been undermined by several challenges, including limited local governance capacity to support IWRM and insufficient funds to finance it fully. Similarly, inadequate and disconnected institutional frameworks have rendered the implementation of water governance policies ineffective in Zimbabwe. Challenges destabilized and continue to undermine the stability of water supply and provisioning of services that were built up in the urban setup, particularly in a city like Harare, where dimensions of governance failure compound (Tanyanyiwa and Kanyepi, 2021). The most instrumental accounts are those of Bakker (2017), Tanyanyiwa and Kanyepi (2021), and the Water Research Commission [WRC] (2017) on the crucial aspects of governance failures. This has brought to light how institutional weaknesses precipitate the condition through inadequate policy support and fragmented governance frameworks that fail to control the situation properly; thus, water insecurity is exacerbated. Governance failures do not take into consideration the increasing effects of climate change on the capacity of already weakened institutions. In addition, governance studies have overlooked the importance of infrastructure in water management. As a result, service failures arise from deteriorated infrastructure or underinvestment in climate-resilient technologies. Thus, a substantial gap in the literature becomes evident. In such a case, the existing gap suggest that the literature has missed a significant opportunity. Therefore, the gap between governance, climate change, and infrastructure calls for better integration of institutional capacity with climate impacts and infrastructure resilience pathways that drive water security outcomes.

While governance and climate change have been central attention of many studies, water infrastructure has often been treated as a tertiary issue in the literature. Infrastructure challenges in Southern Africa are largely a rural phenomenon; old systems or the total lack thereof continue to militate against effective water delivery. Households in Mozambique, South Africa, and Zambia lack access to potable water due to infrastructure deficits in rural areas, where most households depend on unsafe sources such as rivers and unprotected wells (AIM News, 2024; Mokone and Gumede, 2024; World Bank, 2020). The outdated infrastructure in most urban areas is also associated with frequent shortages

stemming from inefficiencies in the system; for example, in the city of Harare, Zimbabwe, infrastructure failures have rendered the supply highly unreliable, thereby compounding water access challenges during high-demand periods (Tanyanyiwa and Kanyepi, 2021). Though these technical challenges are highlighted in infrastructure studies, they are more often than not separated from broader governance and climate change contexts. For instance, an infrastructure study does not discuss the failure of governance that has allowed so much degradation, because it is not strictly an infrastructural problem. Similarly, the impacts of climate change, including droughts and rains that do not fall within normal patterns, are seldom related to problems of infrastructure, even though resilient, climate-adaptive infrastructure is relied upon to cope with such environmental stresses.

From the foregoing, the significant gap in the literature on water security in Southern Africa is the lack of integrated research on the interaction between climate change, governance, and infrastructure. Therefore, this paper seeks to bridge this lacuna by offering a more integrated framework for climate change adaptation, improved governance practices, and infrastructure development. It also highlights gendered aspects of water governance that are normally marginalized. This further focus the discussion on water security in Southern Africa and provide new, actionable recommendations for improving this critical resource. In simple terms, it constitutes a novel contribution by integrating climate change analysis with governance and water infrastructure within a single framework in Southern Africa. Challenges and adaptive solutions that synthesize the interlinked nature of water security come from an essentially comprehensive review of literature findings on climate change, governance, and infrastructure. More pragmatically, these constitute results to be translated into recommendations for policymakers and regional bodies in their quest for better water governance systems, higher resilience to climatic shocks, and equitable access to water across all strata of the different sectors.

The article is organized as follows: after the current introduction, follows the materials and methods, findings and discussions. Lastly, the conclusion and recommendations

2 Materials and methods

2.1 Study design

A systematic literature review was conducted according to the PRISMA 2020 protocol, which is a research method that employs systematic and transparent procedures to identify, select, assess, and synthesize studies aimed at achieving specific research

