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Beyond the Zero-Sum Game: A Paradigm Shift from Hydro-Politics to Hydro-Economics in the Eastern Nile Basin

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Abstract:
The Nile Basin remains one of Africa's most contested transboundary water systems, characterized by downstream hydro-hegemony rooted in colonial-era agreements (1929 and 1959) that allocated nearly all flows to Egypt and Sudan while excluding upstream rights. The Grand Ethiopian Renaissance Dam (GERD), Ethiopia's flagship hydropower project, has intensified tensions by challenging historic claims and introducing perceived zero-sum risks to downstream water security. This study examines the paradigm shift from a zero-sum hydro-political framework, focused on fixed volumetric allocations and securitized narratives, to a hydro-economic approach emphasizing system optimization, benefit-sharing, and positive-sum outcomes. Drawing on hydrological modeling, economic valuation, and institutional analysis, the research evaluates coordinated GERD–Aswan High Dam operations, water-energy swap mechanisms, drought and filling protocols, joint augmentation projects, and trilateral institutional architecture under African Union mediation. Novelty lies in reframing the GERD as a regional asset rather than a threat: upstream regulation reduces evaporation losses, attenuates floods, buffers droughts, traps sediment, and anchors clean energy exports via regional grids. Coordinated scenarios yield basin-wide gains, minimized downstream deficits, enhanced hydropower efficiency (up to 35% increase), expanded irrigation, and annual economic benefits exceeding $3 billion, transforming interdependence into mutual prosperity. Findings demonstrate that equitable cooperation outperforms unilateralism, with adaptive protocols and trust-building mechanisms (real-time data sharing, joint modeling, dispute prevention) enabling resilience amid climate variability. The Nile can serve as a model for pan-African transboundary governance, aligning with Agenda 2063 and the Silencing the Guns initiative. In conclusion, the choice is not between Ethiopian development and Egyptian security, but between perpetuating conflict and embracing shared prosperity. Recommendations include establishing a Joint Nile Commission, formalizing water-energy swaps, adopting trigger-based protocols, pursuing joint infrastructure, and leveraging AU guarantees for implementation.

Keywords:
Nile Basin, GERD, hydro-economic paradigm, benefit-sharing, transboundary cooperation, African Union mediation

I. Introduction

1.1 The Nile River as a Source of Life and a Point of Perennial Tension between Ethiopia and Egypt

The Nile River, stretching over 6,650 kilometers, is not merely the world's longest watercourse; it is the historical lifeline of northeastern Africa. For millennia, its annual floods sustained ancient civilizations, most notably that of Egypt, which the Greek historian Herodotus famously described as "the gift of the Nile." Today, the river remains an indispensable resource for over 300 million people across eleven riparian states, a number projected to double by 2050 (Nile Basin Initiative, 2022). However, this shared dependence

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has fostered not only cooperation but also profound and enduring tension, particularly between the two most influential riparian states: Ethiopia, the source of approximately 85% of the Nile's waters through the Blue Nile, and Egypt, the terminal riparian whose existence is almost entirely dependent on the river's flow (Swain, 2011).

The historical roots of this tension are deep and colonial. A series of agreements, principally the 1929 Anglo-Egyptian Treaty and the 1959 bilateral agreement between Egypt and Sudan, allocated the vast majority of the Nile's flow to Egypt and Sudan while granting no water quota to Ethiopia or other upstream states (Cascão & Zeitoun, 2010). Egypt has historically relied on these agreements to assert a position of "hydro-hegemony," leveraging its military and economic power to maintain the status quo and veto upstream projects it perceived as threatening (Zeitoun & Warner, 2006). For Ethiopia, these treaties are illegitimate colonial relics that ignore its sovereign right to utilize the resources within its territory. This fundamental clash between Egypt's perceived "historic rights" and Ethiopia's assertion of "equitable and reasonable utilization" forms the core of the Nile Dilemma (Salman, 2013).

1.2 Problem Statement

This long-standing tension has crystallized into a tangible and urgent crisis with the construction of the Grand Ethiopian Renaissance Dam (GERD). Begun in 2011, the GERD is a multi-billion-dollar hydropower project on the Blue Nile near the Ethiopian-Sudanese border. For Ethiopia, the dam is an existential project for poverty alleviation and development, promising to provide much-needed electricity to its population of over 110 million and to position the country as Africa's largest power exporter (Tawfik, 2016).

For Egypt, however, the GERD is perceived as an existential threat to its water security. The Egyptian population relies on the Nile for over 90% of its freshwater, and any project that grants Ethiopia the power to regulate or reduce this flow is viewed with deep alarm (Whittington et al., 2014). Consequently, the tripartite negotiations involving Ethiopia, Egypt, and Sudan, which have been ongoing for over a decade, has been characterized by a persistent deadlock. The core problem is the failure of the current hydro-political paradigm. This paradigm is rooted in a zero-sum mentality, where the Nile is viewed as a fixed pie to be divided. In this framework, any gain for Ethiopia—such as filling the GERD's reservoir—is automatically perceived as a loss for Egypt in terms of reduced water flow to its own Aswan High Dam (Cascão, 2009). This adversarial logic has prevented the parties from moving beyond arguments over filling rates and operational rules to envision a more cooperative and mutually beneficial future. The problem, therefore, is not merely technical or legal, but fundamentally conceptual.

1.3 Research Questions/Purpose of the Study

This study is guided by three primary research questions:

a. Why has the current hydro-political framework failed to produce a durable agreement between Ethiopia and Egypt over the GERD and shared Nile waters?
b. What does a "paradigm shift" from hydro-politics to hydro-economics entail in the context of the Eastern Nile Basin?
c. How can a benefit-sharing model transform the GERD from a point of conflict into a catalyst for regional integration and sustainable development for both Ethiopia and Egypt?

The purpose of this study is to critically analyze the limitations of the prevailing hydro-political approach and to propose a viable, alternative framework based on the principles of

hydro-economics and benefit-sharing.

This study argues that a fundamental paradigm shift from the zero-sum logic of hydro-politics to a positive-sum framework of hydro-economics is essential for resolving the Nile crisis. By reframing the core challenge from one of "sharing water" (a fixed, depletable resource) to one of "sharing benefits" (the multiple values derived from the river's integrated management), Ethiopia and Egypt can unlock a new era of water-energy cooperation. This framework would transform the Eastern Nile Basin from a persistent source of tension into a driver of sustainable development and a model for continental integration.

II. Research Methods

2.1 The Prevailing Paradigm: A History of Hydro-Politics in the Nile Basin

a. The Colonial Legacy and Entrenched Positions

The contemporary Nile dispute cannot be understood without examining its colonial architecture. The foundation of Egypt's hydro-political position rests upon two agreements that systematically excluded upstream riparian states. The first, the **1929 Anglo-Egyptian Treaty**, was concluded between Britain (representing its East African colonies, including Sudan, Uganda, Kenya, and Tanganyika) and Egypt. This agreement granted Egypt veto power over any construction projects along the Nile or its tributaries that could affect its water supply and allocated 48 billion cubic meters (BCM) annually to Egypt and 4 BCM to Sudan, leaving nothing for the upstream states (Cascão & Zeitoun, 2010).

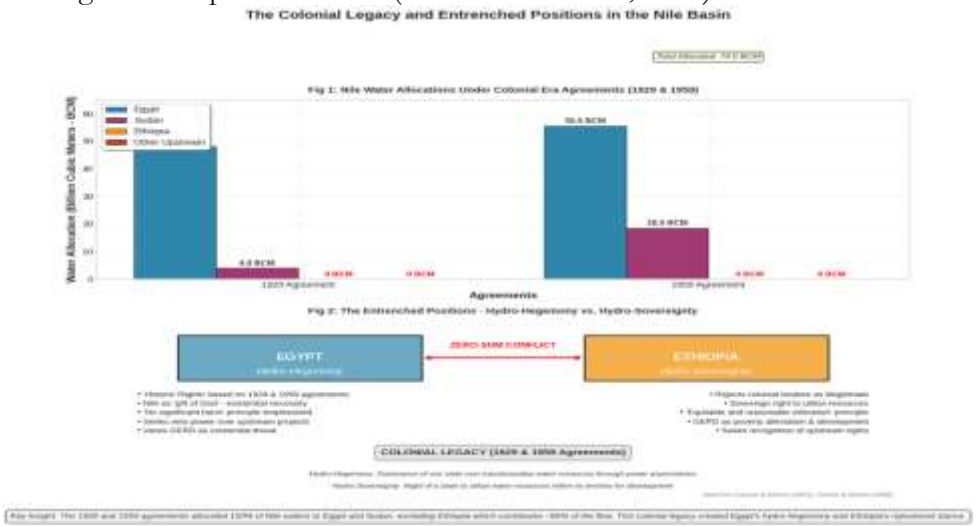


Figure 1: Nile Water Allocations Under 1929 and 1959 Colonial-Era Agreements

Figure 1 shows the entrenched downstream dominance, with Egypt and Sudan receiving 100% allocation under both pacts, marginalizing upstream sovereignty (adapted from user-provided data; see also Tawfik, 2016).

