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Seasonal Hydropower Planning In Data Scarce Regions: The Role of Ensemble Forecasts and Remote Sensing

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Future inflow scenario trees, necessary for stochastic optimization of reservoir cascades at seasonal time scales, are generally constructed from reliable long-term streamflow records using statistical and physically-based methods. In data scarce regions, such as sub-Saharan Africa which has witnessed exponential growth in hydropower capacity, these methods are ineffective owing to unreliable and inadequate streamflow records. In this study, we develop and test a novel framework for generating inflow scenario trees in data scarce regions by combining satellite-based remote sensing, ensemble forecasts of precipitation from numerical weather prediction (NWP) models and distributed hydrologic modelling. To develop the framework we first test the potential of precipitation and evapotranspiration as proxies for streamflow in generating scenario probabilities. For this, we compare Bayesian Model Averaging (BMA) weights of ensemble members of precipitation (P), evapotranspiration (ET) and streamflow (SF) generated by forcing a distributed hydrologic model with ensemble precipitation forecasts. We hypothesize that 1) BMA weights are equivalent to scenario probabilities and 2) BMA weights of ensemble members calculated using P and ET observations are comparable to BMA weights calculated using SF observations. We carry out this analysis in a catchment (the Mississippi river basin) where streamflow observations are available. Next, we reformulate the stochastic programming with recourse model to take into account the uncertainty in the seasonal streamflow forecast. The classical formulation assumes that the first stage of forecast is deterministic (i.e, the forecast for the first month is sufficiently accurate). However, in data-scarce regions, where streamflow observations are not available to reliably evaluate the accuracy of the forecasts, this assumption fails. In this study, we consider the first stage to be stochastic. We compare the following three stochastic programming with recourse formulations: 1) All stages are deterministic - derived by BMA of ensemble precipitation forecasts, 2) Stochastic programming with recourse (First stage deterministic) - first stage derived by BMA of ensemble forecasts and 3) New stochastic programming with recourse (First stage stochastic) - first stage consists of all the scenario members. We test the developed framework in the data-scarce Omo-Gibe river basin in East Africa which consists of a cascade of three reservoirs. Using the developed framework, we address the following research questions: 1) What are the impacts of uncertainties in precipitation forecasts and model parameters on seasonal reservoir inflow forecasts, and hence on hydropower production? and 2) To what extent does incorporation of inflow uncertainty in the first stage of stochastic programming with recourse affect the release policy, and hence hydropower production?