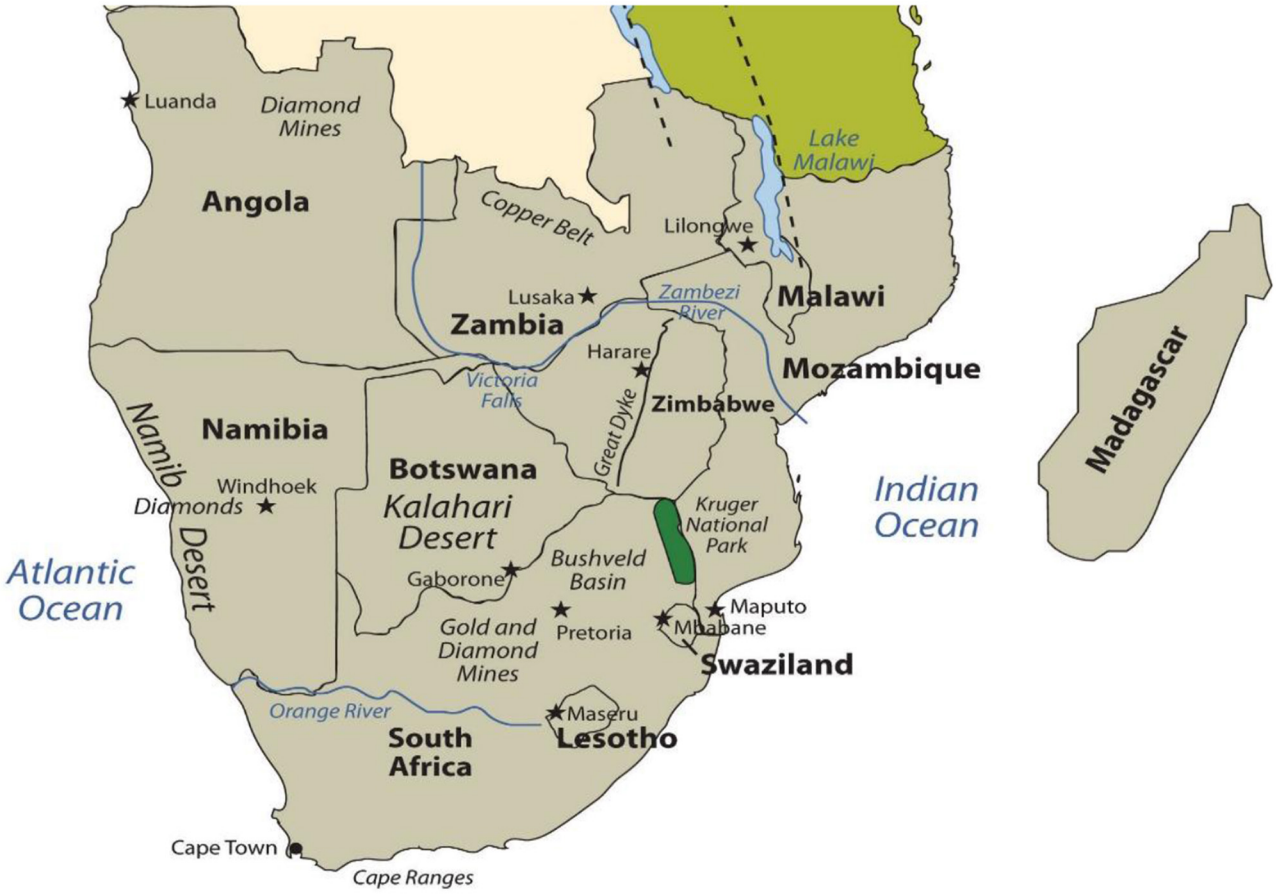

FIGURE 1
Map of Southern Africa. Source: LibreTexts (2023).

objectives (Page et al., 2021). The PRISMA framework ensures clear and open reporting of the review's objectives, methodologies, and outcomes. The review focuses on studies related to water availability, access, infrastructure, governance, and the impacts of climate change within the region.

2.2 Eligibility criteria

The inclusion criteria for this review are studies that address water security issues within Southern Africa. It includes studies that deal with problems of water security in the countries of Southern Africa. It thus covers the countries such as Botswana, Lesotho, Malawi, Namibia, South Africa, Zambia, and Zimbabwe. As depicted in Figure 1 on the map below. Studies considered eligible include peer-reviewed articles, policy documents, and reports that contain empirical data, either as case studies or analyses of the region's water security situation. The studies must also be published between 2015 and 2025 in English. Exclusion criteria included studies that fall outside the Southern African context, those that fall outside the subject of water security, and those having inadequate empirical evidence or relevance to this study on climate change and water governance. A map highlighting the countries considered in the study, including Botswana, Lesotho, Eswatini, Malawi, Namibia, South Africa, Zambia, and Zimbabwe is depicted in Figure 1:

2.3 Information sources

Data for this systematic review were collected from academic databases such as Google Scholar, Research Gate, Scopus, and Web of Science. Over and above peer-reviewed journal articles, gray literature from government reports, policy documents, and publications from international organizations (e.g., the Southern African Development Community, World Bank) was included to ensure a comprehensive understanding of the regional water security context.

