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From scarcity to abundance: Innovative solutions for Africa's water crisis

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Abstract

Africa faces a critical water security challenge, with far-reaching implications for human health, economic development, and environmental sustainability. This article examines the continent's current state of water security, analyzing key challenges such as climate change impacts, rapid population growth, and significant infrastructure deficits. It reviews major policy frameworks and initiatives to address these challenges, including the African Water Vision 2025 and investments by the African Development Bank. The paper explores innovative approaches to enhance water security, presenting case studies from across the continent. It concludes by discussing the role of international cooperation and providing recommendations to strengthen water security policies. This comprehensive analysis aims to inform evidence-based policymaking and support the achievement of Sustainable Development Goal 6, ensuring water and sanitation for all by 2030.

Keywords: Water security; Climate change; Water pollution; Water infrastructure; Innovative technologies; Transboundary water management

1. Introduction: Current State of Water Security in Africa

The current state of water security in Africa presents a complex landscape of challenges and emerging opportunities. At the heart of the issue lies a stark reality: approximately 400 million people in sub-Saharan Africa lack access to basic drinking water services, representing nearly 40% of the region's population (WHO/UNICEF, 2021). This water scarcity has profound implications for the continent's public health, economic development, and social stability.

The spatial and temporal variability of freshwater resources in Africa exacerbates the water security challenge. Many regions face prolonged droughts, while others experience destructive floods, which are expected to intensify due to climate change. The Intergovernmental Panel on Climate Change (IPCC) identifies Africa as one of the most vulnerable continents to climate variability and change, projecting that between 75 and 250 million people will be exposed to increased water stress due to climate change by 2030 (IPCC, 2014).

Transboundary water management adds another layer of complexity to Africa's water security landscape. The continent has 63 transboundary river basins, covering about 64% of its land area and containing 93% of its total surface water resources (UNEP, 2010). Kanyerere et al. (2018) highlight that limited cooperation among riparian states in transboundary water management significantly impacts water quality and availability across national boundaries.

Infrastructure deficits further compound water security challenges in Africa. The African Development Bank estimates an annual infrastructure funding gap of \$68-108 billion, with a significant portion needed for water and sanitation projects (AfDB, 2018). This lack of investment has resulted in inadequate water storage, treatment, and distribution systems across much of the continent, particularly in rural areas and rapidly growing urban centers.

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Water pollution is an increasingly severe threat to water security in Africa. Nkiaka et al. (2021) reveal that a wide range of hazardous compounds have been detected in both surface water and groundwater, posing significant risks to human health and ecosystems. Industrial effluents, agricultural runoff, and inadequate sanitation facilities contribute to this growing problem, with implications for both human health and environmental sustainability.

Despite these challenges, there are signs of progress and innovation in addressing water security issues across Africa. The African Water Vision 2025, adopted by the African Union in 2000, set ambitious targets for improving water security across the continent. While progress towards these goals has been uneven, with some countries making significant strides while others continue to struggle, the vision has provided a crucial framework for action.

The African Development Bank has played a pivotal role in addressing water security challenges, investing over \$3.3 billion in water projects since 2003 (AfDB, 2020). These investments have supported various initiatives, including the Rural Water Supply and Sanitation Initiative and the African Water Facility, contributing to improved water access and management in numerous countries.

Innovative approaches are emerging to enhance water security in Africa. Climate-resilient water infrastructure projects are being implemented in several countries, with Ethiopia's Climate Resilient Green Economy strategy serving as a notable example of integrating water security considerations into broader economic and environmental planning.

Water resource mapping using geospatial technologies is another promising approach. Kapalanga et al. (2020) demonstrated the potential of Earth Observation techniques for large-scale monitoring of water resources, which could help address critical data gaps in the region and improve water resource management.

Integrated Water Resources Management (IWRM) is gaining traction as a holistic approach to water security. However, its implementation faces challenges due to fragmented governance structures and limited institutional capacity in many African countries. Addressing these governance issues will be crucial for the successful implementation of IWRM principles across the continent.

The role of international cooperation in addressing Africa's water security challenges cannot be overstated. Donor support and financing mechanisms have been crucial in driving progress. However, as Lefore et al. (2019) pointed out, there is a need for more sustainable and locally driven solutions, particularly in areas like irrigation governance.

