Using Integrated Water Resources Management (IWRM) to Enhance Climate Resilience in Transboundary Water structure Projects. A Case Study of the Zambezi River Basin.

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Abstract

The Zambezi River Basin is one of the largest and most important river systems in Africa, affecting the environment and economy of eight countries. These countries include Zambia, Zimbabwe, Angola, Botswana, Mozambique, Namibia, Tanzania and Malawi. With climate change, population growth, and adding water demands, it's more important than ever to manage water resources in a way that works for all the countries sharing the river basin. This paper looks at how Integrated Water resources Management (IWRM) can help meliorate climate rigidity and make water systems in the Zambezi Basin more sustainable. The paper uses samples from the Kariba Dam Rehabilitation Project (KDRP), the Batoka Gorge Hydro-Electric Scheme (BGHES), and newer systems like the Floating Solar Photovoltaic (FSPV) Project to show practical ways of planning, working together, and involving everyone in decision-making under the Water-Energy-Food-Ecology (WEFE) Nexus. The study also points out the openings and challenges in aligning public pretensions with cooperative sweats across the sluice container. Ultimately, it talks about how technical tools, programs, and design operation can be bettered to support global targets related to water, energy, climate change, and guarding the terrain.

Key words:

Integrated Water Resources Management (IWRM), Climate Change, Zambezi River Basin, Transboundary Water Structure Projects, Climate Resilience, Water Governance, Stakeholder Engagement.

1. Background and Context

The Zambezi River Basin is one of Africa's largest and most critical transboundary water systems, spanning eight countries and supporting a diverse range of water-dependent sectors including hydropower generation, agriculture, domestic consumption, industrial activities, and ecological conservation (Katusiime and Schutt, 2020). However, the basin is increasingly vulnerable to multiple pressures, notably the impacts of climate change, rapid population growth, and escalating demand for the water resource.

Climate change has intensified these vulnerabilities through shifts in rainfall patterns, prolonged droughts, and an increase in the frequency and severity of floods. These climatic disruptions threaten not only water availability but also the reliability of energy production, the stability of ecosystems, and the livelihoods of millions of people. According to the Zambezi Watercourse Commission (ZAMCOM), the population dependent on the basin is expected to have exceeded fifty-one million by 2025, further exacerbating pressure on shared water resources.

Understanding how resource-dependent populations perceive and respond to climate impacts is also vital for designing effective adaptation policies. Localized knowledge and coping strategies among communities in the Zambezi River Basin play a critical role in shaping context-specific climate responses (Muringai et al., 2022).

The Zambezi River Basin is shared by Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, and Zimbabwe. Regional infrastructure projects must now navigate the complexities of water security, energy demand, and climate resilience under a shared governance structure.

This paper advocates for the adoption of Integrated Water Resources Management (IWRM) as a strategic framework to enhance climate resilience in transboundary water infrastructure projects. IWRM promotes coordinated planning, equitable stakeholder participation, and sustainable use of water resources across national boundaries, critical principles for managing the Zambezi River Basin in the face of climate change.

1.1 Introduction to Integrated Water Resources Management (IWRM)

Integrated Water Resources Management (IWRM) is defined by the Global Water Partnership as "a process which promotes the coordinated development and management of water, land, and related resources in order to maximize economic and

social welfare in an equitable manner without compromising the sustainability of vital ecosystems." This holistic approach has been widely adopted across the globe as a response to the growing complexity of water resource challenges. IWRM addresses issues of competing water demands, environmental sustainability, and intersectoral coordination, making it a particularly effective and adaptable framework for managing shared water resources in transboundary river basins.

In operational terms, IWRM builds on the four Dublin Principles, which were established during the 1992 International Conference on Water and the Environment in Dublin. These principles emphasize that: (1) freshwater is a finite and vulnerable resource essential to sustaining life and development; (2) water development and management should be based on a participatory approach; (3) water should be recognized as an economic good with value in all its competing uses; and (4) women must play a central role in water provision, management, and protection(ICWE, 1992; GWP, 2000).

