An Analysis of Transboundary River Water Management of Northern Africa and Ethiopia's Struggle to Access Clean Water

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

In 2018, Gete, a local resident, embarked on her daily journey to secure clean water for her family. Burdened with the weight of forty-pound jerry cans, her endeavor illustrates a routine yet arduous struggle faced by many Ethiopians due to water scarcity (Linegar, 2018). However, this scenario is not an isolated event. In fact, Ethiopia is known for its inadequate water infrastructure and frequent contamination of water sources which pose serious health risks for locals. The narrative of Gete highlights a broader issue of how transboundary river management, influenced by both political and societal actors, shapes access to clean water in Ethiopia.

Today, Ethiopia finds itself at a crossroads concerning the management of transboundary rivers like the Nile and preserving the country's peace from surrounding nations. As these rivers stretch across multiple national borders, the need for a diplomatic and cooperative framework for sustainable management becomes increasingly apparent. This study aims to explore the impact of public policy on shared transboundary rivers on Ethiopia's water resources. It will dive into the roles that political actors play in shaping these policies and examine the potential technologies and sustainable practices that could enhance Ethiopia's access to clean water while mitigating conflicts with neighboring countries.

The research conducted as part of this paper will draw parallels on global water scarcity issues, focusing on innovative solutions such as advanced water purification technologies and cooperative water management strategies. To achieve this goal, the paper is broken up into five separate parts. First, the methodology section will describe how the Social Construction of Technology (SCOT) framework can be used to fix Ethiopia's current water management strategies. This framework is implemented to understand the underlying motivations and

challenges faced by various political actors involved in Ethiopia's struggle. Next, a results section will organize the findings of this research into three parts: a case study; the socio-economic impacts of current water management policies; and potential water technology solutions. From here an analysis section will be implemented to share insights into why the result findings are significant. Following the analysis section will be a discussion that synthesizes the findings from the results and will further emphasize Ethiopia's need to revise its approach to transboundary water management. Finally, a conclusion section will summarize the research findings in addition to answering the research question.

Methodology

This research uses the Social Construction of Technology (SCOT) framework to examine transboundary river water management and its impact on Ethiopia's access to freshwater. SCOT hypothesizes that technology is shaped by social and political actors rather than inherently shaping society. This theory illustrates technological outcomes, such as a standard modern bicycle, emerge from social processes and negotiations among various user groups, challenging the notion of technological inevitability. This theory is outlined by Trevor Pinch and Wiebe Bijker (1987) (Sismondo, 2010). In this study, the SCOT framework is used to dissect the interactions among various social groups influencing Ethiopia's water policies and management strategies, such as local farmers, the urban populous, policymakers, and other neighboring riparian states such as Egypt and Sudan.

The methodology involves a detailed examination of Ethiopia's participation in the Nile Basin Initiative (NBI) and the development of the Grand Ethiopian Renaissance Dam (GERD). It explores how these initiatives are constructed within political and technological contexts and

assesses their impact on both national and regional water security. The analysis included an in-depth case study of the Western Bug River Basin to provide comparative insights into the socio-political factors that Ethiopia faces in transboundary water management. The Western Bug River Basin study revealed the challenges of shared water resource governance and the need for updated legislation and cooperative action. Primary data for this research was gathered through academic journals, federal reports, and legal documents outlining water rights and treaties. Secondary data was sourced from documented analyses and critiques of the NBI and GERD projects, providing insights into their successes as well as ongoing challenges. The methodology emphasized understanding how various social groups interpreted these projects and their implications for water management policies.

This research methodology also acknowledges potential biases and limitations within the data, particularly those arising from political agendas and regional tensions. Throughout the collection of these biases, I purposely researched various stakeholders to identify alternative solutions to finding fresh water for Ethiopia without the expense of other countries' access to water sources. These alternative solutions also accounted for the welfare of surrounding countries to ensure as much equality amongst the regions. Additionally, the analysis accounted for various social group perspectives to ensure all voices are heard when striving for equitable water distribution. For individuals looking to pick up this study, I used key phrases like "Egypt and Sudan concerns about GERD impact on Nile River" and "Renewable energy and water management technologies in Ethiopia" when researching this topic.

Lastly, the SCOT framework provided an understanding of how Ethiopia's water management technologies and policies are embedded in socio-political negotiations and conflicts. By examining the motivations and influences of stakeholders such as rural

communities, urban populations, policymakers, and international donors, this study proposed realistic and sustainable solutions to Ethiopia's challenges in water management.