Looking ahead, achieving water security in Africa will require a multi-faceted approach. This includes strengthening water governance structures, increasing investment in water infrastructure, promoting regional cooperation in transboundary water management, and leveraging innovative technologies for water resource monitoring and management. As the continent works towards meeting Sustainable Development Goal 6 (Clean Water and Sanitation) by 2030, addressing these water security challenges will be paramount for sustainable development and improved quality of life for millions of Africans.

2. Policy Frameworks and Initiatives

The African continent has witnessed the development of several policy frameworks and initiatives aimed at addressing water security challenges over the past few decades. These efforts reflect a growing recognition of the critical role water plays in sustainable development and the need for coordinated action to manage this vital resource.

One of the most significant policy frameworks is the African Water Vision 2025, adopted by the African Union in 2000. This vision set ambitious targets for improving water security across the continent, aiming to create "an Africa where there is an equitable and sustainable use and management of water resources for poverty alleviation, socio-economic development, regional cooperation, and the environment" (AMCOW, 2000). The vision outlined four key goals: strengthening the governance of water resources, improving water wisdom, meeting urgent water needs, and strengthening the financial base for the desired water future.

However, progress towards these goals has been uneven. While some countries have made significant strides, others continue to struggle with basic water access and management issues. A study by Kanyerere et al. (2018) highlighted that limited cooperation among riparian states in transboundary water management significantly impacts water quality and availability across national boundaries.

Sustainable Development Goal 6 (SDG6), which aims to ensure the availability and sustainable management of water and sanitation for all by 2030, has also become a crucial policy framework for African countries. However, achieving

this goal remains a significant challenge. Kapalanga et al. (2020) found that many African countries are not on track to meet SDG6 targets, citing issues such as inadequate infrastructure, insufficient funding, and weak governance structures.

The African Development Bank (AfDB) has played a crucial role in addressing water security challenges, investing over \$3.3 billion in water projects since 2003 (AfDB, 2020). These investments have supported various initiatives, including the Rural Water Supply and Sanitation Initiative and the African Water Facility. The AfDB's Water for Africa Initiative aims to provide universal access to safe water and sanitation across the continent by 2025.

Regional initiatives have also emerged to address specific water challenges. For instance, the Nile Basin Initiative, established in 1999, brings together ten countries sharing the Nile River to promote cooperative management and sustainable development of the basin's resources. Similarly, the Lake Chad Basin Commission, formed in 1964, works to manage the water resources of Lake Chad and its basin, which is shared by several countries in West and Central Africa.

Despite these policy frameworks and initiatives, implementation remains a significant challenge. Nkiaka et al. (2021) identified several barriers to effective water governance in Africa, including fragmented institutional arrangements, inadequate financing, and limited technical capacity. The authors emphasize the need for more integrated approaches to water management that consider the interconnections between water, energy, and food security.

Climate change adds another layer of complexity to water security policies in Africa. The Intergovernmental Panel on Climate Change (IPCC) projects that climate change will exacerbate existing water stress in many regions of Africa, with potentially severe consequences for food security, economic development, and human health. This underscores the need for climate-resilient water policies and infrastructure.

3. Innovative Approaches to Enhance Water Security in Africa

Africa faces numerous water security challenges, but innovative approaches are emerging to address these issues and enhance water security across the continent. These approaches span technological, policy, and management innovations, offering promising solutions to longstanding water-related problems.

One of the most significant innovations in recent years has been the application of remote sensing and Earth Observation (EO) technologies for water resource management. Kapalanga et al. (2020) demonstrate the potential of EO techniques for large-scale monitoring of water resources in Africa. These technologies allow for real-time monitoring of water bodies, assessment of water quality, and prediction of droughts and floods. For instance, the Africa Regional Data Cube, launched in 2018, uses satellite imagery to help five countries (Kenya, Senegal, Sierra Leone, Ghana, and Tanzania) address food security and issues related to agriculture, deforestation, and water access.

Another innovative approach gaining traction is the use of nature-based solutions (NBS) for water management. NBS involves working with nature to address societal challenges, providing both human well-being and biodiversity benefits. In the context of water security, NBS can include the restoration of wetlands for water purification, the creation of urban green spaces for stormwater management, and the protection of watersheds for water supply. Oral et al. (2020) highlight the potential of NBS in addressing water security challenges in Africa, particularly in urban areas facing rapid growth and climate change impacts.