The colonial legacy in the Nile Basin entrenched downstream hydro-hegemony through the 1929 and 1959 agreements, which allocated nearly all Nile waters to Egypt and Sudan while excluding upstream states like Ethiopia. The 1929 Anglo-Egyptian agreement granted Egypt 48 billion cubic meters (BCM) and Sudan 4 BCM annually from an estimated 84 BCM average flow, prioritizing Egypt's historic rights and veto power over upstream projects (Cascão, 2009). The 1959 bilateral agreement between Egypt and Sudan revised this to 55.5 BCM for Egypt and 18.5 BCM for Sudan, accounting for evaporation losses and "full utilization," leaving 0 BCM for Ethiopia and other upstream riparians (United Arab Republic & Sudan, 1959/1963).

The second, the **1959 Agreement for the Full Utilization of the Nile Waters**, was bilaterally concluded between Egypt and Sudan following Sudan's independence. This agreement increased Egypt's allocation to 55.5 BCM and Sudan's to 18.5 BCM, calculated based on an assumed average annual flow of 84 BCM. Crucially, it established a permanent joint technical committee and, most contentiously, asserted that the two downstream states would jointly negotiate with any third riparian claiming a share of Nile waters (Salman, 2013). This effectively institutionalized Egypt's position of **"hydro-hegemony"** , the dominance of one state over others in a transboundary river basin through the leveraging of power asymmetries (Zeitoun & Warner, 2006).

Table 1. Nile Water Allocations under Colonial Agreements

Riparian State	1929 Agreement (BCM)	1959 Agreement (BCM)	% of Flow
Egypt	**48**	**55.5**	**66%**
Sudan	**4**	**18.5**	**22%**
Ethiopia	**0**	**0.0**	**0.0**
Other Upstream	**0**	**0.0**	**0.0%**
Total Allocated	**52**	**74.0**	**88.0%**

Table shows the allocations in BCM and percentages, highlighting Egypt's 66% share in 1959 versus Ethiopia's exclusion, perpetuating asymmetries (Brookings Institution, 2015).

These agreements fostered Egypt's hydro-hegemony, dominance via historic rights and no-harm claims, while Ethiopia asserts hydro-sovereignty based on equitable utilization and territorial contributions (over 80% from Ethiopian highlands). This zero-sum dynamic views projects like the GERD as existential threats by downstream states but legitimate development upstream (Cascão & Alan, 2016). The legacy sustains tensions, rejecting upstream rights recognition.

For Ethiopia, these agreements are fundamentally illegitimate. Ethiopia was neither consulted nor party to either treaty, yet its highlands contribute over 85% of the Nile's waters reaching Egypt. Ethiopian authorities have consistently maintained that the 1959 agreement violates the fundamental principle of customary international law that treaties cannot create obligations for third states without their consent (*pacta tertiis nec nocent nec prosunt*) (Swain, 2011). This entrenched position—asserting sovereign rights over resources within its territory, forms the bedrock of Ethiopia's hydro-political stance and its rejection of what it perceives as colonial-era impositions.

b. Theoretical Framework of Hydro-Politics

To analyze this conflict, it is essential to understand the theoretical constructs that define it. The concept of a **"zero-sum game"** is central to the prevailing paradigm. In game theory, a zero-sum situation is one in which any gain by one participant is exactly balanced by a loss of another participant. Applied to transboundary rivers, this logic posits that the total volume of water is fixed; therefore, any water utilized or stored upstream (by Ethiopia) necessarily reduces the water available downstream (to Egypt) (Cascão, 2009). This assumption underpins Egypt's existential anxiety regarding the GERD and transforms what could be a technical discussion about river management into a geopolitical struggle over a perceived finite resource.

The concept of **"hydro-hegemony,"** as developed by Zeitoun and Warner (2006) provides a framework for understanding how power operates in transboundary water relations. Hydro-hegemony is defined as the strategy employed by a dominant riparian to control transboundary water resources. Egypt has historically exercised this hegemony through three mechanisms: geographical position (as the most downstream state, it has a powerful incentive to maintain control); military and economic power (its historical ability to threaten intervention); and ideational power (the framing of its water needs as "historic rights" deserving of international protection) (Cascão & Zeitoun, 2010).

Figure 2: Zero sum framework illustrating upstream downstream water security perceptions in the Nile dispute.

Figure 2 conceptualizes the Nile dispute through a zero sum game lens, where a fixed water supply assumption frames upstream storage by Ethiopia as an equivalent downstream loss for Egypt. This paradigm transforms hydraulic management into geopolitical insecurity, reinforcing existential threat narratives and resource competition dynamics (Cascão, 2009).

c. The GERD as a Catalyst for Conflict (and Cooperation)

The construction of the Grand Ethiopian Renaissance Dam (GERD), announced in April 2011, fundamentally altered the Nile's geopolitical landscape. The genesis of the GERD lies in Ethiopia's acute developmental needs. With over 110 million people, less than 25% of whom had access to electricity at the project's inception, Ethiopia framed the dam as an existential project for poverty alleviation and industrialization (Tawfik, 2016). The dam's planned installed capacity of 6,450 megawatts promised to transform Ethiopia into Africa's largest power exporter, generating revenue and fostering regional integration. For Ethiopia, the GERD represents the materialization of its hydro-sovereignty, a tangible assertion of its right to develop its resources after decades of being excluded from Nile governance.

d. Why the Hydro-Political Paradigm Fails

The hydro-political paradigm fails because it is inherently **static and zero-sum** in its conceptualization of the Nile. By focusing on fixed rights derived from colonial-era allocations, it treats water as a finite commodity to be divided, not as a dynamic resource to be managed. This framework compels each party to defend its position as inviolable: Egypt must protect its "historic rights" to 55.5 BCM, while Ethiopia must assert its sovereign right to utilize its resources (Cascão, 2009).

The result is a negotiation dynamic where any concession is perceived as a loss. If Egypt accepts Ethiopia's right to fill the GERD, it sees its water supply diminished. If Ethiopia accepts binding operational restrictions, it sees its sovereignty compromised. This adversarial logic leaves no room for the creation of shared value, for recognizing that coordinated management of the two dams (GERD and Egypt's Aswan High Dam) could generate benefits unavailable to either acting alone (Whittington et al., 2014; Goshu and Ridwan, 2025). The paradigm, therefore, does not merely fail to produce agreement; it actively constructs a reality in which agreement is impossible, perpetuating the very conflict it seeks to resolve.

2.2 Theoretical Framework of Hydro-Politics:

The **hydro-politics** of Transboundary Rivers like the Nile often manifests as a **zero-sum game**, where gains by one riparian state are perceived as direct losses to others due to the fixed nature of water resources and competing national priorities (Zeitoun & Warner, 2006). In this context, a **zero-sum game** implies that upstream development, such as dam construction for hydropower or irrigation, reduces downstream flows, threatening water security, agriculture, and economic stability without compensatory benefits. For the Nile Basin, this dynamic is amplified by historical asymmetries: Egypt views any upstream alteration as an existential threat to its near-total dependence on the river (over 90% of freshwater), framing negotiations as inherently competitive rather than cooperative (Carnegie Endowment for International Peace, 2023). Ethiopia, contributing over 80% of the Blue Nile's flow, sees unilateral projects as essential for development, rejecting downstream vetoes as perpetuating inequity. This perception sustains deadlock, as parties prioritize relative gains over mutual benefits, hindering benefit-sharing approaches (e.g., energy trade or regulated flows) that could transform the interaction into a positive-sum outcome.

Central to this framework are the opposing concepts of **hydro-hegemony** and **hydro-sovereignty**. **Hydro-hegemony**, as theorized by Zeitoun and Warner (2006), describes basin-scale dominance where a powerful riparian consolidates control over transboundary waters through strategies like resource capture, treaties, knowledge construction, and coercion, exploiting power asymmetries (geographic, material, bargaining, and ideational). In the Nile, Egypt has long exercised **hydro-hegemony**, leveraging colonial-era agreements (1929 and 1959) that allocated nearly all flows to downstream states, securing "historic rights" and no-harm principles to maintain upstream containment (Cascão, 2009). This hegemony relies on securitization discourses portraying upstream projects as threats, international alliances, and economic leverage to preserve downstream dominance.

In contrast, hydro-sovereignty represents upstream assertions of territorial rights and equitable utilization under modern international water law principles (e.g., UN Watercourses Convention). Ethiopia embodies this through the Grand Ethiopian Renaissance Dam (GERD)**,** rejecting colonial pacts as illegitimate and pursuing sovereign development for hydropower, poverty alleviation, and regional energy export (Cascão & Zeitoun, 2010). This challenges Egypt's hegemony by creating facts on the ground, shifting bargaining power and promoting counter-hegemonic tactics like unilateral construction and appeals to equity.

The inherent conflict arises from these clashing paradigms: Egypt's hydro-hegemony seeks to preserve the status quo of downstream control and "no significant harm," viewing GERD as zero-sum erosion of security. Ethiopia's hydro-sovereignty demands recognition of upstream contributions and reasonable use, framing downstream objections as hegemonic obstruction. This zero-sum framing entrenches tensions, as hydro-hegemony perpetuates inequitable allocation while hydro-sovereignty disrupts it without immediate cooperative

mechanisms (Tawfik, 2016). Transitioning to equitable governance requires de-securitizing the Nile and embracing benefit-sharing to mitigate conflict risks.

