Subject category and title

Adaptive river basin planning: Negotiating Nile infrastructure management should consider climate change uncertainties

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Standfirst

High uncertainty exists in the projected climate change impacts on the Nile's economies and water-dependent sectors. Under these uncertainties, managing the Grand Ethiopian Renaissance Dam (GERD) cooperatively and adaptively can produce economic and water management benefits for Ethiopia, Sudan, and Egypt.

The policy problem

Designing management strategies for large dams requires adopting a multi-dimensional approach to foster synergies, identify efficient tradeoffs, and optimize economic performance. Dam negotiations between the Nile riparian countries have traditionally used biophysical

metrics only, such as irrigation water supplies and hydropower generation, even though governments often build dams to achieve wider economic goals. The implications of climate change uncertainty for the Nile hydrology (e.g., streamflow and irrigation demands) and the economies of its riparian countries (e.g., economic development pathways, population growth, and climate policies) mean non-adaptive dam management can perform poorly. The construction of the GERD on the Nile triggered political tensions between Ethiopia, Sudan, and Egypt, with negotiations between the countries yet to reach an agreement. While negotiations over the GERD have been ongoing since 2011, economy-wide metrics alongside climate change uncertainties have not been considered in developing and evaluating dam operation proposals for the Nile.

The findings

Based on 29 climate projections, we find that both the sign and magnitude of potential changes in naturalized streamflow of the Nile in 2021-2050 are highly uncertain. These uncertainties spark the need for an adaptive and cooperative approach. We show that cooperative adaptive management of the GERD yields compromise solutions with economy-wide benefits to Ethiopia, Sudan, and Egypt compared to a proposal discussed in Washington D.C. in 2020 (Fig. 1). Under an example compromise solution (Fig. 1), the mean (based on 29 projections) discounted (at 3%) real GDP increases by 0.77, 0.67, and 0.18 billion USD in 2020-2045 for Ethiopia, Sudan, and Egypt, respectively, relative to the Washington Draft Proposal. These benefits are more pronounced under extreme climate scenarios, with rises in discounted real GDP of up to 15.8, 6.3, and 3.0 billion USD over 2020-2045 for Ethiopia, Sudan, and Egypt, respectively. Our results should be complemented by evaluating the impacts on ecology, groundwater, and riparian populations.