Climate-resilient water infrastructure is another area of innovation crucial for enhancing water security in Africa. Given the continent's vulnerability to climate change, there is a growing focus on developing infrastructure that can withstand and adapt to changing climate conditions. Ethiopia's Climate Resilient Green Economy strategy is a notable example, integrating water security considerations into broader economic and environmental planning. This approach includes the development of multi-purpose dams that can provide water for irrigation, hydropower generation, and flood control, while also being designed to withstand increased variability in rainfall patterns.

In the realm of water supply and sanitation, decentralized systems are emerging as an innovative solution, particularly in peri-urban and rural areas where centralized infrastructure is lacking. These systems, which include technologies like rainwater harvesting, small-scale water treatment plants, and decentralized wastewater treatment systems, can provide more flexible and cost-effective solutions for water access. Eggimann et al. (2018) demonstrated the potential of decentralized systems in Africa, highlighting their ability to improve water access in areas not served by centralized infrastructure.

Digital technologies are also playing an increasingly important role in enhancing water security. Mobile applications for water point mapping and monitoring, such as the Water Point Data Exchange (WPDx), are improving data collection and decision-making in the water sector. These tools allow for real-time monitoring of water infrastructure, enabling quicker responses to breakdowns and more efficient resource allocation. Furthermore, blockchain technology is being explored for its potential to improve water governance and transparency in water transactions.

Innovative financing mechanisms are crucial for addressing the significant investment gap in Africa's water sector. Blended finance, which combines public, private, and philanthropic capital, is gaining traction as a way to mobilize additional resources for water projects. The African Development Bank's Room2Run initiative, launched in 2018, is an example of an innovative financing approach that could be applied to water sector investments.

These innovative approaches offer promising solutions to Africa's water security challenges. However, their successful implementation will require sustained investment, capacity building, and supportive policy frameworks. By embracing these innovations and addressing the barriers to their implementation, African countries can make significant strides toward achieving water security for all.

4. Role of International Cooperation in Enhancing Water Security in Africa

International cooperation plays a pivotal role in addressing water security challenges in Africa. The transboundary nature of many water resources, coupled with the complex interplay of socio-economic and environmental factors, necessitates collaborative efforts that transcend national borders.

4.1. Transboundary Water Management

Africa's 63 transboundary river basins, covering 64% of its land area, underscore the importance of international cooperation (UNEP, 2010). Initiatives like the Nile Basin Initiative and the Lake Chad Basin Commission exemplify efforts to foster cooperation in managing shared water resources. These platforms facilitate dialogue, joint planning, and equitable resource allocation among riparian states.

4.2. Financial Support and Investment

International financial institutions are crucial in bridging the funding gap for water infrastructure and management in Africa. The African Development Bank (AfDB) has been at the forefront, investing over \$3.3 billion in water projects since 2003 (AfDB, 2020). The World Bank, through its Water Global Practice, has also been instrumental in supporting water security projects across the continent.

4.3. Bilateral and Multilateral Aid Programs

Donor countries and international organizations provide substantial support through various aid programs. For instance, USAID's Water and Development Plan, under its Global Water Strategy, focuses on improving health outcomes through water and sanitation interventions in Africa. The European Union's Water Initiative (EUWI) has been pivotal in supporting water governance reforms and promoting integrated water resources management.

4.4. Role of International NGOs

Organizations such as WaterAid, Water.org, and Charity: Water work closely with local communities and governments to implement water and sanitation projects. These NGOs often bring innovative approaches and technologies to address water challenges in resource-constrained settings.

4.5. United Nations System Support

UN agencies play a crucial role in monitoring progress towards SDG6 and providing technical assistance. The WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) produces regular reports that guide policy and investment decisions.

4.6. Climate Change Adaptation

International cooperation is essential in addressing the impacts of climate change on water resources in Africa. The Green Climate Fund (GCF) and the Adaptation Fund provide crucial resources for climate-resilient water infrastructure and management practices.

4.7. Knowledge Sharing and Capacity Building

Initiatives like the Global Water Partnership (GWP) facilitate the exchange of best practices and promote integrated water resources management across Africa. The African Ministers' Council on Water (AMCOW) serves as a platform for high-level dialogue and cooperation on water and sanitation issues.

4.8. Research Collaborations

Partnerships between African institutions and international research centers contribute to building the evidence base for effective water management policies. The REACH programme, funded by the UK FCDO, is an example of such collaboration aimed at improving water security for the poor in Africa and Asia (REACH, 2021).