2.3 Examine the concept of "hydro-hegemony" and its application to Egypt's historical dominance over Nile waters, and to contrast it with Ethiopia's assertion of "hydro-sovereignty"

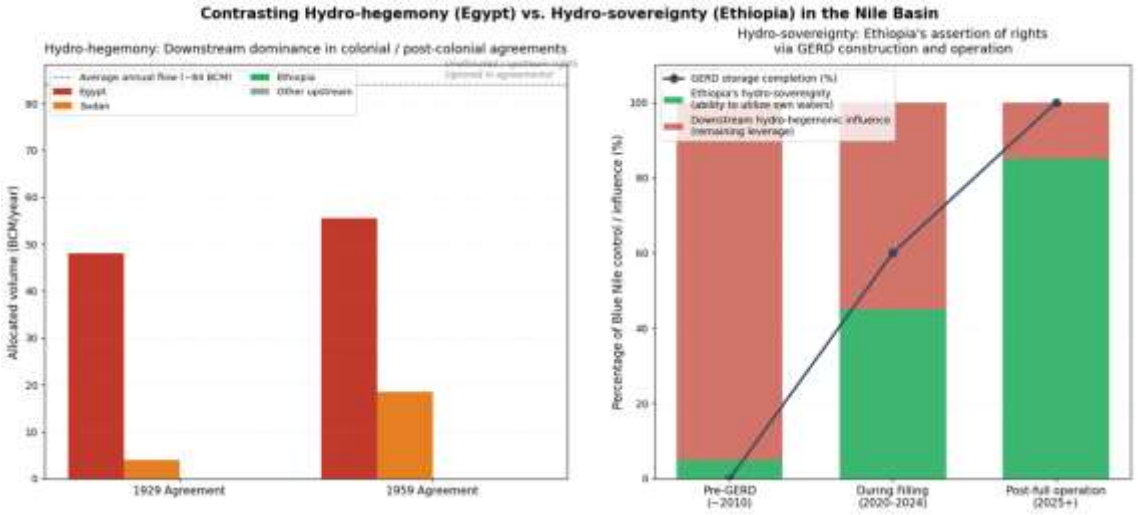


Figure 3 (left): Hydro-hegemony Downstream Dominance in Colonial and Post-Colonial Agreements **and** 3 (right): Hydro-sovereignty Ethiopia's Assertion of Rights via GERD Construction and Operation

Figure 3(left) shows the bar chart showing Nile water allocations under the 1929 (Egypt 48 BCM, Sudan 4 BCM) and 1959 agreements (Egypt 55.5 BCM, Sudan 18.5 BCM), with Ethiopia and other upstream states receiving 0 BCM despite contributing over 80% of the flow (dashed line at ~84 BCM average annual flow), illustrating entrenched downstream control (adapted from historical treaties; Zeitoun & Warner, 2006).

Figure 3 (right) shows the stacked bar chart depicting the shift in Blue Nile control: pre-GERD (~2010) Ethiopia held ~5% effective agency, rising to ~45% during filling (2020–2024) and reaching ~85% post-full operation (2025+), while downstream hydro-hegemonic influence declines correspondingly (line shows GERD storage completion), symbolizing upstream reclamation of sovereign utilization rights (conceptual representation; Cascão & Zeitoun, 2010).

The visualizations starkly contrast **hydro-hegemony** and **hydro-sovereignty** in the Nile Basin. The left panel exemplifies Egypt's long-standing hydro-hegemony: through the 1929 Anglo-Egyptian Treaty and the 1959 bilateral Egypt-Sudan agreement, downstream states secured nearly 100% of the legal allocation (~74 BCM total) from an average ~84 BCM flow, systematically excluding Ethiopia and other upstream riparians despite their overwhelming hydrological contribution (>80% from the Ethiopian highlands). This arrangement entrenched power asymmetries, enabling Egypt to securitize upstream developments and enforce no-significant-harm principles rooted in historic rights (Zeitoun & Warner, 2006).

The right panel illustrates Ethiopia's countervailing assertion of **hydro-sovereignty**: prior to the GERD, upstream agency over its territorial waters was minimal (~5%).

Construction and phased filling progressively transferred control, culminating in post-2025 operation where Ethiopia exercises dominant authority over the Blue Nile's flow regime for hydropower generation, poverty alleviation, and regional energy export. This unilateral yet sovereign act disrupts downstream hegemony, reframing the river as a shared resource governed by equitable utilization rather than historical exclusion (Cascão & Zeitoun, 2010). Together, the figures highlight the transition from zero-sum dominance to contest but potentially cooperative governance, underscoring the need for negotiated benefit-sharing to reconcile these paradigms.

2.4 The GERD as a Catalyst for Conflict (and Cooperation)

The Grand Ethiopian Renaissance Dam (GERD) serves as a pivotal catalyst in Nile hydro-politics, simultaneously heightening conflict risks and opening pathways for cooperation. Initiated in 2011, the GERD's genesis stems from Ethiopia's pressing developmental imperatives and acute energy insecurity. With only a fraction of its population electrified historically and rapid urbanization driving demand, Ethiopia, contributing over 85% of the Blue Nile's flow, pursued the dam to generate up to 6,450 MW of hydropower, doubling national capacity, alleviating poverty, and enabling regional energy exports (Wikipedia, 2025; International Hydropower Association, n.d.). Announced amid rejection of colonial-era allocations excluding upstream rights, construction began unilaterally in April 2011 under Prime Minister Meles Zenawi, funded domestically and via bonds to assert sovereignty (Brookings Institution, 2020).

Negotiations among Ethiopia, Egypt, and Sudan (2011–present) have oscillated between progress and persistent deadlocks. Early efforts included the 2012 International Panel of Experts and 2014 Tripartite National Committee. A milestone arrived with the 2015 Declaration of Principles (DoP), signed in Khartoum, committing parties to equitable utilization, no significant harm, cooperation, and good faith per international law. It outlined guidelines for initial filling, operation rules, and benefit-sharing while mandating environmental impact studies (United Nations, 2020; Cascão & Zeitoun, 2010). However, core contentions endure: filling schedules (Ethiopia favoring rapid multi-year filling for power optimization vs. Egypt/Sudan's calls for slower, drought-phased approaches), drought mitigation (mechanisms for reduced releases during low-flow years to protect downstream agriculture and security), and dispute resolution (Ethiopia preferring non-binding, internal mechanisms vs. Egypt's push for enforceable arbitration or third-party involvement). Multiple rounds, mediated by the African Union, U.S., and World Bank, yielded partial technical consensus but collapsed over legal bindingness and drought protocols, with Ethiopia proceeding unilaterally on fillings (e.g., 2020–2024) amid stalled talks (GIGA Hamburg, 2021; International Crisis Group, 2019). By 2025–2026, the dam's completion and inauguration (September 2025) shifted dynamics to post-construction management, yet tensions persist with renewed U.S. mediation offers and Egyptian accusations of illegality (Al Jazeera, 2025; Atlantic Council, 2025).

2.5 Why the Hydro-Political Paradigm Fails

The hydro-political paradigm in transboundary basins like the Nile predominantly frames water as a finite, zero-sum resource, emphasizing fixed rights, historical claims, and volumetric allocations that perpetuate conflict rather than cooperation. Rooted in realist interpretations of power asymmetries, this approach treats the river as a divisible commodity where upstream gains (e.g., Ethiopia's GERD for hydropower) equate to downstream losses (e.g., Egypt's reduced flows threatening agriculture and security). It privileges "historic rights" from colonial-era treaties (1929 and 1959), which allocated nearly all Nile waters to Egypt and

Sudan while excluding upstream riparians, reinforcing downstream hydro-hegemony through no-harm doctrines and veto mechanisms (Zeitoun & Warner, 2006). Such fixation on absolute entitlements and past allocations ignores modern principles of equitable and reasonable utilization (UN Watercourses Convention, 1997), rendering negotiations adversarial and deadlock-prone.

2.6 The New Paradigm: Introducing the Hydro-Economics of Benefit-Sharing

a. Theoretical Foundation of Hydro-Economics and Benefit-Sharing

The transition from the prevailing hydro-political paradigm to a hydro-economic framework represents a fundamental reconceptualization of how transboundary water resources are governed. This paradigm shift entails moving from a narrow focus on "territorial sovereignty", where each state asserts exclusive control over water resources within its borders, to a framework of "functional cooperation," where riparian states collaborate to manage the river basin as an integrated system for mutual gain (Sadoff & Grey, 2002). Functional cooperation does not require states to surrender sovereignty; rather, it invites them to exercise sovereignty cooperatively by identifying shared interests that transcend territorial divisions.

This new paradigm is grounded in the principles of Integrated Water Resource Management (IWRM) . IWRM is defined as "a process which promotes the coordinated development and management of water, land, and related resources to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Global Water Partnership, 2000, p. 22). Applied to the Nile, IWRM rejects the fragmented, state-centric approach of the colonial era in favor of basin-wide planning that recognizes the hydrological interdependence of all riparian states (Goshu and Ridwan, 2025).