2.4 Search strategy

To leverage the strengths of PRISMA as a systematic literature review methodology, peer-reviewed articles were sourced from Google Scholar, Research Gate, Scopus, and Web of Science. Search terms included "water security," "Southern Africa," "climate change," "water infrastructure," "water availability," and governance of water resources." Boolean operators AND/OR were used to combine various permutations of the above words in order to filter the search. The timeframe was set from 2015 to 2025 to ensure recent studies could be identified, thus meeting the requirements of this article. This search across these databases yielded the articles, reports, and case studies that meet this article's criteria. Table 1 shows both the generic and refined search criteria. Both searches were conducted from 02 April 2025. Table 2 show additional information that led to the exclusion and inclusion of other articles.

TABLE 1 Search criteria—generic and refined (search conducted from 02 April 2025).

Search type	Search criteria	Database used	Date of search	Documents yielded
Generic	"water security", "Southern Africa", "climate change", "water infrastructure", "water availability", "governance of water resources"	Google Scholar, Research Gate, Scopus, and Web of Science.	02 April 2025	204
Refined	"water security AND Southern Africa AND climate change AND water security AND infrastructure AND governance of water resources"	Google Scholar, Research Gate, Scopus, and Web of Science.	02 April 2025	134

TABLE 2 Reasons for inclusion and exclusion of articles.

Inclusion criteria	Exclusion criteria
Studies focusing on water security issues in Southern Africa	Articles outside the Southern African context
Studies published in English between 2015 and 2025	Studies not related to water security or governance
Empirical studies, policy documents, reports	Studies lacking sufficient empirical evidence or relevance to climate change and governance
Studies covering water availability, access, infrastructure, governance, and climate impacts	Studies that were duplicates
Relevant gray literature from government reports and international organizations	Articles without full text or empirical data

2.5 Article selection and assessment

A total of 209 articles were identified in Google Scholar, Research Gate, Scopus, and Web of Science. After duplicates were removed, 204 articles remained to be thoroughly screened. The article selection process followed a two-step procedure. From the 209 articles that were identified initially, five (5) duplicates were removed and 204 articles were screened. Initially, titles and abstracts of articles were screened for relevance to the article's focus on water security, climate change, and Southern Africa. In the second step, the full text of the remaining 134 articles was assessed for eligibility, and a further sixty (60) articles were removed based on the inclusion and exclusion criteria. A PRISMA