Results

The Western Bug River Basin Case Study

The study of how nations manage the rivers that cross their boundaries is an important piece of understanding international water diplomacy. Originating in Ukraine, the Western Bug River borders Poland and Belarus and provides drinking water for roughly one million Warsaw residents (Krengel, et. al., 2018). The case of the Western Bug River Basin offers key lessons in this field, providing a direct parallel to the challenges Ethiopia faces with the Nile River. The Western Bug River has suffered from inadequate water treatment, agricultural runoff, and industrial pollution. Similarly, these challenges mirror those faced by the Nile River basin. This case study not only highlights the consequences of outdated environmental practices but also stresses the need for modernized legal frameworks to preserve river health and manage shared resources.

The Western Bug River, plagued by water quality issues from outdated wastewater treatment infrastructures, agriculture, and industry, mirrors similar complexities facing the Nile River basin (Krengel, et. al., 2018). This case study underlines the impact of human intervention on river health issues that strongly match with the Nile's management challenges. Additionally, this example emphasizes the importance of updating environmental legislation to meet modern standards. This global context offers a comparative framework for analyzing the Nile's situation, considering the challenges faced by Ethiopia and other Nile Basin countries in managing transboundary waters.

Building upon insights from the Western Bug's case study, recent developments such as the Nile Basin Initiative (NBI) offer strategic frameworks for addressing similar challenges in

transboundary water management. Established in 1999, the NBI represents a collaborative effort among Nile Basin countries to promote equitable and sustainable utilization of the Nile's water resources. Despite its achievements, the NBI has been criticized for its weaknesses, including the lack of overall political leadership and the lack of agreement on water allocation among riparian states (Mason, 2004). Furthermore, political conflicts and mutual suspicions among member countries have hindered cooperation within the NBI. The remaining primary legal frameworks governing water allocation of the Nile Basin include the 1929 bilateral treaty between Egypt and Britain, and the 1959 treaty between Egypt and Sudan (Teshome, 2008). Unfortunately, this only exacerbates current tensions among the riparian states. These challenges highlight the need for collaborative solutions to ensure access to fresh water.

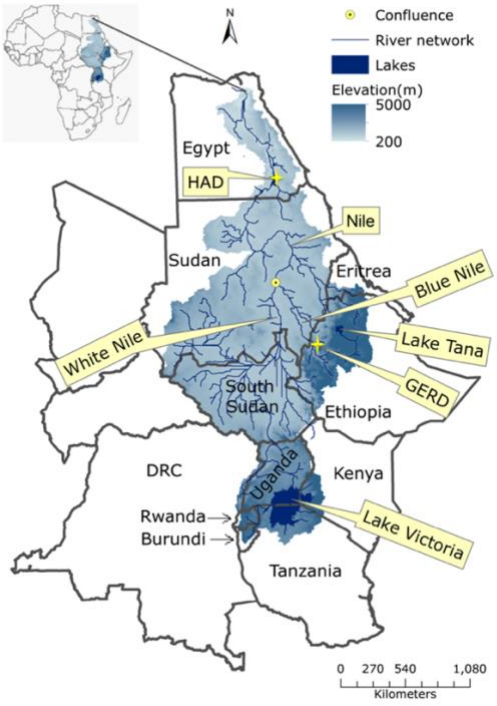

Figure 1. Map of the Nile River Basin and Key Hydrological Features

(Source: Andualem, et al., 2021)

Considering these challenges, Ethiopia also faces distinct pressure in managing its water resources, not only for drinking water but also for power generation to drive economic growth and development; thus, the Grand Ethiopian Renaissance Dam (GERD) project was initiated. The GERD, situated on the Blue Nile, represents Ethiopia's effort to harness its water resources for hydropower generation development. The GERD promised to provide Ethiopia with much-needed electricity through hydroelectric generation, potentially lifting millions out of poverty. However, concerns persist regarding its impact on downstream countries like Egypt and Sudan, particularly regarding reductions in available water flow and the potential for economic losses (Taye, et. al., 2016). The nation's pursuit of greater water access in the Nile basin aims to address domestic energy needs and provides a driving force for economic growth. However, concerns regarding the potential downstream impacts show the importance of collaboration between the Nile's co-riparian states and Ethiopia itself.