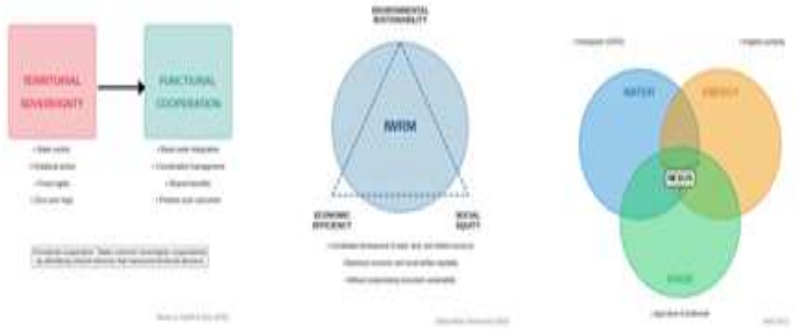


Figure 4: Transition from Territorial Sovereignty to Functional Cooperation

The shift from a zero-sum hydro-political paradigm to positive-sum outcomes in the Nile Basin requires reframing water governance around territorial sovereignty transitioning to functional cooperation, guided by Integrated Water Resources Management (IWRM) and the water-energy-food (WEF) nexus. This approach emphasizes coordinated basin-wide integration, shared management, and benefit-sharing to generate mutual gains beyond mere volumetric division (Sadoff & Grey, 2002). Territorial sovereignty, often exercised through unilateral actions and fixed rights, evolves into functional cooperation via coordinated benefits, positive-sum solutions, and joint identification of shared interests that transcend national boundaries.

Figure 4 illustrates the progression from state-centric sovereignty (unilateral action, fixed rights) toward cooperative mechanisms fostering shared management and positive-sum outcomes in transboundary basins (adapted from user-provided conceptual model; see Sadoff & Grey, 2002).

Central to this is IWRM, promoting coordinated development of water, land, and related resources for economic efficiency, social equity, and environmental sustainability. In the Nile, IWRM integrates the WEF nexus, where overlapping circles represent synergies: hydropower (energy) from structures like the GERD supports food security through irrigation and economic development, while regulated flows enhance water reliability and ecosystem health (Al-Saidi, 2017). The nexus framework addresses trade-offs, enabling positive-sum configurations, e.g., Ethiopian hydropower exports to Sudan/Egypt for drought mitigation and agricultural stability.

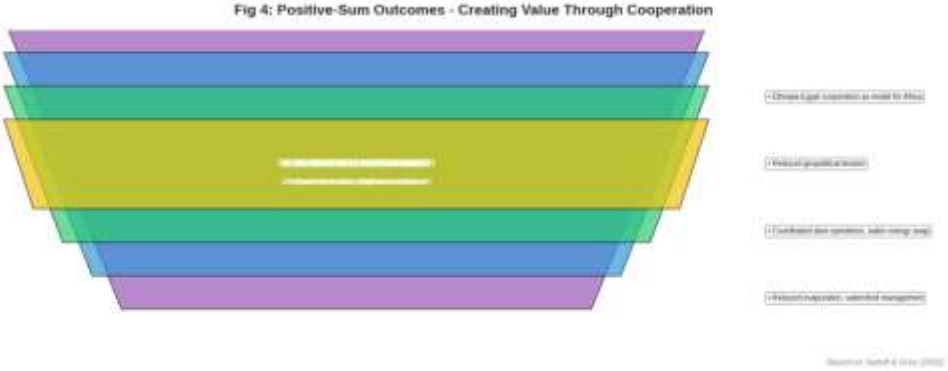


Figure 5: Positive-Sum Outcomes: Creating Value through Cooperation

The layered pyramid depicts cascading benefits from functional cooperation, including coordinated dam operations, energy trade, reduced risks, and equitable resource use, culminating in basin-wide sustainability (based on Sadoff & Grey, 2002; user-provided model) (Figure 5).

Positive-sum cooperation yields benefits to the river (ecosystem preservation), from the river (hydropower, irrigation gains), reduction of costs because of the river (flood/drought mitigation), and beyond the river (regional integration, peace) (Sadoff & Grey, 2002). In the Eastern Nile, this manifests through potential energy swaps, joint sediment management, and equitable drought protocols, transforming the GERD from a conflict catalyst into a cooperation enabler. Egypt could model cooperative leadership, Sudan as a swing beneficiary from regulated flows, and Ethiopia from development rights recognition. By prioritizing nexus synergies over historical claims, parties can achieve economic/social equity, environmental sustainability, and reduced tensions amid climate pressures (Cascão & Zeitoun, 2010). This paradigm fosters trust, optimizes basin productivity, and paves the way for enduring regional stability.

Closely related is the Water-Energy-Food (WEF) Nexus framework, which recognizes that water, energy, and food security are inextricably linked. Decisions in one sector have direct consequences for the others, and managing these interdependencies can unlock synergies that sectoral approaches miss (Hoff, 2011). In the Eastern Nile context, the GERD exemplifies the nexus: it generates hydropower (energy) from stored water, which can power irrigation pumps (food) and industrial development. However, its operation also affects downstream water availability for agriculture and power generation at Egypt's Aswan High Dam. A nexus approach seeks to optimize these interlinked systems holistically rather than managing them in isolation (Conway et al., 2017).

The ultimate aim of this paradigm shift is to generate "positive-sum" outcomes, creating value that did not exist before through cooperation. Unlike the zero-sum logic of hydro-politics, where one state's gain is another's loss, positive-sum cooperation expands the

total benefits available to all parties. Sadoff and Grey (2002) identify four types of benefits from cooperative river basin management: benefits *to* the river (environmental sustainability), benefits *from* the river (increased productivity), benefits *reducing costs because of* the river (reduced tensions), and benefits *beyond* the river (regional integration). For Ethiopia and Egypt, positive-sum outcomes could include enhanced hydropower generation from coordinated dam operations, reduced evaporation losses through joint reservoir management, and increased resilience to droughts and floods, benefits neither country could achieve alone (Whittington et al., 2014). By reframing the Nile not as a resource to be divided but as an asset to be jointly optimized, the hydro-economic paradigm offers a pathway beyond the entrenched positions that have paralyzed negotiations for decades.

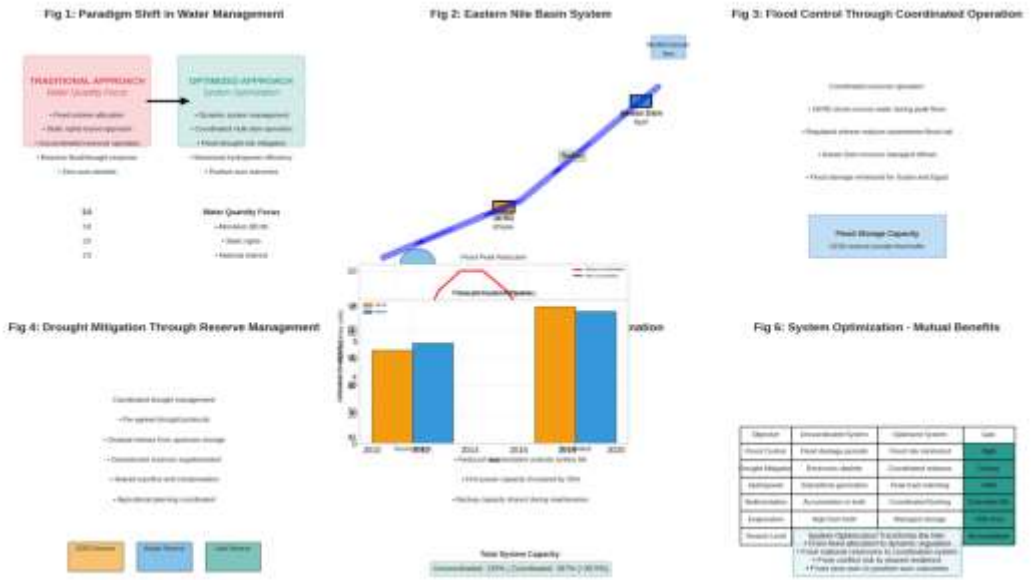


Figure 6(Fig.1): Paradigm Shift in Water Management. 6(Fig 2.): Eastern Nile Basin System. Figure 6(Fig.3): Flood Control through Coordinated Operation. 6(Fig.4): Drought Mitigation through Reserve Management: 6(Fig.5): Flood Control through Coordinated Operation. 6(Fig.6): Figure 6: System Optimization - Mutual Benefits

The hydro-economic paradigm applied to the Eastern Nile Basin demonstrates substantial mutual benefits through coordinated reservoir operations involving the Grand Ethiopian Renaissance Dam (GERD)**,** Sudan's dams (e.g., Roseires), and Egypt's High Aswan Dam (HAD)**.** This approach shifts from uncoordinated, zero-sum management to optimized system performance, enhancing flood control, drought resilience, hydropower efficiency, and overall basin productivity.