4.9. Challenges and Future Directions

While international cooperation has yielded significant benefits, challenges remain. These include ensuring the sustainability of donor-funded projects, aligning international support with local priorities, and addressing power imbalances in transboundary water negotiations. Moving forward, there's a need for more equitable partnerships that prioritize local ownership and capacity building.

5. Case Studies of Water Security Initiatives in Africa

Examining specific case studies provides valuable insights into the practical implementation and impacts of water security efforts across Africa. These examples highlight diverse approaches, challenges, and outcomes in addressing water security issues.

5.1. Morocco's National Water Plan

Morocco's ambitious National Water Plan launched in 2009, aims to secure the country's water resources through 2030. Key components include:

- Large-scale infrastructure development: Construction of 14 large dams between 2010 and 2019, increasing total dam capacity by 2.5 billion cubic meters (Hssaisoune et al., 2020).
- Water demand management: Initiatives to improve irrigation efficiency and reduce urban water losses.
- Desalination projects: To augment freshwater resources in water-scarce coastal regions.

5.1.1. Challenges

- Persistent drought conditions straining water resources.
- Environmental concerns related to large dam projects.
- Need for a greater focus on demand management and equitable water allocation (Molle and Tanouti, 2017).

5.1.2. Outcomes

- Increased water storage capacity and improved water security in some regions.
- Growing recognition of the need for a more balanced approach between supply augmentation and demand management.

5.2. Ethiopia's Climate Resilient Green Economy (CRGE) Strategy

Ethiopia has integrated water security considerations into its broader CRGE strategy, launched in 2011. Key aspects include:

- Hydropower development: The Grand Ethiopian Renaissance Dam on the Blue Nile, is expected to generate 6,000 MW of electricity.
- Small-scale irrigation and watershed management: To improve agricultural productivity and climate resilience.
- Emphasis on green economy principles in water resource management.

5.2.1. Challenges

- Transboundary water tensions, particularly regarding the Nile Basin (Yihdego et al., 2017).
- Balancing economic development goals with environmental sustainability.

5.2.2. Outcomes

- Increased water availability and reduced soil erosion in areas with watershed management interventions (Gebrehiwot et al., 2021).
- Potential for a significant increase in clean energy production and irrigation capacity.

5.3. South Africa's Water and Sanitation Master Plan

In response to severe water shortages, including the 2015-2018 Cape Town water crisis, South Africa developed a comprehensive Water and Sanitation Master Plan in 2018. Key elements include:

- Reducing water demand and increasing supply through infrastructure investments.
- Improving the performance of water and sanitation services.
- Addressing water and sanitation needs in informal settlements.
- Enhancing water governance and regulation.

5.3.1. Challenges

- Funding constraints and institutional capacity issues.
- Aging infrastructure and high levels of water loss in urban systems.

5.3.2. Outcomes

- Successful water conservation efforts in Cape Town, resulted in a sustained 30% reduction in water consumption compared to pre-crisis levels (Muller, 2020).
- Increased awareness and political prioritization of water security issues.

5.4. Kenya's Water Sector Trust Fund

Kenya has taken an innovative approach to financing water and sanitation projects through the Water Sector Trust Fund (WSTF), established in 2002. Key features include:

- Focus on results-based financing and community-driven development.
- Support for projects in underserved rural and urban areas.
- Emphasis on leveraging additional resources from development partners and the private sector.

5.4.1. Challenges

- Ensuring the long-term sustainability of community-managed projects.
- Balancing urban and rural water needs.

5.4.2. Outcomes

- Between inception and 2022, WSTF-supported projects provided increased access to water and sanitation for over 5 million underserved Kenyans and contributed to the conservation and rehabilitation of about 372 water sub-catchment areas (Water Sector Trust Fund, 2022).
- Increased community ownership and participation in water management.

These case studies illustrate the diverse approaches being taken to address water security challenges across Africa. They highlight the importance of context-specific solutions, the need for integrated approaches that consider both supply and demand management, and the potential for innovative financing and governance models. While challenges remain, these examples provide valuable lessons for enhancing water security efforts across the continent.

6. Future Outlook and Recommendations for Enhancing Water Security in Africa

The future of water security in Africa presents both significant challenges and opportunities. As the continent grapples with rapid population growth, urbanization, climate change impacts, and increasing water demand across sectors, innovative approaches and strategic investments will be crucial to ensure sustainable water management and access for all.