Socio-Economic Impacts of Water Management Policies

From a technical standpoint, the socio-economic implications of Ethiopia's water management policies are important to understanding their broader impacts on the nation's development. Many researchers have studied different aspects of Ethiopia's water management strategies including economic growth, social equity, and the sustainability of urban and rural water supplies.

Concerning economic development, Ethiopia's aim to evolve into a lower-middle-income country by 2025 is heavily influenced by the enhancement of agricultural and industrial productivity, which in turn is heavily reliant on more modernized water management systems. Investments in hydropower and irrigation are positioned as the catalysts for stimulating

economic activity (*Water for Sustainable Development in Ethiopia, 2022).* However, we must ask if the expected economic yields justify the substantial costs and complex logistics involved, or if the promise of progress is diminished by financial and operational burdens.

Furthermore, the pursuit of water security and resilience in the face of climate variability further complicates Ethiopia's water management skills. Ethiopia has adopted a varied approach encompassing data collection, risk modeling, and institutional capacity building. This approach is designed to solidify the reliability and availability of water access, while also perpetuating agricultural viability and empowering communities to withstand the changing climate (The Federal Democratic Republic of Ethiopia, n.d.). Yet, research suggests that the journey from strategic design to on-the-ground implementation has its' own challenges, particularly when it comes to tailoring policies to the needs of local communities. Additionally, the issue of urban water resilience is particularly pressing as Ethiopia undergoes rapid urbanization. Initiatives aimed at integrating nature-based solutions are vital for mitigating risks associated with urban water scarcity and supporting sustainable urban development.

Despite significant efforts to amend the policy, disparities in access to water persist, especially among rural and marginalized communities. Only about 17% of Ethiopia's population has access to clean water, underscoring the need for policies that not only expand water access but also ensure equitable distribution (Anderson, E., & Hagos, F, 2008). From a technical perspective, researchers argue for more inclusive policy frameworks that actively engage local communities in the planning and execution of water management strategies, thereby enhancing the policies' effectiveness and sustainability.

In summary, while Ethiopia's water management policies are designed to address a range of socio-economic challenges, technical analyses often show gaps between policy intent and

practical outcomes. Recommendations for future policy adjustments include enhancing policy approaches to water management. These adjustments are essential for optimizing the socio-economic benefits of water management in Ethiopia, ensuring sustainability, and supporting the nation's developmental goals.

Innovative Water Technology and Solutions

In Ethiopia's endeavor to enhance water supply and ensure equitable distribution, the country needs to turn its focus towards innovative technologies that offer promise without exacerbating regional tensions over shared water resources. The following technologies may offer a viable solution to their long-term water scarcity issue.

Desalination Plant

Desalination refers to the method of extracting mineral salts dissolved in water, often utilized in treating seawater, to produce water suitable for human consumption or agricultural use. This technique is becoming increasingly prevalent to secure freshwater resources (Iberdrola, S. A., 2021). However, this type of technology is highly energy-consuming, including operating equipment at very high pressures to remove the salt contents from the water. Not only is it costly to keep such equipment under high pressure, but the cost to maintain this equipment may outweigh its practicality in providing Ethiopian communities with fresh water. Using the Middle East as a reference, a 5 MGD (million gallons per day) plant is estimated to cost around $10 to $15 million total in capital costs. Similarly, factors like energy costs, site conditions, and labor rates may influence the price of one of these plants (Herber, G., 2024). This type of investment should not be overlooked, especially considering Ethiopia's economic disadvantages compared to other countries.

The Desolenator

Similar to a small-scale desalination plant, the Desolenator offers innovative use of solar desalination, an approach that taps into seawater as a resource. This technology harnesses solar energy to remove 99.9% of contaminants from seawater, providing an eco-friendly solution to water scarcity. Capable of generating approximately 15 liters of fresh water daily, the Desolenator presents itself as a long-term investment with an estimated 20-year lifespan. Priced at around $774 per unit, it represents a sustainable and economically viable option for communities facing chronic water stress (*New Technologies to Help Solve the Water Crisis*2022). With relatively low maintenance, this type of technology could help provide an adequate water source to Ethiopia's more rural communities.