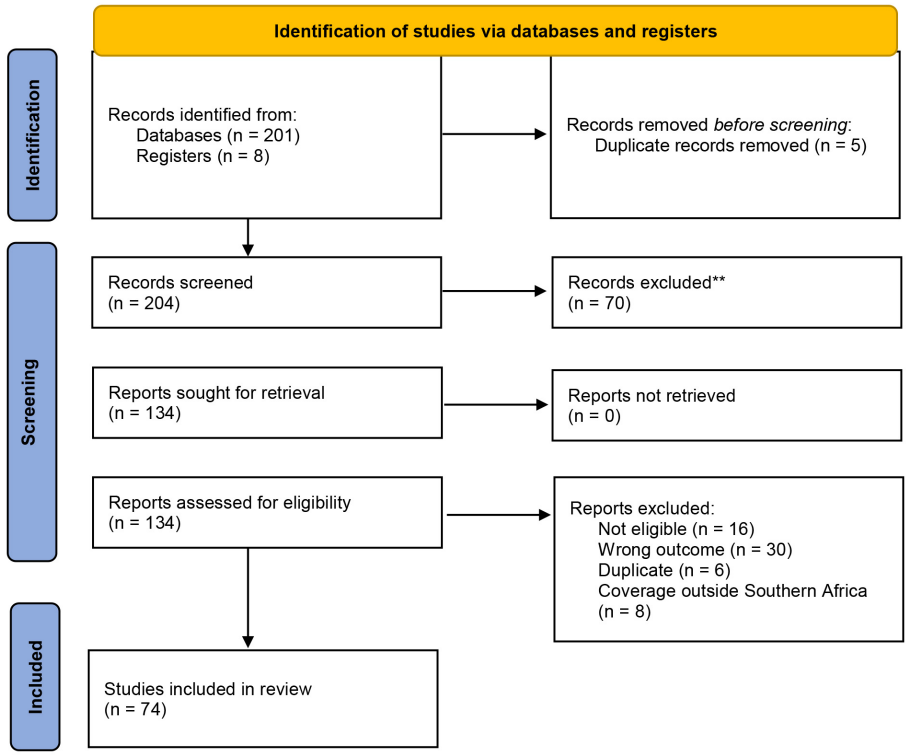

FIGURE 2
PRISMA flow diagram.

flowchart, shown in Figure 2, illustrates the number of studies identified, screened, assessed for eligibility, and included in the final review.

2.6 Data extraction

Data were extracted from the selected studies, covering details on water availability, infrastructure reliability, climate change, and governance mechanisms. Data extraction was done using a structured Excel template, capturing key details such as the study's location, methodology, findings, and the specific challenges addressed. This process was standardized to ensure consistency and comprehensiveness.

2.7 Synthesis of results

The results were blended using a narrative synthesis strategy. Studies were grouped according to key themes such as climate change, water availability and access, infrastructure challenges, governance, and climate adaptation strategies. Successively, findings were then analyzed to identify common patterns, regional differences, and the importance of water governance and infrastructure in influencing water security. Where applicable and relevant, statistical data from the included studies were combined to provide a clearer understanding and a holistic picture of the regional water security status.

3 Results and discussions

This section presents the findings and discussions concurrently. Seven themes have been identified and are discussed below:

3.1 Water availability and access

Water availability is highly uneven in Southern Africa, with most of the region faced extreme dry climate, with precipitation anomalies and rising temperatures. Urban centers with better infrastructure, such as Cape Town in South Africa and Lusaka in Zambia, are facing resource overexploitation and strain, while rural areas in countries like Mozambique and Zimbabwe are struggling with drinking water challenges. For instance, Mozambique indicates access to improved water sources for only 45% of its rural population compared to 82% of the urban population (World Bank, 2022; AIM News, 2024). Similarly, most of the rural population in Zimbabwe also depends on unprotected sources, increasing vulnerability toward water-borne diseases (United Nations Development Programme, 2021). Such disparities in water supply, therefore, create a need for demands that the different urban and rural sectors allocate more water to meet their specific needs. This finding aligns with the works of Kusangaya et al. (2014) and Olivier and Marchand (2020), which document that rural areas have a predominantly insufficient and unreliable water supply. In contrast, urban areas are overwhelmed by population growth. Hence, policymakers have to prioritize

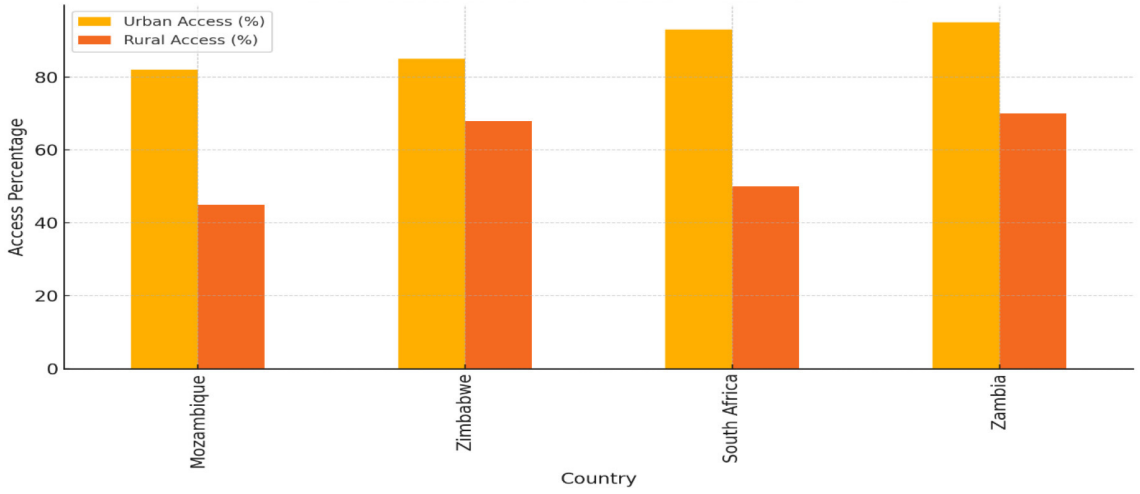

FIGURE 3
Water access (urban vs. rural) in Southern Africa.

