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The Eastern Nile Multi-Sector Investment Opportunity Analysis

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Abstract

The absence of a comprehensive water resource development strategy for the Eastern Nile region poses a significant obstacle to the negotiation of an agreement regarding the Grand Ethiopian Renaissance Dam among the riparian states. This research delves into potential strategies for a holistic, multi-sector investment plan across the basin, aimed at fostering sustainable water resource development and management. The methodology employed involves conducting a basin-level analysis that takes into account the relative strengths and advantages of the various Eastern Nile sub-basins. The study's findings highlight feasible approaches for accommodating the development needs of the upper riparian states while also creating opportunities for equitable benefit-sharing without causing substantial harm to downstream users.

Keywords: Eastern Nile • Multi-sector opportunity analysis • Cooperative Regional Assessment (CRA) • Benefit sharing • Equitable utilization • No-significant harm

Introduction

The Eastern Nile Basin (ENB) is a region inhabited by over 266 million people, encompassing Egypt, Ethiopia, South Sudan, and Sudan, and spanning approximately 1.7 million square kilometers. Within this vast basin, four sub-basins exist: The Baro-Sobat-White Nile, the Abbay-Blue Nile, the Tekeze-Atbara, and the Main Nile from Khartoum to the Nile delta [1].

Development in the ENB faces significant challenges, including rapid population growth, land degradation, and inadequate storage infrastructure. Despite its immense size, the Nile in this region is considered water-scarce on an international scale and faces increasing demands due to factors such as population growth, rapid urbanization, and expanding irrigation needs [2]. Moreover, the basin experiences substantial rainfall variability, leading to erratic river flows and frequent occurrences of extreme floods and droughts. Addressing these challenges in the face of climate change requires effective water storage solutions. Additionally, substantial evaporation losses, estimated at around 20 Billion Cubic Meters (BCM) annually, occur from both human-made reservoirs and natural water bodies, necessitating international cooperation to minimize these losses. To reduce sedimentation, especially from the Ethiopian Highlands, strategic dam placement in regions with lower evaporation rates, like cooler highland areas, is essential, although this too demands international collaboration. The Eastern Nile Basin also contends with issues of salinity and waterlogging, which are exacerbated by inadequate drainage systems. Studies indicate that salinity levels in drainage water increase closer to the Mediterranean Sea, mainly due to salt leaching from the soil and upward seepage of brackish groundwater. Furthermore, rising sea levels in the Mediterranean Sea pose a threat of increased flooding and saltwater intrusion along the 950 kilometer-long Egyptian coastline [3].

Recognizing the importance of irrigation development in the ENB countries, all nations prioritize it as a means to mitigate the impacts of climatic variability and enhance rural development and food security. Several studies have been conducted since 2002 by the Eastern Nile Technical Regional Office (ENTRO) as part of the Nile Basin Initiative (NBI). These studies covered various aspects such as watershed management, power generation, interconnection, irrigation, and drainage. However, while these studies provided valuable insights, their analyses and findings have not been effectively integrated across sectors to inform a comprehensive, basin-level water resource optimization and efficiency strategy [4].

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Therefore, there is a pressing need for a multi-sector investment assessment to identify coordinated water resource strategies for the ENB, promoting shared economic growth, and environmental sustainability. The Multi-Sector Investment Opportunities Assessment (MSIOA) aims to undertake a basin-level analysis of water resources that achieves two key objectives: Sustainable management of the Eastern Nile's shared water resources and cooperative investment planning. This approach considers the basin's water scarcity and the social, environmental, and economic implications of proposed investments.

While various studies have explored the economic, filling, and operational aspects of the Grand Ethiopian Renaissance Dam (GERD), limited attention has been given to its integration with future water resource development plans in the three ENB sub-basins. The absence of cooperative regional water resource development plans has significantly hindered the resolution of conflicts surrounding GERD negotiations. To facilitate a sustainable long-term agreement among the ENB riparian states, a two-track negotiation process is proposed: one track focusing on the short-term filling and operation of the dam and the other on exploring long-term cooperative regional multi-sector plans. The MSIOA's scope is to support the latter track by considering the development needs of the upper riparian states, identifying opportunities for benefit-sharing, and ensuring no adverse impact on downstream water users [5-10].

Materials and Methods

The primary objective of the Multi-Sector Investment Opportunities Assessment (MSIOA) is to delineate various scenarios of water resources management and development across sectors, termed as "Development States." Subsequently, an analysis is conducted to evaluate the implications of each development state on water resources availability, poverty reduction (including economic returns and employment creation), and the social and biophysical environments within the Eastern Nile Basin (ENB).

Definition of development states

The study's approach differs from conventional single-project feasibility analyses as it aims to assess the overall impacts of various combinations of water resources development and management options, encompassing different water-using sectors, known as development states. Initially, four basic development states were considered:

Current Situation (CS): This represents the baseline state, including all existing irrigation and hydropower projects, excluding the Grand Ethiopian Renaissance Dam (GERD).

