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Exploring Synergetic Benefits of Water-Food-Energy Nexus through Intelligent Multi-objective Water Allocation

Fi-John Chang, Yanlai Zhou, Hang-yeh Lin, and Tinn-Shuan Uen
National Taiwan University, Department of Bioenvironmental Systems Engineering, Taipei, Taiwan (changfj@ntu.edu.tw)

Water, Food and Energy (WFE) are the essential elements of current and growing urban centers which sustains healthy urban metabolism. Under the scope of Sustainable Urbanisation Global Initiative: Food-Water-Energy Nexus (SUGI-FWE) Call, our goal is to promote Green Urban Centers of Tomorrow by constructing effective exchange mechanisms for WFE elements from sources to urban centers and then optimizing the FWE factors related to societal health. We use state-of-the-art techniques such as Artificial Intelligence (AI), big-data mining, system dynamics and scenario analysis to construct the optimal resources allocation models. We seek to understand the interrelation of FEW and provide feasible solutions tacking WFE resources allocation and utilization.
Due to the uneven Spatio-temporal distribution of water resources and increasing water demands caused by urbanization, making effective water allocation for public, commercial and industrial consumption, food production and energy generation is a critical and challenging issue nowadays. The pivotal Shihmen Reservoir and its neighboring urban areas in northern Taiwan form the study case, where the total impoundment of irrigation ponds spreading over Taoyuan area can reach one-fourth of the total capacity of the Shiemen Reservoir. In this study, we propose a holistic methodology that optimizes the synergies of the WFE Nexus by integrating the operation of a multi-objective reservoir with irrigation ponds as a backup under urbanization. The methodology consists of four stages: (1) we make forecasts on future water demands under urbanization by using the system dynamics (SD) theory based on historical agricultural and industrial data as well as population statistics; (2) during typhoon seasons, we maximize both hydropower generation amount and final reservoir storage by optimizing daily reservoir operation with the non-dominated sorting genetic algorithm-II (NSGA-II); (3) during non-typhoon seasons, we incorporate irrigation ponds into multi-objective reservoir operation for making joint water supply to both agricultural and public sectors; and (4) we assess the collaborative benefits of the WFE Nexus based on the optimal joint operation of the reservoir and irrigation ponds.
The results obtained from the NSGA-II under pre-designed scenarios demonstrate that the optimal reservoir operation can much increase the amount of hydropower generation but just slightly affects the water supply. By coupling the reservoir with irrigation ponds, the results indicate that agricultural and public water shortages can be mitigated during non-typhoon seasons, as compared to those of reservoir operation excluding irrigation ponds. The results for a wet year show that water shortage rates can be decreased by at most 10%, the food production rate can be improved by at most 45%, and the annual revenue of hydropower generation can increase to 9 million USD, respectively. Consequently, the proposed methodology can be a promising tool to increase the collaborative benefits of the WFE Nexus in response to future urban water demands, and therefore provide decision makers with reference guidelines for sustainable water resources management.