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HOW CAN AFRICAN AGRICULTURE ADAPT TO CLIMATE CHANGE? INSIGHTS FROM ETHIOPIA AND SOUTH AFRICA

Integrated Management of the Blue Nile Basin in Ethiopia under Climate Variability and Climate Change

Hydropower and Irrigation Modeling

Paul J. Block, Kenneth Strzepek, and Balaji Rajagopalan

Ethiopia possesses abundant water resources and hydropower potential, yet less than 5 percent of irrigable land in the Blue Nile basin has been developed for food production, and more than 80 percent of Ethiopians lack access to electricity. Consequently, the Ethiopian government is pursuing plans to develop hydropower and irrigation along the Blue Nile River in an effort to tap into this underused potential.

Although approximately 84 percent of the inflow to Lake Nasser at Aswan, Egypt, initiates from Ethiopia through the Blue Nile and Atbara Rivers, Ethiopia has limited rights to use these resources. Egypt and Sudan, through the Agreement of 1959, are allotted 55.5 and 18.5 billion cubic meters each year, respectively, with no allotment to Ethiopia. In 1998 the Nile Basin Initiative was created to stimulate cooperation among all countries in the Nile basin and work toward amicable alternatives and solutions for water resources benefits.

This brief is based on a paper that analyzes potential hydropower generation and irrigation supply for four large-scale dams and reservoirs along the Blue Nile River within Ethiopia—Karadobi, Mabil, Mendaia, and Border—as proposed by the United States Bureau of Reclamation in 1964. The total installed hydropower capacity would be 5,570 megawatts of power, about 2.5 times the potential of the Aswan High Dam in Egypt. Irrigation associated with the Mendaia and Border reservoirs could expand by 250,000 hectares or 35 percent of the estimated total irrigable land in the Blue Nile basin.

The challenges of implementation, however, are not inconsequential. The proposed reservoirs not only raise financing, investment, political, and institutional challenges, but may also require many years to fill, which will affect downstream flows depending on variable climate and climate change conditions. Using a model for hydropower and irrigation analysis, the paper explores dam implementation viability under various policy options.

PLAUSIBLE FLOW RETENTION POLICIES AND CLIMATE SCENARIOS

The model simulates two different flow policies, both of which represent plausible scenarios for retaining water within Ethiopia (neither of which is acceptable under current agreements). The first allows for Ethiopia to retain 5 percent of the annual flow (the 5-percent policy) passing the Sudano-Ethiopian border. The second only allows Ethiopia to retain water in years within which the annual border flow exceeds 50 percent of historical flows (the 50-percent policy), and in that event the entire excess may be withheld. The model provides a benefit–cost analysis of the implementation of this project, including both hydropower generation and irrigation development for the two flow policies under three different climate scenarios. One scenario projects future climate variability based on historical data (1961–90), whereas the other two scenarios project potential climate variability based on increased frequency of El Niño or La Niña events due to climate change.

Costs and benefits of project implementation are assessed over a 100-year period, 2000–99, which includes a construction phase of seven years (2000–06) for the first dam and three years (2004–06) for the irrigation system before any benefits are realized. Additional dams are constructed in subsequent seven-year periods. The transient (filling) phase of the model begins in 2007 when water may first be impounded in the initial dam. Postconstruction benefits (beyond 2036) are assumed to be constant at the design level.

HISTORICAL AND CLIMATE CHANGE SCENARIO RESULTS

Table 1 presents benefit–cost ratios for the three potential climate conditions and two flow policies. The expected benefit–cost ratios for an increased frequency of La Niña events are approximately equal to those of the historical scenario under the 5-percent flow retention policy. Under the 50-percent policy, the La Niña benefit–cost ratios are slightly greater than the historical scenario, owing to generally wetter conditions.