Integrated Water Resources Management (IWRM) is widely recognised as a strategic framework for promoting sustainable and equitable water resource use, particularly in transboundary river basins affected by climate change (Agarwal et al., 2000; UNECE and WHO, 2008). It emphasises coordinated planning, stakeholder participation, and ecosystem sustainability by addressing the interconnected needs of water, land, and related resources (Xie, 2006). Agarwal et al. (2000) support this view, highlighting that IWRM moves beyond fragmented sectoral approaches by integrating water governance across institutional, social, and ecological dimensions. Similarly, UNECE and WHO (2008) underscore the importance of IWRM in enhancing resilience to climate-induced pressures such as floods and droughts, especially in shared basins.

GWP-Caribbean and Cap-Net UNDP (2015) further argue that IWRM supports long-term climate adaptation through inclusive, cross-sectoral planning and by fostering a more secure and prosperous future. The UNEP-DHI (2020) initiative also reinforces IWRM's role as a practical climate adaptation tool, pointing out its value in reducing vulnerability and strengthening water governance systems. Collectively, these perspectives demonstrate that IWRM is not only a theoretical concept but a practical and adaptable solution for managing complex water systems in the face of increasing climatic and developmental pressures.

1.2 Water-Energy-Food-Ecology (WEFE) Nexus and IWRM in the Zambezi Basin

The Water-Energy-Food-Ecology (WEFE) nexus framework emphasizes the interconnectedness of water, energy, food security, and ecological sustainability (FutureWater, 2024). Recognizing that these sectors are interdependent, effective management requires integrated approaches that consider their synergies and trade-offs (Hoff, 2011). In the Zambezi River Basin, where multiple countries rely on shared

water resources for hydropower, agriculture, fisheries, and ecosystem services, the WEFE nexus provides a comprehensive lens to address competing demands and vulnerabilities, especially under climate change pressures (Liu et al., 2018).

Integrated Water Resources Management (IWRM) aligns closely with the WEFE nexus by advocating for coordinated planning and management across sectors and governance levels (Global Water Partnership, 2000). The application of IWRM within the WEFE nexus framework can facilitate enhanced resource use efficiency, conflict reduction, and improved climate resilience in transboundary projects (Ringler et al., 2013). Thus, adopting a WEFE-IWRM integrated approach is essential for sustainable development and the equitable sharing of benefits across riparian states of the Zambezi Basin.

2. Methodology

This paper adopts a qualitative case study methodology, drawing from project documentation, field experiences, and stakeholder consultations related to three major transboundary infrastructure initiatives in the Zambezi River Basin:

- The Kariba Dam Rehabilitation Project
- The Batoka Gorge Hydro-Electric Scheme
- The Floating Solar Project on Lake Kariba

These case studies were selected based on their relevance to Integrated Water Resources Management (IWRM) principles and their potential contributions to climate resilience. This methodological approach is informed by international comparative studies such as the AMNH (2011) review of the Rhine, Mekong, and Zambezi basins, which underscores the value of cross-basin analysis in understanding governance models and institutional cooperation in IWRM settings. Additionally, this paper draws on lessons from UNEP (2022) and GWP (2022), which document the effectiveness of IWRM-driven projects in regions facing similar climatic and governance challenges.

The analysis further incorporates perspectives from GIZ (2020), which illustrates how combining IWRM with Ecosystem-based Adaptation (EbA) enhances resilience and sustainability in climate-vulnerable water systems. The methodology includes qualitative content analysis of policy documents, environmental and social impact reports, and project evaluations, as well as alignment assessments with IWRM and WEFE Nexus frameworks.

By integrating insights from these global case studies, this paper ensures that the evaluation of the Zambezi Basin projects is anchored in internationally validated methodologies for climate-resilient transboundary water governance.