Warka Water Tower

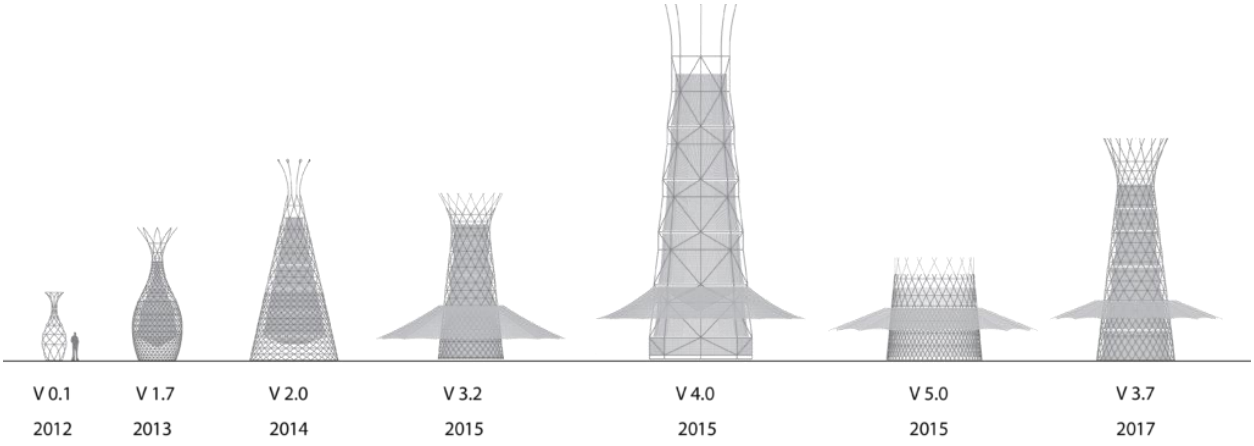

Figure 2. Evolution of the Warka Water Tower between 2012 and 2017 (Source: Haidar, 2018)

On the other hand, Warka Water towers introduce a unique method of harvesting potable water from the atmosphere. This 30-foot-tall tower, which can be installed in under a week without mechanical tools, captures dew droplets using a specialized netting material. The water

condenses and accumulates, yielding up to 26 gallons of drinking water each day. At a cost of roughly $1,000 per tower, Warka Water offers a relatively low-tech but effective solution to address the water needs of communities in Ethiopia (*Warka Tower*, 2022).

Analysis

The Western Bug River Basin Case Study

The results from the Western Bug River Basin case study reveal the complexities of transboundary river management, offering insights that are relevant to Ethiopia's situation with the Nile River. The direct parallel drawn from the Western Bug's experience underlines the broader implications of shared water resource governance and the role of modern environmental legislation in preserving river health. The Western Bug River's deterioration due to outdated infrastructures and unregulated agricultural and industrial activities mirrors the Nile's struggles. Such parallels highlight the urgency of revisiting and updating environmental legislation, a process that Ethiopia and other riparian states need to undertake to safeguard their shared waters effectively.

The case study of the Western Bug River Basin also demonstrates the need for cooperative action among riparian states. Historical treaties governing the Nile, all of which contribute to regional tensions today, require reevaluation and modernization. The criticisms raised against the Nile Basin Initiative (NBI) reflect the mutual trust required for such cooperation. The historical treaties governing the Nile's water, which now contribute to regional tensions, highlight the need for new agreements that reflect the current socio-political and economic realities. Moreover, Ethiopia's initiation of the GERD project is a great example of the country's need to secure water for both consumption and power generation. While the GERD holds promise of economic relief for millions, it also poses potential risks to downstream nations. Therefore, emphasizing the balance that must be kept in transboundary water management. This

case study suggests that Ethiopia must navigate these challenges with a combination of updated policy frameworks, robust diplomacy, and a commitment to sustainable and equitable water use.

The Western Bug study also highlights the need for new agreements that recognize the diverse social groups and their differing interpretations of water management policies and technology. Local farmers may prioritize productivity and economic stability, while environmental organizations advocate stricter regulation to preserve river health. Governments and international organizations often find themselves mediating between these types of interests. In Ethiopia, similar groups influence the interpretation of the GERD project, where farmers along the Nile are more likely to emphasize irrigation needs; urban populations rely on the promise of electricity generation. However, despite these differing perspectives, Ethiopia must navigate these challenges by updating its current policy frameworks, engaging in proactive diplomacy, and investing in more sustainable infrastructure.

Ultimately, this analysis also reinforces the need for collaborative solutions that consider the socio-economic state of the entire Nile Basin, ensuring equal access to fresh water for all riparian states. Several social groups including local farmers, the urban population, policymakers, and international organizations are affected by the modernization of these policies. Furthermore, the challenges of transboundary river management require frameworks that reflect modern realities and a mutual understanding of the interests and perspectives of all relevant parties.