In contrast, the expected benefit–cost ratios for an increased frequency of El Niño events produce noticeably lower benefit–cost ratios compared with the historical scenario. This outcome is a direct result of generally drier conditions, particularly during the transient phase, and clearly represents conditions under which construction of the hydropower and irrigation projects may not prove worthwhile. Moreover, the benefit–cost ratios for the increased frequency of El Niño events may well be an overestimation because the likelihood of achieving full benefits for irrigation and hydropower beyond the transient stage is small.

IRRIGATION VERSUS HYDROPOWER

In the historical and La Niña scenarios, hydropower and irrigation are almost always both maximized. Irrigation benefit–cost ratios are generally close to 1.0. For drier conditions, however, such as the El Niño scenario, the model reserves water for hydropower generation and forgoes crop irrigation in order to meet downstream flow requirements.

For the El Niño 5-percent flow policy, the number of hectares irrigated in the early years may be lower than for other climatic conditions given the generally drier conditions. However, the number of hectares irrigated may grow quickly thereafter, reaching the maximum level within a two- to four-year period. For the El Niño 50-percent flow policy, however, little or no irrigation may take place during the transient stage, which is not helpful for cropland management and planning and, consequently, contributes to benefit–cost ratios below 1.0. Understandably, a surge in crop yields or commodity prices associated with a decrease in demand for energy may reverse these trends. Other political decisions—related to national food security, for example—might also favor irrigation over the energy development strategy.

CONCLUSION

Climate change could play a major role in determining the success or failure of proposed large-scale hydropower and irrigation projects in Ethiopia's Blue Nile Basin. Climate change scenarios, represented by changes in the frequency of El Niño and La Niña events, indicate potential for small benefit–cost increases, but they also reflect the potential for notable decreases relative to historical climate conditions. Stochastic modeling of scenarios representing a doubling of the historical frequency of El Niño events indicates benefit–cost ratios as low as 1.0, with numerous runs producing potentially infeasible hydropower and irrigation projects due to a lack of timely water. Overall, the 5-percent flow policy appears to be more robust to modeled climate changes than the 50-percent flow policy. It consistently outperforms the 50-percent flow policy in drier conditions and is nearly on par with it in wetter conditions.

Although considerable effort has been devoted to creating as comprehensive and accurate a model as possible, the Blue Nile within Ethiopia remains largely ungauged, and some degree of uncertainty must be factored into the use of specific hydrologic and climatic conditions. Undoubtedly, site-specific testing and modern technology will alter earlier reservoir plans, possibly changing the potential or overall scope for hydropower and irrigation development. Nonetheless, the results of this study are thought to be representative of prospective future hydropower and irrigation development scenarios and at least give an indication of feasibility under varying conditions.

Coordinating plans with downstream riparian countries is vital to the success of the hydropower and irrigation development projects. Potential benefits of collaboration for the countries involved include increased energy and food production, regulated streamflow, increased water conservation through reduced evaporation losses, and redistributed water rights through a renegotiation of the 1959 Agreement.

FOR FURTHER READING

Block, P. J., K. Strzepek, and B. Rajagopalan, *Integrated Management of the Blue Nile Basin in Ethiopia: Hydropower and Irrigation Modeling*, IFPRI Discussion Paper No. 700 (Washington, DC: International Food Policy Research Institute, 2007).

Table 1 Benefit–cost ratios for two flow policies for historical and climate change scenarios

Type of flow policy	Historical conditions	Increased frequency (2x) of La Niña (wetter conditions)	Increased frequency (2x) of El Niño (drier conditions)
5-percent policy	1.48–1.72	1.49–1.76	1.43–1.66
50-percent policy	1.18–1.82	1.41–1.91	1.07–1.63

SOURCE: Block, P. J., K. Strzepek, and B. Rajagopalan, *Integrated Management of the Blue Nile Basin in Ethiopia: Hydropower and Irrigation Modeling*, IFPRI Discussion Paper No. 700 (Washington, DC: International Food Policy Research Institute, 2007).
NOTE: The interest rate is 10 percent.

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