3. Case Studies and Analysis

3.1 Kariba Dam Rehabilitation Project (KDRP)

Kariba Dam, jointly managed by Zambia and Zimbabwe through the Zambezi River Authority (ZRA), is one of Africa's largest reservoirs and a key hydropower source for the region. The rehabilitation project includes reshaping the plunge pool and refurbishing the spillway to enhance dam safety and reduce downstream risk. The initiative demonstrates practical application of IWRM principles through transboundary coordination, environmental risk assessments, and joint governance structures. According to AMNH (2011), such basin-scale cooperation and also observed in the Rhine and Mekong Rivers, can significantly enhance adaptive capacity and climate resilience in shared water systems.

The Kariba project reflects key IWRM principles in action, particularly through multi-sectoral participation, equitable stakeholder involvement, and joint governance mechanisms that ensure shared benefits across riparian states. This includes the participatory approach to decision-making (Principle 2), the recognition of water as an economic good through shared hydropower revenues and cost-sharing (Principle 3), and the safeguarding of ecosystems via coordinated environmental risk assessments (Principle 1). These measures collectively enhance climate resilience and promote long-term sustainability within a transboundary context.

3.2 Batoka Gorge Hydro-Electric Scheme (BGHES)

The Batoka Gorge Hydro-Electric Scheme Project, a planned 2,400 MW facility upstream of Kariba, represents a major infrastructure initiative requiring robust cross-border coordination. IWRM principles are embedded in the project's design through bilateral planning, Environmental and Social Impact Assessment (ESIA) and the Environmental and Social Management Plan (ESMP), and stakeholder engagement. These approaches align with findings from the UNEP (2022) case studies, where similar projects in the Mekong River Basin showcased how IWRM-based planning supported climate adaptation and reduced hydrological risk. The BGHES project also embodies lessons from GWP (2022), which found that incorporating stakeholder participation into project design increases resilience, improves legitimacy, and strengthens long-term water governance in West African river basins.

The Batoka Gorge Hydropower Project demonstrates the application of IWRM principles by embedding participatory stakeholder engagement (Principle 2), bilateral cooperation in planning and financing (Principle 3), and proactive environmental and social assessments to mitigate ecosystem impacts (Principle 1). The project also reflects efforts toward gender and community inclusion, aligning with the IWRM principle that women play a central role in water management (Principle 4). These

elements contribute to a more integrated, inclusive, and climate-resilient approach to large-scale hydropower development.

3.3 Floating Solar Photovoltaic (FSPV) Project

The Floating Solar Photovoltaic Project on Lake Kariba introduces a climate-resilient innovation by integrating renewable solar energy into the hydropower-dominated energy system. This dual-source strategy reduces dependency on river flow during droughts, which are becoming more frequent due to climate change. GIZ (2020) reports that combining IWRM with Ecosystem-based Adaptation (EbA) can further enhance resilience in water-energy systems, particularly when nature-based infrastructure is paired with stakeholder-driven planning. While the Kariba Floating Solar initiative is still in the planning stage, its alignment with IWRM principles - particularly diversification of energy sources and cross-sectoral integration - places it within the broader global movement toward sustainable, climate-smart water infrastructure.

The Floating Solar Project introduces a novel application of IWRM principles by integrating renewable energy with water infrastructure in a climate-resilient manner. It exemplifies cross-sectoral coordination between water and energy systems (Principle 2), reduces reliance on hydropower alone thus recognizing the economic value of diversified water use (Principle 3), and supports environmental sustainability by minimizing land use and pressure on aquatic ecosystems (Principle 1). Though still in the planning phase, the project sets a precedent for climate-smart, nexus-oriented infrastructure development in the Zambezi Basin.

Table 1 provides a comparative summary of three major transboundary infrastructure projects within the Zambezi River Basin. It highlights the key Integrated Water Resources Management (IWRM) principles applied, the implementation challenges encountered, and the respective contributions of each project to climate resilience and sustainable resource governance.

Table 1-Summary of three major transboundary infrastructure projects within the Zambezi River Basin.