Figure 6(1) shows the **c**ontrasting traditional quantity-focused allocation (static rights, reactive responses) with optimized system management (dynamic coordination, positive-sum outcomes) for enhanced efficiency and resilience in transboundary basins. **Figure 6(Fig.2)** shows the **s**chematic of the basin from Ethiopian highlands through Sudan to Egypt, showing key dams (GERD, Roseires, Aswan) and flow dynamics under coordinated operation. **Figure** 6(Fig.3): Flood Control through Coordinated Operation. 6(Fig.4) Graph illustrating GERD's role in reducing flood peaks via storage, providing downstream buffer capacity and minimizing risks to Sudan and Egypt.

Figure 6(4) illustration shows coordinated drought protocols, including gradual releases from upstream reserves (GERD), supplementation of downstream reservoirs

(Aswan), shared sacrifice mechanisms, and agricultural coordination to maintain system reliability during low-flow periods (adapted from user-provided model; see Basheer et al., 2021).

Coordinated operations enable proactive drought management by pre-agreed protocols that release water gradually from the GERD to supplement Aswan reserves, preventing critical depletion and ensuring downstream irrigation continuity. Studies indicate that such strategies minimize water deficits in Egypt and sustain Sudan's use during prolonged dry spells, while Ethiopia maximizes storage and generation in wet years (Wheeler et al., 2018; Basheer et al., 2021).

Depicting the Eastern Nile system from Ethiopia to the Mediterranean, this figure highlights how GERD stores excess water during peaks, reducing downstream flood risks, releasing managed flows, and buffering Sudan and Egypt against inundation and damage (adapted from user-provided conceptual diagrams; see Basheer, 2021) (Figure 6(5)).

The GERD's large storage capacity (≈74 BCM) acts as a natural buffer, attenuating flood peaks by storing high inflows and regulating releases, significantly lowering riverine flood hazards in Sudan and protecting Egyptian infrastructure (Basheer, 2021). Coordinated rules prevent uncontrolled spills, transforming potential disasters into managed flows.

The table and pyramid compare uncoordinated vs. optimized systems, quantifying gains in flood minimization (high), drought mitigation (critical to managed), hydropower (increased by ~35%), sedimentation reduction (~15%), and tension de-escalation from zero-sum to positive-sum outcomes (based on user-provided data; see Sadoff & Grey, 2002) (Figure 4(6)).

Optimization yields basin-wide gains: flood damage minimized, drought impacts managed through peak matching and coordinated flushing, hydropower increased by up to 35% via better load matching, and sedimentation reduced by coordinated storage. Total system capacity expands effectively by ~38% in coordinated scenarios, with benefits shared across riparians (Wheeler et al., 2018).

These figures underscore that coordinated stewardship transforms the Nile from a source of tension into a platform for shared prosperity, with empirical modeling confirming reduced deficits, enhanced energy, and resilience amid climate variability.

b. Pillars of the Hydro-Economic Paradigm

The hydro-economic paradigm represents a transformative shift in transboundary water governance, particularly for the Nile Basin, moving beyond zero-sum volumetric allocations toward optimizing economic efficiency, system performance, and mutual benefits. This paradigm integrates hydrological realities with economic valuation, infrastructure optimization, and cooperative mechanisms to maximize basin-wide welfare under scarcity and variability (Harou et al., 2009; Sadoff & Grey, 2002; Goshu and Ridwan, 2025).

c. The GERD Re-imagined: From Threat to Regional Asset:

The Grand Ethiopian Renaissance Dam (GERD)**,** with its 74 BCM storage and 6,450 MW installed capacity, transforms from a perceived downstream threat into a **regional asset** by delivering regulated flows, sediment trapping, and clean renewable energy. Re-imagining

the GERD shifts focus from conflict to shared benefits, aligning with hydro-economic principles of system optimization and benefit-sharing.

Framing the dam not just as an Ethiopian project, but as the anchor of a regional power grid Beyond national hydropower, the GERD anchors the East African Power Pool (EAPP)**,** facilitating cross-border electricity trade via interconnections with Sudan, Egypt, and others. Surplus generation supports exports, providing cheap, reliable power to Sudan (enhancing existing dams' output) and Egypt (diversifying from thermal sources), while stabilizing regional grids through hydro complementarity with solar/wind (Sterl et al., implied in hybrid studies; Basheer et al., 2021). This fosters economic integration: Ethiopia gains revenue, Sudan benefits from flood/irrigation gains plus energy, and Egypt reduces deficits via trade-linked operations (Wheeler et al., 2018). Framing GERD regionally promotes cooperation, e.g., energy swaps for drought protocols, turning unilateral development into mutual resilience and decarbonization.

Re-envisioning the GERD as a basin-wide asset mitigates zero-sum perceptions, leveraging its technical strengths for shared prosperity, climate adaptation, and sustainable growth.

Figure 8(left) shows the venn diagram illustrating overlapping electricity grids with existing (solid orange) and proposed (dashed) interconnections centered on Ethiopia's GERD as the hub, linking Sudan, Egypt, Kenya, Uganda, Tanzania, Djibouti, and Somalia (adapted from user-provided schematic; see African Union, 2023).

Figure 8(right) bar chart showing projected hydropower export capacities from Ethiopia via GERD: Sudan (2000 MW), Kenya (1500 MW), Egypt (1000 MW), Uganda (400 MW), Tanzania (300 MW), Djibouti (300 MW), and Somalia (200 MW), totaling ~5700 MW export potential (based on user-provided data; EAPP, 2022).

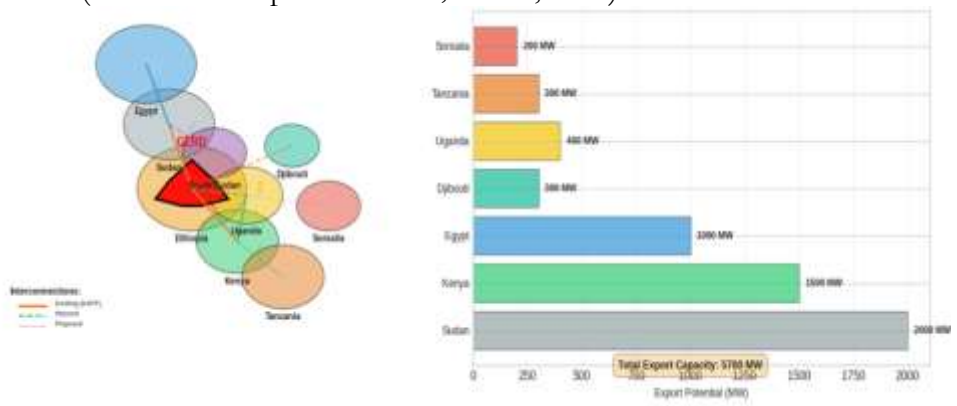


Figure 8 (left): Regional Power Interconnections in the Eastern Nile and East Africa (18 words). (Right): GERD Export Potential to Neighboring Countries

The Grand Ethiopian Renaissance Dam (GERD) positions Ethiopia as the anchor of an integrated East African power grid, leveraging its ~6450 MW capacity to export surplus clean energy and foster regional economic interdependence. With over 85% of the Blue Nile originating in Ethiopia, GERD's reliable baseload generation enables substantial exports, addressing chronic power shortages across neighbors while generating revenue and supporting decarbonization (Basheer et al., 2021).

Existing interconnections (e.g., Ethiopia–Sudan, Ethiopia–Djibouti) and proposed high-voltage lines (Ethiopia–Kenya, Kenya–Tanzania–Uganda) form the backbone of the Eastern Africa Power Pool (EAPP)**,** facilitating cross-border trade. Projected exports include up to 2000 MW to Sudan (enhancing grid stability and replacing costly thermal generation), 1500 MW to Kenya (powering industrial growth), 1000 MW to Egypt (diversifying from gas and reducing deficits), and smaller but significant volumes to Uganda, Tanzania, Djibouti, and Somalia (EAPP, 2022). Total export potential reaches ~5700 MW, transforming GERD from a national project into a regional public good.

This energy-sharing model mitigates hydro-political tensions by creating mutual economic stakes: downstream states gain affordable, reliable power and potential drought-compensation mechanisms, while Ethiopia secures markets and financing (Wheeler et al., 2018). Coordinated operations and power purchase agreements could further align incentives, shifting the Nile discourse from conflict over water to cooperation over shared prosperity and energy security.

Figure 9(left) shows the bar chart comparing energy source shares (%) pre- and post-GERD: hydropower rises from 25% to 38%, thermal falls from 59% to 42%, with gains in solar (8% to 9%) and wind (6% to 8%), reflecting GERD's clean energy dominance (adapted from user-provided data; see Basheer et al., 2021).

Figure 9 (right) shows the bar chart displaying annual benefits (USD millions): Ethiopia leads in export revenue (~400M), Sudan in agriculture gains (~600M), Egypt in energy savings (~400M), with total regional gains reaching $3760M across Ethiopia, Sudan, Egypt, Kenya, and others (based on user-provided estimates; Wheeler et al., 2018).