infrastructure development in rural and peri-urban areas with a focus on sustainable water resources as well as improvement in the water distribution systems. Solar-powered pumps and rainwater harvesting are among immediate relief interventions that can be adopted. As shown in Figure 3, water access significantly varies between urban and rural areas in Southern Africa, with rural populations in Mozambique, Zimbabwe, and South Africa facing greater challenges in accessing reliable water sources.

3.2 Infrastructure challenges

Infrastructure remains the major challenge for water security in Southern Africa, as it is a problem mainly in rural and peri-urban areas where basic water supply systems do not exist or are unreliable or poorly maintained. For example, Harare, in Zimbabwe, faces challenges with its aging water infrastructure because the city cannot keep up with demand driven by the increasing population (Tanyanyiwa and Kanyepi, 2021). Zambia is another country that has been facing challenges in securing sufficient support for infrastructure to keep up with its increasing population in the urban area, though efforts have been made to improve service coverage (World Bank, 2018; Olivier and Marchand, 2020). This fairly reflects and align with the Bertelsmann Stiftung (2024) findings regarding deficits in the region's water infrastructure. Largely, infrastructure maintenance is poor and investment is inadequate; hence, access to water cannot be reliable unless infrastructure is upgraded to increase coverage and reliability, as emphasized by the World Bank (2018). Governments, local authorities, and international organizations should work within a long-term investment plan targeting both system upgrades and the expansion of water supply infrastructure in underserved areas, accompanied by capacity building for local authority-owned and managed water systems, supported by public and private financing. Table 3 has summarized the infrastructure challenges across the Region.

3.3 Climate change and water resources

Findings revealed that climate change in Southern Africa is punishingly exacerbating a grave situation concerning water scarcity through rainfall distribution and intensified evaporation accompanied by dry spells and floods. A strong, one of the largest recorded-2015–2016 El Niño brought extreme drought to Southern Africa, impacting agricultural hydrology dependent on rainfall significantly. Zambia experienced low hydroelectric capability due to decreased precipitation and low reservoir water levels, and Botswana faced dry conditions that affected their water supply systems and low lake levels (Siderius et al., 2018). Such incidents once again proved, with evidence now growing stronger, that this climatic zone happens to be extremely vulnerable when involved in climate-induced conflict regarding resources; therefore, adaptive management of water resources should take precedence (Gannon et al., 2018). The agricultural sector uses most of the available water resources; hence, Chipomho et al. (2024) argued about how complicated it is to predictively manage challenges in availability due to increased variability resulting from climate change. Governments must adopt climate-resilient water management policies, such as building water storage infrastructure to manage variable rainfall and investing in climate-smart irrigation systems. Water conservation measures should also be promoted through public awareness campaigns and incentivizing water-efficient technologies in both urban and rural areas. Table 4 presents the impact of climate change on water resources, particularly drought and shifting rainfall patterns.

TABLE 3 Infrastructure challenges in water supply.

Country	Urban Access to infrastructure (%)	Rural Access to infrastructure (%)	Findings	References
Mozambique	75%	55%	Inadequate water supply systems in rural areas leading to reliance on unsafe sources.	Nhaurire and Capurchande, 2025; David, 2021
South Africa	85%	50%	Municipalities in rural areas struggle with implementation of water policies.	Water Research Commission, 2017
Zambia	80%	60%	Urban areas face outdated infrastructure, and rural areas suffer from lack of investment.	World Bank, 2018; Olivier and Marchand, 2020
Zimbabwe	75%	45%	Aging infrastructure in urban areas; rural areas have severe deficits.	Tanyanyiwa and Kanyepi, 2021; Water Corporation, 2024

TABLE 4 Impact of climate change on water resources.

