A Holistic Framework for Evaluating the Sustainability of the Water-Energy-Food-Ecosystem Nexus Under Multiple Socioeconomic and Climate Change Conditions

Water scarcity, energy demand, declining crop yields, and environmental damage present interconnected challenges in the 21st century. This study addresses these issues through the Water-Energy-Food (WEF) nexus framework, focusing on the Sakarya Basin in Türkiye. The objective is to develop a methodology for evaluating the Water-Energy-Food-Ecosystem (WEFE) nexus under evolving climatic and socioeconomic conditions, while emphasizing the often-ignored ecosystem component. The proposed methodology incorporates cutting-edge climate projections and socioeconomic scenarios, employing dynamical downscaling and integrating them into a coupled water-energy systems model (WEAP-LEAP). The future climate projections were downscaled to 18 km resolution using the WRF model. Socioeconomic changes were captured through the application of the Shared Socioeconomic Pathways (SSPs) scenarios (SSP1, SSP2, and SSP5). The ecosystem component was assessed using a methodology inspired by the Index of Hydrologic Alteration (IHA) and Range of Variability Approach (RVA). Three scenarios (RCP4.5_SSP1, RCP4.5_SSP2, RCP8.5_SSP5) were developed to evaluate the impacts on WEFE nexus sectors. The overall WEFE Nexus Index values and pillar scores were calculated for the seven subbasins of the Sakarya Basin. The results indicate challenges in agricultural irrigation across almost all subbasins, regardless of the scenario. The tradeoff between the ecosystem and food pillars within the WEFE Nexus is noteworthy, while the energy pillar consistently falls short of targets such as the Paris Agreement and renewable energy utilization. Limited utilization of hydropower potential exacerbates this issue. Prioritization based on subbasin characteristics is crucial, e.g., with a focus on sustainable agricultural strategies in agricultural subbasins, which can be further examined through smaller-scale studies. The developed WEFE Nexus Index can serve as a valuable tool for policy-making and public communication, enhancing understanding of the sustainability and security of the WEFE Nexus.

By Dr. Zeynep Özcan

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