Socio-Economic Impacts of Water Management Policies

The socio-economic outcomes derived from Ethiopia's water management policies are essential in determining their broader impact on national development and sustainability. This analysis can be applied to Ethiopia's progress toward economic growth, social equity, and the sustainability of its urban and rural water supplies. Ethiopia's ambition to elevate its economic status by 2025 is heavily dependent on developing water-dependent sectors like agriculture and energy. The findings from this study indicate that Ethiopia is making strides in investments, particularly in hydropower with projects like the GERD and in improving irrigation tactics. However, the benefits of these investments must be weighed against the high costs and operational challenges associated with this movement.

Urban populations in Ethiopia view the country's investments in hydropower projects, like the GERD, as essential for ensuring economic growth, while also providing a stable power supply. For them, large-scale hydropower presents a sustainable solution for the growing energy demands of local cities and industries. However, local farmers and members of rural communities may interpret these investments as potential threats to their livelihoods due to fears of reduced water availability. Members of these communities rely heavily on access to the Nile's waters for irrigation and agriculture. Historically, farmers have been marginalized in national policymaking, so engaging them in water management decisions can help address these concerns.

Furthermore, John Mbaku explains that "Egypt, which depends almost entirely on the Nile waters for household and commercial uses, sees the dam as a major threat to its water security." (Mbaku, 2022). This concern highlights Egypt's resistance to the GERD's development and filing without legally binding agreements. Moreover, Egypt relies on colonial-

era treaties because the Nile holds historical significance to the country and is essential for maintaining their dependence on a predictable water supply. However, Egypt is not alone in being affected by the construction of the GERD. Similarly, Mbaku brings Sudan into the discussion by stating "Sudan is caught between the competing interests of Egypt and Ethiopia. Although Khartoum initially opposed the construction of the GERD, it has since warmed up to it, citing its potential to improve prospects for domestic development." (Mbaku, 2022). This shows that Sudan has changed its interpretation of the GERD after seeing the potential benefits of its development while remaining cautious of how the dam could affect its existing agricultural and domestic projects. Overall, this analysis shows how interpretations of technology can shift over time as different groups reevaluate their priorities.

Now what does this mean for Ethiopia's approach to its water scarcity crisis? First, the country must incorporate the perspectives of all relevant social groups. The government should revise its water policies to be more inclusive, thus enhancing community engagement in decision-making as well as investing in new technology that supports sustainable water use. Additionally, Ethiopia should consider revising existing legal frameworks to promote equitable water distribution across all riparian states. Finally, a cooperative framework must also involve a clear course of action on managing droughts and reservoir levels to secure downstream access for all affected social groups.

In conclusion, Ethiopia's approach to resolving its water scarcity crisis requires a balance between economic development objectives and the sustainability of its natural resources. The insights from this study suggest that Ethiopia should consider revising its water policies to be more inclusive regarding the local community, adaptive, and sustainable. Such revisions could involve enhancing community engagement in water management decisions, investing in newer

types of technology that support sustainable water use, and adopting legal frameworks that promote equitable water distribution across all riparian states.

Innovative Water Technology and Solutions

The results from this section highlight several key solutions that address the pressing water scarcity issues in Ethiopia. The exploration of desalination plants, the Desolenator, and Warka Water towers provides a diverse selection of methods that Ethiopia should consider when attempting to broaden its water supply. Using just one of these methods could ensure equitable distribution of clean water across its community.

The introduction of desalination technology particularly a large-scale desalination plant, presents a promising yet complex solution for Ethiopia. While traditional desalination plants offer a reliable source of fresh water, their high energy consumption and substantial capital investment pose considerable challenges given Ethiopia's economic constraints. These factors make large-scale desalination ventures less attractive without significant foreign investment or technological aid.

In contrast, the Desolenator represents a more accessible technology for Ethiopia due to its affordability and sustainability. Utilizing solar energy to purify water aligns with Ethiopia's push toward renewable energy sources and reduces the operational costs associated with traditional desalination. Generating approximately 15 liters of fresh water daily, this device could serve individual households or small communities, particularly in remote areas where a day's worth of travel is required to reach freshwater sources.