Country	Climate event	Impact on water resources	Findings	References
Botswana	Prolonged Drought	Lower lake levels, water scarcity	Drought caused severe impacts on agriculture and water supply systems.	World Bank, 2021a,b; Omari et al., 2023
Namibia	Increased Temperatures	Higher evaporation rates	Extended droughts led to agricultural water demand issues and scarcity.	David, 2021; Chipomho et al., 2024
Zambia	2015-2016 El Niño	Decreased hydroelectric power generation	Low water levels in reservoirs, leading to power shortages.	Siderius et al., 2018; Pulitzer Cener, 2023

TABLE 5 Governance issues in Southern Africa.

Country	Key governance issue	Findings	References
South Africa	Local government capacity issues	Poor technical capacity at local government levels prevents effective policy enforcement.	Water Research Commission, 2017; Mokone and Gumede, 2025; Olivier and Marchand, 2020
Zambia	Weak institutional coordination	Inadequate coordination between sectors exacerbates water access issues.	Patole, 2015; SADC-GMI, 2025
Zimbabwe	Political instability	Corruption and weak enforcement hinder water policy implementation.	Tanyanyiwa and Kanyepi, 2021; Bertelsmann Stiftung, 2024

3.4 Governance and policy frameworks

Poor governance, institutional fragmentation, and inconsistent policy implementation have been noted as significant challenges in achieving successful water management. For example, in Zimbabwe, policies on water governance do exist; however, enforcement at community levels has been rated poorly due to political instability and corruption. This has led to several problems, including infrastructure in a state of disrepair and unequal access to water in many urban cities, such as Harare, which has an unreliable supply, among others. Such was noted by Tanyanyiwa and Kanyepi (2021) as well as Bertelsmann Stiftung (2024), who described how political instability and weak institutional capacity in Zimbabwe compound problems relating to issues of water management. Challenges of water governance in Zambia relate weakly to the coordination of national and local authorities. Patole (2015) and SADC-GMI (2025) noted that ineffective governance and poor coordination contribute much to problems related to access to water. Thus, there is a need for the strengthening of institutional frameworks at both the local and national levels. This can be achieved by capacity building of the institutions on water management at all levels of government and improving the coordination between these agencies, which should have a clear policy on water pricing, with tiered pricing promoting equity but encouraging conservation. Table 5 highlights the main challenges in governance and how they affect water security.

3.5 Equity and social inequalities in water access

The central thematic factor in Southern Africa is thus equity of access, because, as noted, huge rural populations, plus marginalized groups—mostly women—face an acute water shortage. In most rural households, the burden of procuring water falls on women. This takes up a lot of their time, which could be used for other productive ventures, such as attending school or engaging in economic activities. These findings concur with those of Naiga et al. (2023) and Nhamo and Mutanda (2024), who also found that rural women are mainly responsible for fetching water, thereby increasing gender inequality. This type of inequality

TABLE 6 Social inequalities in water access.

Country	Urban vs. Rural disparities	Rural water access (%)	Gender Disparities (%)	Findings	References
Mozambique	Urban areas have better access	45%	80% of rural women fetch water	Significant disparity between rural and urban access, particularly for women.	Nhaurire and Capurchande, 2025; UNICEF, 2023
South Africa	Major urban areas have higher coverage	50%	65% of rural women fetch water	Rural areas lack basic water supply and have low sanitation access.	Greenpeace Africa, 2023; Mokone and Gumede, 2025
Zambia	Rural areas have poor water systems	70%	60% of rural women fetch water	Rural Zambians face issues of access, with women bearing the brunt of water collection.	World Bank, 2020; Siderius et al., 2018
Zimbabwe	Rural areas face unreliable sources	67.9%	70% of rural women fetch water	Rural areas struggle with unreliable infrastructure and poor water quality.	United Nations Development Programme, 2021; Tanyanyiwa and Kanyepi, 2021

TABLE 7 Climate-induced vulnerabilities and adaptation strategies.

