Multi-Objective Optimization for Analysis of Changing Trade-Offs in the Nepalese Water-Energy-Food Nexus with Hydropower Development

While the water-energy-food nexus approach is becoming increasingly important for more efficient resource utilization and economic development, limited quantitative tools are available to incorporate the approach in decision-making. We propose a spatially explicit framework that couples two well-established water and power system models to develop a decision support tool combining multiple nexus objectives in a linear objective function. To demonstrate our framework, we compare eight Nepalese power development scenarios based on five nexus objectives: minimization of power deficit, maintenance of water availability for irrigation to support food self-sufficiency, reduction in flood risk, maintenance of environmental flows, and maximization of power export. The deterministic multi-objective optimization model is spatially resolved to enable realistic representation of the nexus linkages and accounts for power transmission constraints using an optimal power flow approach. Basin inflows, hydropower plant specifications, reservoir characteristics, reservoir rules, irrigation water demand, environmental flow requirements, power demand, and transmission line properties are provided as model inputs. The trade-offs and synergies among these objectives were visualized for each scenario under multiple environmental flow and power demand requirements. Spatially disaggregated model outputs allowed for the comparison of scenarios not only based on fulfillment of nexus objectives but also scenario compatibility with existing infrastructure, supporting the identification of projects that enhance overall system efficiency. Though the model is applied to the Nepalese nexus from a power development perspective here, it can be extended and adapted for other problems.