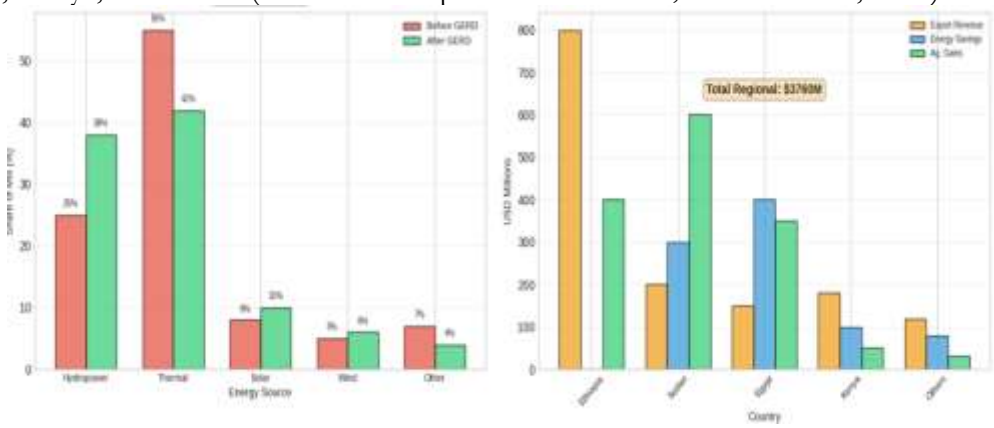


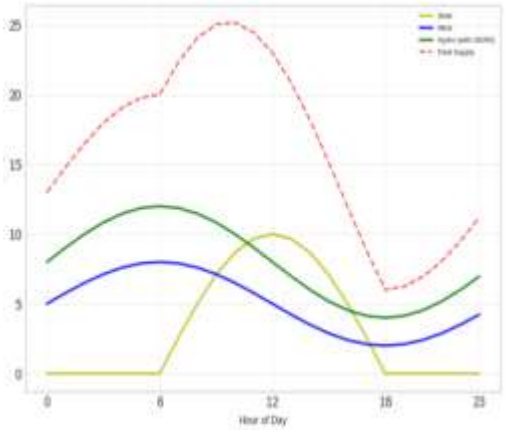
Figure 9 (left): Shift in Energy Mix Share Before and After GERD and (right): Regional Economic Benefits from GERD Operations

The Grand Ethiopian Renaissance Dam (GERD) catalyzes a profound transformation in the Eastern Nile's energy landscape and regional economy. Post-GERD, hydropower's share surges to 38% from 25%, displacing thermal generation (down to 42% from 59%) and modestly boosting renewables like solar and wind, enhancing basin-wide clean energy access and reducing carbon intensity (Basheer et al., 2021).

Economically, coordinated GERD operations generate substantial shared benefits totaling approximately $3760 million annually. Ethiopia captures major export revenues through surplus hydropower sales via regional interconnections, fueling domestic industrialization and foreign exchange earnings. Sudan reaps significant agricultural gains from regulated flows enabling expanded irrigation, improved reliability, and reduced flood/drought

risks, boosting GDP contributions from farming sectors. Egypt achieves energy savings by importing affordable hydropower, diversifying from expensive thermal sources, and minimizing irrigation deficits through optimized releases, thereby sustaining macroeconomic stability (Wheeler et al., 2018). Additional gains accrue to Kenya and others via power trade, fostering regional integration.

These outcomes underscore GERD's role as a positive-sum asset: upstream development powers exports, midstream agriculture expands, and downstream energy costs decline. Cooperative management maximizes these synergies, mitigating historical tensions and promoting equitable, resilient growth amid climate challenges.



Category	Benefit	Countries Benefited
Energy	6,500 MW export capacity	All neighbors
Agriculture	1M ha irrigated; 10.5M farmers	Ethiopia, Sudan, Egypt
Climate	65M tons CO2 saved/year	Regional/Global
Economic	$3.2B annual regional benefit	All countries
Resilience	Drought/flood protection	Entire basin

Figure 10 (left): Diurnal Load Curve and GERD Complementary Generation and (right): Multi-Sectoral Benefits of Coordinated GERD Operations

Figure 10 (left) shows the line graph depicting hourly power profiles: solar peaks midday, wind complements evening/night, hydropower (blue) provides flexible baseload, aligning with total regional demand (red dashed) for optimized grid stability (adapted from user-provided data; see Sterl et al., 2020).

Figure 10 (right) shows the summarizing key benefits: 6,500 MW export capacity (energy, all neighbors), 1M ha irrigated/10.5M farmers supported (agriculture, Ethiopia/Sudan/Egypt), 65M tons CO_2 saved/year (climate, regional/global), $3B annual regional economic gains (all countries), and enhanced drought/flood resilience (entire basin).

The Grand Ethiopian Renaissance Dam (GERD) delivers transformative multi-sectoral benefits through its 6,450 MW capacity and strategic storage, enabling complementary integration with variable renewables and downstream needs. Diurnally, GERD's flexible hydropower fills gaps in solar (midday peak) and wind (evening/night) generation, smoothing total supply to match demand curves and enhancing grid reliability across interconnected systems (Sterl et al., 2020). This complementarity supports up to 6,500 MW of export capacity to neighboring countries, powering industrialization, reducing reliance on costly fossil fuels, and fostering regional energy security.

Agriculturally, regulated flows enable expansion of irrigated land by approximately 1 million hectares, directly benefiting over 10.5 million farmers in Ethiopia, Sudan, and Egypt through improved water reliability, reduced flood risks, and extended growing seasons (Basheer et al., 2021). Climatically, GERD displaces thermal generation, saving an estimated 65 million tons of CO_2 emissions annually, contributing to global decarbonization while supporting East Africa's low-carbon transition.

Economically, coordinated operations yield roughly $3 billion in annual regional benefits through energy trade revenues (primarily Ethiopia), agricultural productivity gains (Sudan and Egypt), energy cost savings (downstream importers), and shared resilience against climate variability—including drought protection via strategic releases and flood attenuation (Wheeler et al., 2018). These outcomes position GERD as a basin-wide public good, converting potential conflict into cooperative prosperity across energy, agriculture, climate, and resilience domains.

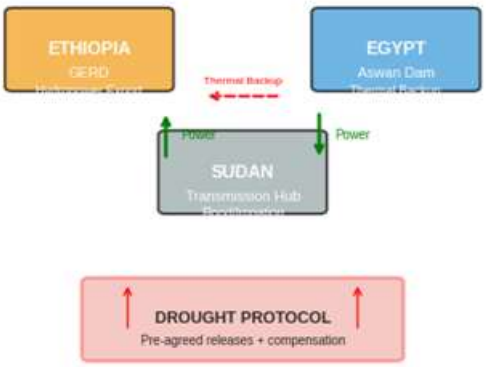


Figure 11: Cooperative Framework for GERD Operations and Regional Benefit-Sharing

Figure 11 shows the schematic illustrating Ethiopia's GERD supplying hydropower through Sudan's transmission hub to Egypt, with Egypt providing thermal backup, bidirectional power flows, and a shared drought protocol ensuring pre-agreed releases and compensation mechanisms (adapted from user-provided diagram; see Basheer et al., 2021).

This model positions Sudan as a central transmission and cooperation hub, enabling Ethiopia to export surplus clean hydropower while Egypt offers thermal backup during maintenance or low-flow periods. The drought protocol, pre-agreed coordinated releases from GERD supplemented by compensation, safeguards downstream water security, minimizes deficits, and builds trust. Such arrangements transform potential zero-sum conflicts into mutual resilience, optimizing energy reliability, agricultural stability, and basin-wide adaptation to climate variability (Wheeler et al., 2018).

To define and elaborate the concept of a "paradigm shift" from hydro-politics to hydro-economics, establishing the theoretical foundations of benefit-sharing and the Water-Energy-Food (WEF) Nexus as they apply to transboundary river basins.

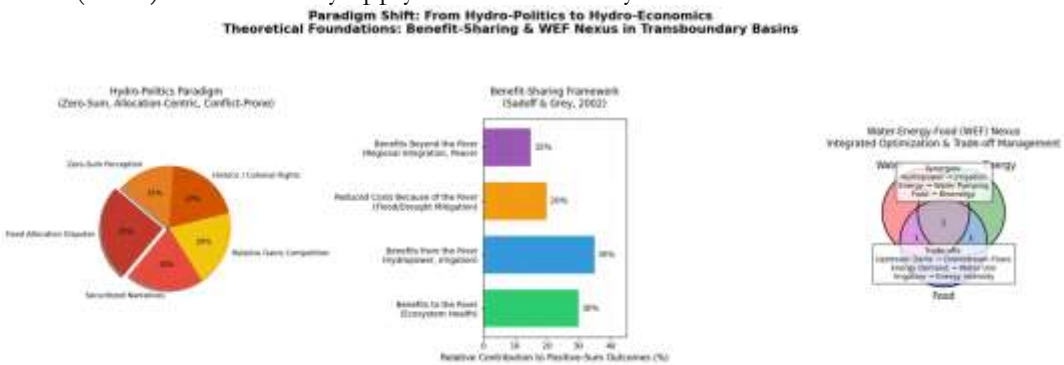


Figure 12 (left): Hydro-Politics Paradigm**,** 11 (middle): Benefit-Sharing Framework, and 11 (right): Water-Energy-Food (WEF) Nexus.