Improved Situation (IS): A 'near future' or short-term state that builds upon the current situation. It involves investments in irrigation modernization and the rehabilitation of existing schemes (deemed economically viable) and ongoing hydropower projects, including GERD.

Large Development (LD): Corresponding to a 'medium-term' state, the large development state adds potential irrigation and hydropower projects identified in country master plans, either at the feasibility or pre-feasibility study stage.

Full Development (FD): This is akin to a 'long-term' state and includes all irrigation and hydropower potentials identified as projects. Additional livestock resulting from expanded irrigated agriculture and supplementary fisheries due to planned reservoirs are also considered part of FD [11].

These development states were meant to be incremental, moving from CS to IS to LD to FD. Following a consultative workshop with participants from Ethiopia, South Sudan, and Sudan, the initial four development states were expanded to twelve, designed to be additive. Table 1 provides a summary description of these development states.

Development state	Key impacts on water resources	Strategic implications
2: Improved Situation (IS) all hydropower and irrigation projects being developed currently	The IS has limited impact on EN water resources, with a small decrease in inflows to the High Aswan Dam (HAD) and some increased abstraction, because irrigation schemes use their full command areas.	The development of hydropower and efficient irrigation can result in significant benefits without having a major impact on water resources further downstream.
3: IS+Full Hydropower (IS+FDH) IS+all potential hydro-power projects.	Here inflow to the HAD are reduced further (due to evaporation losses in the new reservoirs) but there is no impact on flows into the downstream delta or the Mediterranean Sea–as excess storage in the HAD allows releases as before.	Hydropower can be developed at all potential sites without having a major impact on the availability of water downstream (but without irrigation development).
4: IS+Full Irrigation. (IS+FDI) IS+all potential irrigation projects.	The development of full irrigation potential will have a major impact on the availability of water downstream: It creates an overall water deficit of 19.3 BCM per year in the ENB.	This s not a viable state as uncoordinated irrigation expansion will cause major water shortages and/or the abandonment of some irrigation schemes.
5: IS+Large Hydropower Development (IS+LDH) IS+all feasible hydropower projects	Closely linked to State 3 (IS+FDH), planned hydropower development has minimal impact on ENB water resources compared to other development states.	Implement all feasible hydropower projects and investigate the conversion of less viable hydropower schemes into run-of-river schemes.
6: IS+Large Irrigation Development (IS+LDI)IS+all feasible irrigation projects.	There is still insufficient water in the ENB to meet all the irrigation requirements of locally/nationally feasible irrigation projects.	This development state is also not viable because it will lead to a shortage of water in the Nile Delta.

7A: IS+Large Hydro+ Large Irrigation (BAS+TSA) IS+all feasible hydro-power projects+irrigation only in the BAS and TSA sub-basins not in the Sudanese part of the basin.	This State has feasible irrigation projects developed only in the BAS and TSA sub-basins–but not in the Sudanese part of the basin–but this also results in a deficit of water in the ENB (though it is a much smaller deficit than in State 6 above or State 7B below)	Only the most economically viable schemes in BAS and TSA with the most efficient irrigation should be undertaken in the lowland areas of Sudan/South Sudan. Crop choice should become a part of irrigation project planning.
7B: IS+large hydro+large irrigation (Sudan) IS+all feasible hydro-power projects+feasible irrigation projects only in the Sudanese part of the basin (not in BAS and TSA).	This State is the reverse of 7A: Feasible irrigation projects are only developed in the Sudanese part of the basin and not in the BAS and TSA sub-basins–but this also results in a deficit of water in the ENB (though higher than in 7A).	
8A: IS+large hydro+moderate irrigation IS+all feasible hydro-power projects+top irrigation priorities of ENB countries.	All three variants result in the same amount of inflow at HAD, but have different implications for the inflow into the Mediterranean Sea.	Three imperatives for water management in the ENB are: Appropriate crop choices and replacement of inappropriate choices with those more suitable to the agro-climatic zones-A regional approach to food security.
8B: IS+Large Hydro+Moderate Irrigation+cropping pattern changes in the Main Nile	The introduction of cropping pattern changes in the Main Nile sub-basin that are more compatible with the agro-climatic zone, result in some water savings–reducing the deficit in the ENB as a whole.	A regional approach to markets and the entire logistic chain getting agricultural produce to principal regional market centers.
8A+cropping pattern changes		
8C: IS+large hydro+moderate irrigation+cropping pattern changes in the Main Nile+reduced HAD operating levels. 8B+ reduced HAD operating levels.	Lowering the operating level of the HAD (and consequent decreases in evaporation) results in further savings.	
9: IS+large hydro+Management Irrigation IS+feasible hydro-power projects+managing irrigation within the available water.	This state builds on state 8 and aims to reduce the water deficit at the Delta through a small reduction in hydropower generated, and the area under irrigation. But there is still a deficit at the Nile delta.	This requires a strong level of coordination among the ENB countries, and an enabling environment of cooperation.

