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Managing Urban Water Supplies under Future Uncertainties: A Case Study of Bengaluru, India

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The future uncertainties, spanning both climatic (e.g., precipitation) and non-climatic (e.g., population growth) factors, will significantly impact urban water demands and supplies. To enhance future water security in urban areas, the Integrated Urban Water Management (IUWM) approach has gained popularity globally. The IUWM approach emphasizes a varied water supply source, addresses multiple sustainability objectives, and ensures the provision of fit-for-purpose water. This study uses an Integrated Urban Water Balance Model (IUWBM), developed in eWater Source platform version 5.10.0.11841, which utilizes different types of water (i.e., river water, groundwater, harvested stormwater, rooftop rainwater, and recycled wastewater) to meet future water needs. However, depending on how much water each source supplies, combining different water sources to meet the demand may result in trade-offs with the integrated urban water system's total cost and energy consumption. Given the future uncertainties, it is crucial to develop robust optimal water mix solutions that are minimal in total costs and total energy consumption across various future scenarios. This study proposes to address this challenge, focusing on Bengaluru (i.e., a city in India) as a case study due to its relevance to the identified issues. The IUWBM is linked to an optimization tool (i.e., Insight Version 5.10.0.11841, which uses the NSGA-II algorithm). Three robustness metrics—Laplace Principle of Insufficient Reasons, Hurwicz Optimistic-Pessimistic Rule, and Signal-to-Noise Ratio—are added to a multi-scenario, multi-objective optimization problem to make the decision-making more robust. All optimal solutions generated adhere to constraints, maintaining an average volumetric and time reliability of water supply above 99.50% for the study area. The findings reveal that low-cost optimal water mix solutions tend to exhibit higher energy consumption as they prioritize savings in the capital costs of building the new water supply infrastructure. Capital costs, therefore, significantly impact the total costs, while operating energy plays a crucial role in total energy consumption in Bengaluru urban water supplies. The present research also found that harvested stormwater and recycled wastewater emerge as potentially low-cost, low-energy, and reliable sources for potable and non-potable water, respectively, under future uncertainties. Additionally, recycled wastewater is preferable for non-potable uses as it offers the added benefit of mitigating adverse environmental impacts on Bengaluru's valleys and lakes.