Most notably, the Warka Water Tower offers an innovative and culturally adaptive approach to collecting atmospheric water through condensation. This low-tech solution is particularly suitable for Ethiopia's rural areas, where conventional water piping systems are limited. The cost-effectiveness and ease of installation make Warka Water a viable solution for immediate relief in areas where drought and chronic water shortages are common.

However, it is important to examine the motivations behind various social groups affected by the implementation of these technologies. Understanding their perspectives provides insight into how each group perceives the potential benefits and challenges to new solutions. For example, policymakers and government officials often seek technological solutions aligned with national development goals. The Desolenator, which harnesses solar energy to purify water, aligns well with Ethiopia's renewable energy agenda while being affordable for small-scale use. However, larger desalination plants could appeal to policymakers because of their potential to address broader water scarcity issues, even if significant foreign investment is required. Similarly, international donors may interpret the Desolenator and Warka Water towers favorably due to their affordability and smaller environmental impact. On the other hand, donors may find desalination plants unfavorable due to their high energy requirements and initial capital costs. Finally, rural communities are more likely to side with the Warka Water towers due to their ability to provide immediate relief in isolated regions. In contrast, urban populations may prioritize large-scale desalination to meet the growing water demands of cities and industrial sites.

Different interpretations among these social groups lead to conflicts and complex challenges when choosing the best technology for the Ethiopian population. Therefore, the combination of these technologies must be carefully integrated into Ethiopia's national water

management plan. This study recommends pilot projects be implemented to ensure international donors, local communities, and the government can work together to overcome both social and technical challenges before full-scale technology is introduced to the community. This kind of cooperation can then be used to refine policies and encourage future investments. Furthermore, this study also suggests that the Warka Water towers be implemented first in rural areas that require water immediately. Over time the Desolenator and larger-scale desalination plants can begin being built, but not without overlooking the help needed from foreign investors.

Discussion

The significance of this research into Ethiopia's transboundary water management using the SCOT framework provides insights into Ethiopia's socio-economic and environmental future. Through a detailed examination of various water management initiatives and their socio-political foundation, this study shows the urgent need for Ethiopia to revise its approach to water management.

Currently, the nation faces challenges in its water management practices, particularly in negotiating shared resources like the Nile River. The Western Bug River Basin case study emphasized that outdated environmental legislation and uncooperative transboundary management can exacerbate water quality issues and regional tensions. Ethiopia's involvement in the NBI and the development of the GERD illustrate the need for updated legal frameworks and stronger political leadership. Given the critical state of Ethiopia's water management, it is essential that the country advocates for modernized treaties and more cooperative frameworks. This may involve moving beyond historical agreements that no longer serve the collective needs of the Nile basin countries.

Additionally, the exploration of innovative water technologies such as desalination plants, the Desolenator, and Warka Water towers presents promising solutions to address Ethiopia's water crisis. Each technology offers specific benefits, yet also poses unique challenges. For instance, while large-scale desalination plants provide a reliable water source, their high energy demands, and substantial costs may be impractical without external financial support. Conversely, the Desolenator and Warka Water towers, which are more affordable and environmentally friendly, could be rapidly deployed to provide immediate relief in rural areas.

Ethiopia's strategy should, therefore, prioritize the integration of these technologies based on regional needs, economic viability, and potential for sustainable impact. Pilot projects involving these technologies should focus on community involvement and ecological considerations to assess their adaptability to local conditions as well.

Future research should aim to quantitatively measure the impact of implemented technologies and policy reforms on both local and regional water stability. Additionally, studies could explore the socio-economic impacts of water management on women and marginalized groups, who are disproportionately affected by water scarcity but often excluded from policy-making processes. Moreover, a subsequent research question to ask would be the long-term impacts of integrated water technology systems on Ethiopia's agricultural productivity and urban development. Assessing the scalability of technologies like the Desolenator and Warka Water throughout Ethiopia would provide a deeper insight into how practical they are when spread across different ecological zones.

Conclusion

In summary, this study through the SCOT framework illustrates that Ethiopia's water management issues are intertwined with socio-political factors that require a diverse group of perspectives to resolve. The country must not only update and enhance its water policies and cooperative agreements but also embrace innovative technologies that cater to its unique landscape. By doing so, Ethiopia can ensure sustainable water management that supports its development goals and relations with surrounding countries. The call to action is clear; Ethiopia must lead with innovative, inclusive, and sustainable water management strategies to secure its future by shared access to freshwater and collaborative interdependence.

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