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Future opportunities and risks in managing the Eastern Nile water-energy-food-environment nexus

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The interlinkages between the water, energy, food, and environment systems of the Eastern Nile Basin are becoming stronger due to an increase in the demand for water, energy, and food and two of the largest multi-year storage dams in the world (i.e., High Aswan Dam and Grand Ethiopian Renaissance Dam (GERD)). Significant benefits can be attained if these resource systems are managed in an integrated manner, which would result in improved efficiencies and reduced trade-offs in resource use, and better and more sustainable solutions to future water-energy-food-environment nexus problems. The ongoing construction of the GERD, the largest hydropower plant in Africa, reveals opportunities and challenges in managing the resource nexus of the Eastern Nile Basin. This study integrates an Eastern Nile river system model with a power system model comprising the Eastern portion of the East African Power Pool (i.e., Ethiopia, Sudan, Egypt, Djibouti, and Libya) to investigate how GERD influences the integrated resources of the Eastern Nile Basin countries. The system is modelled using an open-source water resource system simulator (Pywr) and an open-source Python power system simulator. The two simulators are linked using an open-source agent-based model integration framework (Pynsim). Based on existing and plausible future states of the system, three scenarios are formulated and examined: (1) a baseline scenario representing the existing system before GERD, (2) GERD added to the system, including the initial filling and long-term operation phases of the dam, and (3) increased irrigation water abstractions in Ethiopia and Sudan with GERD. Results show that GERD operation reduces (i) electricity curtailments in Ethiopia and Sudan, (ii) irrigation water deficits in Sudan, (iii) Sudan's greenhouse gas emissions, and (iv) hydropower generation and irrigated water consumption in Egypt. Increasing irrigation water abstraction in Ethiopia and Sudan reduces hydropower generation basin-wide and irrigation water consumption in Egypt. This study demonstrates the benefits of an integrated modelling approach for exploring water-energy-food-environment nexus inter-connections in the Eastern Nile multi-resource system.