6.1. Projected Water Security Scenarios

According to the World Resources Institute, by 2040, 14 of the 33 most water-stressed countries in the world will be in Africa. Climate change is expected to exacerbate water scarcity in many regions, with the IPCC projecting that between 75 and 250 million people in Africa will be exposed to increased water stress by 2030. The rapid urbanization trend in Africa, with urban populations expected to nearly triple by 2050, will place unprecedented pressure on urban water infrastructure and management systems.

However, there are also positive trends and opportunities. The African Development Bank's investments in the water sector have shown promising results, with projects approved between 2011 and 2018 expected to provide access to improved water supply and sanitation for 43.6 million and 32.2 million people, respectively. The growing adoption of innovative technologies and management approaches offers hope for more efficient and sustainable water resource management across the continent.

6.2. Recommendations for Policymakers and Stakeholders:

- **Strengthen Transboundary Water Cooperation:** Given that 90% of Africa's surface water resources are in transboundary basins, enhancing cooperation among riparian countries is crucial. Policymakers should prioritize the development and implementation of comprehensive basin-wide agreements and joint management mechanisms.
- **Invest in Climate-Resilient Water Infrastructure:** African countries need to significantly increase investments in water infrastructure, with a focus on climate-resilient designs. Governments should explore innovative financing mechanisms, such as blended finance and green bonds, to bridge the investment gap.
- **Promote Integrated Water Resources Management (IWRM):** Countries should strengthen their legal and institutional frameworks to support IWRM implementation, balancing competing water demands and ensuring sustainable use.
- **Leverage Technology and Innovation:** Policymakers should prioritize the adoption of innovative technologies for water management, including remote sensing, AI-driven predictive models, and decentralized water treatment systems.
- **Enhance Data Collection and Management:** Improved data collection, analysis, and sharing are essential for effective water resource management. Countries should invest in strengthening their hydrometeorological monitoring networks and promote open data policies.
- **Build Capacity and Promote Knowledge Sharing:** Investing in human capital and institutional capacity is crucial for sustainable water management. Governments should prioritize water-related education and training programs, and promote knowledge-sharing platforms.
- **Mainstream Gender in Water Management:** Policies should explicitly address gender issues and promote women's participation in decision-making processes related to water management.
- **Improve Water Use Efficiency:** Given increasing water scarcity, improving water use efficiency across all sectors is critical. This includes promoting water-saving technologies in agriculture and implementing water demand management in urban areas.

6.3. Areas for Further Research

- **Climate Change Impacts:** More localized studies on the impacts of climate change on water resources and effective adaptation strategies are needed.
- **Groundwater Management:** Research on sustainable groundwater management practices and aquifer recharge methods is crucial.
- **Water-Energy-Food Nexus:** Further research on the interlinkages between water, energy, and food security in the African context can inform more integrated policy approaches.
- **Economic Valuation of Water:** Studies on the economic value of water resources and ecosystem services can help in more effective water allocation and pricing policies.
- **Innovative Financing Mechanisms:** Research on new financing models for water infrastructure and services can help address the investment gap.

7. Conclusion

Water security remains a critical challenge for sustainable development across Africa, with far-reaching implications for human health, economic growth, and environmental sustainability. This comprehensive analysis has highlighted the complex array of water-related issues facing the continent, from physical water scarcity and deteriorating water quality to inadequate infrastructure and weak governance structures.

However, the landscape of water security in Africa is not uniformly bleak. Numerous examples of innovation, progress, and successful interventions offer hope and guidance for the future. Policy frameworks such as the African Water Vision 2025 and initiatives by the African Development Bank have set ambitious targets and mobilized significant resources for improving water access and management.

Innovative approaches, including the application of remote sensing technologies, nature-based solutions, and climate-resilient infrastructure, are emerging as powerful tools for enhancing water security. International cooperation plays a vital role in addressing these challenges, providing financial resources, technical expertise, knowledge sharing, and platforms for regional collaboration.

As Africa works towards meeting Sustainable Development Goal 6 by 2030, addressing water security challenges will be paramount for sustainable development and improved quality of life for millions of Africans. The path forward requires a multi-faceted approach that combines policy reforms, technological innovation, capacity building, and sustainable financing.

While the challenges are substantial, with concerted efforts at local, national, and regional levels, and support from the international community, Africa can overcome its water security challenges and build a more sustainable and prosperous future for its people. The journey towards water security in Africa is complex and challenging, but it is also filled with opportunities for innovation, cooperation, and transformative change.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest is to be disclosed.

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