Table 1. Feasibility and strategic implications of the development states.

Understanding potential impacts of development states

The study assessed impacts across various dimensions, encompassing environmental, economic, and social aspects. These impacts were examined in a two-step process:

Step 1: To ascertain the water demand requirements for each Development State, the study utilized the Eastern Nile Basin Simulation Model, as detailed in Asegdew et al. 5 illustrate schematics of the upper sub-basins considered within the simulation. The objective was to model the functioning of the ENB's hydrological systems, including natural and artificial reservoirs, wetlands, irrigation, and hydropower schemes. It aimed to ensure the satisfaction of water demand for irrigation, hydropower, water storage operations, and environmental flows under different water resources management and development states [12]. The simulation incorporated 52 demand nodes to model existing and potential future water extractions, two wetlands, and spill flows. Moreover, 30 reservoir modes were included to simulate existing and potential water storage infrastructure in the basin. The model's validity was confirmed by comparing observed monthly flows at selected stations with model inflows at those stations, demonstrating good agreement.

Step 2: An annual mass balance analysis of water use was conducted using an Excel-based tool, which relied on the water demand requirements generated by the EN basin simulation model. This analysis revealed the implications of different development states on water availability at each node in the system [13]. The tool incorporated detailed databases of existing and potential hydropower and irrigation investment schemes, their infrastructure, operational details, productivity, historical water abstractions, and economic viability. It also considered factors such as water requirements for irrigation schemes, production costs, net revenues, and socio-economic impacts of investment projects [14].

Economic assessments of major infrastructure investments were conducted over a 30-year time horizon in US dollars, assuming an 8% social discount rate. Parameters like Net Present Values (NPVs), Economic Internal Rates of Return (EIRRs), and Benefit-Cost (B-C) ratios were calculated for irrigation and hydropower projects in Sudan, South Sudan, and Egypt. Data on EIRRs, NPVs, and B-C ratios for Ethiopian irrigation projects were extracted from previous studies. Similar economic assessments were performed for large-scale hydropower schemes in Ethiopia and Sudan, based on studies conducted under the EN power trade study.

Multi-criteria analysis of potential impacts

To compare the impacts of each development state, especially concerning water resource management and sustainable development in the ENB countries, a multi-criteria analysis was employed. This process occurred in two stages:

Stage 1 (Selection of criteria): Stakeholders representing various thematic areas from Ethiopia, Sudan, and South Sudan played a pivotal role in selecting the criteria. They proposed appropriate criteria and assigned weights to indicate their relative importance. Three broad categories of criteria emerged:

Economic criteria: These encompassed Net Present Value (NPV) of net revenues generated by hydropower and irrigation schemes (NPV-HP and NPV-IR, respectively) and Water Productivity (WP) in the irrigation sector (USD per hectare).

Social criteria: These included Employment (EMPL) created in the irrigation, fisheries, and livestock sectors, Resettlement (RESTL) of displaced individuals, and the Gini index reflecting the equity of benefit distribution.

Environmental criteria: These consisted of annual flow at the Nile Delta in Egypt (BCM-Eg) and total evaporation losses from reservoirs in the basin (Evapt.).

Stage 2 (Weighting the criteria): The weighting of criteria was also determined through stakeholder input. Table 2 provides the weighting and ranking of criteria, reflecting their relative importance as perceived by the participants.

Criteria	Number ranking	Weights as percentages
Evap	29	19%
WP	29	19%
NPV	28	18%
BCM-Eg	21	13%
Equity	21	13%
Resetl	17	11%
Empl	11	7%
Total	156	100%

Table 2. Weights of criteria reflecting stakeholder preferences.

Results and Discussion

The feasibility of the various development states was rigorously analysed, taking into account their potential environmental, economic, and social impacts. It's worth noting that development states 4 (IS +FDI) and 6 (IS+LDI) were found to have water requirements that significantly exceeded the available resources within the Eastern Nile Basin (ENB), rendering them unviable (Table 1).

Scores for seven key economic, social, and environmental indicators for different Development States were weighted according to input from key stakeholders (Table 2). The results of this assessment underscore the consensus that uncoordinated expansion of irrigation in the ENB is unviable (Table 3). Notably, development states 4 and 6 have not been presented in detail due to their unviable water requirements.