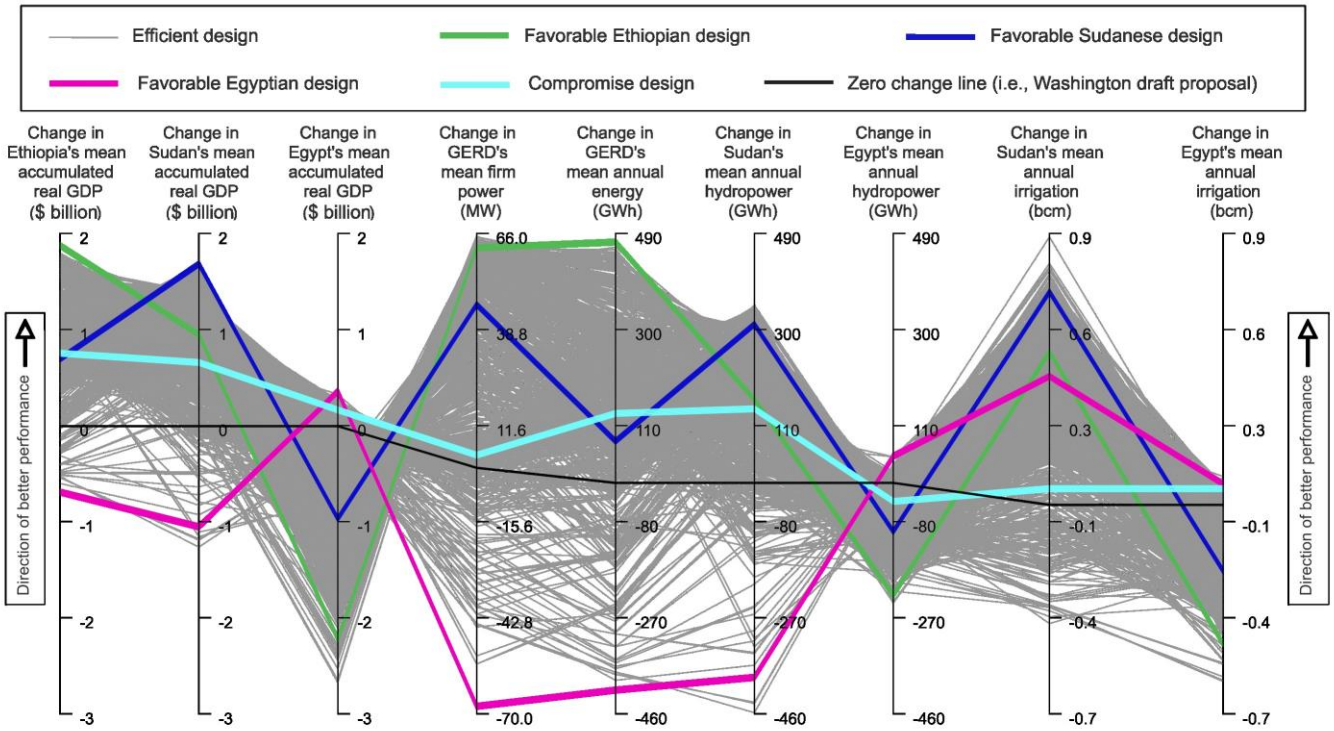

Fig. 1 Ethiopian, Sudanese, and Egyptian economic and river system performance under the best performing designs of an adaptive Grand Ethiopian Rennaissance Dam (GERD) operating approach considering 29 climate change projections for 2020-2045. Each line of the parallel coordinates plot shows the performance achieved by one of the Pareto-efficient adaptive designs or policies, i.e., a policy which, if further improved for one performance metric, would imply a reduction in one or more other performance metrics. All change values are calculated from a baseline in which the GERD is operated based on the Washington draft proposal. The upward direction on each axis indicates better performance (i.e., a 'perfect adaptive plan' would be a straight line across the top); diagonal lines between neighboring axes imply tradeoffs, whereas horizontal ones show synergies. The firm power values are calculated based on a 90% reliability, and the real GDP values are discounted at a 3% rate.

The study

We developed a planning framework for Nile infrastructure management considering the socio-economic and hydrological uncertainties of climate change. The framework integrates hydrological, economy-wide, and river system simulators driven by climate and socio-economic data from the Coupled Model Intercomparison Project (CMIP) 6. This framework enables the estimation of multiple economy-wide and engineering performance metrics under various infrastructure management plans and climate change projections. The simulators were calibrated and validated, and the climate change data were bias-corrected and

downscaled before being used. The climate scenario ensemble includes members synthesized to address the wetting tendency of climate models known as the "East Africa climate paradox." The most efficient operational designs for a cooperative and adaptive GERD management formulation were identified by linking the integrated simulators with an artificial intelligence search algorithm over thousands of iterations. We then compared the performance under the identified efficient, optimized plans with that of the Washington Draft Proposal.

Messages for Policy

- There are deep uncertainties around the impacts of climate change on the Nile streamflow, reservoir evaporation rates, crop evapotranspiration, and socio-economic development.
- Adaptive management plans for Nile infrastructure are vital for coping with climate change uncertainty; such plans involve short-term actions and adaptation mechanisms as climate change unfolds.
- Cooperative adaptive management of the Grand Ethiopian Renaissance Dam provides economy-wide and water management benefits to Ethiopia, Sudan, and Egypt compared to the Washington Draft Proposal.
- Adaptive management plans of the Grand Ethiopian Renaissance Dam that maximize the economy-wide gains of one country result in losses for at least one of the other two countries compared to the Washington Draft Proposal; however, adaptive solutions exist that improve performance for all countries.

Source research

Basheer, M., Nechifor, V., Calzadilla, A., Gebrechorkos, S., Pritchard, D., Forsythe, N., Gonzalez, J.M., Sheffield, J., Fowler, H.J., Harou, J.J., 2022. Cooperative adaptive management of the Nile River with climate and socio-economic uncertainties. Nature Climate Change.

Further Reading

Basheer, M., Nechifor, V., Calzadilla, A., Siddig, K., Etichia, M., Whittington, D., Hulme, D., Harou, J.J., 2021. Collaborative management of the Grand Ethiopian Renaissance Dam increases economic benefits and resilience. Nature Communications 12, 5622. https://doi.org/10.1038/s41467-021-25877-w

This study describes the integrated economy-wide and river system simulation used to model the interlinkages between the Nile river system and the economies of Ethiopia, Sudan, and Egypt.

Basheer, M., Nechifor, V., Calzadilla, A., Ringler, C., Hulme, D., Harou, J.J., 2022. Balancing national economic policy outcomes for sustainable development. Nature Communications 13, 5041. https://doi.org/10.1038/s41467-022-32415-9

This article connects economy-wide simulation with artificial intelligence search and machine learning. This shows that the multiobjective design approach used in the present study is general; it can be used in a wide range of contexts to find efficient policies and the trade-offs and synergies they imply.

O'Neill, B.C., Tebaldi, C., Van Vuuren, D.P., Eyring, V., Friedlingstein, P., Hurtt, G., Knutti, R., Kriegler, E., Lamarque, J.F., Lowe, J., Meehl, G.A., Moss, R., Riahi, K., Sanderson, B.M., 2016. The Scenario Model Intercomparison Project (ScenarioMIP) for CMIP6. Geoscientific Model Development 9, 3461–3482. https://doi.org/10.5194/gmd-9-3461-2016

This paper describes the climate change scenarios of the Coupled Model Intercomparison Project (CMIP) 6, from which some scenarios have been bias-corrected, downscaled, and then used in simulating the impacts of climate change on the Nile Basin and its riparian economies. More scenarios were synthesized to address the "East Africa climate paradox."

Marchau, V.A.W.J., Walker, W.E., Bloemen, P.J.T.M., Popper, S.W., 2019. Decision making under deep uncertainty: from theory to practice. Springer Nature. https://doi.org/10.1007/978-3-030-05252-2

This book provides a review of methods for decision-making under deep uncertainty (such as climate change), which motivated the adaptive management formulation used for the GERD in our study.

Edrees, M., 2020. Letter from the permanent representative of Egypt to the United Nations addressed to the President of the Security Council. https://digitallibrary.un.org/record/3931750?ln=en

This document is a letter from the permanent representative of Egypt to the United Nations to the President of the United Nations Security Council in which the Washington Draft Proposal for filling and operating the GERD is annexed.

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Competing interests

The authors declare no competing interests.