Country	Climate impact	Vulnerability	Adaptation strategy	Findings	References
Botswana	Prolonged droughts, rising temperatures	Decreased water supply, impacts on agriculture	Adoption of climate-smart agriculture, water conservation techniques	Extreme weather events exacerbate water scarcity in semi-arid areas.	World Bank, 2021a,b; Omari et al., 2023
Mozambique	Extreme rainfall and flooding (2019)	Destruction of water infrastructure, increased disease risks	Strengthening flood protection, disaster response systems	Flooding worsens the reliability of water systems, especially in rural areas.	Nhaurire and Capurchande, 2025
Namibia	Reduced rainfall, higher evaporation rates	Increased droughts, impacts on food security	Enhanced water storage, soil moisture conservation	Prolonged dry spells reduce water availability for both domestic and agricultural needs.	David, 2021; Chipomho et al., 2024
South Africa	Cape Town water crisis (2018), erratic rainfall	Urban water systems stressed, water demand outpacing supply	Investment in water infrastructure, public water conservation campaigns	Urban centers like Cape Town face severe water stress from drought and population growth.	Calverley and Walther, 2022; Mokone and Gumede, 2025
Zambia	2015–2016 El Niño drought	Reduced water availability for agriculture, hydropower	Rainwater harvesting, improved irrigation techniques	Droughts lead to water shortages, particularly affecting hydroelectric power generation.	Siderius et al., 2018; Pulitzer Cener, 2023

prevents women from engaging in other educational or income-generating activities by consuming time that would otherwise be available for them. For example, this problem is seen in Mozambique, where 80% of rural women are responsible for collecting water, while in Zimbabwe is 70% and in South Africa is 65% comparatively (UNICEF, 2023; Nhamo and Mutanda, 2024). These findings are consistent with Naiga et al. (2023). Collecting water in most rural areas is highly gendered as shown by the findings. The overwork placed on women amplifies existing gender inequalities. It reduces the time that women can use for productive economic and educational activities. Water governance policies must therefore, adopt a gender perspective and ensure the representation of women's voices in decision-making at all levels. Relatively, supporting women's roles in water collection and management, as well as community-based water management programs, is important for achieving water security and promoting gender equality. An integrated policy that tackles these inequalities promotes gender governance in the water sector. Also, community-based water management programs that support women's roles in water collection and management can aid to achieve both water security and gender equality. Social inequalities with a focus on rural, marginalized, and female-headed households in Southern Africa are summarized in Table 6.

3.6 Climate-induced vulnerabilities and adaptation

The results reveal that Southern Africa suffers from water scarcity due to climatic factors. Prolonged drought, extreme weather events, and changes in rainfall patterns reduce agricultural output in the semi-arid regions of Namibia and Botswana. As Liu and Zhou (2021) noted for Namibia, reduced rainfall adversely affects smallholder agriculturalists. Botswana is more vulnerable to drought because it receives less rainfall, which is accompanied by high evaporation rates, leading to food insecurity. Three consecutive years of below-average rainfall had already brought dam levels to dangerously low levels long before what was termed Day Zero could occur in Cape Town, South Africa, as an example of the urban impacts of water shortages and a clear need for resilient management. Such includes adaptive strategies

TABLE 8 Gendered burden of water collection.

Country	Percentage of women responsible for water collection (%)	Findings	References
Mozambique	80%	Women in rural areas are predominantly responsible for water collection, limiting time for other activities.	UNICEF, 2023; World Bank, 2024
South Africa	65%	Women in rural areas face significant time burdens fetching water, limiting economic and educational opportunities.	Nhamo and Mutanda, 2024; UNICEF, 2023
Zimbabwe	70%	Women's water collection burdens exacerbate gender inequality in rural areas.	Naiga et al., 2023; Tanyanyiwa and Kanyepi, 2021

such as rainwater harvesting and efficient irrigation systems that governments should enforce, among many other climate-smart practices, to minimize farmers' vulnerability to the negative effects of droughts; specifically, promoting drip irrigation and rainwater harvesting together with soil moisture conservation integrated into farming practices. Such measures can help address water shortages and make food safer amid changing weather patterns. New methods for obtaining water can be used alongside conventional sources, helping build strength in areas with limited water. Table 7 lists exact climate dangers, the countries hit, and plans for how to adjust.