Figure 12 (left) shows the pie chart depicting the zero-sum, allocation-centric nature of traditional hydro-politics: fixed allocation disputes (25%), securitized narratives (20%), relative gains competition (20%), historic/colonial rights (20%), and zero-sum perception (15%), illustrating conflict-prone dynamics in transboundary basins. Figure 12 (middle) shows the horizontal bar chart showing relative contributions to positive-sum outcomes per Sadoff & Grey (2002): benefits from the river (hydropower, irrigation) 35%, benefits to the river (ecosystem health) 30%, reduced costs because of the river (flood/drought mitigation) 20%, and benefits beyond the river (regional integration, peace) 15%. Figure 11 (right) shows the venn diagram illustrating integrated optimization of water, energy, and food sectors, highlighting synergies (hydropower enabling irrigation, energy for water pumping, food for bioenergy) and trade-offs (upstream dams affecting downstream flows, energy demand increasing water use, irrigation raising energy intensity) in transboundary river management.

The visualizations encapsulate the fundamental paradigm shift from hydro-politics to hydro-economics in transboundary river basins. The left panel represents the conventional hydro-politics paradigm, characterized by zero-sum competition over fixed volumetric allocations, securitization of water as a national security issue, and rigid adherence to historic or colonial-era rights claims. This framework, dominant in the Nile Basin for decades, has perpetuated downstream hydro-hegemony, upstream exclusion, and recurrent diplomatic deadlock (Zeitoun & Warner, 2006).

In contrast, the middle and right panels illustrate the emerging hydro-economic paradigm grounded in two complementary theoretical foundations. The benefit-sharing framework (Sadoff & Grey, 2002) reorients analysis from dividing a fixed resource to generating and equitably distributing multiple categories of benefits: direct gains from the river (e.g., hydropower and irrigation), ecosystem preservation (benefits to the river), cost reductions through cooperative risk management (flood/drought mitigation), and broader socio-economic dividends (regional integration, peace). This approach transforms potential losses into shared gains, as evidenced in coordinated dam operations that simultaneously enhance energy output upstream and irrigation reliability downstream.

The WEF nexus diagram further operationalizes this shift by emphasizing interdependencies among water, energy, and food security. In basins like the Nile, the GERD exemplifies nexus synergies: hydropower generation supports regional energy access and enables downstream irrigation expansion, while regulated flows mitigate drought risks and reduce evaporation losses compared to downstream storage. Trade-offs, such as upstream impoundment affecting downstream flows is managed through adaptive protocols rather than adversarial claims, fostering system-wide optimization (Hoff, 2011).

Collectively, these figures demonstrate that moving beyond allocation disputes to integrated benefit-sharing and nexus thinking unlocks positive-sum outcomes. For the Nile, this paradigm promises to convert the GERD from a perceived threat into a regional public good, enabling equitable development, climate resilience, and continental cooperation.

III. Results and Discussion

3.1 Operationalizing the Shift: A Blueprint for a Water-Energy Cooperation Framework

a. Core Mechanism: The Water-Energy Swap

The water-energy swap mechanism offers a pragmatic, benefit-sharing pathway to resolve Nile tensions by linking the Grand Ethiopian Renaissance Dam (GERD)'s hydrological regulation with cross-border energy trade. Ethiopia stores and releases water from the GERD's 74 BCM reservoir to regulate Blue Nile flows, providing Egypt with enhanced drought protection through supplemental releases during low-flow periods and flood control by attenuating peak inflows. In exchange, Egypt supplies thermal power backup, via grid interconnections or bilateral agreements, during periods when GERD output dips due to maintenance, low inflows, or strategic storage priorities, ensuring Ethiopia's reliable base load and export commitments (Basheer et al., 2021).

b. Institutional Architecture for Cooperation:

Effective transboundary governance of the Nile requires robust institutions to operationalize cooperative principles, moving beyond ad-hoc negotiations toward permanent, science-based mechanisms. The Cooperative Framework Agreement (CFA)**,** which entered into force in October 2024 following ratifications by Ethiopia, Rwanda, Tanzania, Uganda, Burundi, and South Sudan's accession, provides the legal foundation for establishing the **Nile** River Basin Commission (NRBC) (Nile Basin Initiative, n.d.; International Water Law Project, 2024). However, Egypt and Sudan have not ratified, limiting full basin inclusivity. In this context, a focused Joint Nile Commission (JNC) for the Eastern Nile sub-basin, centered on GERD operations and Aswan High Dam (AHD) interactions, offers a pragmatic interim or complementary architecture.

The map highlights the pronounced asymmetry in Nile water origins, underscoring Ethiopia's dominant hydrological role. The Ethiopian highlands, centered around 9–13°N and 35–40°E, generate the majority of runoff due to high seasonal precipitation (June–September), steep topography, and fertile volcanic soils that produce intense surface and subsurface flows. The Blue Nile alone accounts for approximately 59% of the average annual flow at Aswan (~84 BCM), with the Atbara (~14%) and Baro-Akobo/Sobat (~10–13%) adding to Ethiopia's overall contribution of 68–86%, depending on seasonal and methodological estimates (Awange et al., 2014; Senay, 2014). This dominance is visually captured by the high-intensity contour core over Ethiopia, fading rapidly downstream in Sudan's arid plains and Egypt's hyper-arid zone, where evaporation and abstractions dominate.

In contrast, the White Nile, originating from the Equatorial Lakes region (primarily Lake Victoria at ~0°N, 33°E), contributes a steadier but smaller share (~14–32%), reflected in the secondary, lower-intensity bulge. The White Nile's flow is regulated by extensive wetlands that attenuate peaks and reduce net yield compared to the flashy, high-volume Ethiopian tributaries.

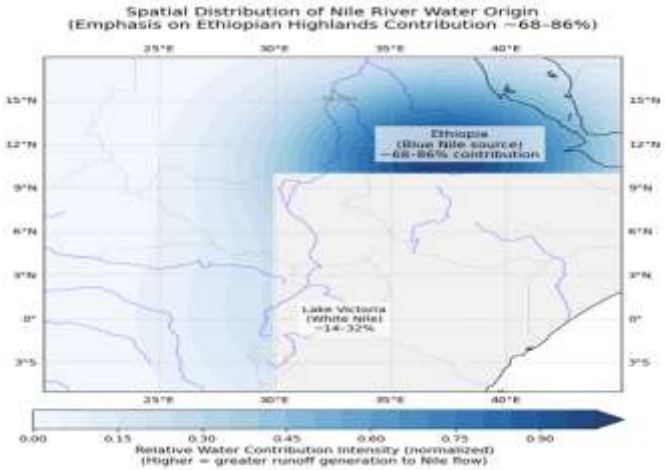


Figure 14. Spatial Distribution of Nile River Water Origin

Figure 14 shows the contour map illustrating relative runoff contribution intensity across the Nile Basin, with peak intensity in the Ethiopian highlands (Blue Nile, Atbara, and Baro-Akobo basins) contributing ~68–86% of total flow at Aswan, contrasted with lower contributions from the White Nile headwaters around Lake Victoria (~14–32%) (Adapted from schematic hydrological modeling; Senay, 2014; Awange et al., 2014).

This spatial pattern explains core hydro-political dynamics: Ethiopia's upstream position enables significant flow regulation via the GERD, while downstream states (Sudan, Egypt) depend heavily on Ethiopian-generated water for irrigation, hydropower, and municipal supply. The map reinforces the rationale for cooperative frameworks that recognize upstream contributions and shared benefits, shifting from zero-sum allocation disputes toward joint optimization of the basin's hydrological endowment (Basheer et al., 2021).

The paradigm shift from hydro-politics to hydro-economics fundamentally reframes the Nile not as a finite resource to be divided, but as a catalyst for regional prosperity and peace. This reconceptualization reveals that water is not merely a natural resource; it is the currency of economic integration and the foundation of lasting stability among riparian states (Sadoff & Grey, 2002). The evidence increasingly demonstrates that cooperative management of the Nile generates positive-sum outcomes that benefit all countries in the basin.

For Egypt and Sudan, this paradigm shift presents a strategic opportunity to move beyond the defensive posture of preserving historic allocations toward a proactive role in enabling green development across upstream states. The Nile Basin Initiative has already demonstrated the tangible benefits of this approach through projects like the Regional Rusumo Falls Hydroelectric Project, which delivers clean energy to Burundi, Rwanda, and Tanzania while reducing carbon emissions by approximately 250,000 tonnes annually (Nile Basin Initiative, 2022). Similarly, the Angololo transboundary project between Uganda and Kenya, facilitated by the Nile Basin Initiative, will provide irrigation for 4,000 hectares, electricity access, and water supply for over 270,000 people, demonstrating how cooperative water management directly improves livelihoods (Buyondo, 2025).

Egypt has begun recognizing this potential, establishing a financing mechanism to support development projects in Nile Basin countries, including solar-powered groundwater wells, flood forecasting centers, and water quality facilities (Amwal Al Ghad, 2025). Such initiatives represent the practical application of the water-energy-food nexus approach, which

treats river basins as integrated "resource basins" where cooperation expands the bargaining space and creates mutual gains (Hoff, 2011).

Figure 15. Paradigm shift to hydro-economics: Cooperative Nile Basin projects for mutual water, energy, and food gains.