Project Name	Location	Key IWRM Features Implemented	Challenges Identified	Climate Resilience Outcomes
Kariba Dam Rehabilitation Project	Zambia-Zimbabwe border	Stakeholder collaboration, basin-wide planning	Funding constraints, coordination gaps	Improved dam safety, hydropower stability
Batoka Gorge Hydro-Electric Scheme	Zambia-Zimbabwe border	Multi-sectoral integration, environmental	Transboundary negotiations,	Increased renewable energy,

		flow management	ecological impacts	ecosystem protection
Floating Solar Project	Zambia-Zimbabwe border	Innovation in water-energy integration	Technical capacity, policy support	Diversified energy, reduced emissions

4 Discussion

The three case studies demonstrate varying degrees of IWRM implementation. Key enabling factors include political will, institutional coordination, data sharing, and access to financing. However, challenges remain, such as policy fragmentation, limited community capacity, and overlapping jurisdictional mandates. Aligning national development plans with basin-wide strategies remains a key area for improvement.

Integrated Water Resources Management (IWRM) is increasingly recognised as an effective framework for addressing such challenges, particularly in transboundary river basins facing climate-related stress. It promotes coordination across sectors, inclusive decision-making, and the sustainable use of water, land, and associated resources (Xie, 2006). According to Agarwal et al. (2000), IWRM overcomes the limitations of fragmented water governance by integrating environmental, institutional, and socio-economic dimensions. The UNECE and WHO (2008) also highlight IWRM's value in managing floods, droughts, and other climate impacts through basin-wide cooperation. Further, GWP-Caribbean and Cap-Net UNDP (2015) emphasize its role in building long-term climate resilience and supporting inclusive, cross-sectoral planning. UNEP-DHI (2020) reinforces this perspective by identifying IWRM as a practical tool for reducing vulnerability and improving governance structures in the face of climate change. These complementary perspectives affirm that IWRM is not only a theoretical model but a flexible, applicable strategy for enhancing resilience in complex, multi-country systems like the Zambezi River Basin.

5 Conclusion

This paper has demonstrated the pivotal role that Integrated Water Resources Management (IWRM) can play in enhancing climate resilience in transboundary water infrastructure projects within the Zambezi River Basin. By adopting IWRM principles, riparian countries can better coordinate their efforts to balance water, energy, food, and ecological needs, consistent with the Water-Energy-Food-Ecology (WEFE) nexus framework. The case studies examined reveal both progress and persistent challenges, including institutional coordination, funding limitations, and stakeholder engagement barriers.

To realize the full potential of IWRM in this context, strengthened regional governance, inclusive stakeholder participation, and investment in capacity-building are essential. Furthermore, aligning basin management with the WEFE nexus can help optimize resource use, reduce conflicts, and improve adaptive capacity to climate change. Future research should focus on developing quantitative models to measure WEFE-IWRM impacts and exploring innovative financing mechanisms for transboundary water projects.

5.1 Policy Recommendations

Based on the findings, the following policy recommendations are proposed to enhance the integration of IWRM and climate resilience in the Zambezi River Basin:

Strengthen Regional Institutions: Empower entities like the Zambezi Watercourse Commission (ZAMCOM) with greater authority and resources to facilitate multi-sectoral coordination and dispute resolution.

Enhance Stakeholder Engagement: Establish inclusive platforms for dialogue among governments, communities, private sector, and civil society to ensure transparent decision-making.

Promote Data Sharing and Joint Monitoring: Develop interoperable information systems to support evidence-based planning and early warning systems.

Integrate WEFE Nexus in Planning: Encourage basin-wide strategies that explicitly consider water, energy, food security, and ecological interdependencies.

Mobilize Sustainable Financing: Explore innovative funding mechanisms including climate finance, public-private partnerships, and green bonds to support infrastructure resilience.

5.2 Limitations and Suggestions for Future Research

This study primarily utilized qualitative methods, including literature review and stakeholder consultations, which may limit the generalizability of findings. Additionally, access to comprehensive data on some infrastructure projects was constrained by confidentiality and political sensitivities. Future research should incorporate quantitative analyses such as hydrological modelling and economic impact assessments to provide deeper insights into WEFE-IWRM dynamics. Investigations into the social dimensions of transboundary water governance, including gender and equity issues, would also enhance understanding of resilience-building processes.

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