3.7 Gender and water governance

The issue of water governance thus easily falls within the gendered contours as per these findings in Southern Africa. Rural women are mostly at the lower end of the water insecurity spectrum. Since it is women who, in most cases, have to fetch water for the household, they do not find time to participate in educational and economic activities just like their male counterparts. The findings suggested that empowering women in water governance leadership would make it more sustainable and effective. Nhamo and Mutanda (2024) and Naiga et al. (2023), share the same sentiments, by stating that female inclusion leads to equity and sustainability in water governance. Also, fetching water is often a time-consuming task for women and girls, as reported by UNICEF (2023). A concerted effort should be made to involve women in water governance at all levels and aspects of decision-making. Policies should also consider gender-responsive budgeting so that the policy on water access is inclusive and equitable. Table 8 provides summation on: gender disparities in water collection tasks, particularly in rural areas. Followed by Table 9, which presents a summary of the key findings and themes of the study.

TABLE 9 Summary of key findings by theme.

Theme	Key findings	References
Water Availability and Access	Rural areas facing water shortages with uneven water security. Urban areas face pressure from over use of the resource. Mozambique has only 45% of the population in the rural areas with access to improved water sources.	Kusangaya et al., 2014; Olivier and Marchand, 2020
Infrastructure Challenges	Infrastructure is inadequate, especially in rural areas. Many regions lack basic water supply systems, while urban centers are overburdened.	Tanyanyiwa and Kanyepi, 2021; Olivier and Marchand, 2020
Climate Change and Water Resources	Climate change exacerbates water scarcity, causing more frequent droughts and altering rainfall patterns. The 2015-2016 drought severely impacted hydropower generation.	Chipomho et al., 2024; Kusangaya et al., 2014
Governance and Policy Frameworks	Fragmented governance and weak enforcement of water regulations contribute to uneven water distribution. Zambia and Zimbabwe face political instability that hinders effective management.	Tanyanyiwa and Kanyepi, 2021; Nhamo and Mutanda, 2024
Equity and Social Inequalities in Water Access	Significant inequities exist between urban and rural areas. Women are particularly burdened, limiting their educational and economic opportunities.	Naiga et al., 2023; Nhamo and Mutanda, 2024
Climate-Induced Vulnerabilities and Adaptation	Southern Africa is highly vulnerable to climate-induced water stress. Droughts and extreme weather events affect agricultural productivity, especially in semi-arid regions.	Chipomho et al., 2024; Mpandeli et al., 2019
Gender and Water Governance	Women, especially in rural areas, are disproportionately affected by water insecurity. Including women in water governance is crucial for sustainable water management.	Naiga et al., 2023; Nhamo and Mutanda, 2024

4 Conclusion

Water security is a serious growing concern in Southern Africa, where climate change, unreliable infrastructure, and poor governance are deteriorating the problem. The region is faced by a dry climate, with precipitation anomalies and rising temperatures resulting in water scarcity, especially in rural areas

where the communities depend on unsustainable sources. Poor governance, fragmented institutions, and political instability impede the effective management of water resources, increasing inconsistencies in access to water. The impacts of climate-induced stresses, such as drought or flooding, on agriculture, public health, and energy production provide a strong case for the urgent need for adaptation strategies; hence, large-scale investments in rural water infrastructure, accompanied by improved practices and institutional capacity to implement principles, are needed. In the context of gender-responsive, integrated, climate-resilient management practices, regional cooperation should be built to share cross-border water resources. Therefore, from the viewpoint of the paper, the following recommendations are made:

1. Challenges and adaptation strategies for water security in Southern Africa have been identified. What should logically follow is implementation, not another analysis. Integrated rainwater harvesting and water recycling at the household, community, and municipal levels can make a substantial difference if implemented. Measures of this sort greatly alleviate the strain on overburdened surface and groundwater resources, which rural and peri-urban settlements rely on when piped schemes fail to deliver adequate water supplies.
2. As part of adaptive water management, decentralized systems shall include piloting rooftop rainwater harvesting with the reuse of greywater in drought-prone areas. It can be used to assess and improve the situation throughout Southern African countries. Such projects can build and strengthen community resilience at the household level, thereby enhancing water security. Strengthening households supports policy drives toward sustainable and equitable water security through technology adoption, community participation, and policy innovation.
3. Research in the future should study the long-term impacts of climate change and local governance over water resources, and whether or not climate adaptation technologies on water resources prove effective. If such measures are adopted, the Southern African region will be able to improve its water security and build resilience against increasing climate and socioeconomic hardships.

Author contributions

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