S. no.	Indicators	Units	Development states							
			3	5	7A	7B	8A	8B	8C	9
			IS+ FDH	IS+ LDH	IS +LDH+LD (BA+TZA)	IS +LDH+LD (Sudan)	IS+LDH +MDI	IS+LDH +MDI+Nile Crops	8B+Less HAD	IS+LDH +Man. I.
1	NPV: Hydro-power (NPV-HP)	Billion US$	69.6	46.8	56.6	56.8	54.9	54.9	54.9	46.6
2	NPV: Irrigation, fisheries, livestock (NPV-IR)	Billion US$	5.8	5.8	6.7	7.5	6.8	6.8	6.8	6.8
3	Water Productivity of Irrigation (WP)	US Cents/ Hectare	4.11	4.11	4.15	4.59	4.01	4.01	4.01	4.2
4	Equity of benefit Distribution	Gini Index	0.78	0.71	0.75	0.81	0.76	0.76	0.76	0.71
5	Total Employment Generated (Empl)	Million Jobs	102	102	110	106	111	111	111	109
6	Water Balance at Delta (BCM-Eg)	BCM/year	8.55	9.54	-0.82	-0.82	-3.35	-0.71	0.31	-0.95

7	Reservoir Evaporation Losses (Evapt.)	BCM	23.8	22.9	23.5	23.3	23.3	23.3	23.3	23.3
Weighted scores			4.2	4.4	4.6	6.6	4.3	4.5	4.6	5

Table 3. Impact indicator values and weighted scores for development states.

To provide a visual representation of the findings, these development states are graphically depicted. The graph illustrates the return from total investments in each state (with larger circles indicating greater Net Present Value, NPV) and the available water resources in the ENB for either hydropower generation (in GigaWatt-hours, GWh) or irrigation (in thousands of hectares). States positioned outside the oval 'envelope of water availability' are constrained by water scarcity. This graphical representation supplements the analysis results presented in Table 3.

Assessing feasibility of development states under emerging climate change scenarios

Analysing the information provided in Table 3, it becomes apparent that there is a water balance deficit at the Delta for certain development states, with a maximum deficit of 3.35 Billion Cubic Meters (BCM) based on a downstream water allocation of 55.5 BCM from the High Aswan Dam (HAD).

Recent research conducted by Siam and Eltahir reveals the potential for increased water yield in the upper Blue Nile and Atbara rivers, with an estimated increase of 5 BCM and 2 BCM, respectively. This increase is primarily attributed to higher rainfall and changes in land use in the Ethiopian highlands. While this study indicates an overall increase in average annual yield, it also highlights significant seasonal and interannual variability. This underscores the importance of additional year-round water storage capacity to effectively cope with the challenges posed by climate change.

Considering the prospects of climate variability offers an opportunity to unlock an additional 7 BCM of water for utilization. This presents an avenue for accommodating long-term water resources development plans, which should be negotiated around the potential Development States or trajectories outlined in this study. It's crucial to emphasize that the objective of this analysis is not to advocate for a specific development path or trajectory. Instead, it highlights the possibility of negotiating a lasting agreement based on a non-zero-sum gain approach, taking into account the evolving dynamics of water availability in the face of climate change.

Conclusion

This study was conceived to provide a holistic assessment of the overall impacts stemming from various combinations of water resources development and management options within the Eastern Nile Basin (ENB). It examined a total of 12 distinct Development States, expanding upon four fundamental ones: Current Situation (CS), Improved Situation (IS), Large Development (LD), and Full Development (FD). These development states were designed as an incremental progression from CS to IS, then LD, and finally FD.

To evaluate the water demand requirements for each development state, the Eastern Nile Basin simulation model was employed. Subsequently, a multi-criteria analysis was utilized to compare the impacts of these development states, particularly concerning their alignment with the water resource and sustainable development aspirations of the ENB countries.

The feasibility of these development states was rigorously assessed, considering their potential environmental, economic, and social implications. It's important to note that certain development states revealed a deficit in the water balance at the Delta, with the maximum shortfall being 3.35 Billion Cubic Meters (BCM) based on a downstream water allocation of 55.5 BCM from the High Aswan Dam (HAD).

However, there is a glimmer of hope in the face of climate variability. Recent research indicates the potential to unlock an additional 7 BCM of water for utilization, primarily driven by increased rainfall and evolving land use patterns in the Ethiopian highlands. This presents an opportunity to accommodate long-term water resources development plans, which could be negotiated around the proposed Development States or trajectories outlined in this study.

Recommendations

In light of these findings, it is strongly recommended that negotiations regarding the Grand Ethiopian Renaissance Dam (GERD) be structured around two parallel tracks. The first track should concentrate on addressing the short-term filling and operational aspects of the dam. Simultaneously, the second track should prioritize the establishment of a comprehensive regional water resources development and management plan. This dual-track approach will facilitate the negotiation of a long-lasting agreement that fosters cooperation, recognizes non-zero-sum gains, and takes into account the evolving dynamics of water availability in the ENB.

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