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Evaluating the robustness of the water-energy-food nexus using integrated climate and socio-economic scenarios

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Population growth and rising economic prosperity combined with alterations of hydroclimatic conditions are expected to pose major challenges for water management policies, particularly in fast-developing economies. Growing energy and food demands will likely trigger major investments in large dam projects, whose performance strongly depends on unknown future conditions in the coming decades. In contrast to traditional impact assessments that focus on climate and socio-economic divers separately, in this work we propose an integrated framework to better understand the nested interdependencies of those drivers across sectors and processes at different scales. We integrate an ensemble of climate projections generated from Representative Concentration Pathways with a large factorial dataset of socio-economic scenarios derived from the Socio-Economic Pathways evaluated using the Global Change Assessment Model (GCAM). As a demonstration, we study the Zambezi River, one of the largest river basins in Africa and a paradigmatic of most basins in developing countries. The four largest dams are mainly operated for hydropower production and irrigation supply, with considerable negative effects on the aquatic ecosystems due to the alteration of the natural flow regime.
To assess the robustness of the water-energy-food nexus in the Zambezi River basin against future integrated scenarios of changing socio-economic and climate drivers, we first downscaled climate projections to feed local hydrological models and produce projections of water availability in the basin. In parallel, we spatially and temporally downscaled GCAM outputs via the Tethys software to obtain projections of irrigation demands. Numerical results show that the current management of the system is highly vulnerable to changing conditions, with critical risks of failure in terms of food security due to unreliable irrigation supply. Our framework demonstrates that these critical conditions are mostly generated by global socio-economic drivers, namely the alternative regimes of land-use change taxation, rather than predicted changes in water availability due to climate change.