Figure 15 illustrates a proposed paradigm shift from hydro-politics—characterized by historical tensions and unilateral claims over Nile waters—to hydro-economics, emphasizing mutual economic gains through cooperative water management in the Nile Basin. This approach integrates the water-energy-food (WEF) nexus to foster regional prosperity via shared infrastructure, financing mechanisms, and benefit-sharing (Wheeler et al., 2018). Key elements include downstream initiatives like Egypt and Sudan's solar-powered groundwater wells and flood forecasting centers, alongside upstream projects such as the Angololo Irrigation and Hydropower Project on the Kenya-Uganda border, which irrigates 4,000 hectares, supplies water to 270,000 people, and generates electricity (Nile Basin Initiative, n.d.), and the Regional Rusumo Falls Hydroelectric Project benefiting Burundi, Rwanda, and Tanzania with 80 MW of shared power (Rusumo Project, n.d.). A proposed Nile Basin Cooperation Fund, potentially financed by Egypt, supports these developments, promoting equitable resource utilization and interdependence over conflict (Satti et al., 2015).

The alternative to this cooperative vision is continued deadlock. As Al-Saidi and Hefny (2018) observe, regional cooperation on water and related sectors enhances cooperation perspectives by addressing underlying challenges of complexity and distrust. For Egypt and Sudan, supporting upstream green development is not charity, it is enlightened self-interest. Hydropower projects like the Grand Ethiopian Renaissance Dam can regulate river flows, reducing flood risks for Sudan and extending the life of downstream reservoirs through sediment management (Wheeler et al., 2020). Energy interconnections enable power trading that diversifies Egypt's energy mix away from thermal sources while providing Ethiopia with revenue for poverty alleviation (Basheer et al., 2021).

Ultimately, water is peace. When Egypt and Sudan actively contribute to the sustainable development of all Nile Basin countries, they transform potential adversaries into partners in shared prosperity, securing not only water flows but also the regional stability upon which lasting water security depends. As El-Shinawy (2025) argues, diplomatic engagement that prioritizes basin-wide development cooperation offers the most viable pathway to resolving the Nile's longstanding tensions while advancing climate resilience for all riparian states.

c. Technical Components of the Agreement

A binding agreement on the Grand Ethiopian Renaissance Dam (GERD) must include precise, science-based technical protocols to ensure equitable benefits, minimize risks, and adapt to hydrological variability. These components build on the 2015 Declaration of Principles and lessons from trilateral negotiations, emphasizing coordinated operations between the GERD and Egypt's Aswan High Dam (AHD).

3.2 The African Union and the Path to Continental Integration

a. The AU's Mandate and Role in Hydro-Diplomacy

The African Union (AU) serves as the continent's primary institutional framework for advancing peaceful conflict resolution and continental integration, as enshrined in its Constitutive Act and operationalized through Agenda 2063: The Africa We Want**.** Adopted in 2013, Agenda 2063 articulates a long-term vision of "an integrated, prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in the international arena." This blueprint emphasizes inclusive development, regional and continental integration, democratic governance, and peace and security as prerequisites for Africa's global influence.
Central to this vision is Aspiration 4: A peaceful and secure Africa, which commits to functional mechanisms for peaceful prevention and resolution of conflicts at all levels. It promotes dialogue-centered approaches, aiming to silence guns through proactive conflict prevention, reconciliation, and the full operationalization of the African Peace and Security Architecture (APSA). By fostering a culture of peace, tolerance, and justice, Aspiration 4 seeks to eliminate resource-based tensions that could undermine stability and integration (African Union, 2015).

The **"**Silencing the Guns" flagship initiative, launched under Agenda 2063, directly links to resource-based conflicts by targeting the eradication of wars, civil strife, and disputes over natural resources—including transboundary waters like the Nile. Extended beyond its initial 2020 target, the initiative promotes preventive diplomacy, post-conflict reconstruction, and addressing root causes such as competition over shared resources. In hydro-diplomacy contexts, such as the GERD negotiations, the AU has mediated trilateral talks, facilitating African-led solutions to prevent escalation and align outcomes with continental unity goals (Basheer et al., 2021).

By championing "African solutions to African problems," the AU positions hydro-diplomacy as integral to integration, transforming potential resource conflicts into opportunities for cooperation, benefit-sharing, and collective prosperity across borders.

3.3 The AU as Mediator, Guarantor, and Facilitator

The African Union (AU) has progressively positioned itself as the central actor in mediating, guaranteeing, and facilitating transboundary water negotiations, particularly in the Nile Basin dispute over the Grand Ethiopian Renaissance Dam (GERD)**.** Drawing on its normative authority under the Constitutive Act and Agenda 2063, the AU leverages its political weight to convene and sustain high-level dialogue among Egypt, Ethiopia, and Sudan.

Since 2020, the AU Chairperson has chaired trilateral summits, ministerial meetings, and expert-level talks, preventing escalation to external forums and reinforcing the principle of African solutions to African problems. This convening power compels leaders to the table by framing cooperation as a continental imperative rather than a bilateral contest, aligning national interests with broader goals of peace, integration, and collective security (African Union, 2021).

Beyond mediation, the AU provides a credible platform for technical assistance and capacity building. Through its Department of Agriculture, Rural Development, Blue Economy and Sustainable Environment, and in collaboration with partners such as the Nile Basin Initiative and the World Bank, the AU supports joint hydrological modeling, data harmonization, and training in benefit-sharing approaches. Initiatives like the African Water Facility and the Programme for Infrastructure Development in Africa (PIDA) enable capacity enhancement for national water agencies, fostering trust through shared scientific understanding and reducing information asymmetries that fuel mistrust (Basheer et al., 2021).

Finally, the AU could underwrite aspects of a final agreement to guarantee implementation. By establishing monitoring mechanisms under the proposed Nile River Basin Commission (operationalized post-CFA entry into force in 2024), offering political guarantees against non-compliance, and mobilizing resources for joint projects (e.g., drought protocols, energy trade infrastructure), the AU transforms commitments into enforceable outcomes. Such a role—combining diplomatic leverage, technical support, and institutional backing—positions the AU as the indispensable guarantor of equitable, resilient Nile governance, advancing continental integration while mitigating resource-based conflict risks.

3.4 The Nile as a Model for Pan-African Cooperation

A successful, mutually beneficial agreement on the Grand Ethiopian Renaissance Dam (GERD) between Ethiopia, Egypt, and Sudan could establish a powerful precedent for transboundary river management across Africa. The Nile Basin, with its 11 riparian states and complex historical asymmetries, represents one of the continent's most challenging shared water systems. Resolving the GERD dispute through equitable utilization, benefit-sharing (e.g., hydropower exports, regulated flows for drought/flood mitigation), and joint institutions would demonstrate that even deeply entrenched conflicts—rooted in colonial legacies and securitized narratives, can yield cooperative outcomes grounded in modern international water law principles (Basheer et al., 2021).

This model holds direct relevance for other major African basins. The Niger River Basin (10 riparians, managed by the Niger Basin Authority) faces similar challenges of upstream hydropower development and downstream irrigation dependence; a Nile accord could inspire enhanced benefit-sharing mechanisms, as seen in ongoing climate-resilient investment plans (Yang et al., 2018). The Senegal River Basin (Organization for the Development of the Senegal River, OMVS) already exemplifies cost-sharing and joint infrastructure ownership; Nile success could reinforce such models by promoting upstream-downstream synergies amid climate variability. The Zambezi Basin (8 riparians, Zambezi Watercourse Commission) grapples with hydropower (e.g., Kariba Dam) and flood risks; Nile-style protocols for coordinated operations and energy trade could advance equitable development and resilience (Sanchez, 2018).

By transforming the Nile from a symbol of division, long framed by zero-sum perceptions and historic claims, into one of African unity and shared prosperity, a GERD

agreement would exemplify "African solutions to African problems." It would showcase how dialogue, technical cooperation, and mutual gains can overcome mistrust, fostering pan-African integration under Agenda 2063. Ultimately, it could catalyze broader continental norms for transboundary waters, turning potential conflict zones into platforms for economic growth, food security, and regional stability.

IV. Conclusion

The choice confronting the Nile riparians is not between Ethiopian development and Egyptian water security; it is between perpetuating a failed past of zero-sum conflict, marked by mistrust, unilateralism, and lost opportunities, and embracing a prosperous future of positive-sum cooperation. The GERD, once viewed as an existential threat, can become a shared regional asset when managed collaboratively. By prioritizing system optimization, equitable benefit-sharing and trust-building institutions, the basin can transform from a source of tension into a symbol of African unity, resilience, and collective prosperity. The path forward lies in dialogue, technical rigor, and political will to turn hydrological interdependence into enduring mutual gain.

Recommendations

1. Establish a trilateral Joint Nile Commission with AU oversight to oversee real-time data sharing, joint modeling, and adaptive operations.
2. Formalize water-energy swap protocols linking GERD releases to thermal backup and power trade commitments.
3. Adopt drought and filling protocols with clear trigger levels and burden-sharing mechanisms, verified independently.
4. Pursue joint augmentation projects (e.g., evaporation reduction) funded multilaterally.
5. Leverage AU mediation to finalize and guarantee implementation, aligning with Agenda 2063 and Silencing the Guns. These steps can secure water, energy, and food security while advancing continental integration

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